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2004-2005 Statewide Nonresidential Standard Performance Contract Program Measurement and Evaluation Study

Impact, Process and Market Evaluation – Final Report

04-05 Program ID#s 1121, 1177, 1240, 1347, 1507

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Volume 2 of 2 – Appendices

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A.

Appendix A: Site Level Net-to-Gross Findings

A

Appendix A: Site Level Net-to-Gross Findings

Site	IOU Application Number	IOU	NTG Ratio
A001	2K4-S0031E	PG&E	0.41

Site A001 expanded their production line and contacted an insulation vendor, Polarclad to sponsor the application for multiple new wine tanks. The SPC incentive was very significant to Site A001's decision to install and the help from the vendor. Polarclad, was only somewhat significant because if not Polarclad they would have found someone else to help or installed a less efficient type of insulation on their own. Site A001 also indicated that they may have installed approximately the insulation at a later time (1 year) later without the SPC program. Since the 2004 project, Site A001 has replaced incandescent bulbs with CFLs and is currently planning on insulating more tanks and glycol lines. This suggests a medium probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A002	2K5-L0399E	PG&E	0.46

This project was one of three SPC approved applications submitted by Site A002. Multiple VSDs were installed at their Madera site for the sole purpose of improving energy efficiency and reducing costs. It is difficult to say that the SPC program at this site had impact on other energy projects at this site or others because the consultant company was hired to work on energy efficiency projects for Site A002 across the nation and has been contracted with them for some time. However without this program it was speculated that this project wouldn't have been started for two more years. This suggests a medium probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A003	2K4-L0084E	PG&E	1.00

Site A003 decided to replace 5 500-hp motors on air compressors with premium efficiency motors, in part because the existing equipment was outdated. The old motors had been rewound many times, and were very inefficient. The project also allowed the company to meet its broader goal of improving efficiency and lowering the operating cost of their refrigeration plant. They view the incentive provided through the SPC program as ‘very significant’ in their decision to install premium efficiency motors, in that it helped them sell the project internally by increasing the project’s return on investment to above their required minimum level. Without the incentive, they would not have replaced the motors but would have continued using them until they failed.

Site	IOU Application Number	IOU	NTG Ratio
A004	2K4-L0232E	PG&E	0.36

Site A004 decided to also utilize their grape crushing tanks as annual wine storage tanks which required a refrigeration system and tank insulation to reduce energy costs. The company was a participant in the SPC program originally in 1993, which first sparked their interest in incentives for energy efficiency projects. The incentive played a very significant role in their decision to add the tank insulation and but they probably would have done the project regardless just approximately one year later. The company always looks for incentives for energy efficiency projects and has done many after the SPC 2004/2005 project year. This suggests a medium to high probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A005	2K4-L0288E	PG&E	1.00

Site A005 retired a 20 year chiller that as a result of new Freon requirements was retrofitted in 1993 and became more inefficient. Without the SPC program and help from their EESP, Site A005 wouldn’t have replaced the chiller until it failed, which they estimated would be in 2009. This was their first energy efficiency project. Since then they have begun to research a cogeneration project and have applied for incentives. All of these suggest a low probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A006	2K5-L0426G	PG&E	0.67

Site A006 added 9 edible oil tanks to their facility. They pursued an SPC incentive for the high temperature insulation, as they have in the past for other energy efficient projects. They decided on their own to install installation but had help with the design and regulation requirements. The company probably would have added high temperature insulation regardless of the SPC program, but indicated that the SPC incentive allowed them to insulate a greater number of tanks. The operations manager was not sure if the SPC program affected the timing of the insulation addition. All of these suggest a medium probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A007	2K4-L0132G	PG&E	0.79

Before Site A007 insulated its large condensate storage tank, they were aware that the uninsulated tank was losing a lot of energy. This is a 600-gallon tank which holds liquids that are between 160 to 170 degrees F. The tank is in ambient conditions where temperatures could go as low as 30 degrees, resulting in considerable heat loss. The project concept was basically a ‘no-brainer’. Despite this, the SPC incentive was viewed as very important to the project’s viability. This was an early project and the incentive provided by the SPC helped to jump-start their efforts to sell this and other energy efficiency projects to senior management. Without the SPC incentive, they would not have installed the tank insulation, despite the project’s considerable merits.

Site	IOU Application Number	IOU	NTG Ratio
A008	2K5-L0445EG	PG&E	0.17

Site A008 replaced a 25 year old boiler that was too large with a more efficient, correctly-sized boiler thereby improving the boiler performance. They learned of the SPC program while they were investigating boiler replacement options. The company indicated that the incentive and the SPC program were somewhat significant in their plans to pursue installation, however they would have installed the boiler at the same time regardless of the SPC program. The company has not pursued incentives for energy efficient upgrades since then due to a lack of knowledge about available programs and their requirements. This indicates a high free ridership probability.

Site	IOU Application Number	IOU	NTG Ratio
A009	2K4-L0080G	PG&E	0.36

Site A009, a food processing facility, received an incentive to install a boiler heat recovery system. The SPC incentive was reported to be very significant in the company's decision to install this measure: it covered at least half of the initial measure cost. Without it Site A009 probably wouldn't have installed the heat recovery system at that time but would have installed it within 12 months. Since this project, Site A009 has done other condensate recovery upgrade projects, some with and some without incentives from PG&E. This suggests a medium to high probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A010	2K4-L0158E	PG&E	0.83

This is a case where Site A010 wanted to upgrade the efficiency of their existing equipment and to improve the control of the system by adding VSDs to cooling tower fans and condenser pump. Both the account representative and the incentive were reported to have significantly influenced their decision to participate in the program. Also, this company has a policy of conserving a set percentage of their annual energy usage. However, they do not aggressively participate in energy efficiency programs to meet this goal. All of this information suggests a low probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A011	2K5-L0411E	PG&E	0.46

Site A011's corporate director of energy services vigorously promotes participation in the utilities' EE programs to aid the company in achieving its corporate-mandated energy conservation goal each year. For Site A011, adding programmable thermostats to existing equipment helped it to meet two objectives: reducing energy usage in guest rooms and increasing the comfort levels of guests. The incentive played a key role in the company's installation of EE technologies. The estimated payback period of 15-16 months was reduced to 11 months when the incentive was factored in. Similar projects are being done at other locations. A medium level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A012	2K4-L0128E	PG&E	1.00

Site A012's primary motivation for this chiller replacement project was to save energy. They have 27,000 tons of chillers and are always looking for ways to save cooling energy. VSD allowed them to run the chiller to match their building's cooling load, and to realize additional energy savings beyond those resulting from replacement of outdated and less efficient equipment with new energy efficient chillers. The SPC incentives were a "very big part" of their decision making. The program incentives brought the chiller project ROI down to within their required level. Site A012 indicated that the SPC program has been a wonderful tool to sell energy efficiency projects to their senior management. No free ridership is indicated for this project.

Site	IOU Application Number	IOU	NTG Ratio
A013A	2K5-L0371EG	PG&E	0.97

This project consisted of the installation/replacement of several types of EE technologies. Site A013a did an overall energy audit of its facilities using an RFP process to identify a vendor. Based on the audit recommendations, Site A013a upgraded and replaced technologies using a 'phased approach' for its 3 largest energy using sites. The incentive was factored in as part of their cost/benefit analysis for each project. The incentive offset most of the cost of the project, and the payback periods were greatly reduced. As a result, the incentive significantly influenced their installation decisions. Without the incentive, they would probably not have installed energy efficient technologies. The program also influenced them to participate in the NR Demand Response program. A low free ridership level is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A014	2K4-L0227E	PG&E	0.00

Growth in the company's cooling loads over the past few years led them to outgrow their existing air-cooled chillers. They were replaced with three 550 ton air- water-cooled chillers. The incentive did not factor into their business decision because they needed to expand their chillers to meet capacity needs anyway. The incentive was a 'pleasant benefit'. In addition, the company performed its own detailed energy audit and PG&E did a checklist audit that confirmed their recommendations. However, participation in the SPC program did influence them to replace roof-top packaged units with water-cooled chillers at another location outside of California, which is evidence of participant spillover. With a $130 million energy usage expense, the company focuses on its energy cost portfolio and tries to utilize energy-efficient programs when possible to reduce these costs. For this chiller expansion project, the information collected suggests a very high free ridership level.

Site	IOU Application Number	IOU	NTG Ratio
A015	2K4-L0213EG	PG&E	1.00

This controls upgrade came about for a number of reasons. Site A015 has 5.5 million square feet of conditioned space and has been interested in standardizing on its cooling controls for a number of years. Several things enabled them to go forward with this project. The incentives from the SPC program were a major factor, because they brought down the return on investment to within acceptable levels. The new control system has allowed them to realize significant efficiencies beyond the upgrade itself. For example, they are now able to use the economizers, which they couldn't previously with their pneumatic control system. Also, they are achieving significant non-energy benefits, in terms of improved comfort in their facility, improved worker productivity, and reduced maintenance requirements. They hope to eventually install DDC controls throughout all their facilities. All of this information points to a low level of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A016	2017	SDG&E	0.92

Site A016 replaced a fairly old centrifugal chiller functioning with significant problems based on a vendor's recommendation. The vendor provided substantial assistance during the planning phase of the project. The company said they would have installed as the same level of efficiency if no SPC incentive had been available but considerably later. Since this project, the company has and will look for incentives for all EE upgrades. This suggests a low probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A018	2050	SDG&E	0.83

Site A018 installed Vedas and upgraded to DDC controls on their HVAC equipment. The company is always looking to improve its energy efficiency but the SPC program shortened the measure paybacks, making it financially feasible to install more than 30VFDs at that time. An engineering consulting company that Site A018 often works with on EE projects, provided a lot of help with the calculations and had a large role in planning the project. Without the incentive, the company wouldn't have installed this additional EE equipment, but they did indicate that they have done less expensive EE measures without incentives. This suggests that if EE measures are financially feasible, they will install them even without incentives. All of this information indicates a low probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A019	2232	SDG&E	0.28

Site A019 received an incentive to improve the efficiency of some of their bio gum production lines by taking several actions: caustic cleaning one of the heat exchangers, replacing the heat exchanger of still #2, adding steam injection control valves and improving still back flush systems. Caustic cleaning was done to improve the performance of the heat exchanger. The incentive helped to decrease the payback time and Site A019 wouldn't have done the caustic cleaning without the incentive at that time, but would have potentially done it around 1 year later. The company has no new measures planned as a direct result of their participation in the SPC program. Without the incentive the company may not have installed all the measures at the same time but all would have been done eventually. The above suggests a high probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A020	2046	SDG&E	0.00

Site A020 replaced a 10 year old press that had failed. In seeking to replace this machine, they also to increase its capacity. This was the first time they had replaced the press and they indicated that the program incentive wasn't very significant in their decision to install. They would have taken the same action at the same time even without the incentive. However, now that Site A020 knows about the program they will look for incentives whenever possible. All of the above suggests a very high probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A021	2094	SDG&E	0.17

Site A021 replaced a ten year old functioning dust collector in one of their production lines without any third party help as part of the SPC program. The production line process was changed and the dust collector was not adequate for the new production line. The company would have replaced the dust collector at the same time regardless of the SPC program incentive, but reported that the incentive was somewhat significant in their decision to pursue replacement. In addition, the SPC program has been very significant to the company pursuing additional measures. These findings suggest a high probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A022	2K4-L0270E	PG&E	1.00

Site A022, a broad service food distributor, decided on their own with the help of the PG&E website and a bit of help from the equipment vendor, to pursue replacement of their high pressure sodium lamps with T-5s. Their current sodium vapor lamps were fully functional but they sought to reduce energy costs, and consumption as this was soon after the energy crisis. They had never done a T-5 retrofit project prior to this installation. They have since pursued other PG&E rebates for a LED exit sign retrofit and are currently looking into installing occupancy sensors in the hallways. All of these findings are indicative of no free ridership for the current project.

Site	IOU Application Number	IOU	NTG Ratio
A023	2K4-L0168E	PG&E	0.25

This lighting retrofit project was motivated by a number of different factors. Existing lighting equipment was out-of-date, and many different types and vintages of measures were installed. In undertaking this project, Site A023 desired to update and standardize installed lighting measures and upgrade to energy efficient fixtures. In selecting energy efficient equipment, their primary goal was to reduce energy use, and mitigate the environmental impact of the installed equipment. Site A023 also sought to reduce maintenance requirements. Incentive dollars from the SPC program helped to meet their financial requirements by bringing down their payback period to within 7 years and providing for self-funding (i.e., positive cash flow) of the equipment within 10 years. The technical assistance provided by their EESP was fairly significant in their decision to upgrade to energy efficient equipment, while the incentive provided through the SPC program was not as important.

Site	IOU Application Number	IOU	NTG Ratio
A024	2K4-L0177E	PG&E	0.88

The opportunity to improve the energy efficiency of Site A024's chillers resulted from a combination of factors. Site A024 was having problems with their chillers because they weren't designed properly for their designated application, and were oversized. Faced with the need to replace its chillers to address these problems, Site A024 elected to install smaller, more energy efficient chillers. A secondary goal was to eliminate CFCs and they were able to use CFC replacement dollars to fund a portion of the equipment cost. Incentive dollars from the SPC program helped to meet their financial requirements by bringing down their payback period to within 7 years and providing for self-funding (i.e., positive cash flow) of the equipment within 10 years. Site A024 indicated that although they appreciated the incentive, they probably would have installed the more energy efficient equipment even without it, suggesting there is a high probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A025	2K4-L0105E	PG&E	0.92

Site A025 is a refined energy products transportation company that received an SPC incentive to increase the pipe diameter on three sections of their transportation pipelines. The current pipe was undersized but fully functional. Spec Services, a vendor, verified the company's design. The incentive was very significant to the replacement of the pipe sections and wouldn't have ever done the upgrade without an incentive. The company has also previously done pipeline upgrades with SPC incentives. The above findings indicate a low probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A026	2K5-L0650E	PG&E	1.00

Site A026 upgraded their compressor to a 75 HP single stage rotary screw compressor with VSD. They were approached by West Coast Compressors their sponsor who gave the company the idea and played a very significant role in the planning and implementing of the project. However, due to their initial company contact leaving West Coast Compressors before the project application was complete, they encountered difficulty and were unsure of the calculated energy savings on the application. The SPC incentive and help from the EESP were both very significant in the company's decision to upgrade the noisy 7 year old functioning compressor. Site A026 also indicated that without the program they definitely would not have upgraded the compressor at that time and are unsure if they would have at a later date. The above findings indicate no free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A027	2K4-L0160E	PG&E	0.38

This self-sponsored applicant replaced an aging chiller, with a high efficiency screw compressor. The former chiller was about to break down. The facility is a luxury hotel/spa, which is run by directors with a "bottom-line" mentality. According to the interviewee, the company installs EE equipment as standard practice to save money in the long run. While they highly appreciated the generous rebate, they indicated they were going to have to buy an

EE chiller at some point anyway. Findings suggest a medium to high probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A028	2K4-L0272E	PG&E	0.17

This is a case where the audit had more of an influence than the incentive rebate. The facility manager said that he had been trying to convince the corporate decision makers for years to install EE lighting, but it was not until an outside party came in to point out the savings, that corporate began to act. The rebate really did not have much of an impact, as the decision was made as a result of the information provided in the audit. A high free ridership level is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A029	2K4-L0033E	PG&E	1.00

This company is a non-profit organization. The facility manager expressed that they had been in dire financial trouble due to high natural gas prices, and the company was on the verge of going bankrupt. “This project saved my job”, said Larry Schell, the facility manager, “I was able to justify my paycheck by saving the company money on the new lighting fixtures.” Due to the lack of available investment capital, this non-profit company would never have been able to finance the lighting project without help from the program. All of this suggests no free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A030	2K4-L0092E	PG&E	1.00

This project could be considered an ideal SPC candidate and maybe ever the "Poster Boy" of incentive program. The customer did not provide any evidence of free ridership. Site A030 had just installed standard lighting only a couple of years ago but the incentive gave them the idea to install high efficiency lighting. They said there was no chance this installation would have taken place without the program. As a result of SPC participation, the Company has initiated EE projects nationwide in 17 other facilities (provided there is an incentive) providing evidence of spillover.

Site	IOU Application Number	IOU	NTG Ratio
A031	2K4-L0203E	PG&E	0.58

The project involved installing efficient lighting throughout Site A031's many buildings. The customer may have gone ahead with the installations on their own but the incentive did help accelerate installations of these measures. The plant manager highlighted the unique benefits of EE project in an educational facility helps lower tuition; improves quality of education via improved lighting; gives students and EE mindset that they will take with them into the future. A moderate level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A032	2K4-L0352E	PG&E	0.33

This project concerns the replacement of an old HVAC system with a liquid nitrogen unit. Site A032 frequently upgrades equipment at its facilities around the country, while participating in efficiency programs when available. The SPC program got the attention of upper management and pushed the project along. A high level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A033	2K4-L0039G	PG&E	0.46

This project consisted of installing a new double-skin acrylic transparent roof on a greenhouse. The facility cited rising natural gas prices as the principle driver behind the upgrade. The material is very high-tech and the cost of installing the upgraded roof would be too high for the greenhouse to complete the project without the incentive. Without the rebate, the same measure would have been installed up to two years later. This suggests a medium level of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A034	2K5-L0475G	PG&E	0.63

This was a boiler blow down project for heat recovery at a food processing plant. The old boiler worked fine, but it operated 24 hours per day. The new unit pressurizes better and is not continuously blowing out steam. The incentive paid for about half the project and without it, Site A034 could not have afforded the new boiler. A medium level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A035	2K4-L0287G	PG&E	0.51

This project involved the replacement of an old VOC incinerator with a new one (VOC abatement). The customer received a large incentive through the program and indicated that without the rebate, there was a 50/50 chance of the project going through. He also noted that the incentive money help move the project along and allowed Site A035 to buy the most efficient equipment available. The customer does have some qualities of a freerider, however, because they recently installed high efficiency lighting in three building without applying for incentives. A medium level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A037	2K5-L0358G	PG&E	0.63

This applicant received a rather large incentive for the replacement of six or seven heat exchangers at a sugar processing plant. The prior equipment was 42 years old but worked fine. Without the incentive they probably would have upgraded two or three heat exchangers, but certainly not all of them. This suggests a medium level of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A038	2K5-S0142EG	PG&E	0.85

Site A038 acquired a property that was formerly a long-term care facility with 24/7 occupancy and loads. The building's HVAC system had pneumatic controls which were well suited for continuous load. The current operating schedule is tied to standard business hours, and energy usage is more variable. The DDC controls which they installed are more efficient for this non continuous usage patterns and are able to adjust to the actual run time of facility. These electronic controls have significantly improved comfort levels in the facility and have also reduced maintenance requirements, by allowing remote monitoring of HVAC equipment and troubleshooting of problems. The incentive provided by the SPC program was "somewhat significant" in their decision to upgrade their control system. A low level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A039	2K5-S0143E	PG&E	0.75

Site A039's installation of new chiller pumps was a small part of a much larger chiller upgrade project. Although this was a minor component, the new pumps have allowed them to realize significant energy savings. They now have a much more efficient pumping set-up with VSDs and smaller pumps that are better matched to their loads. The new pumps have made this possible. Given that this was only a fraction of their total project, the SPC incentive was "somewhat insignificant" in their decision to upgrade the pumps, and they acknowledged they probably would have purchased the same equipment even without the program incentive. This suggests a low level of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A041	2K5-L0895E	PG&E	0.29

This project was for a company that replaced its overhead lighting with EE lighting. This company is very "green-minded" and would like all future projects to be EE. However, they are currently undergoing some structural changes and are not considering such projects at this time. The facility was audited both before and after the project was completed. The customer stated that the audit was not really a factor in his company's decision to install the equipment, as they would have installed the same equipment without the audit. Without the incentive, the company would have installed the EE lighting buy maybe would have "phased" the project in over 18 months. A high level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A042	2208	SDG&E	0.54

Site A042 upgraded to interior high bay linear fluorescent fixtures, added a high bay lighting sensor, photocells and 4 ft T-8/T-5 lamp and electric ballasts. Although they were first contacted by the EESP, Site A042 developed the idea for this project on their own and was not convinced by the EESP to pursue installation. However, the vendor/EESP told them about the SPC program and played a very significant role in their decision to pursue installation. The company also would have either not installed at all or installed the measure at a later date or installed less of the measure without the SPC program. They now do more energy efficient projects on their own which they attribute to their participation in the SPC program. The above findings indicate a medium probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A043	2032	SDG&E	0.20

Site A043 replaced two 10 ton AC units and 7 economizers at the recommendation of a vendor. This vendor also sponsored the application and assisted with the planning and implementation. The old equipment was fully functioning but undersized and not as efficient as they would have liked. The company would have installed the higher efficiency equipment regardless of the incentive, but at a later time. All of the above suggests a high probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A044	2247	SDG&E	0.50

Site A044 replaced a 15 year old centrifugal chiller with a broken motor. They would have replaced it with a high efficiency model regardless of the SPC program and the help from numerous personal third party consultants. However, with the incentive, the payback period was reduced to within 4 years, thus making the upgrade more attractive. There is a medium to high probability of free ridership since the company said they would have installed high efficiency equipment regardless of the program.

Site	IOU Application Number	IOU	NTG Ratio
A045	2115	SDG&E	1.00

Site A045 replaced 17 fully functional compressors with a 150 ton water cooled chiller with VSD. They did this to reduce energy costs, and improve measure performance. They knew of the SPC program before they began gathering information on the compressors. After that they contacted the third parties for assistance. They indicated that the EESP help was somewhat significant and the SPC program was very significant in their decision to replace the compressors. Without the SPC program they definitely would not have replaced the compressors until the compressors failed, therefore there is no probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A046	2184	SDG&E	0.36

Site A046 upgraded to a 700 ton chiller from a smaller 15 year old one with significant problems because they wanted to decrease energy costs and improve performance. They had significant help from numerous third party vendors and funding sources. The company said they would have upgraded the chiller regardless of the SPC program, but at a later date. Site A046 was a SPC participant both before and after the PY2004-2005 program making it difficult to quantify this particular program year’s influence. Overall, this suggests a high probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A048	2004-88	SCE	0.92

For Site A048, the incentive was very critical in the decision to move forward with this phased-in energy-efficiency project for the entire school district. The EESP sold the idea to the school district for upgrades of technologies at all of Site A048's 26 sites and informed them of the SPC program. The incentives played two important roles in this case: (a) reduced the payback period so the project met financial criteria; (b) reinforced the School Board decision to implement to project now rather than waiting another 5 years, or more. A low level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A049	2004-134	SCE	1.00

This project involved installation of economizers on 25 roof-top packaged AC units**.** Reasons for installing the economizers were to reduce energy costs and to acquire the latest technology. The incentive from the program was essential to doing this project; without it, the project would not have been done. No free ridership is indicated for this project.

Site	IOU Application Number	IOU	NTG Ratio
A050	2004-155	SCE	0.28

Site A050 installed an additional piping header to reducing pumping head (load). The project was undertaken to solve a problem: too much pressure drop in existing piping resulting in increased flow rates. Additional capacity was also desired to accommodate future expansion. The incentive was somewhat significant in the installation decision. Without the SPC program and incentive, the measure would probably have been installed anyway, six months to one year later. This suggests a high level of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A051	2004-204	SCE	0.28

Site A051 said they would have done the project anyway, though it would have been delayed six months or more. A major driver is their company's CO_2 reduction goal. In fulfilling this requirement, they are aggressive, but reported that the SPC incentives were nonetheless significant in moving this project forward. A high level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A051A	2004-181	SCE	0.58

This is one of three sites for this company that received incentives through the SPC program in 2004. The company hired an outside vendor to evaluate the institution's national energy use. The vendor suggested a lighting project including fluorescents, controls and HID replacement Site A051A to help reduce energy costs since the current lighting equipment was beginning to deteriorate, resulting in reduced lighting levels at the facility. An EESP was subcontracted through this vendor to complete the application, and install the measures. The SPC program was somewhat significant to the decision to install the fluorescents and the Company probably would not have installed the lighting at this site without the SPC incentive. They also indicated it is "somewhat likely" they would have purchased fewer measures, and most likely would have installed them 2 to 3 years later. Since completing this SPC project, the Company has installed additional high efficiency equipment with and without incentives, but not at this site. It is difficult to gauge the influence of this particular SPC project on future and national energy projects because the Company participates regularly in the IOU's energy efficiency programs. The SPC program has led to a change in the internal energy program. All of this is suggestive of a medium probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A052	2004-226	SCE	0.77

This project involved re-piping and connection of one domestic hot water station to another hot water station to allow shutdown of one station, and included installation of about 500-600 feet of piping. In addition to building in this redundancy, the customer desired to reduce energy use. The SPC financial incentive was considered “somewhat significant” in the decision to install this measure. Without the program, equipment installed would not be as efficient. A moderate level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A054	2004-227	SCE	0.17

The company need to expand injection molding capacity (hence larger chiller capacity) and said they would have done the project anyway without delay. The timing of the project was driven by the failing of their old chiller. Whenever a new capital project involving energy efficiency is undertaken, it is handed off to the EESP and the company gets a check when project is completed. This process works well, but is suggestive of high free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A055	2004-447	SCE	0.38

This project involved the installation of 557 setback programmable thermostats in the guestrooms of a large hotel. The hotel desired to reduce energy costs by replacing old, outdated equipment. The program incentive was “somewhat significant” in the installation decision; without it, it would have been harder to convince the hotel owner to do the project. The payback with the incentive was 1.7 yrs., without it was 2.0 years. Without the program and the incentive, they probably would have installed these programmable thermostats, suggesting a high level of free ridership for this project.

Site	IOU Application Number	IOU	NTG Ratio
A058	2004-552	SCE	0.41

This project involved a compressed air system upgrade. Stated reasons for undertaking this project were the program rebate, the desire to reduce energy costs, and the need to replace old, outdated equipment. Without the program, they probably would have upgraded the compressed air system anyway, within six months to a year later. This suggests a medium to high free ridership level.

Site	IOU Application Number	IOU	NTG Ratio
A059	2004-594	SCE	0.25

The impetus for this project came from prior (corporate) experience from a similar project at a Missouri plant. The company previously had 3 compressors at capacity; this project resolved this problem (by freeing up compressor capacity). This suggests a high level of free ridership, since the Company said they would have done the project even without an incentive.

Site	IOU Application Number	IOU	NTG Ratio
A061	2004-660	SCE	0.77

Corporate HQ was motivated to install 480 setback programmable thermostats in all rooms because replaced room thermostats were still functioning fine, but had limited functions. The program and financial incentive was very significant in influencing the Company's decision to install the measures earlier than planned. The incentive significantly reduced the payback time period into a reasonable range. However, program incentives work well for the company only when their projects and program incentive availability are in sync. The Company has installed additional EE measures, with some receiving incentives and some not. A low to medium level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A062	2004-784	SCE	0.05

The company had a capacity constraint challenge and needed to replace its old and outdated compressors which was not meeting load needs and was constantly malfunctioning – slowly failing. The program/incentive had very little impact on the decision to install. The equipment was constantly malfunctioning and company decided to replace it for business reasons. This site is most likely a free-rider since participating in the program was an afterthought. The incentive was simply an 'added bonus'. The company would have replaced the compressors if the incentive was not available.

Site	IOU Application Number	IOU	NTG Ratio
A063	2004-270	SCE	0.72

This project involved a retrofit of T12 4- and 6-lamp fixtures with 4- or 6-lamp T8 fixtures with electronic ballasts. Stated reasons for doing this project were to reduce energy costs, to obtain a rebate from the program, and to reduce poor-performing, outdated lighting equipment. The program incentive was considered “very significant” in the installation decision, reducing the payback to one year. Without the incentive, the upgrade probably would not have taken place, indicating a low level of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A064	2004-450	SCE	0.33

This Company manufactures prosthetic heart valves and heart valve products for individuals fighting cardiovascular disease. This project involved replacement of 188 250-watt metal halide fixtures with T5 fixtures in the packaging area and the clean room area (most of the fixtures). These are controlled by an EMS system. The basic reason for installing the lighting fixtures was to reduce energy costs. Participating in energy efficiency programs helped company achieve its annual energy consumption goals. Findings suggest a fairly high level of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A065	2004-595	SCE	0.54

The lighting retrofit project was motivated by a number of different factors. The existing lighting measures were between 20-40 years old. Site A065 was in the process of updating all of their lighting equipment to make properties more desirable for tenants. It participated in the program to reduce energy costs and to get a rebate from the program. This Company has a payback threshold of 3 years; with the incentive the payback was 1.45 yrs. Without the incentive, the company would have phased the project in across 11 sites within two years later. A medium level of free ridership is suggested.

Site	IOU Application Number	IOU	NTG Ratio
A066	2005-251	SCE	0.45

A vendor performed a technical analysis of energy efficiency options and this information significantly influenced Site A066's decision to move forward with the project. This Company has a 3-year payback threshold for these types of projects. The incentive reduced the payback to under 3 years. The Company is very proactive in pursuing EE and finds the incentives from the SPC program to always be significant in terms of reducing paybacks. These incentives usually make or break projects, especially HVAC projects. A medium level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A067	2005-186	SCE	0.47

Site A067 performed a lighting retrofit, replacing 400MH lamps with 4 lamp 4-foot T8 fixtures with electronic ballasts. Their primary motivation was to reduce energy costs. The financial incentive was considered "very significant"; without it, they probably would have not undertaken the upgrade. A moderate level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A068	2004-713	SCE	1.00

This company's skylights were inadequate, so they sought improvements in their lighting. However, to justify their project, they needed to demonstrate significant energy and cost savings. The SPC program and the financial incentive were very critical components in company's decision to install measures; for example, the rebate covered $44 of $50 for motion sensor and was very influential in getting sensors to be installed in their facility. Also, the Company said they would not have installed any equipment without the rebate and would have only installed standard efficiency measures upon equipment burnout. No free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A069	2005-184	SCE	0.67

Site A069's project involved the installation of ceiling mounted occupancy sensors. They sought to reduce energy costs, and to receive a rebate for the installation. They rated the SPC program and incentive as "very significant" in their decision to install these sensors. Without the program, they probably would not have installed this equipment, or they would have installed it much later than they did. Free ridership is low to medium in this case.

Site	IOU Application Number	IOU	NTG Ratio
A070	2005-199	SCE	0.63

Site A070 is both a customer and a 3rd Party implementer who promotes SPC heavily to when selling efficient lighting equipment. Their own SPC project involved different types of measures and fixtures that could be used for demonstration purposes for customers. It received a generous incentive (covering most of project cost, leaving 2 month payback). They definitely would not have done the project at the time without the SPC incentive, but said it would have occurred within two years. A medium free ridership level is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A071	2004-596	SCE	0.17

The roof of Site A071 was functioning but with some leaks. The main motivating factor was to eliminate leaks by installing a new roof; energy cost reduction was a secondary factor. The Company said they would have definitely installed a cool roof without the SPC incentive at the same time (indicating high free ridership). They have a basic need to incorporate EE equipment in their facility and the SPC incentives help to reduce the cost. As a result, company is very familiar with SPC program and utilizes it whenever it conforms to project's timeline/process.

Site	IOU Application Number	IOU	NTG Ratio
A072	2004-207	SCE	0.33

Both the incentive and the EESP were instrumental in the Company participating in the SPC program. The company had no solid payback threshold. They said would have probably installed similar measures without the incentive around the same time period. Improved lighting quality also increased productivity of their employees. All of this suggests a high level of free ridership

Site	IOU Application Number	IOU	NTG Ratio
A073	2004-81	SCE	0.34

This company needed to replace equipment, and indicated that the SPC program was somewhat significant in pushing them to install a higher level of efficiency. Based on the answers given, a high level of free ridership was indicated.

Site	IOU Application Number	IOU	NTG Ratio
A074	2004-9	SCE	0.84

Site A074, a grocery store chain, replaced its open refrigerated cases with refrigerated cases with doors in four of its stores. In addition to seeking to reduce energy costs and receive a rebate through the program, the company wanted to test these new refrigeration cases out in its stores. SPC incentives motivated them to do that. They considered the SPC program and incentives to be "very significant" in their decision making. This suggests a moderately low free ridership level.

Site	IOU Application Number	IOU	NTG Ratio
A075	2004-158	SCE	0.25

This project is comprised of the application of a cool roof coating on a building. This application was applied in at the same time the building's massive leaky roof was being replaced. The incentive influenced the decision to apply the Cool Roof coating. It significantly reduced the cost of the project. A high free ridership level is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A076	2004-605	SCE	0.42

This $1.1 million project (incentive of $281,555) project included replacing the relatively new (<2-yr old) lighting system with more efficient lighting measures at the company's distribution warehouse. The company was going to install the measures at the same time or within six months without the incentive. The motivating factor was to reduce energy costs. Due to participation in the program, Energy Efficiency is now formally considered in their decision-making process when retrofitting their existing sites or building new ones. A moderate level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A077	2004-587	SCE	1.00

This company definitely would not have installed the lighting measures without the SPC program and incentive. The project was proposed by an outside vendor and the Company tested the technology for a year to make sure it worked in a cold warehouse environment before deciding to participate in the program. No free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A078	2005-18	SCE	0.38

This project involved major lighting and controls retrofits. The company had an audit and these measures were included in the recommendations. The audit was most influential in the company's decision to participate in the SPC program, and enabled it to pursue lighting retrofits earlier than it would have on its own; As a result of participation in the program, the company now aggressively pursue program opportunities for installing EE equipment at its facilities, and plans to install other audit-recommended measures in the future. Medium to high free ridership is suggested.

Site	IOU Application Number	IOU	NTG Ratio
A079	2004-14	SCE	0.20

Site A079 upgraded its lighting through the program. This lighting upgrade involved installation of CFLs, occupancy sensors, and delamping. They implemented this project in order to replace older, inefficient lighting measures, and to reduce energy costs. They rated the SPC program and incentive as "somewhat significant" in their decision to upgrade their lighting, but said without the program, they probably would have installed the same equipment anyway. High free ridership is therefore indicated.

Site	IOU Application Number	IOU	NTG Ratio
A080	2004-109	SCE	1.00

Both the SPC incentive and energy savings from upgrading to EE measures were extremely influential in getting approval for project. Without the rebate, the company would have kept the existing lighting measures. The facilities manager had such a positive experience with the program that company (a) has included a new category 'energy efficiency improvements' into their planning tools/budget, and (b) is planning 35 new EE projects under SCE programs with the assistance of the SCE account representative. No free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A081	2004-118	SCE	0.17

Site A081 clearly would have done this project anyway without the SPC incentive; This was a screw-in CFL replacement project; the equipment replaced was only 6 months old; such an opportunity; scalable: The SPC incentive had little influence on their installation decision. The company's EE program has always been aggressive, and the SPC complements their efforts. A very high level of free ridership is suggested.

Site	IOU Application Number	IOU	NTG Ratio
A082	2004-182	SCE	0.50

The audit was most influential in the company's decision to install higher EE lighting retrofit measure through the SPC program. Site A082 installed the measures to increase measure performance and to reduce energy costs. Without the audit and the incentive, the Company probably would have installed the measures 4 to 5 years later. Their lighting quality was also significantly improved. This Company participates regularly in the SPC and Express Efficiency statewide programs. A medium level of free ridership is suggested.

Site	IOU Application Number	IOU	NTG Ratio
A083	2004-269	SCE	1.00

Site A083's primary reason for replacing its lighting was its desire to achieve energy use and cost savings. This helps them to meet the goals of their Sustainability program, called Vision 2010, which calls for them to reduce energy use by a certain percentage by 2010. The removed lighting equipment was between 20 and 40 years old but was still functioning. The incentives provided through the SPC program were somewhat significant in their decision to install the energy efficient lights, and were factored into their economic calculations and decision making. Without the SPC incentives they would not have undertaken this retrofit. No free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A084	2004-460	SCE	0.28

Site A084 installed a series of lighting retrofits. The EESP drove this project; they initiated the project and were very influential in moving the project forward. The economics of the project as presented by the EESP helped get the project approved by the Facilities Manager. They said they probably would have done the project without the incentive within a year. This suggests a high level of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A085	2004-560	SCE	0.79

Site A085, a refrigerated warehouse, undertook a lighting upgrade through the SPC program. They replaced 400W high pressure sodium fixtures with 250W metal halide fixtures. Their sole motivation was to reduce energy costs. They rated the services of the SPC program EESP and incentive as "very significant" in their decision to upgrade their lighting. Without the program, they probably would not have undertaken this upgrade, or would have done it 4 or more years later. Therefore, the level of free ridership is fairly low.

Site	IOU Application Number	IOU	NTG Ratio
A086	2005-308	SCE	0.92

Both the audit and the SPC incentive were very influential in the decision to install energy efficient lighting equipment. The audit recommended EE lighting and HVAC equipment, and incentive provided the means to get approval for the lighting component and participate in the program. Without the audit and incentive, Site A086 would not have participated in the program. In addition, Site A086 has started implementing the other audit recommendations with the help of SCE and SDG&E energy efficiency programs and plans to look for further opportunities to upgrade or install other energy-efficiency measures. Low free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A087	2004-180	SCE	0.50

This project involved a retrofit of 400 watt metal halide lamps with 8 lamp 4-foot T8 fixtures with electronic ballasts, and also a replacement of T12 fixtures with T8 fixtures, including delamping and installation of lighting controls. This process was implemented to reduce energy costs and improve lighting quality. The SPC program and incentive were considered "somewhat significant" in their installation decision. Without the program, they probably would not have undertaken this upgrade. All of this information points to a moderate free ridership level.

Site	IOU Application Number	IOU	NTG Ratio
A089A	2004-524	SCE	1.00

Site A089A's primary reason for replacing its lighting was its desire to achieve energy use and cost savings. This helped them to meet the goals of their Sustainability program, called Vision 2010, which calls for them to reduce energy use by a certain percentage by 2010. The removed lighting equipment was between 20 and 40 years old but was still functioning. The incentives provided through the SPC program were somewhat significant in their decision to install the energy efficient lights, and were factored into their economic calculations and decision making. Without the SPC incentives they would not have undertaken this retrofit. Therefore, there is no free ridership present.

Site	IOU Application Number	IOU	NTG Ratio
A090	2005-222	SCE	0.75

At Site A090, their existing window film was losing its efficiency and needed to be replaced. The SPC incentive was the impetus for the property manager installing the solar film much earlier than they could have otherwise. The incentive reduced the overall project cost and made it easier to get approval from the property owners. Even with $15,000 of unforeseen costs (to remove built-in furniture abutting windows), the project was worth implementing, given the rebate. This suggests low free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A091	2005-369	SCE	0.25

The roof of Site A091's building was deteriorating and starting to leak. In the process of investigating the replacement of the roof, the owner was made aware of cool roofs and their benefits and the SPC program from a contractor who was submitting a bid for the job. The owner called SCE to sign up for the SPC program. The $1,067 incentive 'had nothing to do with the decision to replace the roof. It was just a side benefit. However, participation in the program has impacted his decision to install future energy-efficiency AC measures. A high level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A092	2004-153	SCE	0.28

Site A092 had 22 year old refrigeration equipment that was fully functioning, but with significant problems and sought to replace it. The equipment they installed through the SPC program included controls and a monitoring system, which increased the efficiency of their ammonia refrigeration and ice back system. The incentive was very significant in that it reduced the payback to 6 months (from 11 months), but the company said they definitely would have installed the same level of efficiency without the incentive between 6 months and 1 year later. Participating in the program got the company to think a bit about other projects (even gas) and made company more aware that incentives are available to cover cap costs of projects that provide under 2 yrs. payback threshold. A high level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A093	2004-137	SCE	1.00

In undertaking this project, Site A093's primary goal was to reduce energy use cost-effectively, based on its own 3 year payback rule. The new controls replaced equipment that was quite old and had failed. The company had done these types of retrofits at other distribution centers around the U.S. Therefore, when the project was suggested by their sponsor, they were open to it. The incentive received from the SPC program was "very significant" in Site A093's decision to install the new compressor control systems. Without the incentive, they probably would have installed this equipment more than 5 years after this installation took place. This suggests no free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A094A	2004-259	SCE	0.25

Site A094A manages and leases real estate and has been installing variable speed drives (VSD) for the past 25+ years. Site A094A indicated that they first learned of the rebate from their account representative before gathering information to install the VSD on the 60-80 HVAC fans at multiple sites. They contacted a vendor to sponsor the application and install the VSDs. The only real effect of the SPC program on this company is that it allowed them to complete the project faster, as Site A094A indicated that the installation rate would have been reduced i.e. they would have installed the same number of VSDs but it would have taken longer to complete the project. This is suggestive of a high probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A095	2004-582	SCE	1.00

Site A095 did a benchmarking study several years ago to identify the stores that were using the most energy and prioritized those stores for energy efficiency improvements. This project was undertaken in response to that study.

In undertaking this project, Site A095's primary goal was to reduce energy use cost-effectively, based on its own 3 year payback rule. The incentive received from the SPC program was “somewhat significant” in Site A095’s decision to install the new compressor control systems. Without the incentive, they probably would have installed this equipment more than 5 years after this installation took place. No free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A096	2004-780	SCE	0.41

Site A096 installed VSDs on evaporator fan coils in order to reduce energy costs, upgrade to newer technology, and replace outdated equipment. The SPC program and incentive were “very significant” in their decision to install this equipment. Without the program, they probably would not have undertaken this project, or would have pursued it much later. A high to moderate free ridership level is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A097	2004-505	SCE	0.05

Site A097 indicated that participating in the SPC program and receiving an incentive was simply an added benefit since the company was going to install the energy efficient measures even if it has not receive a rebate. The program made no difference in their decision to install. They would have installed the VSDs at the same time. The Company was already aware of how to make improvements to the foundry with or without the incentives. This is indicative of a very high level of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A098	2004-507	SCE	0.88

The Company was near a chapter 11 status at the time of this equipment replacement / improvement project, which increased their production and product quality, and reduced their energy costs by $15-20K /month. They indicated that the project would not have proceeded at that time without the SPC incentive. The Company has recovered financially, but now integrates SPC incentives into their financial analysis for prospective EE projects. A very low level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A099	2004-27	SCE	0.00

Site A099's primary reason for installing a large VSD was its desire to achieve energy use and cost savings. This helps them to meet the goals of their Sustainability program, called Vision 2010, which calls for them to reduce energy use by a certain percentage by 2010. For VSDs, they look at very large motor applications where the load is highly variable – these are the most cost-effective applications. The incentive provided through the SPC program was not significant in their decision to install the VSD – they perceived the incentive as somewhat risky, and the project had already met their maximum payback requirement of 2.5 years. Without the SPC incentive, they probably would have installed the VSD anyway, since the payback was very attractive regardless. Site A099 is clearly a free rider.

Site	IOU Application Number	IOU	NTG Ratio
A101	2004-34	SCE	0.17

The customer indicated they would have done the project regardless of the program/incentive. On two occasions since 2001 they have been installing VSDs on motors and continue to do so. In 2001, their account representative asked about potential future projects, at which time the customer identified several (including the one sponsored through the PY2004 SPC program). They were told to apply for incentives since they may be available. The 2004 project was pivotal though, as it was a large scale project that demonstrated what was possible, and enabled the company to improve control over their pumping sequence & system pressures. The customer is continuing with more projects, and will continue to seek SPC incentives, but would do projects whether or not an incentive is available. A high level of free ridership is suggested.

Site	IOU Application Number	IOU	NTG Ratio
A102	2004-65	SCE	0.58

Site A102's project involved modifying its water pumps and piping to reduce pump pressure and load requirements. The main objective of this project was to realize a large savings in energy costs. The SPC program and incentive were "somewhat insignificant" in their decision. They said they would have done this project anyway, though more than 3 years later. A medium free ridership level is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A103	2004-237	SCE	0.58

The company had a capacity constraint challenge and needed to replace its old and outdated compressors which were not meeting load needs and were constantly malfunctioning – slowly failing. The program/incentive had little impact on the decision to install. The equipment was constantly malfunctioning and company decided to replace it for business reasons. However, the incentive may have caused them to upgrade to EE compressors, therefore a moderate level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A104	2004-278	SCE	0.58

Site A104's project consisted of installing a VSD on a 1,500 hp pump motor. Their only objective in doing this project was to reduce energy costs. They considered the SPC program and incentive to be "very significant" in their installation decision; the incentive reduced their payback down to 1 year. Without the program, they probably would have installed the VSD, though perhaps not for another two years. A medium level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A105	2004-343	SCE	0.58

Site A105's installation of a new 850 ton evaporative condenser came about because of the efforts of an energy champion on their staff (the Building Engineer). He became a strong advocate for energy efficiency improvements at their facility, and initiated several improvement projects with the assistance of an EESP. At this particular site, the existing evaporative condenser was no longer big enough to handle the load. The choices were either to modify or replace the existing equipment. After talking to the SCE rep and the EESP, the potential for an incentive met the company's payback period threshold (< 2 years). Without incentives, the company would not replace any equipment early. Due to his knowledge of the SPC program and his good relationship with the SCE rep, he assisted other P&O sites with their energy-efficiency projects (e.g., lighting) for which incentives were paid. In all cases, the incentive paid for most of the project. This suggests a medium level of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A106	2005-159	SCE	0.50

Site A106 needed to replace old chillers that ranged in age from over 5 years to an average of 15 years old. Other motivating factors were their need to protect the environment (i.e., eliminate use of freon) and to reduce huge energy expenses. Site A106 would probably have installed the EE equipment without the incentive within three years later. Site A106 is more aggressive because of the potential to receive financial assistance with their projects – incentives are "icing on the cake". It keeps the team motivated. They have been participating in EE programs with all 3 IOUs since 2001. A medium level of free ridership is suggested.

Site	IOU Application Number	IOU	NTG Ratio
A108	2004-117	SCE	0.00

The Company was planning on installing chillers when they found out about the program. The SPC incentive/program did not influence company to install chillers; would have done it at the same time without the incentive. The incentive was a minor added benefit. This project is an obvious free rider.

Site	IOU Application Number	IOU	NTG Ratio
A109	2004-504	SCE	0.41

Site A109's project involved replacing three (3) 150 hp compressors with a single 350 hp VSD unit. This installation was done to accommodate future expansion, to gain more control over the equipment operation, and to reduce energy costs. The SPC program and incentive are deemed "very significant" in their decision-making. Without the program, they probably would have installed this equipment between 6 and 12 months later. This suggests a medium to high level of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
A111	2004-247	SCE	0.17

Site A111's project involved installation of a high-efficiency cement separator. Primary motivations behind this project were expanded process capacity, a more efficient separation process, and a higher quality product. The SPC program and incentive are "somewhat significant" in their decision-making. Without the program, they said they definitely would have installed this equipment at the same time as they did. Very high free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A112	2004-69	SCE	1.00

Site A112 takes advantage of all of the statewide energy-efficiency programs available in order to reduce its energy use and peak demand. The SPC incentive was very instrumental in their installation of energy efficient measures. Incentives were needed for the company to meet its 3-year payback period. Without them, the lighting measures would not have been installed. Energy usage is the company's second largest expense and since participating in SCE's SPC program, it has done several EE projects to help reduce its energy usage with the help of EE programs. No free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A113	2005-215	SCE	0.28

Site A113's lighting upgrade project involved replacing 400 watt Metal Halide fixtures with 4-lamp T5 fixtures with occupancy sensors. They sought to reduce energy costs and improve lighting quality. The SPC program and incentive are "somewhat significant" in their decision-making. Without the program, they probably would have installed this equipment, between six months and one year later than they did. Therefore, a high level of free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
A114	2004-663	SCE	0.08

In undertaking this project, Site A114 wanted to replace old outdated equipment and save on energy costs at this facility. The T-12 retrofit measure was identified through SCE Audit done in 2001, and the project was submitted as an internal proposal (without incentive); it was approved prior to seeking incentive and an installation contractor was secured as the EESP. Incentive was secured after decision to move forward with project. However, the incentive allowed customer to buy more fixtures than originally planned. Still, very high free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
R053	2K4-S0091E	PG&E	0.38

A PG&E auditor visited this site and recommended that a storage tank and lines feeding it be insulated. The tank insulation was rebated, but the line insulation was not due to complications in calculating the energy savings. The facility manager mentioned that he would have insulated the equipment at some point, but the audit and the SPC money moved things along faster. Otherwise it would have taken up to two years to have the work done. The audit and the SPC incentive had equal influence in the project. Medium to high free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
R167	2004-208	SCE	0.17

Site R167 is a food processing plant. They needed to replace a compressor and the associated controls due to a facility expansion and aging existing equipment. The company completed the application and calculations internally but required assistance from the vendor in equipment selection and energy calculations. This project would have happened at the same time regardless of the SPC program. This is suggestive of a high probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
R183	2004-440	SCE	1.00

This Company definitely would not have installed any equipment without the assistance of the incentive; their lighting system was fully functional but inefficient. The Facilities Manager conducted internet research to learn about lighting technologies and realized that he could also significantly reduce the company's $3.5 million /year energy costs by replacing inefficient lights. The Company is currently investigating other EE opportunities for heavy machinery. No free ridership is indicated.

Site	IOU Application Number	IOU	NTG Ratio
R186	2004-603	SCE	0.64

This Company was advised by a lighting EESP to pursue replacement of their high pressure sodium bulbs with fluorescent bulbs and addition of motion sensors at three of their distribution sites. The EESP prepared the calculations for the application, installed the lighting and has been following up with the project since completion. Without the help from the EESP and the financial assistance provided by SPC program, Site R186 would not have completed this lighting project at this time. They estimated they would have replaced with fluorescent bulbs at a later date, perhaps 2 years later. Since participation in the SPC program, the Company has changed to LED exit signs, and is currently gathering information on a solar energy project. This is suggestive of a medium probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
R195	2004-482	SCE	0.25

Site R195 is a cold food storage and distribution facility. They replaced a 24+ year old condenser as part of the 2004 SPC program. The condenser had significant problems and would have been replaced around the same time with an oversized, more efficient condenser regardless of the assistance that the SPC program provided. Site R195 indicated however, that the rebate was somewhat significant to their decision to install and now they always look for incentives for all their energy efficiency improvement projects. This is suggestive of a high probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
R204	2004-399	SCE	0.17

Site R204 installed an HVAC control system to reduce energy costs as advised by the sponsor of their application. The vendor contacted Site R204, evaluated the overall HVAC system, recommended the control system, and installed the equipment. The contact at Site R204 indicated that Site R204 would have installed some equipment or done something to reduce the energy costs without the help of the vendor and the SPC program at around the same time. This was their first EE project and since then Site R204 has been looking at other ways to reduce energy costs. This is suggestive of a high probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
R209	2004-592	SCE	0.17

The motivating factor for participating in the program was the replacement of an old leaky roof. In researching the many options for replacing the roof, the Project Manager found out about a cool roof seminar that SCE offered in their periodic newsletter. The Company chose the most efficient roof to improve comfort and reduce its energy costs. Since the company “needed a new roof – no matter what, the incentive was an added benefit”, according to the project manager However, the program did get the company to go with a cool roof since the benefits of the cool roof far outweighed installing a traditional roof. After participating in the program, the program manager also installed EE lighting for which the company received rebates for some of the lighting measures. This suggests a high level of free ridership for the cool roof measure.

Site	IOU Application Number	IOU	NTG Ratio
R210	2004-786	SCE	1.00

Site R210 replaced their interior high bay fixtures with 6 lamp T-8 fixtures on recommendation by a lighting vendor who contacted them and also sponsored their application. Site R210 was interested in replacing these fixtures previously but didn’t have the financial means to pursue the project. They wouldn’t have done the project without the SPC program until the fixtures died and it is very unlikely that they would have replaced less of the fixtures to cut costs. After their participation in the SPC program in 2004, Site R210 changed fixtures at another site, and is currently looking into upgrading other energy efficient products utilizing incentive programs including motors, air conditioning systems, and air compressors. All of this is suggestive of no free ridership.

Site	IOU Application Number	IOU	NTG Ratio
R228	2159	SDG&E	0.83

City Front Terrace, a home owners association, received the idea to install VFDs on their two condenser pumps from Green Mechanical, whom they frequently work with on EE projects. Without the SPC program, City Front Terrance probably would have installed the VFDs, but would have installed less at the same time or installed both at condenser pump failure. Also SPC has influenced City Front Terrace to pursue lighting projects, increase their payback threshold and bundle projects for bid. This is suggestive of a medium to low probability of free ridership.

Site	IOU Application Number	IOU	NTG Ratio
R231	2218	SDG&E	0.25

Site R231 manages movie theaters. As a result of a 10 year old VFD air handling unit failure, they contacted a vendor for evaluation and replacement equipment recommendations. Although the Company indicated that the SPC and EESP help was very significant in Site R231's decision to install, they said that without the program they would have definitely installed a new VFD at the same time. This is suggestive of a high probability of free ridership.

B.

Appendix B: SPC Site Reports

FINAL SITE REPORT

SITE A001 HANN **IMPACT EVALUATION**
SAMPLE CELL: ORIGINAL TIER: 5 END USE: 4-P

Measure	Exterior Wine Tank Insulation
Site Description	Winery

1. Measure Description

Apply insulation to 19 exterior wine storage tanks. The tanks are used for wine processing and storage and are insulated with Polarclad wine tank insulation. Insulation on the wine storage tanks reduces the load on the process chiller, which in turn saves energy. The project file states that the tanks are cooled with a process chiller. There are 19 tanks that are being insulated, most of which are different dimensions. The baseline for this measure is 19 tanks without any insulation.

2. Summary of the Ex Ante Calculations

Initially the savings were calculated using a tool developed by the project sponsor. These results were deemed unreasonable by the reviewers and the savings were recalculated using the SPC software tool. The new calculations resulted in reduced estimates for energy savings and largely reduced peak savings.

The ex ante impacts were calculated as follows:

- Demand Savings: 103.6 kW
- Annual Energy Savings: 187,453 kWh/yr

The incentive was calculated as follows:

- $0.08 per kWh
  Rebate was $0.08 x 187,453 = $14,996.24

3. Comments on the Ex Ante Calculations

The project file does not contain details of the ex ante calculations. The savings estimates were calculated using the SPC calculator tool. Critical input variables used in the calculator to estimate the energy savings are not indicated in the project file and there was limited documentation of the calculation details. Input details that are missing include the R-value of insulation, temperature of solution, and operating hours of the tanks. Therefore, many of these details had to be determined during the onsite visit. However, many of them could not be estimated from the onsite visit and engineering judgment was used for reasonable estimates.

The total savings in the Installation Report Review were given as 187,453 kWh/yr. This is identical to the figure in the utility tracking system.

The SPC tool accepts few critical input variables to generate the energy savings out put. The list of these inputs is as follows:

- Number of tank types (sizes)
- Tank material
- Tank dimensions (ft)
- Wall thermal transmittance (Btu/h·ft2·°F)
- Roof thermal transmittance (Btu/h·ft2·°F))
- Tank color (light, medium, or dark)
- Sun exposure (none, minimal, partial, or total)
- Wind exposure (none, minimal, partial, or total)
- City
- Location of tanks (outside, inside [unconditioned space] or inside [conditioned space])
- Refrigeration system efficiency (kW/ton)
- Condenser Type (air-cooled, water-cooled, or evaporative-cooled)
- Controls (fixed or floating head)
- Insulation Specifications for existing and proposed: (thermal resistance [h·ft2·°F/Btu·in] and thickness [in])
- Conditioned space temperature (°F)
- Glycol/water temperature refrigeration system setpoint (°F)
- Tank Temperature (average monthly temperature (°F) set point inside tank)
- Operating days per month

The above inputs imply the calculation is performed in monthly bins. The primary drivers for heat transfer calculations of this type are wind speed and temperature difference, which suggests that an hourly analysis with typical weather data may be more appropriate. However, the evaluation team felt that the difference in savings was negligible and a monthly bin analysis still gave reasonable estimates for the energy savings. Additionally, the evaluation team could not reverse engineer the SPC tool to evaluate the equations being used and apply them to an hourly analysis. Therefore, the SPC tool was used with the monthly averages.

4. Measurement & Verification Plan

This measure reduces the heat transfer into the wine storage tanks. The savings realized by this measure is the energy (kWh) required to compensate for the additional heat transfer. The fundamental premise in development of the measurement and verification plan was to determine the amount of energy consumed if the tanks had not been insulated. The M&V plan was implemented in the following four basic steps:

1. Verify insulation installation (type, thickness, area covered and installation quality), tank size and hours of operation.
2. Obtain monitored and archived data from customer records
3. Determine the reduction in annual heat transfer due to additional tank insulation and estimate kWh requirement of that heat transfer reduction by using the SPC Calculator tool
4. Compare ex ante savings estimates to ex post estimates

Industrial facilities of this type typically monitor their processes and keep records of monitored data, operational schedules and product throughput. The site contact has agreed to gather these data prior to our site visit. The requested data include:

- Operational schedules of the tanks
- Tank temperature set points
- Materials
- Fill levels
- Refrigeration compressor data, name plate information and/or documentation

The existence of these data and the willingness of the client to share these data with the evaluation team ultimately determined the M&V approach. If some data is unavailable, the evaluation team will use a self-reported approach.

Our on-site verification attempted to determine the overall quality of the monitoring installation and that any measurements are taken at the correct physical location. The accuracy of the temperature readings was verified by redundant spot measurements. Using existing data streams often introduces some uncertainty; however, when a site is fully instrumented, it can be the most accurate and most cost effective way to proceed

Formulae & Approach

The evaluation team did not use any formulae on this site since the SPC tool was used. It is believed the SPC tool was used which uses formulas based on thermodynamics and heat transfer. Unfortunately, these formulas could not be extracted from the tool.

There is uncertainty in calculating the savings associated with several factors. In general, a generic winery that installs a tank insulation measure will generate an estimated 10-15% error.

Uncertainty for the savings estimate for the insulation can be more fully understood by setting projected ranges on the primary variables.

Ts = tank surface temperature (+/-10 %, - 10 %)

Hr = Annual Operating hours (+/-5 %, - 5 %)

Accuracy and Equipment

The outside surface temperature of the tanks was measured with a Fluke 50D digital thermometer with type k thermocouples with instrumental accuracy of 0.1% +1.3°F. A small temperature gradient across the metal tank was assumed, which adds a small percentage of error.

All data collected was reviewed to ensure it conformed to realistic values and was cross verified with other data collected at the site to identify any anomalies. No data were removed from the analysis and all of the collected data were reasonable.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 7, 2007. Information on the equipment and operating conditions was collected by inspection of the tanks and cooling system. In addition, data were collected by interviewing the facility representative. We verified the tank surface temperature for all the tanks by spot temperature measurement.

Installation Verification

The site inspection verified that there were 19 insulated tanks. The tanks had approximately 3” of Polarclad insulation, corresponding to approximately R-12. During the onsite visit, the evaluation team verified the following SPC tool inputs:

- 19 total tanks with 5 different sizes
- Polarclad insulation on stainless steel tanks
- Tank Dimensions (varying for each tank)
- White tank color
- Total sun exposure
- Partial wind exposure
- Tanks located outdoors

- Refrigeration system efficiency of 1.1 kW/ton
- Air-cooled packaged chiller
- Fixed head controls
- Insulation value of approximately 4 [h·ft2·°F/Btu·in] with 3 inches installed on each tank
- Glycol/Water temperature refrigeration system setpoint of 44°F
- Monthly tank temperature varies by season
- Operating days per month vary by season

The evaluation team found that the tanks are in five different dimensions. Table 1 shows the monthly average tank temperatures and their operating schedules for all five different dimensions.

Table 1: Tank Temperature Schedule

	White			Red		
	Temp (F)	Days	Notes	Temp (F)	Days	Notes
January	58	20	over average ambient	55	20	over average ambient
February	58	15	over average ambient	55	15	over average ambient
March	58	10	over average ambient	55	10	over average ambient
April	58	4		55	4	
May	58	2		55	2	
June	58	1		55	1	
July	58			55		
August	45	4		45	4	
September	58	10	Exothermic period not considered	55	24	Exothermic period not considered
October	58	31		55	31	
November	58	30	over average ambient	55	30	over average ambient
December	58/32	30	Cold Settling at 32F for 16 days (average)	55	30	over average ambient

The facility operator reported that the season for the tanks begins in late August/ early September and are at full capacity from October 1 to January 15. The wine in the tanks is at varying temperatures during this time. The tanks are kept at 45 °F for three to four days. Then, the tank temperature is brought to 60°F while the yeast is added. Next, the tank is kept at 58°F for whites and 80°F for red wine, while an exothermic reaction takes place. The reaction occurs for approximately one month for white and ten days for red wine. The tank is kept at 58° for another three months once the reaction has finished (55°F for red wine).

For the purposes of calculating an average temperature for the SPC tool input, the red and white wine temperatures were allocated to different set of tanks to model the tank temperatures and the approximate proportion of 65% white and 35% as reported by facility staff. Months where the tank temperature was above average ambient were not input into the calculator because the calculator incurred energy penalties for these months.

Note that the cooling efficiency of the chiller was found onsite through manufacturer documentation on the specific chiller model.

This is the only measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table Table 6 below.

Scope of the Impact Assessment

The impact assessment scope is for the insulation tank end use measures in the SPC application (the "Other" end use category). This is the only measure in the application for this site.

Summary of Results

The ex ante calculations were performed using the SPC tool. The ex post savings were estimated using the same method. Some of the inputs to the SPC tool were estimated. The wall U-factor, jacket U-factor, and roof U-factor used SPC Calculator defaults. The temperatures and schedules which the facility personnel reported were input into the tool, along with the quantity of tanks and their respective sizes. Other important inputs included the cooling efficiency of the chiller, color of the tanks, wind and sun exposure, location, and chilled water temperature.

The ex post calculations were performed using the SPC 2007 Calculator module. Five separate calculations were performed for five sets of tanks.

The ex post impacts were calculated using the verified inputs listed above along with the SPC tool.

- The baseline energy consumption is 11,182 kWh/yr
- The proposed energy consumption is 650 kWh/yr
- The resulting annual kWh savings is 10,487 kWh/yr

Peak savings were also calculated using the SPC calculator.

- The baseline demand is 14.8 kW
- The proposed demand is 0.5 kW
- The resulting demand savings is 14.3 kW

The engineering realization rate for this application is 0.14 for kW demand reduction and 0.06 for kWh energy savings. The majority of the SPC calculator inputs were verified onsite and it is unclear why the evaluation savings estimates differ so widely from the ex ante estimates. A summary of the realization rate is shown in Table 5.

Utility billing data for the site was reviewed. In the 12 month period from February 2003 to January 2004 (pre-retrofit), the facility consumed 101,520 kWh. Peak demand was 46 kW in June, July and August of 2003. Table 2 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	46	101,520
Baseline End Use	14.6	11,042
Ex Ante Savings	103.6	187,453
Ex Post Savings	14.3	10,487

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results were 225% of total meter kW, 710% of tank refrigeration end use kW, 185% of total meter kWh, and 1698% of tank refrigeration end use kWh. The ex post results were 31% of total meter kW, 98% of tank refrigeration end use kW, 10% of total meter kWh, and 95% of tank refrigeration end use kWh.

Table 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/ Demand Reduction	kW	kWh	kW	kWh
Total Verified %	225%	185%	31%	10%
Baseline End Use %	710%	1698%	98%	95%

6. Additional Evaluation Findings

The ex post energy savings are significantly less than the ex ante estimate. The evaluation team believes that the discrepancies are due to incorrectly assumed tank temperatures and annual operating hours in calculating ex ante savings using the SPC tool.

We were unable to physically verify the pre-retrofit system and hours of operation. There is some uncertainty regarding preexisting conditions at the facility. Only one third of tanks were operating at the facility prior to the insulation "retrofit'. The facility representative also reported that the tanks had some kind of insulation installed, but that the preexisting insulation was not performing sufficiently and would not have been left it in place. However, he also relayed that "an uninsulated tank was not an option". Thus, a standard baseline may be applicable, but this was not able to be determined from the customer. It is also noteworthy that some of the other tanks were new, and others were requisitioned from other facilities.

The level of post retrofit M&V employed at this site is sufficient to accurately determine the impacts of the installed measures. Detailed pre retrofit condition and use assessment would enable a better impact analysis.

The costs appear realistic for the size and scale of the retrofit.

With a cost of $47,000 and a $14,996 incentive, the project had a 1.3 year simple payback based on the ex ante calculations. Due to the large difference between ex ante and ex post savings estimates, the simple payback based on the ex post savings is 23.5 years. A summary of the economic parameters for the project is shown in Table 4.

The effective useful life of the tank insulation is 20 years. Table 3 shows projected annual ex ante and ex post energy savings for multiple years 2004 through 2025.

7. Impact Results

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Energy Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ Incentive, yrs	Simple Payback w/o Incentive, years
Installation Approved Amount (Ex Ante)	5/4/2004	$47,000	103.6	187,453	-	$24,369	$14,996	1.31	1.93
SPC Program review (Ex Post)	9/11/2007	$47,000	14.3	10,487	-	$1,363	$14,996	23.48	34.5

Table 5: Realization Rate Summary

	kW	kWh	Therms
SPC Tracking System	103.6	187,453	-
SPC Installation Report (Ex Ante)	103.6	187,453	-
Impact Evaluation (Ex Post)	14.3	10,487	-
Engineering Realization Rate	0.14	0.06	-

Table 6: Installation Verification Summary

Measure Description	End Use Category	Other Measure Description	Count	Equipment Description	Installation Verified	Verification Realization Rate
Refrigerated Tank Insulation	O	Install insulation on refrigerated tanks	19	Storage Tanks	Physically verified tank quantity and insulation thickness	1.0

Table 7: SPC Calculator Inputs and Results

Site Specification

Tank Insulation Desc.	12,8,10	**Number of Tanks**	2
Standard Rated Cooling Eff.	1.0054		
Tank Material	Stainless Steel 304	**Wall U-factor**	1 Btu/h·ft^2·°F
Jacket U-factor	1 Btu/h·ft^2·°F	**Roof U-factor**	1 Btu/h·ft^2·°F
Tank Wall Height	12 ft.	**Exterior Cooling Jacket Height**	8 ft.
Tank Roof Diameter	10 ft.	**Tank Color**	Light
Solar Exposure	Total	**Wind Exposure**	Partial
City	Santa Rosa (Sonoma)	**Tank Location**	Outside.
Condenser Type	Air cooled	**Pressure Head Type**	Fixed pressure head

Existing Tank Insulation Characteristics

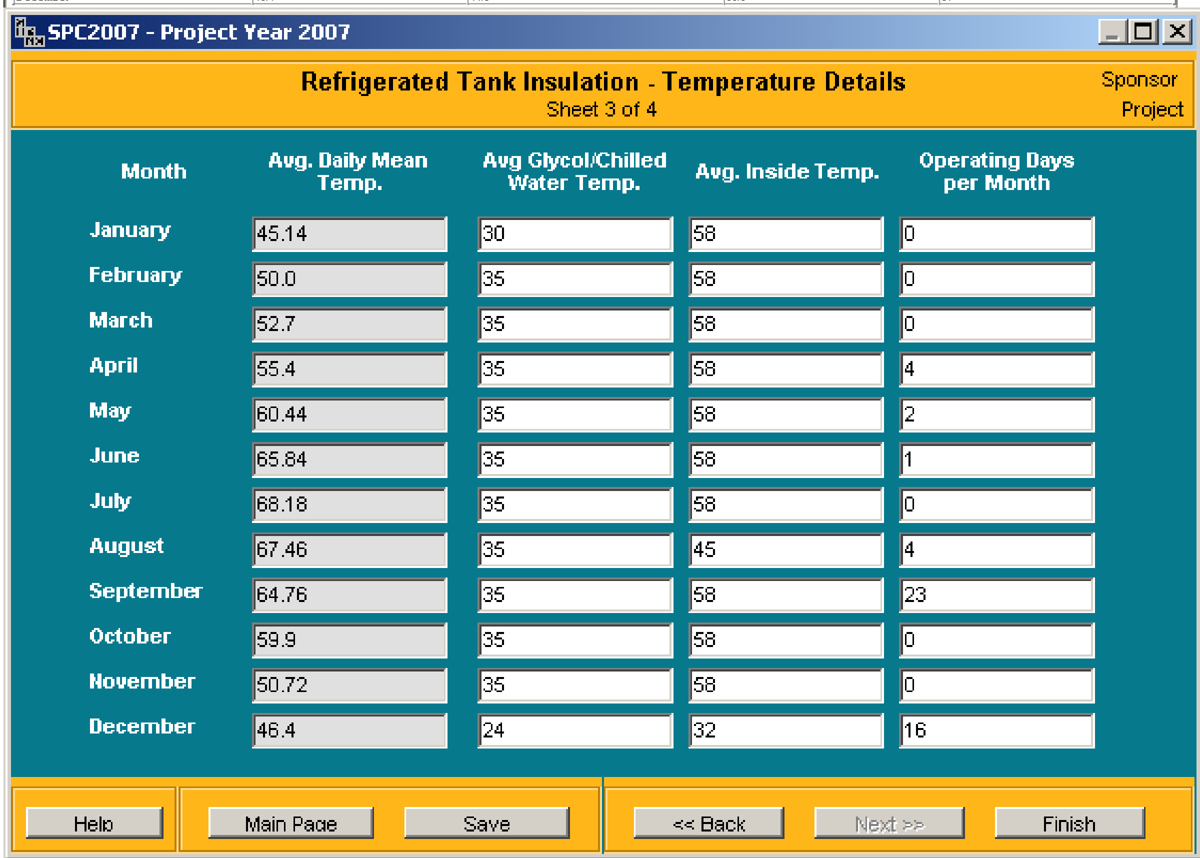
Insulation Type	none	**R-Value**	0 h·ft^2·°F/Btu·in
Wall Thickness	1 in.	**Roof Thickness**	1 in.

Proposed Tank Insulation Characteristics

Insulation Type	polarclad	**R-Value**	4 h·ft^2·°F/Btu·in
Wall Thickness	3 in.	**Roof Thickness**	3 in.

Operating Characteristics

Month	Avg. Daily Mean Temp.	Avg. Glycol/Chilled Water Temp.	Avg. Inside Temp.	Operating Days Per Month
January	45.1	44.0	56.5	22
February	50.0	44.0	56.5	1
March	52.7	44.0	56.5	1
April	55.4	44.0	56.5	1
May	60.4	44.0	56.5	1
June	65.8	44.0	56.5	1
July	68.2	44.0	56.5	1
August	67.5	44.0	56.5	1
September	64.8	44.0	49.0	4
October	59.9	44.0	60.7	31
November	50.7	44.0	56.5	30
December	46.4	44.0	56.5	31



SPC2007 - Project Year 2007

Refrigerated Tank Insulation - Temperature Details

Sheet 3 of 4

Sponsor

Project

Month	Avg. Daily Mean Temp.	Avg Glycol/Chilled Water Temp.	Avg. Inside Temp.	Operating Days per Month
January	45.14	30	58	0
February	50.0	35	58	0
March	52.7	35	58	0
April	55.4	35	58	4
May	60.44	35	58	2
June	65.84	35	58	1
July	68.18	35	58	0
August	67.46	35	45	4
September	64.76	35	58	23
October	59.9	35	58	0
November	50.72	35	58	0
December	46.4	24	32	16

Help | Main Page | Save | << Back | Next >> | Finish

SPC2007 - Project Year 2007

Refrigerated Tank Insulation - Savings

Sheet 4 of 4

Sponsor
Project

Measure Energy Savings, Runtime Hours & Incentive

Line Item	Baseline Energy Usage		Proposed Energy Usage		Savings		
	Energy Demand (kW)	Energy Usage (kWh)	Energy Demand (kW)	Energy Usage (kWh)	Energy Demand (kW)	Energy Usage (kWh)	Incentive Payment
1	1.9	1,330.6	0.1	80.3	1.9	1,250.3	$100.03
2	3.1	2,182.2	0.1	126.0	3.0	2,056.2	$164.50
3	3.6	2,843.1	0.1	174.9	3.5	2,668.2	$213.45
4	0.6	433.6	0.0	26.3	0.6	407.3	$32.58
5	5.4	4,252.5	0.2	281.3	5.2	3,971.2	$317.70
Total	14.6	11,042.0	0.5	688.8	14.1	10,353.2	$828.26

Help | Main Page | Save | << Back | Next >> | Finish

SPC2007 Submittal

Tank Insulation Desc.	1R	**Number of Tanks**	2
Standard Rated Cooling Eff.	1.1		
Tank Material	Stainless Steel 304		
Tank Wall Height	12 ft.	**Exterior Cooling Jacket Height**	8 ft.
Tank Roof Diameter	10 ft.	**Tank Color**	Light
Solar Exposure	Partial	**Wind Exposure**	Partial
City	Santa Rosa (Sonoma)	**Tank Location**	Outside.
Condenser Type	Air cooled	**Pressure Head Type**	Fixed pressure head
Wall Conductivity	324 Btu·in/h·ft²·°F	**Wall Thickness**	0.105 in.
Roof Conductivity	324 Btu·in/h·ft²·°F	**Roof Thickness**	0.105 in.
Jacket Conductivity	324 Btu·in/h·ft²·°F	**Jacket Thickness**	0.105 in.

Existing Tank Insulation Characteristics

Insulation Type	None	**R-Value**	0 h·ft²·°F/Btu·in
Wall Thickness	0 in.	**Roof Thickness**	0 in.

Proposed Tank Insulation Characteristics

Insulation Type	Polarclad	**R-Value**	4 h·ft²·°F/Btu·in
Wall Thickness	3 in.	**Roof Thickness**	3 in.

Operating Characteristics

Month	Avg. Daily Mean Temp.	Avg. Glycol/Chilled Water Temp.	Avg. Inside Temp.	Operating Days per Month	Existing kWh	Proposed kWh	Saved kWh
January	45.1	30.0	55.0	0	0	0	0
February	50.0	35.0	55.0	0	0	0	0
March	52.7	35.0	55.0	0	0	0	0
April	55.4	35.0	55.0	4	10	3	8
May	60.4	35.0	55.0	2	56	3	53
June	65.8	35.0	55.0	1	57	3	54
July	68.2	35.0	55.0	0	0	0	0
August	67.5	35.0	45.0	4	410	17	393
September	64.8	35.0	55.0	10	405	22	384
October	59.9	35.0	55.0	31	532	39	493
November	50.7	35.0	55.0	0	0	0	0
December	46.4	24.0	55.0	0	0	0	0

Tank Insulation Desc.	2R	**Number of Tanks**	4
Standard Rated Cooling Eff.	1.1		
Tank Material	Stainless Steel 304		

Help | Main Page | Save | << Back | Print | Finish

Table 8: Multi Year Savings Table

Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	124,969	6,991	103.6	14.3	-	-
2	2005	187,453	10,487	103.6	14.3		
3	2006	187,453	10,487	103.6	14.3		
4	2007	187,453	10,487	103.6	14.3		
5	2008	187,453	10,487	103.6	14.3		
6	2009	187,453	10,487	103.6	14.3		
7	2010	187,453	10,487	103.6	14.3		
8	2011	187,453	10,487	103.6	14.3		
9	2012	187,453	10,487	103.6	14.3		
10	2013	187,453	10,487	103.6	14.3		
11	2014	187,453	10,487	103.6	14.3		
12	2015	187,453	10,487	103.6	14.3		
13	2016	187,453	10,487	103.6	14.3		
14	2017	187,453	10,487	103.6	14.3		
15	2018	187,453	10,487	103.6	14.3		
16	2019	187,453	10,487	103.6	14.3		
17	2020	187,453	10,487	103.6	14.3		
18	2021	187,453	10,487	103.6	14.3		
19	2022	187,453	10,487	103.6	14.3		
20	2023	187,453	10,487	103.6	14.3		
TOTAL	**2004-2023**	3,686,576	206,244				

SITE A002 (2005-XXX) Geor IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: Other

Measure	Install VFDs on blower motors
Site Description	Corrugated Products Manufacturing Plant

1. Measure Description

This measure is the installation of variable frequency drives (VFD) on seven blower motors on a dust collection system for a box production line. The facility manufactures corrugated boxes and generates scrap cardboard as a byproduct of the process. The scraps are sent to a central dust collection system through a duct by blowers. Each of the cardboard cutting machines has a dedicated blower.

The VFD controls are an open loop system; they vary the blower motor speed based on the amount of material in the duct. The VFD frequency is regularly 50 Hz. The blower flow rate at the associated frequency is sufficient for most of the time; however, there are points in the production cycle where more particulates are generated. Under this condition, particulates begin to clog the ducting, which places additional load on the blower motor, the increased motor load, which triggers a signal to increase the VFD frequency to 60 Hz to increase flow in order to clear the ductwork. When the material is cleared, the drive decreases the VSD frequency back to 50 Hz. The incented VFD blower motors vary in horsepower and specifications.

There is discussion in the project file about installation of an interlock to turn off the blowers when the associated cutting machine is not in use. However, this additional measure did not appear to be implemented and no ex ante savings were claimed for the interlock.

2. Summary of the Ex Ante Calculations

This measure is a calculated measure. The project file indicates that the facility used the SPC calculator and other software to determine energy savings. The calculator had many inputs, some of which included the annual operating hours, motor horsepower, and motor efficiency. The project file is lacking information on what parameters affected the savings results and which equations were used.

The energy savings are a result of reducing the fan speed and reducing the operating hours. The ex ante calculations estimate an annual savings of 415,064 kWh. An incentive of $33,205 was calculated per kWh of energy savings. However, the rebate was capped $25,401 due to the 50% capital cost limitation. The program verification consisted of verifying the VSD installation, verifying the power and current readout on each motor, and verifying the speed of each fan. Spot data were taken post installation by the verification team. The annual operating hours were estimated to be 6,912 hours, operating 24 hours a day, 6 days a week, and 48 weeks a year.

The baseline and as-built energy usages were not reported in the project file, only the savings were reported.

The ex ante impacts were as follows:

- Annual Energy Savings: 415,064 kWh/ yr
- Demand Savings: 59.8 kW

The incentive was calculated as follows:

- $0.08 per kWh
  Incentive was $0.08 x 415,064 = $33,025
- Measure cost adjustment was $7,803.64
- Rebate was only $33,025 - $7,803.64 = $25,401

The ex ante savings agree with the utility tracking system.

3. Comments on the Ex Ante Calculations

The inputs and equations used to calculate the savings are not clearly defined in the project application file. However, the motor curves are presented for each motor. It is suggested in the project file that the motors run at a constant speed of 50 Hz. The full speed of the motor is 60 Hz. The calculation methodology will need to be investigated by the evaluation team.

The ex ante savings and incentive were based on the difference of preexisting power consumption and post retrofit power consumption. The baseline power consumption was calculated from blower power, assumed load factor and annual operating hours. Similarly, the proposed power consumption of the blowers was calculated by multiplying a VSD energy saving control factor to the baseline power consumption. The SPC calculator assumes the VSD blowers to be running at 75% of full load speed for the entire period of operation. In this case, the control fraction was taken to be 0.6 assuming the baseline speed was 50 Hz. The details of the savings calculation are shown in Table 1.

Table 1: Ex Ante Calculation Summary

M #	Measure Description	Baseline kW	Baseline kWh/yr	Proposed kW	Proposed kWh/yr	kW Savings	Usage Savings(kWh/yr)
1	VFD 20 hp Corregator Trim 101 Blower	11.6	80,179	6.9	47,893	4.7	32,286
2	VFD 40 hp Line 122 Blower	31.85	220,147	18.95	130,277	12.9	89,870
3	VFD 40 hp Line 124 Blower	31.85	220,147	18.95	130,277	12.9	89,870
4	VFD 25 hp Line 131 Blower	15.6	107,827	9.2	63,891	6.4	43,936
5	VFD 30 hp Line 134 Blower	19	131,328	11.3	77,739	7.7	53,589
6	VFD 25 hp Line 135 Blower	14	96,768	8.3	57,159	5.7	39,609
7	VFD 40 hp Line 118 Blower	18.3	126,490	8.8	60,586	9.5	65,904
Total		**142.2**	**982,886**	**82.4**	**567,822**	**59.8**	**415,064**

The project file shows no variation in between baseline blower operating hours and ex ante blower operating hours. In other words, ex ante savings estimate did not consider the energy savings associated with interlocking of the blowers with the cardboard cutting machines although this measure was proposed initially.

There is considerable uncertainty involved in the above estimation. The speed of the VFD retrofitted blowers varies with the facility flow demand. Based on the demand the power consumption of the blower can vary from vary from a low of 32% to a high of 106%

4. Measurement & Verification Plan

The facility where the measure was implemented is a 35 year old single story 430,616 sf cardboard box manufacturing facility. Energy consumption was recorded as 6,950,623 kWh from December 2002 to December 2003 and the maximum demand was 1,352 kW in August 2003. This measure reduces energy consumption by reducing fan speed and annual operating hours.

The fundamental premise in development of the measurement and verification plan was to determine the amount of energy required for constant speed motors that were not interlocked with the cutting machines. The M&V plan was implemented in four basic steps:

1. Determine available data from site contact via telephone (operating schedule, etc.)
2. Verify motor data onsite (model number, efficiency, horsepower, speed) and motor quantity. Monitoring of real-time motor power draw. Spot watt measurements of the motors.
3. Obtain short term kW monitoring data of the blowers
4. Calculate the reduction in annual electricity consumption

The initial contact by phone with the client was an essential first step in the development of this plan and helped further define the monitoring scope. During the phone call we inquired as to the operating schedule of the motors. The call also established any metered data that the facility operators have measured and whether or not those data may be available for this evaluation.

Facilities of this type typically monitor their processes and keep records of monitored data, operational schedules and product throughput. The existence of these data and the willingness of the client to share these data with the evaluation team ultimately determined the M&V approach. The requested data included:

- Operational schedules of the motors
- Power and current draw of motors
- Motor name plate information (model number, manufacturer, efficiency, etc.)

From assessment of the project file and experiences from similar facilities, we knew that monitoring the motors with loggers that record current, power factor, and voltage would be useful. Four of the seven motors were monitored.

On-site verification determined the overall quality of the monitoring installation and attempted to verify that the measurements were taken at the correct physical locations. The evaluation calculation for savings used annual operating hours and the difference in baseline and as-built power draw. For further detail on the evaluation calculations, see the "Summary of Results" section below

Formulae and Approach

The ex post savings calculation used basic electrical conversions, annual operating hours, and the difference in pre and post retrofit motor speed and energy consumption. Metered data was essential to calculate the proposed annual energy consumption. An hourly motor profile was created from the data for each day of the week. Since all days were relatively similar, the final hourly profile was an average of all days. The metered energy consumption was extrapolated to represent a full year based on seasonality. The baseline kW data was collected from the project sponsor's original power measurement before the installation of the VFDs. The annual baseline energy usage is the power consumption multiplied by the annual operating hours. Also, we used the motor curves to determine the average percent speed for the motors. This was compared to the 75% speed that the tracking analysis assumed.

The equations used to calculate savings are as follows:

$$P_{VSD} = \frac{A_{monitored} x V x \sqrt{3} x PF}{1000}$$

$$EnergyUsage_{baseline} = P_{baseline} x AnnualHours_{baseline}$$

$$EnergyUsage_{proposed} = P_{VSD} x AnnualHours_{proposed}$$

Where,

P	= motor power (kW)
PF	= power factor
$A_{monitored}$	= measured motor current (amps)
V	= motor voltage (V)
η	= motor efficiency

The annual savings then became:

$$EnergySavings = EnergyUsage_{baseline} - EnergyUsage_{proposed}$$

As the equations show, a key factor in the savings calculation is the annual operating hours and those were calculated from the metered data. The greatest uncertainties in the ex ante savings estimate are associated with the estimate of blower load factor and annual operating hours. The SPC calculator appears to generate a single estimate of load factor and effective full load hours based upon facility flow demand. The SPC Calculator could easily have generated a 10-15% error in its estimate by using a generic VSD fan curve.

Uncertainty for the savings estimate for the VSD blower can be more fully understood by setting projected ranges on the primary variables.

V	= motor terminal rms voltage (volts)	(±5%) (437 to 483 V)
I	= measured motor rms current (amps)	(±5%) (varies with hp)
	▪ 20 hp motor	(23.8 to 26.3 A)
	▪ 25 hp motor	(29.5 to 32.6 A)
	▪ 30 hp motor	(35.2 to 38.9 A)
	▪ 40 hp motor	(38.0 to 42.0 A)
PF	= power factor	(±5%) (0.76 to 0.84)
Hr	= annual operating hours	(±10%) (6221 to 7603 hours)

Accuracy and Equipment

A clamp on power meter LEM 2060 Analyst from Fluke Instruments was used to take spot measurements of the VFD retrofitted blowers. These instantaneous kW measurements were compared with the collected trend kW data and no discrepancies arose. This power meter has the capability of measuring RMS voltage, current, power factor, true power and also it has the capability of measuring total harmonic distortion. This meter is also capable of short term logging. The minimum sampling interval is 1 second and maximum sampling interval is 1 hour. The accuracy of this meter is ±2.5% reading.

In addition, Dent Elitepro loggers with three current transformers will be installed on each of the blowers for a period of at least three weeks. These loggers can sample at intervals up to 3 seconds. Their accuracy is better than 1% of the reading. Also, the accuracy of the current transformers is approximately +/-1%.

All data collected were reviewed to ensure it conformed to realistic values and were verified with other data collected to identify any anomalies.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 28, 2007. Information on the equipment and operating conditions was collected by inspection of the blower motors. Additional data were collected through interviews with the facility representative. Four Elite Pro kW loggers were installed in four of the seven incented blowers. Table 2 below shows the metered blowers.

Table 2: Metered Blowers

M #	Measure Description	Metered
1	VFD 20 hp Corregator Trim 101 Blower	No
2	VFD 40 hp Line 122 Blower	No
3	VFD 40 hp Line 124 Blower	Yes
4	VFD 25 hp Line 131 Blower	No
5	VFD 30 hp Line 134 Blower	Yes
6	VFD 25 hp Line 135 Blower	Yes
7	VFD 40 hp Line 118 Blower	Yes

Installation Verification

The facility representative verified that all seven blower motors were operated continuously before the VFD retrofit. We physically verified the ABB VFDs on all the seven blowers.

This is the only measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 8 below.

	kW	kWh
SPC Tracking System	59.8	415,064
SPC Installation Report (Ex Ante)	59.8	415,064
Impact Evaluation (Ex Post)	58.5	483,316
Engineering Realization Rate	0.98	1.16

Scope of the Impact Assessment

The impact assessment scope is for the "Other" end use measure, covering VFDs and controls, in the SPC application. These are the only measures in the application for this site.

Summary of Results

Five Elitepro kW loggers were installed on four of the seven incented blowers for four weeks (from September 28, 2007-October 30, 2007) to measure the power consumption and operating hours of the blowers. The facility representative stated that the 32-day period had been representative of normal facility operation except the twelve annual holidays. The blowers are off during these 12 annual holidays. Figure 1 shows the raw data of all the four monitored blowers for a period of four weeks.

Figure 1: Raw Ex Post Metered Data for a Period of One Month (#123- Blue, #118-Red, #134- Brown and #135- Green)

The ex ante calculations were performed using the SPC tool and later modified with help of ABB's Fan Save software tool. The ex post savings were calculated using the metered operating schedule and comparing the power draw of the pre-retrofit and VFD blowers, taking into consideration twelve holidays a year and no seasonal variation in the blower motor schedule.

The details of the ex post impacts are shown in Table 3.

Table 3: Ex post Calculation Summary

M #	Measure Description	Pre retrofit kW	Pre retrofit kWh/yr	Post retrofit Peak kW	Calculated hrs/yr	Post retrofit kWh/yr	Ex post kW Savings	Ex post kWh/yr Savings
1	VFD 20 hp Corregator Trim 101 Blower	11.6	74,275	8.0	6,403	43,412	3.63	30,862
2	VFD 40 hp Line 122 Blower	32.2	220,835	14.7	6,858	85,454	17.51	135,382
3	VFD 40 hp Line 124 Blower	32.2	220,835	14.7	6,858	85,454	17.51	135,382
4	VFD 25 hp Line 131 Blower	17.7	113,333	11.1	6,403	54,553	6.57	58,779
5	VFD 30 hp Line 134 Blower	19.5	131,877	14.8	6,763	81,223	4.72	50,654
6	VFD 25 hp Line 135 Blower	17.7	113,333	11.1	6,403	54,553	6.57	58,779
7	VFD 40 hp Line 118 Blower	18.3	120,307.3	16.3	6,574	106,830	2.05	13,477
Total		**149.2**	**994,796**	**90.7**		**511,480**	**58.5**	**483,316**

- Pre-retrofit demand: 149.2 kW
  Annual energy usage: 994,794 kWh/yr
- Based on energy logger data and post-retrofit hours of operation
  Post-retrofit demand: 90.7 kW
  Annual energy usage: 511,480 kWh/yr

  The resulting annual ex post kWh savings is 994,794 kWh/yr – 511,480 kWh/yr = 483,316 kWh/yr.

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit weekday 2 pm to 5 pm connected load.

- Peak kW savings is 149.2 kW – 90.7 kW = 58.5 kW.

The engineering realization rate for this application is 0.98 for kW demand reduction and 1.16 for kWh energy savings. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 7.

Utility billing data for the site was reviewed. In the 12 month period from December 2002 to December 2003 (pre-retrofit), the facility consumed 6,950,623 kWh. Peak demand was 1,355 kW in August of 2003. Table 4 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 4: Total Meter, Ex Ante, Ex Post Results

	Peak Demand (kW)	Annual kWh
Total Meter	1,355	6,950,623
Baseline End Use	149.2	994,796
Ex Ante Savings	59.8	415,064
Ex Post Savings	58.5	483,316

Table 5 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results were 4.4% of total meter kW, 40.1% of blower end use kW, 6.0% of total meter kWh, and 41.7% of blower end use kWh. The ex post results were 4.3% of total meter kW, 39.2% of blower end use kW, 7.0% of total meter kWh, and 48.6% of blower end use kWh.

Table 5: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	4.4%	6.0%	4.3%	7.0%
Baseline End Use %	40.1%	41.7%	39.2%	48.6%

6. Additional Evaluation Findings

The evaluation team physically verified the VFD retrofits and the blower motors, and used metered data to verify operating hours. The evaluation team is satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

The costs seem realistic for these ABB variable frequency drives, based on industry experience.

The project increased energy awareness in the company. The customer also stated that they are always looking for energy efficiency opportunities.

With a cost of $45,554 and a $25,401 incentive, the project had a 0.37 year simple payback based on the ex ante calculations The ex post energy savings estimate for the project is larger than the ex ante, therefore the estimated simple payback is 0.32 years A summary of the economic parameters for the project is shown in Table 6.

The effective useful life of the variable frequency drive is 15 years. Table 9 shows projected annual ex ante and ex post energy savings for multiple years 2004 through 2023.

7. Impact Results

Table 6: Economic Information

Description	Date	Project Cost	Esimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh)	SPC Incentive	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	9/13/2005	$45,554	59.8	415,064	-	$53,958	$25,401	0.37	0.84
SPC Program Review (Ex Post)	9/28/2007	$45,554	58.5	483,316	-	$62,831	$25,401	0.32	0.73

Table 7: Realization Rate Summary

	kW	kWh
SPC Tracking System	59.8	415,064
SPC Installation Report (Ex Ante)	59.8	415,064
Impact Evaluation (Ex Post)	58.5	483,316
Engineering Realization Rate	0.98	1.16

Table 8: Installation Verification Summary

Measure Description	End Use Category	Process Measure Description	Count	Equipment Description	Installation Verified	Verification Realization Rate
Other	O	Install VFDs on blower motors	7	VFD Installation	Physically verified VFDs	1.0

Table 9: Projected Multi Year Ex ante and Ex post Savings of the Variable Frequency Drive

Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004					0	0
2	2005	138,355	161,105			0	0
3	2006	415,064	483,316	59.8	58.5	0	0
4	2007	415,064	483,316	59.8	58.5	0	0
5	2008	415,064	483,316	59.8	58.5	0	0
6	2009	415,064	483,316	59.8	58.5	0	0
7	2010	415,064	483,316	59.8	58.5	0	0
8	2011	415,064	483,316	59.8	58.5	0	0
9	2012	415,064	483,316	59.8	58.5	0	0
10	2013	415,064	483,316	59.8	58.5	0	0
11	2014	415,064	483,316	59.8	58.5	0	0
12	2015	415,064	483,316	59.8	58.5	0	0
13	2016	415,064	483,316	59.8	58.5	0	0
14	2017	415,064	483,316	59.8	58.5	0	0
15	2018	415,064	483,316	59.8	58.5	0	0
16	2019	415,064	483,316	59.8	58.5	0	0
17	2020	276,709	322,211	59.8	58.5	0	0
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	6,225,960	7,249,740				

Variable Frequency Drives with a 15 year life.

SITE A003 (2004-xxx) E&JG1 **IMPACT EVALUATION**
SAMPLE CELL: ORIGINAL TIER: 2 **END USE: OTHER**

Measure	Retrofit three 500hp standard motors with premium efficiency motors
Site Description	Winery

1. Measure Description

The measure involved the early retirement of three standard efficiency 500 hp motors and replacement with same size premium efficiency motors. The project file indicates three motors were incented by the program, but five 500 hp premium efficiency motors were installed at the facility. All of the motors are identical in size, model and manufacturer. The rated efficiency of the new motors is 96.2%. The motors drive refrigeration compressors in a refrigeration plant used in the production of wine.

2. Summary of the Ex Ante Calculations

The project file indicates that the facility used the SPC tool to estimate energy savings. The tool had inputs including the annual operating hours, motor horsepower, motor power factor, pre and post retrofit efficiency, and motor rpm. The project file is lacking detailed information on how exactly savings were calculated by the SPC Calculator.

The energy savings result from reduced losses from the installed premium efficiency. The ex ante calculations show total savings of 3,415,815 kWh over an effective useful life (EUL) of 9 years. The annual energy savings per motor were 75,907 kWh. An incentive of $273,265 was calculated per kilo-watt hour of energy savings based on the total savings over the EUL. However, the rebate was limited to $20,818 due to the 50% capital cost limitation. The program verification consisted of verifying motor count, motor efficiency, and motor speed. Daily hours of operation were not reported, although the motors were estimated to operate 5,270 hours per year.

The ex ante impacts were calculated as follows:

- Baseline Usage: 9,168,890 kWh
- Proposed Usage: 8,789,355 kWh
- Current Minimum Standard (Title 24) Usage: 8,826,053 kWh
- Current Minimum Standard (Title 24) Demand: 1,674.9 kW
- Baseline Demand: 1,740 kW
- Proposed Demand: 1,668 kW
- Annual Energy Savings: 379,535 kWh
- Demand Savings: 72 kW
- Total Energy Savings (9 yr useful life): 3,415,814 kWh

The incentive was calculated as follows:

- $0.08 per kWh
  Incentive was $0.08 x 3,415,814 = $273,265.10
- Project implementation cost = $41,365
- Rebate was only $20,817.50 (due to 50% measure cost limitation)

3. Comments on the Ex Ante Calculations

The program file does not contain details of the ex ante calculation. The inputs to the spreadsheet seem reasonable; however, many of the electrical inputs on the spreadsheet do not match up with the calculated power. It is unclear which equations were used to calculate the final energy savings.

The total savings in the Installation Report Review were given as 379,535 kWh/yr and 72 kW. The demand savings agree with the utility tracking system. However, the utility tracking system notes the total nine year savings of 3,415,814 kWh as the annual savings.

The ex-ante savings and incentive were based on the annual savings for early retirement using the standard efficiency motor as baseline for the first nine years.

	kW	kWh
Baseline Usage	1,740	9,168,890
Current Title-24	1,674	8,826,053
Proposed Usage	1,668	8,789,355
Annual Early Retirement Savings	72	379,535
Total Early Retirement Savings (9 years)		3,415,815

4. Measurement & Verification Plan

This measure reduces electricity usage by having premium efficiency equipment. The fundamental premise in development of the measurement and verification plan is to determine the amount of electricity required if the motors had not been premium efficiency. The M&V plan will be implemented in three basic steps:

1. On-site verification of motor data (model number, efficiency, horsepower) and motor quantity. On-site monitoring of motor(s) amperage or power. Spot watt measurements of the motors will be taken.
2. Collect trend data from site energy management system and logs.
3. Calculate the reduction in annual electricity consumption.

The initial contact by phone with the client will be an essential first step in the development of this plan and will help further define the monitoring scope. During the phone call the evaluation team will inquire as to the operating schedule of the motors.

The call will also establish any metered data that the customer has collected and whether or not that data may be available for this evaluation.

Facilities of this type typically monitor their processes and keep records of monitored data, operational schedules and product throughput. The existence of these data and the willingness of the client to share these data with the evaluation team will ultimately determine the M&V approach. The requested data will include:

- Operational schedules of the motors
- Power and/or amperage draw of motors
- Motor nameplate information (model number, manufacturer, efficiency, input power, power factor, etc.)

If no data are available, the evaluation team will use a self-reported approach.

From our assessment of the project file and our experiences from similar facilities, monitoring the motors with loggers that record the power factor, amperage, and voltage would be useful. All of the motors may not need to be monitored since the motor specifications are the same for all five motors. Enough data should be collected to capture the different schedules of the motors. This will be determined after contact with the facility.

The evaluation calculation for savings will use basic electrical conversions, annual operating hours, and the difference in baseline and as-built motor efficiency.

Formulae and Approach

The evaluation team will use the facility operating schedule and motor load data to calculate energy consumption. The team will use the following equations to determine pre and post installation energy consumption.

$$P_{\text{Pre retrofit}}. = [(\text{motor hp}) \times 0.746/(\text{standard motor efficiency})] \times LF$$
$$P_{\text{Post retrofit}}. = (\text{motor hp}) \times 0.746/(\text{premium motor efficiency}) \times LF$$
$$P_{\text{Ex Post}} = P_{\text{Pre retrofit.}} - P_{\text{Post retrofit}}$$

Where,

$P_{\text{Pre retrofit}}$ = Pre retrofit power consumption (kW)
$P_{\text{Post retrofit}}$ = Post retrofit power consumption (kW)

$P_{Ex\ Post}$ = Ex post Power savings (kW)
LF = Load factor on the motor

The annual savings then become:

$$\text{Annual kWh Savings} = P_{Ex\ post} * \text{Annual Operating Hours}$$

As the equations show, a key factor in the savings calculation is the annual operating hours and the load factor and those will be collected from the facility.

The greatest uncertainties in the ex ante savings estimate are associated with the estimate of motor load factor and annual operating hours. The SPC calculator appears to generate a single estimate of effective maximum kW demand and annual kWh based on collected motor parameters. Using a generic electrical equation for energy consumption the facility can generate an estimate of 10-15% error.

Uncertainty for the savings estimate for the motors can be more fully understood by setting projected ranges on the primary variables.

- LF = motor load factor (-70%, 0, +15%)
  expected 85%, minimum 20 %, maximum 95 %
- Hr = annual operating hours (±5%)
  expected 5,270 hrs/yr, minimum 5,006 hrs/yr, maximum 5,533 hrs/yr

Accuracy and Equipment

The facility provided annual operating hours of the compressor motors at different load conditions.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 30, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the compressor motors and by interviewing the facility representative.

Installation Verification

The evaluation team physically verified the installation of five (5) 500 hp compressor motors. The facility representative stated that the retrofit was completed by in February 2005.

These are the only measures in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 7 below.

Scope of the Impact Assessment

The impact assessment scope for this application is for the motor end use measure in the SPC application covering the premium efficiency motor retrofit. This is the only measure in this application

Summary of Results

Annual operating schedule and motor load factor data were collected from the plant personnel. Table 1 shows the percentage of load and their respective annual hours of operation. Facility personnel also confirmed that all five motors have the identical operating schedule.

Table 1: Operating Schedule of the Compressors

Percentage of Time	Percentage of Load	Annual Peak Operating Hours	Annual Off peak Operating Hours
3.8%	20.0%	82.1	125.4
1.3%	25.0%	28.1	42.9
4.5%	35.0%	97.2	148.5
8.3%	45.0%	179.3	273.9
13.5%	55.0%	291.6	445.5
19.2%	65.0%	414.7	633.6
25.0%	75.0%	540.0	825.0
19.2%	85.0%	414.7	633.6
5.1%	95.0%	110.2	168.3
Total		**2,157.8**	**3,296.7**
			5,454.5

The ex ante calculations were performed using the SPC Calculator module. The ex post savings were calculated using following equation:

$$P_{\text{Pre retrofit}}. = [(\text{motor hp}) \times 0.7457/(\text{standard motor efficiency})] \times LF$$
$$P_{\text{Post retrofit}}. = (\text{motor hp}) \times 0.7457/(\text{premium motor efficiency}) \times LF$$
$$P_{\text{Ex Post}} = P_{\text{Pre retrofit.}} – P_{\text{Post retrofit}}$$

Where,

$P_{\text{Pre retrofit}}$ = Pre retrofit power consumption (kW)
$P_{\text{Post retrofit}}$ = Post retrofit power consumption (kW)

$P_{Ex\ Post}$ = Ex post Power savings (kW)
LF = Load factor on the motor

The annual savings then become:

$$\text{Annual kWh Savings} = P_{Ex\ post} * \text{Annual Operating Hours}$$

The details of the ex post savings calculations are shown in Table 2.

Table 2: Ex Post Calculation Summary

Measure Description	Average Load Factor	Peak Season Operating Hours	Off Peak Operating Hours	Pre retrofit kW	Post Retofit kW	Ex post kW Savings	Ex post kWh Savings
500 hp PE Compressor	20	82.1	125.4	78.5	77.5	1.0	203.2
	25	28.1	42.9	98.2	96.9	1.2	86.9
	35	97.2	148.5	137.4	135.7	1.7	421.2
	45	179.3	273.9	176.7	174.5	2.2	998.8
	55	291.6	445.5	215.9	213.3	2.7	1,985.5
	65	414.7	633.6	255.2	252.0	3.2	3,337.3
	75	540.0	825.0	294.5	290.8	3.7	5,014.0
	85	414.7	633.6	333.7	329.6	4.2	4,364.2
	95	110.2	168.3	373.0	368.3	4.7	1,295.6
Total				**373.0**	**368.3**	**4.65**	**17,706.8**
For all 5 Compressors						**23.26**	**88,534.07**

- Pre-retrofit demand: 1,865.0 kW
  Annual energy usage: 7,097,481 kWh/yr
- Based on motor load factor and post-retrofit hours of operation
  Post-retrofit demand: 1,841.7 kW
  Annual energy usage: 7,008,947 kWh/yr

  The resulting annual ex post kWh savings is 7,097,481 kWh/yr – 7,008,947 kWh/yr = 88,534 kWh/yr.

- Peak kW savings is 1,865.0 kW – 1,841.7 kW = 23.3 kW.

Utility billing data for the site was reviewed. In the 12 month period from January 2003 to December 2003 (pre-retrofit), the facility consumed 32,813,435 kWh. Peak demand was 12,005 kW in September of 2003. Table 3 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results

Table 4 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 0.6% decrease in total meter kW, a 3.9 % decrease in motor end use kW, a 1.2 % decrease in total meter kWh, and a 5.3 % decrease in motor end use kWh. The ex post results showed a 0.2% decrease in total meter kW, a 1.2 % decrease in motor end use kW, a 0.3 % decrease in total meter kWh, and a 1.2 % decrease in motor end use kWh.

Table 3: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	12,005	32,813,435
Baseline End Use	1,865	7,097,481
Ex ante Savings	72	379,535
Ex Post Savings	23	88,534

Table 4: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		**Ex Post**	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	0.6%	1.2%	0.2%	0.3%
Baseline End Use %	3.9%	5.3%	1.2%	1.2%

6. Additional Evaluation Findings

The ex post energy savings and kW demand reduction is less than the ex ante estimate because the ex ante estimate was based on single annual load factor 84.5 %, where as the data received from the plant showed a variation in motor load ranging from 20% to 100% throughout the year.

We were unable to physically verify the pre-retrofit compressor motors, quantities and hours of operation. However, these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

The costs seem realistic for the 500 hp premium efficiency motors, based on industry experience.

According to facility personnel, this measure increased energy awareness in the company and they continue to look for energy efficiency opportunities in the facility.

With a cost of $41,635 and a $20,818 incentive, the project had a 0.84 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 3.62 years. A summary of the economic parameters for the project is shown in Table 5.

The effective useful life for these motors is 15 years. Table 8 shows projected annual ex ante and ex post energy savings for multiple years 2004 through 2023.

7. Impact Results

The engineering realization rate for this application is 0.32 for kW demand reduction and 0.03 for kWh energy savings. A summary of the realization rate is shown in Table 6.

Table 5: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	2/18/2005	$41,635	72.0	379,535	0	$49,340	20,818	0.42	0.84
SPC Program Review (Ex Post)	8/30/2007	$41,635	23.3	88,534	0	$11,509	20,818	1.81	3.62

Table 6: Realization Rate Summary

	kW	kWh
SPC Tracking System	72.0	3,415,814
SPC Installation Report (ex ante)	72.0	379,535
Impact Evaluation (ex post)	23.3	88,534
Engineering Realization Rate	0.32	0.03

Table 7: Installation Verification Summary

Measure Description	End-Use Category	AC&R Measure Description	Lighting Measure Description	Other Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Motors on Refrigeration Compressors	O			Replacement of Standard Efficiency Motors with Premium Efficiency Motors	5	500 hp Premium Efficiency Compressor Motors	Physically Verified All Five Compressor Motors	1.00

Table 8: Projected Multi Savings

Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings (1)	Ex-Post Net Evaluation Confirmed Program kWh Savings (2)	Ex-Ante Gross Program-Projected Peak Program kW Savings (1**)	Ex-Post Gross Evaluation Projected Peak kW Savings (2**)	Ex-Ante Gross Program-Projected Program Therm Savings (1)	Ex-Post Net Evaluation Confirmed Program Therm Savings (2)
1	2004	221,395	51,645	72.0	23.3	0	0
2	2005	379,535	88,534	72.0	23.3	-	-
3	2006	379,535	88,534	72.0	23.3	-	-
4	2007	379,535	88,534	72.0	23.3	-	-
5	2008	379,535	88,534	72.0	23.3	-	-
6	2009	379,535	88,534	72.0	23.3	-	-
7	2010	379,535	88,534	72.0	23.3	-	-
8	2011	379,535	88,534	72.0	23.3	-	-
9	2012	379,535	88,534	72.0	23.3	-	-
10	2013	379,535	88,534	72.0	23.3	-	-
11	2014	379,535	88,534	72.0	23.3	-	-
12	2015	379,535	88,534	72.0	23.3	-	-
13	2016	379,535	88,534	72.0	23.3	-	-
14	2017	379,535	88,534	72.0	23.3	-	-
15	2018	379,535	88,534	72.0	23.3	-	-
16	2019	158,140	36,889			-	-
17	2020					-	-
18	2021					-	-
19	2022						
20	2023						
TOTAL	**2004-2023**	**5,693,025**	**1,328,011**				

Motors with a 15 year life

Note: If the multi year ex ante savings of 3,415,814 kWh are replaced with first year savings of 379,535 kWh in the realization rate calculations, the kWh realization rate is increased from 0.03 to 0.23 (3% to 23%). The kW realization rate is not affected.

SITE A004 (2004-XXX) Cana **IMPACT EVALUATION**
SAMPLE CELL: ORIGINAL TIER: 3 **END USE: Other**

Measure	Insulate eight wine storage tanks
Site Description	Winery

1. Measure Description

This measure is for the application of insulation to eight exterior wine storage tanks. All of the tanks are the same size and have the same material properties. The tanks are used for wine processing and maintained at ~ approximately 40° F for ten months of the year. Refrigeration is supplied by chillers which have a glycol set point of 25° F. The tanks are reportedly empty during September and October. The tank walls reportedly have 3 inches of insulation, while the roofs have 5 inches of insulation. The insulation has a rated R-value of 6.67 (hr-ft^2-°F/Btu-in) at 75°F. The baseline for this measure is an un-insulated tank.

2. Summary of the Ex Ante Calculations

The project file indicates that the facility used a spreadsheet designed to calculate savings for tank insulation measures to calculate ex ante savings. The inputs to the spreadsheet include the pre and post R-value of insulation, insulation thickness, interior tank temperature, chiller leaving temperature chiller efficiency, tank dimensions, number of operating days, and weather averages for the facility location. All of the spreadsheet calculations are based on average daily mean dry bulb temperature and wind speed by month.

The file did not contain any numbers for baseline energy usage or measure energy usage. We estimated these values by recreating the tank insulation spreadsheet using all available data. Although the savings in the recreated spreadsheet did not exactly match the ex ante values, it was sufficient to render a reasonable estimate for baseline energy usage.

The ex ante impacts were calculated as follows:

- Baseline energy usage: 1,534,028 kWh/yr
- Proposed energy usage: 18,390 kWh/hr
- Demand savings: 363.7 kW
- Annual energy savings: 1,515,638 kWh/yr

The incentive was calculated as follows:

- $0.08 per kWh
  Rebate was $0.08 x 1,515,638 = $121,251.04

These figures in the Installation Report Review agree with the figures in the utility tracking system.

3. Comments on the Ex Ante Calculations

The program file contains a screen snapshot of the tank insulation spreadsheet. Therefore, we were able to ascertain the majority of the inputs used in the savings calculations. The inputs that are visible on the screen snapshot seem reasonable. However, the project file is lacking documentation on how some of the inputs were calculated or chosen. In addition, the algorithms applied in the spreadsheet are missing in the project file.

The project file lacks detailed information on the operational schedules of the tanks, stating only the number of operating days per month. The facility claims the tanks are empty in September and October; however, the initial on-site inspection performed by the utility found the tanks were also empty in July.

4. Measurement & Verification Plan

This measure reduces the heat loss from the wine storage tanks. The savings realized by this measure is the energy (kWh) required to compensate for the additional heat loss. The fundamental premise in development of the measurement and verification plan was to determine the amount of electricity required if the tanks had not been insulated. The M&V plan was implemented in the following four basic steps:

1. Verify tank insulation, refrigeration system/load (insulation type, thickness, area covered, installation quality, chiller efficiency, internal tank temperature, tank size, quantity of tanks), and tank hours of operation.
2. Collect trend data from site energy management system and logs.
3. Calculate the reduction in annual heat transfer due to additional tank insulation and estimate kWh requirement of that heat transfer reduction.
4. Compare ex ante savings estimates to ex post estimates.

The initial contact by phone with the client was an essential first step in the development of this plan and helped further define the monitoring scope. During the phone call, we inquired as to the location of the tanks (inside or outside), operating hours of the tanks and the cooling system (type, number and whether it is a dedicated system), and the months in which the system is shut off. The call also established that the facility had trend data that they would provide for the evaluation effort.

Industrial facilities of this type typically monitor their processes and keep records of monitored data, operational schedules and product throughput. The existence of these data and the willingness of the client to share these data with the evaluation team ultimately determined the M&V approach. The requested data included:

- Operational schedules of the tanks
- Tank temperature set points
- Compressor set points
- Insulation and tank materials
- Tank fill levels
- Cooling source data, chiller name plate information and/or documentation
- Hourly chiller loads

The facility was able to supply us with all of the above information, except for the hourly chiller loads. During the onsite visit, the facility also supplied us with a daily log of the tank temperatures for the months of June 2007 and October of 2006.

Formulae and Approach

The heat loss occurring across the tank wall was calculated twice: once with the insulation and once without the insulation. The difference of these two heat transfer values is the heat saved due to the insulation. We used a spreadsheet which utilized the heat transfer equations presented below for the ex post calculations. The heat transfer was quantified as follows:

$$Q = hA_s(T_s + T_{suneffect} - T_\infty)$$

where,

Q = convective heat transfer
h = heat transfer coefficient
A_s = tank surface area of heat transfer
T_s = tank surface temperature
$T_{suneffect}$ = surface temperature increase due to radiation
T_∞ = ambient temperature.

In this case, the only variable that changed for the baseline and proposed scenarios (with or without insulation) was *h*, the heat transfer coefficient. (the sun effect is assumed to be similar in the insulated and uninsulated cases). The coefficient was estimated using the material properties of the tank and the insulation. The tank temperature was assumed to be constant and the tanks were assumed full.

The energy savings due to the insulation is the difference in the value of *Q* with and without the insulation. However, the chiller efficiency was also taken into account. Therefore, the total energy savings were the following:

$$Q_{savings} = \frac{Q_{non-ins} - Q_{ins}}{\eta_{chiller}} * (annualhours)$$

where,

$Q_{non-ins}$ = heat transfer across tank without insulation

Q_{ins} = heat transfer across tank with insulation
$\eta_{chiller}$ = chiller efficiency
Annual hours = annual hours of operation.

In order to calculate ex post savings, we used a tank insulation spreadsheet which utilized the above equations. The tank insulation spreadsheet used during the project application phase was not available to us, so we recreated the spreadsheet.

Although there is uncertainty associated with several factors when calculating the savings, the uncertainty from using self reported hours of operation appears to be the primary source of uncertainty.

All data collected was reviewed to ensure it conformed to realistic values and was verified with other data collected to identify any anomalies. No data had suspicious elements that needed scrutiny. Therefore, all data collected were considered valid for the ex post savings calculations.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 30, 2007. Information on the equipment and operating conditions was collected by inspection of the tanks and cooling system. In addition, schedule data were collected by interviewing the facility representative.

Installation Verification

The facility representative verified that there were 8 insulated tanks. We physically verified the quantity and size. The tanks had approximately 3” of insulation on the walls and 5” on the roof, corresponding to approximately R-20 and R-33, respectively. During the onsite visit, the evaluation team verified the following parameters:

- 8 total tanks, all identical in size and material properties
- Insulation thickness: 3” on the walls, 5” on the roof
- Tank Dimensions: 24 ¼’ diameter, 36’ height
- Tank location: outdoors with full sun and partial wind exposure
- Refrigeration system efficiency: 1.0 kW/ton
- Chiller set point: 25° F (glycol)
- Internal tank temperature: approximately 40° F
- Operating days per month: always full, except empty mid-August to mid-October (self reported)
- Number of tanks in operation on the date of site visit: 2 (out of 8)

The facility operator reported that the tanks are empty during the fermentation process, which typically takes place from mid-August to mid-October. During the remainder of the year, the facility maintains the tanks at 40°F. In total, there is wine in the tanks for approximately 7,320 hours per year, according to the facility representative. Note that the cooling efficiency of the chiller was found onsite through manufacturer documentation on the specific chiller model. On the day of the site visit, only two of the tanks were being used. The facility representative stated that this was common and rarely are all tanks being used at the same time. The facility uses all of the tanks and rotates the ones they are using, but usually only uses two to four at a time.

This is the only measure in this application. The verification realization rate for this project is 1.0 as all measures were installed. A verification summary is shown in Table 5 below.

Scope of the Impact Assessment

The impact assessment scope is for the insulation tank end use measures in the SPC application. This is the only measure in the application for this site.

Summary of Results

The ex post calculations were performed using a tank insulation spreadsheet similar to the one used in the ex ante calculations. Spreadsheet inputs such as shading, wind exposure, U-value of the tank wall and roof, and operating days per month were estimated using engineering judgment. Other inputs were verified onsite, such as the insulation R-value, chiller set point, and tank dimensions.

The remaining inputs were verified using the temperature log data supplied by the facility. These data are taken once per day by the facility and include the number of tanks being used, the tank temperature set point, and the internal tank temperature. Therefore, the average tank temperature and quantity of tanks being used was calculated using these data. On average, the internal tank temperature was 42.4°F and 47.9°F in June and October, respectively. In addition, the facility's log showed that an average of 2.2 tanks were full during the entire month of October. This indicates the tanks may not be empty from mid-August to mid-October, as stated by the facility. Increasing the tank schedule to include August through October would increase the energy savings due to the insulation. However, the temperature log also showed that in June an average of 2.3 tanks are being used. The facility representative verified this and stated that the facility rarely uses more than four tanks at a time. Reducing the number of tanks greatly reduces the energy savings. The average number of tanks (2.23) were assumed to be operating twelve months of the year, based on the available data. A screen shot of the spreadsheet is shown in Table 6. Note that the values shown are only for one tank.

The ex post impacts were calculated using the verified inputs listed above along with a tank insulation spreadsheet.

- The baseline energy consumption is 470,750 kWh/yr
- The proposed energy consumption is 5,623 kWh/yr
- The resulting annual kWh savings is 465,127 kWh/yr

Peak savings were calculated using the same spreadsheet.

- The baseline demand is 174.6 kW
- The proposed demand is 2.2 kW
- The resulting demand savings is 172.4 kW

The engineering realization rate for this application is 0.47 for demand kW reduction and 0.31 for energy savings kWh. The energy realization rate is low because, on average, the tanks are only in use approximately 28% of the year. The evaluation demand savings are about half of the tracking estimate because the facility's self-report indicated that they used a maximum of four tanks during peak season. The other parameters affecting the energy savings were verified onsite and were reasonably close, if not exactly the same, to the ex ante parameters. A summary of the realization rate is shown in Table 4.

Utility billing data for the site was reviewed. In the 12 month period from December 2003 to December 2004 (pre-retrofit), the facility consumed 32,508,056 kWh. Peak demand was 8,022 kW in October of 2003. Table 1 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results. Table 2 shows the percentages of energy saved at this facility and as compared to the baseline energy use for maintaining the temperature in these tanks.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual Energy, kWh
Total Meter	8,022	32,508,056
Baseline End Use	174.6	470,750
Ex Ante Savings	363.7	1,515,638
Ex Post Savings	172.4	465,127

The baseline use is only for maintaining cooling of product in these tanks.

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	4.5%	4.7%	2.1%	4.7%
Baseline End Use %	208.3%	322.0%	98.7%	98.8%

Post retrofit billing data from the site was also reviewed. In a different 12-month period from above (April 2006- March 2007), the facility consumed 31,401,440 kWh. Peak demand was 7,602 kW in September 2006. These figures are only illustrative, however. There are many variables that could affect the energy use however, and no definitive conclusion can be drawn from the magnitudes of energy decreases.

6. Additional Evaluation Findings

The ex post energy and demand savings were less than the ex ante energy and demand savings due to fewer hours of operation of the storage tanks.

We were unable to physically verify the pre-retrofit system and hours of operation. However, these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measure.

The costs of the insulation seem realistic based on industry experience.

With a cost of $247,872 and an incentive of $121,251, the project had a 0.64 year simple payback based on the ex ante calculations. Due to the difference between ex ante and ex post savings estimates, the simple payback based on the ex post savings is 2.09 years. A summary of the economic parameters for the project is shown in Table 3.

The effective useful life of the tank insulation is 20 years. Table 7shows projected annual ex ante and ex post energy savings for multiple years 2004 through 2026.

7. Impact Results

Table 3: Economic Information

Description	Date	Project Cost, $	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, Therms	Estimated Annual Cost Savings ($0.13/ kWh), $	SPC Incentive, $	Simple Payback w/ Incentive, yrs	Simple Payback w/o Incentive, yrs
Installation Approved Amount (Ex Ante)	11/29/2005	247,872	364	1,515,638	-	197,033	121,251	0.64	1.26
SPC Program Review (Ex Post)	8/30/2007	247,872	172	465,127	-	60,467	121,251	2.09	4.10

Table 4: Realization Rate Summary

	kW	kWh	Therms
SPC Tracking System	363.7	1,515,638	
SPC Installation Report (Ex Ante)	363.7	1,515,638	
Impact Evaluation(Ex Post)	172.4	465,127	
Engineering Realization Rate	0.47	0.31	

Table 5: Installation Verification Summary

Measure Description	End-use Category	HVAC Measure Description	Lighting Measure Description	Other Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Tank Insulation	O			Tank Insulation	1	Eight (8) Wine Storage tanks	Visually Verified	1.0

Table 6: Spreadsheet Inputs and Results

INSULATED LIQUID COLD STORAGE TANK SIZE 1

Customer:
Project Sponsor:
Project Site:

Savings	Walls	Roofs	Total
Demand (kW)	36.0	7.1	43.1
Consumption (kWh/Yr)	170,529	37,848	208,377
Incentive Rate ($/kWh)			$0.08
Potential Rebate			$16,670.16

Cooling Eff.	1.00	kW/Ton
# of Tanks	1	
Tank Material	inless steel	
Wall U-factor	1076	Btu/h·ft²·°F
Roof U-factor	1076	Btu/h·ft²·°F
Ext. Surf. Cond.*	4	Btu/h·ft²·°F
City	Madera	
Weather Zone	13	

* 1.65 still air,4 for 7.5 mph wind, or 6 for 15 mph wind.

Dimensions	Insulation R-Values		Sun	Dimensions (ft)		Area	U_a	
	Existing	Proposed	Effect, (°F)	Diameter	Height	ft²	Existing	Proposed
Tank Walls	0	20.01	2	-	36	2,743	10,510.9	135.3
Tank Cooling Jacket	0	20.01	2	-	0	0	0.0	0.0
Tank Roof	0	33.35	9	24.25	-	462	1,770.1	13.7

Existing Insulation	None
R-Value (h·ft2·°F/Btu·in)	0
Thickness, walls (in)	0
Thickness, roof (in)	0

Proposed Insulation	
R-Value (h·ft2·°F/Btu·in)	6.67
Thickness, walls (in)	3
Thickness, roof (in)	5

Month	Average Daily Mean DB Temp	Average Refrigerant Temp.	Average Inside Temp.	Operating Days per Month	Btu/hour Existing Walls	Btu/hour Existing Roof	Btu/hour Proposed Walls	Btu/hour Proposed Roof	Savings Btu/hour Walls	Savings Btu/hour Roof	Savings Tons Walls	Savings Tons Roof	Savings kWh/month Walls	Savings kWh/month Roof
January	47.1	25.0	42.4	31	70,633	24,286	909	188	69,724	24,098	5.81	2.01	4,323	1,495
February	52.2	25.0	42.4	28	123,608	33,207	1,591	257	122,017	32,950	10.17	2.75	6,834	1,848
March	55.6	25.0	42.4	31	159,555	39,261	2,054	304	157,502	38,957	13.13	3.25	9,769	2,418
April	62.1	25.0	42.4	30	227,666	50,731	2,931	393	224,735	50,338	18.73	4.19	13,486	3,017
May	69.6	25.0	42.4	31	307,128	64,113	3,953	496	303,175	63,617	25.26	5.30	18,793	3,943
June	77.7	25.0	42.4	30	392,267	78,451	5,049	607	387,217	77,844	32.27	6.49	23,234	4,673
July	82.0	25.0	42.4	31	437,674	86,098	5,634	666	432,040	85,431	36.00	7.12	26,784	5,297
August	80.2	25.0	42.4	31	418,754	82,911	5,390	642	413,364	82,270	34.45	6.86	25,631	5,104
September	73.8	25.0	47.9	30	292,834	61,706	3,769	478	289,064	61,228	24.09	5.10	17,345	3,672
October	65.1	25.0	47.9	31	202,019	46,412	2,600	359	199,419	46,053	16.62	3.84	12,365	2,857
November	53.2	25.0	42.4	30	134,960	35,119	1,737	272	133,223	34,847	11.10	2.90	7,992	2,088
December	46.6	25.0	42.4	31	64,957	23,330	836	181	64,121	23,149	5.34	1.93	3,973	1,436

Table 7: Projected Multi Year Ex ante and Ex post Savings of the Tank Insulation

Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	303,128	93,025				
3	2006	1,515,638	465,127	363.7	172.4		
4	2007	1,515,638	465,127	363.7	172.4		
5	2008	1,515,638	465,127	363.7	172.4		
6	2009	1,515,638	465,127	363.7	172.4		
7	2010	1,515,638	465,127	363.7	172.4		
8	2011	1,515,638	465,127	363.7	172.4		
9	2012	1,515,638	465,127	363.7	172.4		
10	2013	1,515,638	465,127	363.7	172.4		
11	2014	1,515,638	465,127	363.7	172.4		
12	2015	1,515,638	465,127	363.7	172.4		
13	2016	1,515,638	465,127	363.7	172.4		
14	2017	1,515,638	465,127	363.7	172.4		
15	2018	1,515,638	465,127	363.7	172.4		
16	2019	1,515,638	465,127	363.7	172.4		
17	2020	1,515,638	465,127	363.7	172.4		
18	2021	1,515,638	465,127	363.7	172.4		
19	2022	1,515,638	465,127	363.7	172.4		
20	2023	1,515,638	465,127	363.7	172.4		
TOTAL	**2004-2023**	27,584,612	8,465,316				

SITE A005 Bake **IMPACT EVALUATION**
SAMPLE CELL: ORIGINAL **TIER: 2** **END USE: AC&R**

Measure	Replacement of 600 ton Chiller
Site Description	Acute Care Hospital

1. Measure Description

This measure is for the replacement of an existing water cooled centrifugal chiller with a more efficient 600 ton water cooled centrifugal chiller rated at 0.57 kW/ ton. The chiller is the lead chiller in a central plant serving 488,000 square feet in an acute care hospital.

2. Summary of the Ex Ante Calculations

The project file shows output of the SPC calculator for chiller replacement.

The ex ante impacts were calculated as follows:

- Baseline Usage: 1,516,543 kWh/yr
- Proposed Usage: 1,223,452 kWh/yr
- Current Minimum Standard (Title 24) Demand: 344.8 kW
- Current Minimum Standard (Title 24) Usage: 1,334,558 kWh
- Baseline Demand: 391.9 kW
- Proposed Demand: 360.1 kW
- Annual Energy savings: 293,091 kWh/yr
- Demand savings: 31.8 kW
- Total Savings (5 years remaining useful life): 1,465,455 kWh
- Run time hours: 5,821 hours

The incentive was calculated (based on five years of savings) as follows:

- $0.14 per kWh
  Rebate was $0.14 x 1,465,455 = $205,163.70

3. Comments on the Ex Ante Calculations

The program file does not contain details of the ex ante calculation. The savings estimates were calculated using the SPC Calculator. Critical inputs, assumptions and algorithms used in the calculator to estimate the energy savings are not indicated in the project file.

No easily traceable documentation was provided as to the actual algorithms used in the SPC Calculator. The SPC Calculator, when used for chillers, utilizes the ASHRAE modified bin method. The actual input and calculation methodology may be a source of significant uncertainty regarding comparisons of ex ante to ex post calculations.

The total five year energy savings were indicated as the ex ante savings in the **initial** Installation Report Review (IRR) and were given as 1,465,455 kWh/yr and 32.0 kW; **these figures agreed with the utility tracking system originally provided. The kWh savings were updated later to reflect first year savings of 293,091 kWh and this figure is used in the realization rate calculations and as the ex ante savings figures.**

The ex-ante savings and incentive were **originally** based on the total annual savings for early retirement using the pre-existing chiller as the baseline for the first five years. Additional lifecycle savings will accrue for 15 years, since the chiller is more efficient than the applicable Title 24 baseline, and the anticipated effective useful life of the chiller is 20 years, according to the California Energy Efficiency Policy Manual (Version 2). Total lifecycle savings are estimated at 3,123,045 kWh as seen in Table 1.

Table 1: Ex Ante Savings Summary

	kW	kWh
Baseline Usage	391.9	1,516,543
Title-24 Baseline	344.8	1,334,558
Proposed Usage	360.1	1,223,452
Annual Early Retirement Savings	31.8	293,091
Total Early Retirement Savings (5 years)		1,465,455
Annual Title 24 Savings	-15.3	111,106
Total Title 24 Savings (15 years)		1,666,590
Total Life Cycle Savings (20 years)		3,132,045

Coincident peak kW demand savings due to the new chiller are 31.8 kW annually for all the five remaining years of the chiller's life. However, according the final revised savings calculation, the new chiller kW is above the kW demand of a Title 24 baseline efficiency unit. Thus, after year 5, peak demand savings will drop to -15.3 kW. This warrants further investigation.

4. Measurement & Verification Plan

This measure reduces chiller energy consumption. The savings realized by this measure are the additional energy required by the pre retrofit chiller as compared to the new chiller. The fundamental premise guiding the development of the measurement and verification plan is to determine the energy consumption of the new chiller and to estimate the consumption of the preexisting efficiency chiller. The M&V plan will be implemented in three basic steps:

1. On-site verification of chiller installation (name plate data). On-site monitoring of chilled water supply and return temperature, condenser water supply and return

temperature, and chilled water flow rate. Spot measurements of temperature and energy
2. Collect trend data from site energy management system and logs
3. Calculate the capacity, efficiency and the annual energy consumption of the chiller from the trend data

The facility has a fully instrumented central plant with trend data available. The following data sets will be requested:

- Chilled water flow rate (GPM)
- Chilled water supply temperature
- Chilled water return temperature
- Condenser water entering temperature
- Condenser water leaving temperature
- Chiller input power
- Outside air dry-bulb temperature
- Humidity sensor data if available (site contact did not believe that ambient humidity sensor was installed)

The site contact has stated that these data are available for the new chiller and possibly for the pre retrofit chiller. We will request these data for the current chiller for the period of at least one year. We will request data from when the pre retrofit chiller was operating, also for the period of one year. Once these data are obtained, we will produce an in-situ efficiency curve for both chillers as a function of load and condenser entering water temperature. Actual data are preferable, but we will use manufacturer's data for the pre retrofit chiller if actual performance data are unavailable to produce the efficiency curve. Chiller load as a function of outside air temperature will also be calculated.

With efficiency curves, a typical year's savings can be calculated by applying the load function to applicable climate zone data. This will generate an estimate of facility load for each hour of a typical year. Next, the efficiency curves for the new and old chillers will be applied to generate new and preexisting chiller typical annual consumption. The anticipated savings is the difference of the two consumption estimates.

Our on-site verification will strive to determine the overall quality of the monitoring installation and attempt to verify that the measurements are taken at the correct physical locations. We will attempt to verify the accuracy of the temperature and power measurements with redundant spot measurements. We will not verify the flow measurements, unless the site visit reveals an obvious instrumentation problem. Flow measurements will significantly increase the complexity and cost of the field activities and will only be performed if there are obvious problems with the filed installation and if Itron approves the additional costs. Using existing data streams always introduces some uncertainty, but when a site is fully instrumented it is usually the most cost effective way to proceed. If our spot measurements identify major discrepancies when compared to the operational data, we will develop an alternative M&V plan.

Formulae and Approach

The evaluation team used DOE2 simulation software to quantify the ex post savings. A simulation model was built for the entire hospital building by defining all end uses. The model was run with the typical climate zone weather data to retrieve hourly kW cooling data of the building. DOE 2 simulations were performed both for the baseline as well as for the post retrofit condition.

$$\text{Annual kWh Savings} = CAC_{old} - CAC_{new}$$

Where,

CAC= Estimated Chiller Annual Consumption

Peak kW savings will be calculated as the average expected demand reduction in the hours between 2 pm and 5 pm on the three hottest contiguous days on the week with the hottest day in the summer months of June, July, August, and September. The hottest days may be the expected hottest days with the highest wet bulb temperatures or as defined in the climate data for that climate zone.

$$\text{Peak demand kW} = kW_{pre} - kW_{post}$$

The greatest uncertainties in the ex ante savings estimate are associated with the estimate of chiller annual load profiles. The SPC calculator appears to generate a single estimate of effective full load hours based upon climate zone and presence of an economizer. Hospitals typically have high outside air requirements and significant internal loads considerably different than other commercial facilities. Using a load estimation tool for a generic commercial facility could easily generate a large amount of uncertainty.

Accuracy and Equipment

A clamp on power meter LEM 2060 Analyst from “Fluke Instruments” will be used to take spot measurements of the chiller. These instantaneous kW measurements will be compared with the collected trend kW data.

This power meter has the capability of measuring RMS voltage, current, power factor, true power and also it has the capability of measuring total harmonic distortion. This meter is also capable of short term logging. The minimum sampling interval is 1 second and maximum sampling interval is 1 hour. These data then can be downloaded to the PC for further analysis. The accuracy of this meter is ±2.5% of the reading.

Likewise, chiller and condenser water temperatures sensor and outside air temperature sensor will be cross checked with a digital thermometer, a Fluke 50D digital thermometers with type k thermocouples and instrumental accuracy of 0.1% +1.3°F.

In addition, a Dent kW logger with three current transformers will be installed on the 600 ton chiller for a period of at least three weeks. This logger can sample at intervals of 3 seconds. The accuracy is better than 1% of the reading. The accuracy of the current transformers is approximately +/-1%.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on July 17, 2007. Information on the new equipment and operating conditions was collected by inspection and interviewing the facility representative. A true power logger was installed on the chiller for a period of two weeks from July 17th through August 1st.

Unfortunately, trend data for this site were not available electronically. A limited amount of hand entered data was available, but it was not complete enough for annual load estimate for the site. The site contact assured the evaluation team that the project sponsor had trend data sufficient to calculate annual load, but multiple calls and emails to the project sponsor went unanswered.

Installation Verification

The evaluation team verified the new 600 ton centrifugal chiller. The new chiller was as described in the project file. The facility representative stated that the retrofit was completed in late 2004.

This was the only AC&R measure this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 7 below.

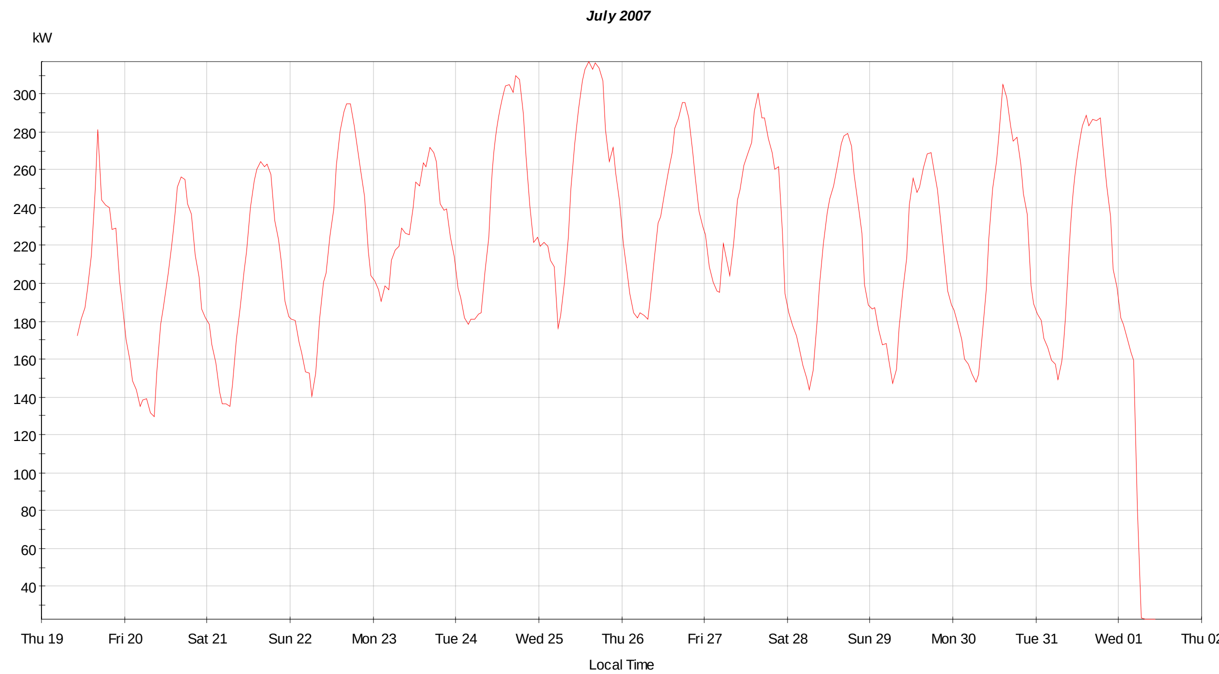
Scope of the Impact Assessment

The impact assessment scope for this application is for the AC&R end use measure in the SPC application covering the chiller replacement. The savings for this site, consisting of a lighting retrofit and the chiller replacement, were dominated by this measure.

Summary of Results

True power loggers were installed on the incented chiller for two weeks (from July 17, 2007-August 1, 2007) to measure the power consumption and operating hours of the chiller

Figure 1: 600 Ton VSD Chiller Raw Meter Data



Ex post energy and demand savings were calculated using DOE2 simulations. A simulation model was built for the portion of the hospital building served by the central plant. The model was run with the applicable CA climate zone weather data to estimate hourly kW cooling data of the building. DOE 2 simulation was performed for both the pre retrofit and post retrofit conditions. The hourly kW is simply the difference between the baseline hourly kW consumption and evaluated hourly kW consumption. The details of the savings are shown in Table 2 below. The baseline end-use is defined as the entire chiller plant, the new lead chiller along with the two preexisting units used as trim chillers. The trim chillers were modeled as “energy neutral”, so the all savings stem from the new chiller.

Table 2: Ex Post Savings Calculations

	kW	kWh
Baseline Usage	631.9	2,058,584
Title-24 Baseline	619.0	2,014,276
Proposed Usage	590.6	1,916,988
Annual Early Retirement Savings	41.3	141,597
Total Early Retirement Savings (5 years)		707,985
Annual Title 24 Savings	28.4	97,288
Total Title 24 Savings (15 years)		1,459,320
Total Life Cycle Savings (20 years)		2,167,305

The early retirement annual energy savings are estimated at 141,597 kWh per year. The first year ex post savings are slightly less than 50% of the forecast first year savings and the realization rate is 0.48 for energy savings. The deviation comes from an increase in the estimation of annual load on the chiller and a decrease in the energy savings available. Since the ex ante assumptions are not available, an exact determination of deviation can not be explained definitively. The increase in peak kW savings was also not able to be explained. There is a discrepancy in the ex ante floor area served by the chiller and the area reported by facility personnel during our site visit, but the discrepancy was only 4%.

Alternatively, the ex post demand reduction is estimated at 39.5 kW for an engineering realization rate of 1.23. A summary of the realization rate is shown in Table 7.

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	3/15/2005	$602,492	32.0	293,091	0	$38,102	205,164	10.4	15.8
SPC Program Review (Ex Post First Year)	7/17/2007	$602,492	41.3	141,597	0	$18,408	205,164	21.6	32.7

Utility billing data for the site was reviewed. In the 12 month period from February 2003 - January 2004 (pre-retrofit), the facility consumed 14,536,452 kWh. Peak demand was 2,510 kW in July 2003. Table 3 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results. The baseline end use is the estimated annual chiller load for the facility's entire chiller plant as estimated by the ex post simulation model. Table 4 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations.

Table 3: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	2,510.4	14,536,452
Baseline End Use	376.6	2,058,584
Ex Ante Savings	32.0	293,091
First Year Ex Post Savings	41.3	141,597
Average Ex Post Savings	31.6	108,365

Table 4: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		First Year Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	1.3%	2.0%	1.6%	1.0%
Baseline End Use %	8.5%	14.2%	10.5%	6.9%

6. Additional Evaluation Findings

Although there is uncertainty regarding the annual load on the facility's central plant, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

Although the evaluation team is confident in the ex post findings, being supplied with actual pre-retrofit data could have improved the impact analysis. Instead, the evaluation depended upon the memory of plant personnel, and needed to make certain assumptions to create a pre-retrofit profile of post retrofit operating conditions.

The measure's incentive calculation was based on five years of early retirement savings. The preexisting lead chiller was installed in 1986, and the five years of remaining useful life would be expected from the SPC Calculator life expectancy of 23 years.

The incentive payment based upon five years of savings is inconsistent with expected first year or annual savings; based on expected first year ex ante savings, the incentive should have been $41,146, or 20% of the incentive paid.

7. Impact Results

With a cost of $602,492 and a $205,164 incentive, the project had a 10.4 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante; as a result, the estimated simple payback is 21.6 years. However, these costs seem very high for a project of this type. A summary of the economic parameters for the project is shown in Table 5. Table 8 shows projected annual ex ante and ex post energy savings through 2023.

Table 5: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	3/15/2005	$602,492	32.0	293,091	0	$38,102	205,164	10.4	15.8
SPC Program Review (Ex Post First Year)	7/17/2007	$602,492	41.3	141,597	0	$18,408	205,164	21.6	32.7

Table 6: Realization Rate Summary

	kW	kWh
SPC Tracking System / **EEGA-Updated**	32.0	293,091
SPC Installation Report (ex ante) **- Updated**	32.0	293,091
Impact Evaluation (first year ex post)	41.3	141,597
Engineering Realization Rate - First Year	1.29	0.48
Impact Evaluation (Average ex post)	31.6	108,365
Engineering Realization Rate (Average)	0.99	0.37

Table 7: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Chiller	AC&R	Replacement of existing water cooled chiller with VSD centrifugal chiller			1	600 ton VSD Chiller	Physically verified the 600 ton VSD centrifugal chiller	1.00

Table 8: Projected Multi Year Ex Ante and Ex Post Savings

Program Name:		SPC 04-05 Evaluation Site A005					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004						
2	2005	293,091	141,597	32.0	41.3		
3	2006	293,091	141,597	32.0	41.3		
4	2007	293,091	141,597	32.0	41.3		
5	2008	293,091	141,597	32.0	41.3		
6	2009	293,091	141,597	32.0	41.3		
7	2010	111,106	97,288	-15.3	28.4		
8	2011	111,106	97,288	-15.3	28.4		
9	2012	111,106	97,288	-15.3	28.4		
10	2013	111,106	97,288	-15.3	28.4		
11	2014	111,106	97,288	-15.3	28.4		
12	2015	111,106	97,288	-15.3	28.4		
13	2016	111,106	97,288	-15.3	28.4		
14	2017	111,106	97,288	-15.3	28.4		
15	2018	111,106	97,288	-15.3	28.4		
16	2019	111,106	97,288	-15.3	28.4		
17	2020	111,106	97,288	-15.3	28.4		
18	2021	111,106	97,288	-15.3	28.4		
19	2022	111,106	97,288	-15.3	28.4		
20	2023	111,106	97,288	-15.3	28.4		
TOTAL	**2004-2023**	**3,020,939**	**2,070,015**				

Adjusted to Annual Savings for Ex Ante and Ex Post – Chillers with 20 Year Life

SITE A006 (2005-xxx) Cali IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 1 END USE: Gas

Measure	Insulate 16 edible oil tanks
Site Description	Edible oils refinery

1. Measure Description

The measure involves the application of insulation to the walls of 16 edible oil tanks with Pittsburg Corning FOAMGLAS insulation. The tanks store edible oils maintained at 150^{o} F with steam from a natural gas boiler. The applied two inches (2") of insulation has a rated R-value of 6.9 at 75º F.

2. Summary of the Ex Ante Calculations

The utility's installation reviewers utilized the itemized measure prescribed savings and incentive to calculate the final savings and incentive. The energy savings are realized due to the reduction in heat loss from the tanks and the incentive is calculated on a per square foot of insulation basis.

The ex ante impacts were calculated as follows:

- Baseline Usage: 1,591,029 therm/yr
- Proposed Usage: 1,036,944 therm/yr
- Annual Energy Savings: 554,085.6 therm/yr
- Surface area of all 16 tanks: 48,604 ft^2

The incentive was calculated as follows:

- \$3 per square foot
  Rebate was \$3/ft^2 x 48,604 ft^2 = \$145,812

The utility tracking system figures agree with the ex ante savings as reported in the Installation Report Review (IRR).

3. Comments on the Ex Ante Calculations

The program file does not contain details of the ex ante calculations. The estimates are based on 11.4 therms per sf for high temperature tank insulation, which is derived from a 180 F solution, 4,200 hours per year of operation, and 2 inches of insulation placed over uninsulated surfaces. This prescribed savings estimate is not specific enough to yield accurate ex ante or ex post estimates. For example, in this application, the temperature is lower, but the hours are longer. These effects are not expected to cancel each other.

The documentation does not indicate the location of tanks (indoor or outdoor) and the operational schedules of the tanks.

The critical input variables used to generate precise energy savings estimates are the following:

- Number of Tank Types
- Tank Material
- Tank Dimensions (ft)
- Wall Thermal Transmittance (Btu/h·ft2·°F)
- Roof Thermal Transmittance (Btu/h·ft2·°F))
- Tank Color (light, medium, or dark)
- Sun Exposure (none, minimal, partial, or total)
- Wind Exposure (none, minimal, partial, or total)
- Geographic Location
- Location of Tanks (outside, inside [unconditioned space] or inside [conditioned space])
- Boiler System Efficiency
- Insulation Specifications for Existing and Proposed: (thermal resistance
- [h·ft2·°F/Btu·in] and thickness [in])
- Conditioned Space Temperature (°F)
- Tank Temperature (average monthly temperature (°F) set point inside tank)
- Operating Days per Month

The above inputs imply the calculation is performed in monthly bins. The primary drivers for heat transfer calculations of this type are heat transfer data, hours of use, and temperature difference, which suggests that an hourly analysis with typical weather data may be more appropriate.

4. Measurement & Verification Plan

This measure reduces the heat loss from the tanks. The savings realized by this measure are due to lower fuel consumption required to compensate for the additional heat loss from un-insulated tanks. The fundamental premise in development of the measurement and verification plan is to determine the amount of fuel required if the tank had not been insulated. The M&V plan will be implemented in three basic steps:

1. On-site verification of insulation installation (type, thickness, area covered and installation quality; collect data on-site for tank size and all other items listed above (as possible)
2. Obtain monitored and archived data from customer records
3. Calculate the reduction in annual heat loss due to additional tank insulation and estimate fuel requirement of that heat loss reduction

Typically, these types of facilities keep archived monitored data of operational schedules and product throughput. The site contact promised to gather these data prior to the site visit. The requested data included:

- Operational schedules of the tanks
- Tank temperature set points
- Insulation materials
- Boiler data, name plate information and related documentation
- Boiler flue gas analysis results

The existence of these data and the willingness of the client to share these data with the evaluation team ultimately determined the M&V approach. If any of the requested data were unavailable, the evaluation team will use a self-reported approach.

Our on-site verification includes attempting to determine the overall quality of the monitoring installation and that any measurements taken were taken at the correct physical location. The accuracy of the temperature readings will be verified by redundant spot measurements. Using existing data streams often introduces some uncertainty; however, when a site is fully instrumented, it can be the most accurate and cost effective way to proceed.

Formulae and Approach

The savings due to the reduction in heat loss at the tank is calculated as the difference in heat transfer from the tank(s) with and without the insulation. The heat transfer occurs primarily due to convection and conduction; radiation effects are negligible and therefore are neglected. The tank temperature is assumed to be constant. The heat transfer equations presented below were used for the ex post calculations. The overall heat transfer was quantified as follows:

$$Q = h_{wall} A_{surface,wall} (T_s - T_\infty) + h_{top} A_{surface,top} (T_s - T_\infty)$$

Where,

Q = overall heat transfer
h = heat transfer coefficient
A = surface area of heat transfer
T_s = tank surface temperature, and
T_∞ = ambient temperature.

The overall heat transfer is calculated separately for the walls and the top of the tank since both A and h will change for these two situations. The three variables that change for the pre and post scenarios (with and without insulation) are *h*, k (thermal conductivity) and Δx (insulation thickness). The heat transfer coefficient is found using the Nusselt number equations below. The subscripts D and L represent diameter and length, respectively for the cylinder wall and cylinder top. In other words, h_D is the heat transfer coefficient for the tank walls and h_L is that for the top of the tank.

$$\overline{h_D} = \frac{\overline{Nu}_D k_{air}}{D}$$

$$\overline{h_L} = \frac{\overline{Nu}_L k_{air}}{L}$$

The Nusselt number is derived from both the Reynolds number and the Prandtl number. For the walls of the cylinder, the Nusselt number is calculated as shown below. This equation applies for a cylinder in cross flow with a Reynolds number $\leq 10^7$.

$$\overline{Nu}_D = 0.3 + \frac{0.62 \, \mathrm{Re}_D^{1/2} \, \mathrm{Pr}^{1/3}}{\left[1 + \left(\frac{0.4}{\mathrm{Pr}}\right)^{2/3}\right]^{1/4}} \left[1 + \left(\frac{\mathrm{Re}_D}{282{,}000}\right)^{5/8}\right]^{4/5}$$

In contrast, if the top of the cylinder is assumed to transfer heat like a flat plate, then the Nusselt number is calculated as follows. This equation applies only for laminar flow with a Prandtl ≥ 0.6 and a Reynolds $\leq 5\times10^5$.

$$\overline{Nu}_L = 0.664 \, \mathrm{Re}_L^{1/2} \, \mathrm{Pr}^{1/3}$$

The Reynolds number and Prandtl number are defined as shown below. For the top of the cylinder the length is assumed to be 1/3 of the diameter.

$$\mathrm{Re}_D = \frac{VD}{\nu}$$

$$\mathrm{Re}_L = \frac{VL}{\nu}$$

$$\mathrm{Pr} = \frac{c_p \mu}{k_{air}} = \frac{\nu}{\alpha}$$

Where,

D = diameter of tank
L = length of top plate

k_{air} = thermal conductivity of air
Re = Reynolds number (dimensionless)
Pr = Prandtl number (dimensionless)
Nu = Nusselt number (dimensionless)
V = average fluid velocity
ν = kinematic fluid viscosity
c_p = specific heat at constant pressure
μ = viscosity
α = thermal diffusivity

The energy savings due to the insulation is the difference in the value of *Q* with and without the insulation. The boiler efficiency also needs to be taken into account. Therefore, the total energy savings are defined as follows:

$$Q_{savings} = \frac{Q_{non-ins} - Q_{ins}}{\eta_{boiler}} * (annualhours)$$

Where,

$Q_{non\text{-}ins}$ = heat transfer across tank without insulation
Q_{ins} = heat transfer across tank with insulation
η_{boiler} = % thermal combustion efficiency of boiler
annualhours = annual hours of operation

Radiant heat transfer was considered negligible. The tank insulation had an unpainted metal jacket that blocked solar radiation, and a tight arrangement of tanks made for substantial shading from other tanks. Furthermore, the insulated walls of the tanks were mostly facing other tank walls, so most radiant heat transfer from the insulated surfaces was with other incented tanks.

There is uncertainty involved in several aspects of the savings calculations. In general, savings estimates for a installing a tank insulation measure will involve an estimated 15-20% error due mainly to the complexity of the heat transfer relationships for outdoor tanks. Additionally, the self reported set point and hours of operation have significant uncertainty.

Accuracy and Equipment

The outside surface temperature of the tanks will be measured with a Fluke 50D digital thermometer with type k thermocouples with instrumental accuracy of 0.1% +1.3°F. A small temperature gradient across the metal tank was assumed.

All data collected was reviewed to ensure it conformed to realistic values and was verified with other data collected to identify any anomalies. No data needed to be scrutinized or removed from the analysis.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on July 17, 2007. Information on the equipment and operating conditions was collected by inspection of the tanks and heating system. In addition, data were collected by interviewing the facility representative. We verified the tank surface temperature for all tanks by spot temperature measurements. It was discovered that the site has considerable process loads that used the same steam heat as the tanks. Therefore, the estimate of annual tank temperature maintenance natural gas usage could not be calibrated to annual facility natural gas usage, since the proportion of process and tank temperature maintenance gas requirements was unknown.

Installation Verification

We physically verified that there were 16 insulated tanks. All of the tanks have 2" of Pittsburgh Corning FOAMGLAS insulation, corresponding to an approximate R-value of 6.89. The insulation appeared to be installed correctly and it covered the entire tank. During the on-site visit, the evaluation team verified the following parameters:

- Tank dimensions and capacity: 48,606 total sf of surface area
- Number of tanks: 16
- Insulation material and thickness: 2" of Pittsburgh Corning FOAMGLAS insulation
- Boiler combustion efficiency: 82.0%
- Internal tank temperature: various
- Location of tanks: outdoors
- Operational schedule: 7,884 annual hours

The tank temperature was reported as 150°F in the project application, but during the interview with the facility representative he stated that the set point temperature was 130°F with a ten degree dead-band, i.e. the heating was called if the temperature was at or below 130 and stayed on until the temperature hit 140, resulting in an average oil temperature 135°F. However, during the field inspection it was found that several of the tanks were not being utilized and others had temperatures below 130°F (ranging from 97°F to 110°F). During stages of oil processing, volumes of oil are being delivered to the tanks at temperatures well below 130°F. A tank requires several days for a tank load of oil to be heated up to set-point temperature: therefore, the effective heat loss for these tanks is lower during this transient condition. According to the site contact, it was common to have several tanks below the desired 130-140 °F range. Furthermore, during the evaluation site visit, the site contact noticed that the heat to a number of the incented tanks had been accidentally turned off (a condensate return valve for an entire tank farm had been shut in error) for an indeterminate amount of time. Therefore, we observed many tanks below setpoint. However, since this scenario was not representative, the evaluation team "trued-up" the effective average with self-reported effective temperatures, in order to be as representative as possible of typical annual operation.

Ultimately, for the purposes of savings estimations, the evaluation team modeled the temperature of three of the most common sized tanks (29' tall, 35' diameter); two tanks (T34 & T35) are modeled at 115°F and one tank (T36) is modeled at 100°F.

The facility representative stated that the tanks operate 24 hours a day, 7 days a week and 52 weeks a year. However, the site contact explained that due to lapses between the transfer of products, and tank cleaning, tanks were not maintained at temperature approximately 10% of the year. We observed of three empty tanks during the site visit. We accounted for this by applying the use factor of 90% to all tanks.

Table 1: Insulated Oil Tanks

Tank #	Area(ft^2)	Temp (°F)	Height (ft)	Diameter (ft)
T1	3,016	135	24	40
T2	3,016	135	24	40
T23	3,393	135	24	45
T24	3,393	135	24	45
T47	3,393	135	24	45
T34	3,189	115	29	35
T35	3,189	115	29	35
T36	3,189	110	29	35
T38	3,189	135	29	35
T39	3,189	135	29	35
T40	3,189	135	29	35
T41	3,189	135	29	35
T43	3,189	135	29	35
T46	3,189	135	29	35
T48	2,714	135	24	36
H6	980	135	26	12
Total	**48,606**			

These are the only measures in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 4a below.

	Therms
SPC Tracking System	554,086
SPC Installation Report (ex ante)	554,086
Impact Evaluation (ex post)	275,814
Engineering Realization Rate	0.50

Scope of the Impact Assessment

The impact assessment scope is for the insulation of oil tanks heated by a natural gas boiler. This is the only measure in this application.

Summary of Results

Spot temperature measurements were carried out using a Fluke 50D digital thermometer on all the insulated oil tanks. It was found that some of the tanks have different operating temperatures, whereas ex ante estimates were based on a common tank temperature of 150°F. It was also verified that the temperature set point is 130°F with a 10°F dead-band resulting in an average temperature of 135°F. Tank surface temperatures were used as quality control checks for the heat transfer calculations.

The ex post calculations were performed through an hourly analysis and using dry bulb temperature and wind speed from typical meteorological year (TMY) weather data for the applicable California climate zone. Seven hourly analyses were performed for each separate combination of tank size and average temperature. Table 2 shows the analysis results for each tank type.

A utility factor of 90% was applied to the total therm savings to account for the 10% of the year during which the tanks are empty and not maintained at temperature.

Table 2: Hourly Analysis Results by Tank Type

Tank #	Total Baseline Q (therms)	Total Post Q (therms)	Total Q Savings (therms)
T1, T2	60,358	20,028	40,330
T23, T24, T47	102,655	35,195	67,460
T34, T35	45,067	13,136	31,931
T36	16,523	4,833	11,690
T38, T39, T40, T41, T43, T46	182,937	53,641	129,296
T48	26,999	8,698	18,301
H6	9,620	2,169	7,451
Total	**444,159**	**137,699**	**306,460**
Usage @ 90%	**399,744**	**123,929**	**275,814**

Utility billing data for the site was reviewed. In the 12-month period from January 2003 - December 2003 (pre-retrofit), the facility consumed 1,603,635 therms. Table 3 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results. Note that the site has considerable process heating loads on the steam heating system in addition to oil temperature maintenance.

Table 4 is a summary of the percent of energy savings for the total metered use and for the baseline end use. Note that the baseline end-use estimate used for both the ex ante and ex post percentages came from the evaluation team's ex post estimate of facility tank temperature natural gas usage. The ex ante results showed a 34.6% decrease in total meter therms and a 138.6% decrease in boiler end use therms. The ex post results showed a 17.2% decrease in total meter therms and 69.0% decrease in temperature maintenance end use therms.

Table 3: Total Meter, Ex Ante, Ex Post Results

	Therms
Total Meter	1,603,635
Baseline End Use	399,744
Ex Ante Savings	554,086
Ex Post Savings	275,814

Table 4: Percent Savings Ex Ante, Ex Post

Therm Savings	Ex Ante Therms	Ex Post Therms
Total Meter %	34.6%	17.2%
Baseline End Use %	138.6%	69.0%

6. Additional Evaluation Findings

The ex post energy savings are less than the ex ante energy savings because we found that the ex ante savings greatly overestimated the tank temperature. No justification was provided in the application for this assumption.

We were unable to physically verify the pre-retrofit tanks and hours of operation However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $416,301 and a $148,812 incentive, the project had a 0.61 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 1.23 years. A summary of the economic parameters for the project is shown in Table 5.

The effective useful life of the insulation system is 20 years.

Table 8 shows projected annual ex ante and ex post energy savings for multiple years 2004 through 2025.

Table 4a: Verification Summary

Measure Description	End-use category	HVAC Measure Description	Lighting Measure Description	Gas Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Insulate the Tanks	G			Insulate the Oil Tanks	16	16 oil tanks insulated with Pittsburgh Corning FOAMGLAS insulation	Physically Verified insulation of all the tanks	1.0

7. Impact Results

The engineering realization rate for this application is 0.50 for therm energy savings. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 6.

Table 5: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, Therms	Estimated Annual Cost Savings ($0.8/therms), $	SPC Incentive, $	Simple Payback w/ Incentive, yrs	Simple Payback w/o Incentive, yrs
Installation Approved Amount (Ex Ante)	11/22/2005	$416,301			554,086	443,268	145,812	0.61	0.94
SPC Program Review (Ex Post)	7/17/2007	$416,301			275,814	220,651	145,812	1.23	1.89

Table 6: Realization Rate Summary

	Therms
SPC Tracking System	554,086
SPC Installation Report (ex ante)	554,086
Impact Evaluation (ex post)	275,814
Engineering Realization Rate	0.50

Table 7: Installation Verification Summary

Measure Description	End-use category	HVAC Measure Description	Lighting Measure Description	Gas Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Insulate the Tanks	G			Insulate the Oil Tanks	16	16 oil tanks insulated with Pittsburgh Corning FOAMGLAS insulation	Physically Verified insulation of all the tanks	1.0

Table 8: Projected Multi Year Ex Ante and Ex Post Savings

Program Name:		SPC 04-05 Evaluation Site A006					
Year	**Calendar Year**	**Ex Ante Gross Program-Projected Program kWh Savings**	**Ex Post Gross Evaluation Confirmed Program kWh Savings**	**Ex Ante Gross Program-Projected Peak Program kW Savings**	**Ex Post Gross Evaluation Projected Peak kW Savings**	**Ex Ante Gross Program-Projected Program Therm Savings**	**Ex Post Gross Evaluation Confirmed Program Therm Savings**
1	2004	0.0	0.0	0.0	0.0	0.0	0.0
2	2005	0.0	0.0	0.0	0.0	92,348	45,969
3	2006	0.0	0.0	0.0	0.0	554,086	275,814
4	2007	0.0	0.0	0.0	0.0	554,086	275,814
5	2008	0.0	0.0	0.0	0.0	554,086	275,814
6	2009	0.0	0.0	0.0	0.0	554,086	275,814
7	2010	0.0	0.0	0.0	0.0	554,086	275,814
8	2011	0.0	0.0	0.0	0.0	554,086	275,814
9	2012	0.0	0.0	0.0	0.0	554,086	275,814
10	2013	0.0	0.0	0.0	0.0	554,086	275,814
11	2014	0.0	0.0	0.0	0.0	554,086	275,814
12	2015	0.0	0.0	0.0	0.0	554,086	275,814
13	2016	0.0	0.0	0.0	0.0	554,086	275,814
14	2017	0.0	0.0	0.0	0.0	554,086	275,814
15	2018	0.0	0.0	0.0	0.0	554,086	275,814
16	2019	0.0	0.0	0.0	0.0	554,086	275,814
17	2020	0.0	0.0	0.0	0.0	554,086	275,814
18	2021	0.0	0.0	0.0	0.0	554,086	275,814
19	2022	0.0	0.0	0.0	0.0	554,086	275,814
20	2023	0.0	0.0	0.0	0.0	554,086	275,814
TOTAL	**2004-2023**	**0.0**	**0.0**	**0.0**	**0.0**	**10,065,888**	**5,010,622**

SITE A007 (2004-xxx) E&J G IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: GAS

Measure	Condensate Storage Tank Insulation
Site Description	Winery

1. Measure Description

This measure is for the application of R-20 urethane foam insulation to a large condensate storage tank. The tank holds condensate which is the by-product of a grape juice concentration process. The condensate is held in the tank to be used as make-up feed water for the boiler. The baseline for this measure is a tank without any insulation. Prior to the application of the insulation, the boiler used the condensate from the uninsulated tank as make-up feed water. The temperature of the condensate water is approximately 140°F, according to the project application file. The energy savings are a result of the reduced heat loss from the tank, which in turn reduces the boiler energy consumption.

2. Summary of the Ex Ante Calculations

The project file indicates that the facility used heat transfer equations to determine ex ante savings. The application paperwork shows estimated inputs for the R-value of insulation, insulation thickness, condensate temperature inside tank, boiler efficiency, tank dimensions, and outside air temperature. However, it is lacking information for the operational schedules of the tank and heating system. The assumption appears to be that the boiler operates 24 hours a day, 7 days a week, all year.

The condensate is the by-product of a grape juice concentration process at the facility. The condensate is stored in the storage tank and then is fed into the boiler for make-up water. Energy is saved because the insulation decreases the heat loss from the tank to the ambient, resulting in a higher temperature feedwater. The program verification consisted of confirming the insulation installation, tank surface area, insulation thickness, inside tank temperatures, and boiler efficiency.

An incentive of $82,739 was calculated per therm of energy savings. However, the incentive was limited to $44,354 due to the 50% capital cost limitation.

The ex ante impacts were calculated as follows:

- Baseline Usage: 86,214 therm/yr
- Proposed Usage: 3,475 therm/yr
- Annual Energy savings: 82,739 therm/yr

The incentive was calculated as follows:

- $1/therm: Incentive is $1/therm x 82,739 therms = $82,739.
  Incentive was $1 x 82,739 = $82,739
- Incentive was only $44,354 due to 50% measure cost limitation.

3. Comments on the Ex Ante Calculations

The ex ante calculations employed heat transfer equations and a temperature bin analysis to calculate savings. The assumptions that went into the calculations include tank temperature, heat transfer coefficient, and hours of operation. The ex ante calculations assumed a tank temperature of 140° F, a baseline heat transfer coefficient of 1.190 Btu/hr-sqft-° F, a proposed heat transfer coefficient of 0.048 Btu/hr-sqft-° F, and 8,760 annual hours of operation. The 140° F temperature was verified onsite during the verification inspection. In addition, the condensate flow rate was measured during the verification inspection. The heat transfer coefficient (U) was based on the thickness and heat transfer resistance of the medium through which the heat is being transferred (the tank and insulation material). It was assumed that these were steel, insulation, and air for the proposed insulation, and only steel and air for the baseline condition.

The ex-ante savings are based on the difference of baseline energy consumption and proposed energy consumption, in therms. An hourly bin analysis of the outside air temperature was carried out in order to calculate the baseline and proposed natural gas consumption of the boiler with altered feedwater temperatures due to the tank insulation.

The total savings in the Installation Report Review were given as 82,739 therms/year and an incentive of $44,354. These values agree with the utility tracking system. However, the measure is listed incorrectly as “Process Boiler – Other”.

4. Measurement & Verification Plan

The facility where the insulation was installed is a 40 acre winery that used 285,938 therms of natural gas from February 2003 to February 2004. The savings are realized by not requiring gas consumption to compensate for the heat loss due to storing preheated feedwater recovered from a distillation process in an uninsulated tank.

The goal of the evaluation is to determine the actual energy savings over the useful life of the measure.

The fundamental premise in the development of the measurement and verification plan was to determine the amount of gas required if the tank had not been insulated. The M&V plan was implemented in three basic steps, as follows:

1. Verify onsite the insulation installation (type, thickness, area covered and installation quality), tank size, and boiler efficiency (using the model number or combustion analysis).
2. Collect trend data, such as tank temperature, from site energy management system and logs.
3. Calculate the annual reduction in heat transfer and estimate the gas required to provide the heat if the insulation were not present.

The initial contact by phone with the client was an essential first step in the development of this plan and helped further define the monitoring scope. During the phone call, the evaluation team inquired as to the location of the tank (inside or outside), operating hours of the tank and the heating system. The call also established any metered data that the facility had collected, and whether or not that data was available for this evaluation.

Facilities of this type typically monitor their processes and keep records of monitored data, operational schedules and product throughput. The following data was requested:

- Operational schedules of the tank and boiler
- Tank temperature set points
- Heating source data, boiler name plate information and/or documentation
- Condensate temperature
- Ambient temperature

The existence of these data and the willingness of the client to share these data with the evaluation team ultimately determined the M&V approach. If some data was unavailable, the evaluation team used a self-reported approach.

Our on-site verification attempted to determine the overall quality of the existing monitoring installation and that any measurements are taken at the correct physical location. The accuracy of the temperature readings was verified by redundant spot measurements. Using existing data streams often introduces some uncertainty; however, when a site is fully instrumented, it can be the most accurate and most cost effective way to proceed.

Formulae and Approach

The heat loss occurring across the tank wall was calculated twice: once with the insulation and once without the insulation. The difference of these two heat transfer values, adjusted for boiler efficiency, is the heat saved due to the insulation. The heat transfer occurs primarily due to conduction; therefore, convection and radiation effects were neglected. We used the heat transfer equations presented below for the ex post calculations. The conductive heat transfer was quantified as follows:

$$Q = UA_s(T_s - T_\infty)$$

where,

Q = convective heat transfer
U = conduction heat transfer coefficient
A_s = tank surface area of heat transfer
T_s = tank surface temperature, and
T_∞ = ambient temperature.

In this case, the only variable that changes for the baseline and proposed scenarios (with or without insulation) is U, the heat transfer coefficient. The coefficient was estimated using the material properties of the tank and insulation. A bin analysis of the outside air temperature was performed in order to give an accurate estimate for the number of operating hours in a given temperature range. The tank temperature was assumed to be constant.

The energy savings due to the insulation is the difference in the value of *Q* with and without the insulation. However, the boiler efficiency was taken into account also. Therefore, the total energy savings were the following:

$$Q_{savings} = \frac{Q_{non-ins} - Q_{ins}}{\eta_{boiler}} * (annualhours)$$

Where,

$Q_{non-ins}$ = heat transfer from tank without insulation
Q_{ins} = heat transfer from tank with insulation
η_{boiler} = % thermal efficiency of boiler
Annual hours = annual hours of operation

The team will measure the temperature, height and diameter of the tank. We used the above equation to calculate the annual energy savings.

Uncertainty for the savings estimate for the boiler can be more fully understood by setting projected ranges on the primary variables.

R = thermal resistance (hr.ft^2.°F/Btu)
- expected, minimum, maximum (0%, -5%, +5%), (20.0, 19, 21)[1]

A = heat transfer area (ft^2)
- expected, minimum, maximum (0%, -3%, +3%), (8524, 8268, 8780)

Ts = tank surface temperature (°F)
- expected, minimum, maximum (0%,- 2 %, +2%) (140, 137, 143)

Hr = Annual Operating hours (hours-self reported)
- expected, minimum, maximum (0%,- 10 %, +0%) (8760, 7884, 8760)

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[1] http://www.polyurethane.org/s_api/sec.asp?CID=909&DID=3622

Accuracy and Equipment

The outside surface temperature of the tanks was measured with a Fluke 50D digital thermometer with type k thermocouples; the overall instrumental accuracy is 0.1% +1.3°F.

All data collected was reviewed to ensure it conformed to realistic values and was verified with other data collected to identify any anomalies. No data needed to be scrutinized or removed from the analysis.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 30, 2007. Information on the equipment and operating conditions was collected by inspection of the tanks and heating system. In addition, data were collected by interviewing the facility representative. The facility provided us with tank temperature data for the month of August 2007. These data were recorded on one second intervals.

Installation Verification

The facility representative verified that there was one insulated condensate tank. We physically verified that the tank had approximately 3" of urethane foam insulation, corresponding to approximately R-20. The insulation appeared to be installed correctly and it covered the entire tank. During the onsite visit, the evaluation team verified the following parameters:

- Tank dimensions and capacity, approximately 8,524 sqft of surface area
- Insulation material and thickness, 3" of urethane foam
- Boiler combustion efficiency, 80.9%
- Internal tank temperature, 150°F
- Location of tanks, outdoors
- Operational schedule, constant operation July through January, half-time operation February through June

The boiler combustion efficiency was found in the previous project review to be 80.9% for the ex ante analyses. This was calculated using the Steam System Assessment Tool (SSAT). The boiler was measured as operating on 20.3% excess air with a stack temperature of 440 °F, according to facility personnel.

The tank temperature was reported as 140 °F in the project application file. However, according to the temperature data collected at the site, it was 150 ° F on average.

The facility representative reported that the tanks operate 24 hours a day, 7 days a week for seven months of the year, typically July through January. The operating time fluctuates during the remainder of the year. On average, the tank is full about 12 hours per day during the remaining five months. Altogether, this results in annual operating hours of 6,935 hours / per year, or approximately 79% of the time.

This is the only measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 6 below.

Scope of the Impact Assessment

This is the only measure in the application for this project at this site. Therefore, the impact assessment scope is for the insulation tank end use measure only, which is in the "Gas" end use category.

Summary of Results

The ex ante calculations were performed using a temperature bin analysis and heat transfer fundamentals. The ex post savings were estimated using the same method since it is appropriate for the application. None of the parameters were changed for the evaluation, except for the tank temperature and the operating schedule. The remainder of the parameters was either verified onsite to have the same value as the ex ante estimates, or accepted as reasonable when there were no data available. In addition, we received one second tank temperature data for the month of August 2007. The average tank temperature was calculated to be 150° F from the monitored data. The maximum recorded tank temperature was 172° F, while the minimum was 85° F. Similarly, the tank was reported as full for approximately 79% of the year, according to facility personnel. The heat transfer coefficient was estimated to be 0.048 Btu/hr ft^2 °F in the ex ante and ex post analysis.

A bin analysis was performed to estimate the number of annual operating hours in a given outdoor air temperature range. We used TMY data to calculate the number of annual hours in each temperature range, and then multiplied the number of hours by 79%, the percentage of the hours per year in which the tank contains preheated feedwater. Table 1 presents the bin analysis and ex post savings calculation results.

Table 1: Bin Analysis, Hours, and Gas Savings

Outdoor Temperature Bin Range (°F)	Annual Hours in Bin	Baseline Gas Consumption, therms	Evaluated Gas Consumption, therms	Gas Savings, therms
15-19	0	0	0	0
20-24	2	25	1	24
25-29	21	317	13	304
30-34	171	2,540	102	2,437
35-39	401	5,683	229	5,454
40-44	564	7,649	308	7,341
45-49	703	9,094	367	8,727
50-54	825	10,150	409	9,741
55-59	724	8,452	341	8,111
60-64	765	8,452	341	8,111
65-69	585	6,094	246	5,849
70-74	481	4,714	190	4,524
75-79	474	4,347	175	4,172
80-84	436	3,726	150	3,575
85-89	333	2,633	106	2,527
90-94	209	1,520	61	1,459
95-99	175	1,163	47	1,116
100-104	53	319	13	307
105-109	2	9	0	8
110-114	0	0	0	0
Total	**6,920**	**76,885**	**3,099**	**73,786**

Figure 1 shows the monitored tank temperature data throughout August 2007. The average measured hourly tank temperature profile is shown in Figure 2for an average day of the week. As expected, the temperature fluctuates slightly, but usually stays between 140 °F and 160 °F. The tank temperature drops a few times throughout the metering period. These drops in temperature were not significant since the temperature begins rising almost immediately afterward the decrease. On average, the tank temperature was 150 °F.

Figure 1: Tank Temperature Data

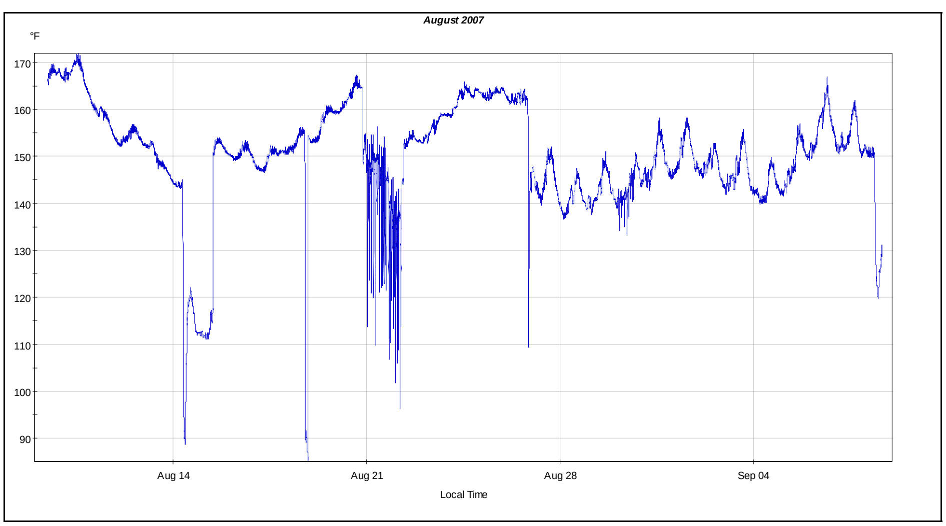
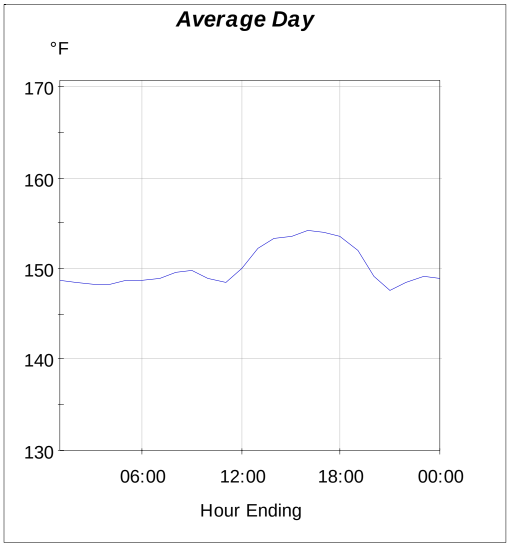


Figure 2: Average Measured Tank Temperature Profile



The ex post impacts were calculated using the verified inputs listed above along with the monitored tank temperature data.

- The baseline energy consumption is 76,885 therms
- The proposed energy consumption is 3,099 therms
- The resulting annual gas savings is 73,786 therms

The engineering realization rate for this measure is 0.89, as shown in Table 5.

Utility billing data for the site was reviewed. In the 12 month period from February 2003 to February 2004 (pre-retrofit), the facility consumed 285,938 therms. Table 2 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 28.9% decrease in total meter therms, a 4.8% decrease in lighting end use kW, a 27.3% decrease in total meter kWh, and a 107.9 % decrease in end use therms. The ex post results showed a 25.8% decrease in total meter therms, a 96 % decrease in end use therms.

Table 2: Total Meter, Ex Ante, and Ex Post Results

	Annual Natural Gas, therms
Total Meter	285,938
Baseline End Use	76,885
Ex Ante Savings	82,739
Ex Post Savings	73,786

Baseline end use represents feedwater heating only.

Table 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante	Ex Post
Therms Savings	Therms	Therms
Total Meter %	28.9%	25.8%
Baseline End Use %	107.6%	96.0%

6. Additional Evaluation Findings

The ex post energy savings are slightly less than the ex ante estimate, mainly because ex ante savings overestimated the annual operating hours of the boiler. The tank temperature was higher than anticipated but this did not completely compensate for the overestimation of operating hours.

We were unable to physically verify the pre-retrofit characteristics and hours of operation. However, these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures. An additional refinement would be the allocation of bin hours into hours and months in which the boiler experienced less than continual use.

With a cost of $88,707 and a $44,353 incentive, the project had a 0.67 year simple payback based on the ex ante calculations and a 0.75 year simple payback for the ex post calculations. The summary of the economic parameters for the project is shown in Table 4.

The effective useful life of the tank insulation system is 20 years. Table 8 shows projected annual ex ante and ex post energy savings for multiple years 2004 through 2026.

7. Impact Results

Table 4: Economic Information

Description	Date	Project Cost, $	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, Therms	Estimated Annual Cost Savings ($0.80/Therm), $	SPC Incentive, $	Simple Payback w/ Incentive, yrs	Simple Payback w/o Incentive, yrs
Installation Approved Amount (Ex Ante)	3/23/2005	88,707	-	-	82,739	66,191	44,353	0.67	1.34
SPC Program Review (Ex Post)	8/30/2007	88,707	-	-	73,786	59,029	44,353	0.75	1.50

Table 5: Realization Rate Summary

	kW	kWh	Therms
SPC Tracking System	-	-	82,739
SPC Installation Report (Ex Ante)	-	-	82,739
Impact Evaluation(Ex Post)	-	-	73,786
Engineering Realization Rate	-	-	0.89

Table 6: Installation Verification Summary

Measure Description	End-use Category	Gas Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Tank Insulation	Gas	Install tank insulation	1	Condensate Tank	Physically Verified insulation and tank	1.00

Table 7: Multi Year Ex ante and Ex post Savings Table

Program Name:		SPC 04-05 Evaluation Site A007					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005					68,949	61,488
3	2006					82,739	73,786
4	2007					82,739	73,786
5	2008					82,739	73,786
6	2009					82,739	73,786
7	2010					82,739	73,786
8	2011					82,739	73,786
9	2012					82,739	73,786
10	2013					82,739	73,786
11	2014					82,739	73,786
12	2015					82,739	73,786
13	2016					82,739	73,786
14	2017					82,739	73,786
15	2018					82,739	73,786
16	2019					82,739	73,786
17	2020					82,739	73,786
18	2021					82,739	73,786
19	2022					82,739	73,786
20	2023					82,739	73,786
TOTAL	**2004-2023**					1,558,251	1,389,636

SITE A008 Napa Impact Evaluation
SAMPLE CELL: ORIGINAL TIER: 3 END USE: Gas

Measure	Boiler Modification and Installation of Blowdown Heat Exchanger
Site Description	Hospital

1. Measure Description

The evaluated measure is the installation of a blowdown to feedwater heat exchanger for a boiler system. The boiler blow down process involves continuous removal of water from the boiler to avoid the negative impacts from a build-up of solids in the boiler water. However, boiler blowdown wastes energy because the blown down water is nearly the same temperature as the steam produced. Much of this heat can be recovered by routing the blowdown water through a heat exchanger that preheats the boiler's makeup water. Prior to the installation of the heat exchanger, the facility discharged the blow down liquid; make-up feed water comes directly for the municipal water supply, assumed to be at ground water temperature. The savings comes from the use of this higher temperature feedwater versus the ground temperature feedwater used previously for boiler make-up water. Other boiler therm savings included in this project were the installation of an O_2 trim capability for the burners and a new smaller burner on one boiler for improved turndown capability.

Only gas measures are evaluated as gas is the primary end use. There are lighting savings and savings from variable speed drives on boiler and chiller plant motors.

2. Summary of the Ex Ante Calculations

The measure is a calculated measure. The ex ante calculations assumes that 0.82 % of the facility's total steam output can be utilized to preheat the boiler make-up water. The savings calculation is as follows:

$$\text{Gas Savings} = (m * \Delta h * d) / \acute{\eta}_{\text{boiler}}$$

Where,

m = Steam Blowdown (Gal/day)
Δh = Heat gain (Btu/gal)
d = days of operation of the boiler
$\acute{\eta}_{\text{boiler}}$ = boiler efficiency

The heat gain was estimated at 1,268 Btu/gal in the project file. The facility operates 24 hours a day and 365 days a year. The boiler efficiency is 82%. The steam blowdown was estimated as 5,443 gallons/day from facility records and a blow down fraction assumption.

The ex ante impacts for the blow down heat exchanger were calculated as follows:

- Daily steam blowdown of the boilers: 5,443 Gallons/day
- Annual Energy Savings: 30,713 theRms/yr.

The O_2 trim ex ante calculations were based on an assumption of efficiency improvement by the contractor.

The ex ante impacts for the O_2 trim were calculated as follows:

- Efficiency savings were assumed to be 2.5%.
  Annual fuel savings were 2.5% x 1,135,761 therms/yr = 28,394 therms/yr.

A new burner with better turndown capacity was installed on boiler #2 only. It was sized at 15,000 pph (pounds per hour) with a minimum firing rate of 1,500 to 2,000 pph. The existing burner had a minimum firing rate of 5,000 pph. This lower rate allows for the boiler to satisfy the summer heating load without cycling on and off.

The ex ante impacts for the smaller burner were calculated as follows:

- Efficiency savings were assumed to be 0.45%.
  Annual fuel savings were 0.45% x 1,135,761 therms/yr = 5,111 therms/yr.

VFDs were installed on all three combustion fans. Boilers #1's 40hp motor was replaced with a new 20hp motor. A VFD was also installed on the feed water pump and that 50hp motor was replaced with a 20hp motor. All savings estimates were calculated by the manufacturer.

The ex ante impacts for the VFDs on the 40hp combustion fans were calculated as follows:

- Pre–modification operation was 100% at 8760 hrs/yr.
  Post-modification operation was assumed to be at 60% load, a % FLA (or load factor) of 0.8 and 4000 hrs/yr.
  This resulted in savings estimates of 57,293 kWh/yr.

The ex ante impacts for the VFDs on the 20hp combustion fans were calculated as follows:

- Pre–modification operation was 100% at 8760 hrs/yr.
  Post-modification operation was assumed to be at 60% load, a %FLA of 0.8 and 4000 hrs/yr.
  This resulted in savings estimates of 78,778 kWh/yr.

The ex ante impacts for the VFD's on the 20hp combustion fans were calculated as follows:

- Pre–modification operation was 100% at 8760 hrs/yr.
  Post-modification operation was assumed to be at 60% load, a %FLA of 0.8 and 4000 hrs/yr.
  This resulted in savings estimates of 71,616 kWh/yr.

The incentive was calculated as follows:

- $1/therm: Incentive is $1/therm x 64,217.9 therms = $64,217.9
- $0.08 per kWh
  Rebate was $0.08/kWh x 207,687 kWh = $16,614.96

3. Comments on the Ex Ante Calculations

The calculations assume the boiler is operating at nominal efficiency. The site may have regular efficiency tests/flue gas analysis that would show actual boiler operating efficiency. The steam blowdown is considered 0.82% of the total steam output of the boilers.

The initial energy savings calculated provided in the application paperwork match with that listed on the final installation report and in the utility tracking system

The total savings in the Installation Report Review and the tracking system were given as 64,217.95 therms/yr and the incentive was $64,217.95.

O_2 Trim
The original basis for savings estimate by the contractor stated that metered controls usually result in savings of 0.5-1.0 % and O_2 trim savings are typically 1.0 %. He also stated that if jackshaft controls are not tuned every 2-3 months, the loss in efficiency can be 2-3% within 6-9 months. Although a savings of around 2% is typical for such a modification, the assumptions that went into this estimation do not take into account all the factors leading to O_2 trim savings and suppose that the boiler would not receive regular tune-ups. The control manufacturer estimated a savings of 4.5% which would have resulted in 51,109 therms/yr. The ex ante savings use 2.5 % as a basis for savings. The supporting calculations behind this estimate were not defined in the project files.

Smaller Burner
There is a lack of detail in the calculations for the smaller burner savings. However, the savings for this portion are relatively small compared to the total gas savings. It is rather difficult to estimate the savings for this type of modification without full load profile information.

VFDs

The savings for the boiler blowers are calculated based on 4,000 hours a year operation with a 60% full load due to the VFDs. VFDs on the blowers reduce the amount of excess air sent to the burner. The total ex ante savings were estimated to be 207,687 kWh per year. The supporting calculations behind this estimate were not defined in the project files. Therefore, there is a certain amount of uncertainty involved with this estimate. However, these are not the primary focus of this evaluation.

4. Measurement & Verification Plan

The facility where the measure is implemented is at a central plant at a large medical facility. Gas use is recorded as 3,384,990 therms per year in the application paperwork. As the major part of the energy savings from the boiler modifications are attributed to the blow down heat exchanger measure, this measure will be evaluated to establish the associated natural gas savings. The savings derive from the use of this high temperature feed water versus the ground temperature feed water used previously for boiler make-up water.

The fundamental premise in the development of the measurement and verification plan is to determine the amount of fuel required if the blow down heat exchanger was not used to recover the waste heat to preheat the make up boiler feed water. The M&V plan for this measure will be implemented in three basic steps:

1. On-site verification of heat exchanger installation, controls and boiler nameplate data (and collect any additional relevant data available on-site)
2. Temperature measurement of the preheated boiler blow down water temperature and baseline feed water temperature
3. Collect trend data from site energy management system and logs

Relevant data to be gathered will include:

- Operational schedules
- Pre-heated boiler feed water flow rate and annual pre-heated boiler blowdown water flow
- Boiler technical specifications
- Boiler flue gas analysis and combustion test efficiency results

On-site verification will attempt to determine the overall quality of the monitoring installation and to verify that the measurements are taken at the correct physical locations. The accuracy of the temperature readings will be verified by redundant spot measurements. Pre-heated boiler feed water flow will be obtained and estimated from plant data .No flow measurements are planned unless the site visit reveals an obvious instrumentation problem. Flow measurements will significantly increase the complexity of the analysis and for corrosive liquids such as condensate may be unreliable if utilizing non-invasive flow metering equipment. Using existing data streams may introduce some uncertainty; however, when a site is instrumented, it can be the most accurate and most cost effective way to proceed. If the spot measurements identify major discrepancies when compared to the operational data, an alternative M&V plan will be developed.

For the O_2 trim and burner downsizing measures the inputs assumed for ex ante calculations appear reasonable. Savings from O_2 trim and the smaller burner measure are much more difficult to evaluate and would require specialized instrumentation and a time frame beyond the scope of this evaluation, as well as unavailable pre retrofit operational data. Therefore, ex post savings will be assumed to be equal to ex ante, if the measures are verified as installed.

Formulae and Approach

The natural gas savings at the facility after the installation of blow down heat exchanger will be calculated using the following equation.

$$E_p = [Q_{feedwater}*(h_{bf}- h_g)]/[\ 100{,}000\ \text{Btu/therm}*\acute{\eta}_{\ boiler}]$$

Where,

E_p = natural gas savings, therms/ yr
$Q_{feedwater}$ = total preheated make up water to the boiler (lbs/yr)
h_{bf} = enthalpy of pre-heated boiler blow down water (Btu/lb)
h_g = enthalpy of water supply, assumed to be ground temperature (Btu/lb)
$\acute{\eta}_{\ boiler}$ = efficiency of the boiler

As the equation indicates, factors affecting the natural gas savings are: the enthalpy difference between pre-heated boiler feed water and the incoming feed water (which will be determined from the monitored temperature data), the mass flow of pre-heated feed water to the boiler, and the efficiency of the boiler. An appropriate annual savings calculation strategy, depending on field findings, will be developed.

Estimates will be adjusted for annual use, which will be collected from the site as possible.

Uncertainty for the savings estimate for the condenser recovery can be more fully understood by setting projected ranges on the primary variables.

$Q_{feedwater}$ (total make up water to the boiler in lbs/yr): + 30%, - 30%
$\acute{\eta}_{\ boiler}$ (efficiency of the boiler: + 5%, - 5%)
(h_{bf}- $h_{g)}$ (enthalpy difference) : + 10%, - 10%

Accuracy and Equipment

HOBO temperature loggers will be used to meter both the ground water and feed water lines to and from the blowdown heat exchanger. The ground water entering the heat exchanger will be measured with a HOBO U12-012 temperature logger. This logger can measure between -20 to 70^{o}C with an accuracy of ±0.35^{o}C. The U12-014 HOBO J-type thermocouple logger will be used to measure the water temperature of the boiler water. The measurement range for this meter is 0 to 750^{o}C with an accuracy of ±2.5^{o}C.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 16, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the blow down heat exchanger and by interviewing the facility representative. Temperature loggers were installed on both ground water temperature and feed water line to the boiler.

Installation Verification

We physically verified the installation of blow down heat exchanger. The facility representative confirmed the installation the O_2 trim capability and smaller burners in the boiler. The heat from the blow down is routed through the heat exchanger and is used to pre-heat the boiler feed water. O_2 trim systems continuously monitor the flue gases and adjust the burner air supply and the new burners in the boilers eliminates the pre-purge and post purge cycles at low firing rates, reducing boiler stack losses. The facility representative stated that the retrofits were completed in 2004.

These are the only gas measures in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 5 below.

Scope of the Impact Assessment

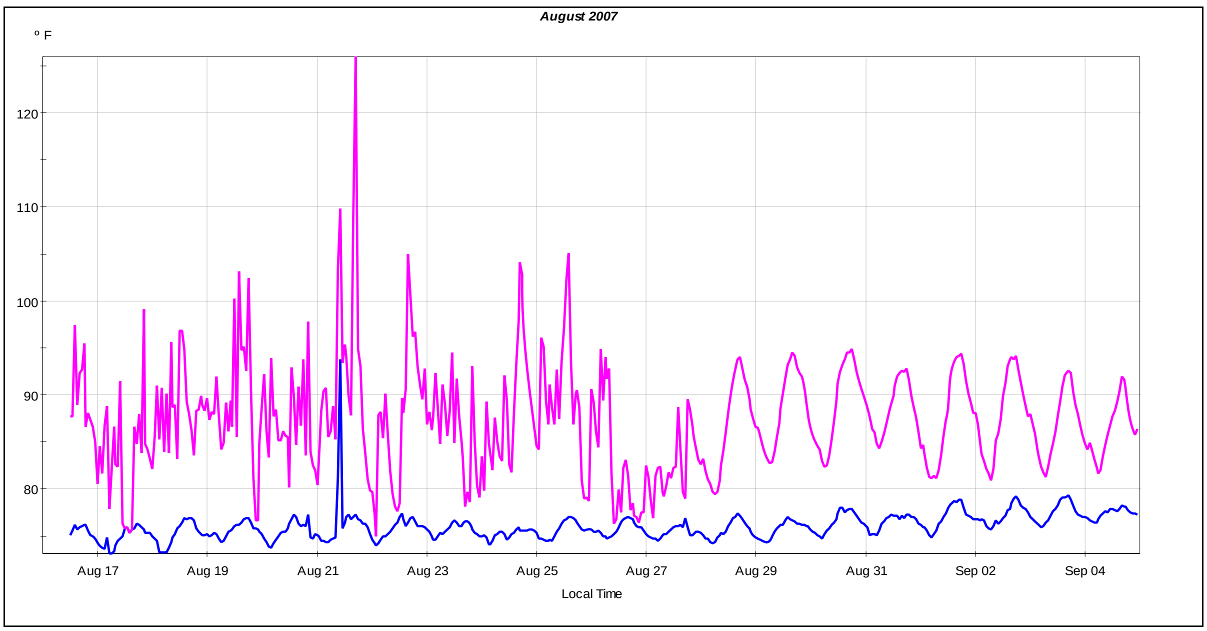
The impact assessment scope is for the natural gas end use measure in the SPC application: the installation of blow down heat exchanger, O_2 trim to the boilers and installation of a new burner.

Summary of Results

HOBO data loggers were installed both the ground water and feed water lines to and from the blow down heat exchanger for four weeks (from August 16, 2007 –September 12, 2007). The ground water entering the heat exchanger was measured with a HOBO U12-012 temperature logger. The U12-014 HOBO J-type thermocouple logger was used to measure the water temperature entering the boiler DA tank used for make up water. The average ground water temperature was calculated to be 76 ºF. The maximum-recorded incoming water temperature was 94 ºF; while the minimum recorded incoming water temperature was 73 ºF. The maximum boiler water feed water temperature after the blow down heat exchanger is 125 ºF, while minimum recorded feed water was 75 ºF. The average calculated temperature after the blow down heat exchanger was 88 ºF. Hourly make up water flow rate for the temperature-monitoring period was also obtained from the facility log. The facility personnel mentioned that the boiler operates twenty-four hours a day and 365 days a year.

The hourly monitored temperature data for both incoming water and preheated feed water is shown in Figure 1.

Figure 1: Monitored Hourly Temperature Profile (Ground Water-Blue, Pre-Heated Boiler water-Pink)



The ex post calculations were performed using the hourly temperature difference between pre-heated boiler feed water and baseline feed water and hourly flow rate obtained onsite. Hourly natural gas savings for each hour for the monitoring period were calculated and aggregated for the monitoring period of 19.5 days (468 hours) by using the following equation.

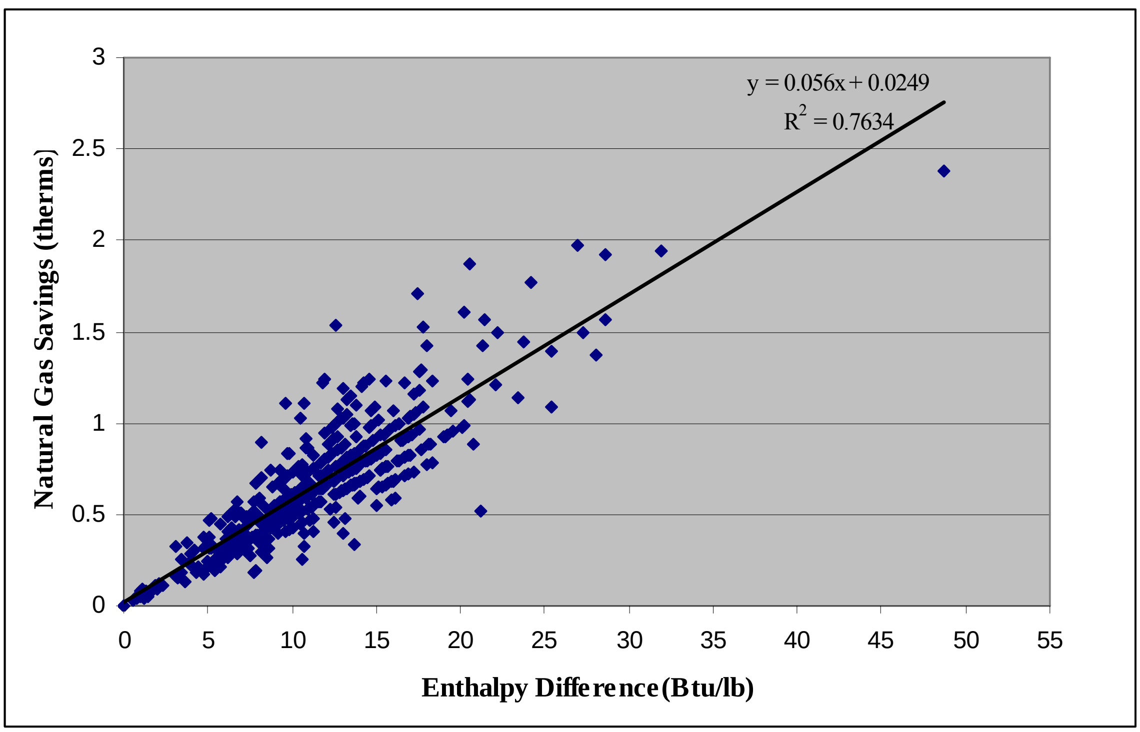
$$E_{pm} = [\sum_{1}^{468} Qfwhm * (hbfh - hgh)] / [100{,}000 Btu / therm * \acute{\eta}_{boiler}]$$

Where,

E_{pm} = natural gas savings for the monitoring period, therms
Q_{fwhm} = hourly flow rate for the monitoring period (lbs/yr)
h_{bfh} = hourly enthalpy of pre-heated boiler feed water (Btu/lb)
h_{gh} = hourly enthalpy of water supply, assumed to be ground water temperature (Btu/lb)
$\acute{\eta}_{boiler}$ = efficiency of the boiler (82%)

Hourly natural gas savings with respect to the differential enthalpy between pre-heated boiler feed water and baseline feed water is shown in Figure 2. Flow rates were available from the facility.

Figure 2: Hourly Natural Gas Savings v. Hourly Enthalpy Difference for the Monitoring Period



Then the total natural gas savings per year due to installation of the blow down heat exchanger were calculated using the following equation.

$$E_p = [E_{pm} / Q_{fwm}] * [Q_{afw}]$$

Where,

E_p = natural gas savings, therms/ yr
E_{pm} = natural gas savings for the monitoring period, therms
Q_{fwm} = total flow for the monitoring period (lbs/hr)
Q_{afw} = annual feed water flow to the boiler (lbs/hr)

For O_2 trim and small burner measures the inputs assumed for ex ante calculation appear to be reasonable. Therefore, ex post savings will be same as the estimated ex ante savings.

The ex post impacts for the boiler modification are calculated as follows:

- The resulting annual therm savings for the blow down heat exchanger is = 7,996 therms
- The resulting annual therm savings for installing O_2 Trim is = 28,394 therms
- The resulting annual therm savings for installing new burners = 5,111 therms

Total natural gas savings from boiler modification = 7,996 + 28,394 + 5,111 = 41,501 therms

The engineering realization rate for this application is 0.65 for energy savings in therms. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 4.

Utility billing data for the site was reviewed. In the 12-month period from December 2003 - November 2004 (pre-retrofit), the facility consumed 3,384,990 therms. Table 1 summarizes the total metered use, the ex ante savings and the ex post calculation results.

Table 2 is a summary of the percent of energy savings for the total metered use and for both the ex ante and ex post savings calculations. The ex ante results showed a 1.9% decrease in total meter therms. The ex post results showed a 1.23% decrease in total meter therms.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Annual Therms
Total Meter	3,384,990
Baseline End Use	NA
Ex Ante Savings	64,218
Ex Post Savings	41,501

Table 2: Percent Savings and Therms Reduction, Ex Ante, Ex Post

	Ex ante	Ex post
Therms Savings	Therms	Therms
Total Meter %	1.90%	1.23%
Baseline End Use	NA	NA

6. Additional Evaluation Findings

The ex post energy savings are significantly less than the ex ante energy savings because we found that the ex ante savings greatly overestimated the amount of heat recovered by routing the blown down liquid through the heat exchanger.

The evaluation team physically verified the blow down heat exchanger and used plant data to verify operating hours. The evaluation team is satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the blowdown heat exchangers; the other measures would require additional pre retrofit operational data.

With a cost of $300,424 and a $64,218 incentive, the project had a 4.6 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 7.1 years. A summary of the economic parameters for the project is shown in Table 3. The effective useful life of the heat exchanger system is 16 years. Table 6 shows projected annual ex ante and ex post energy savings for multiple years (2004 through 2023).

7. Impact Results

Table 3: Economic Information

Description	Date	Project Cost, $	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, Therms	Estimated Annual Cost Savings ($0.8/therm), $	SPC Incentive, $	Simple Payback w/ Incentive, yrs	Simple Payback w/o Incentive, yrs
Installation Approved Amount (Ex Ante)	3/22/2006	300,424			64,218	51,374	64,218	4.60	5.85
SPC Program Review (Ex Post)	9/4/2007	300,424			41,501	33,201	64,218	7.11	9.05

Table 4: Realization Rate Summary

	Therms
SPC Tracking System	64,218
SPC Installation Report(Ex-ante)	64,218
Impact Evaluation(ex-post)	41,501
Engineering Realization Rate	0.65

Table 5: Installation Verification Summary

Measure Description	End-use category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Boiler Modification	Boiler			Installation of a blow down heat exchanger, O2 trim and small burner to the boilers	1	shell type blow down heat exchanger	Verified the heat exchanger, O2 trim and small	1.0

Table 6: Projected Multi Year Savings

Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004					0	0
2	2005					64,218	41,501
3	2006					64,218	41,501
4	2007					64,218	41,501
5	2008					64,218	41,501
6	2009					64,218	41,501
7	2010					64,218	41,501
8	2011					64,218	41,501
9	2012					64,218	41,501
10	2013					64,218	41,501
11	2014					64,218	41,501
12	2015					64,218	41,501
13	2016					64,218	41,501
14	2017					64,218	41,501
15	2018					64,218	41,501
16	2019					64,218	41,501
17	2020						
18	2021						
19	2022						
20	2023						
TOTAL	2004-2023	-	-			963,269	622,514

SPC Custom Measure with 15 year life (installed by end of 2004)

SITE A009 (2004-xxx) Cona **Impact Evaluation**
SAMPLE CELL: ORIGINAL TIER: 2 END USE: Gas

Measure	Evaporator Condensate Collector
Site Description	Food Processing Plant

1. Measure Description

The measure is for the installation of a condensate collection system for the second and third effects on two (2) four-effect evaporators at a tomato paste production facility. The water that is evaporated away from the tomato slurry in the process of becoming tomato paste is condensed, collected, treated, and is subsequently used as make-up feed water for the boiler. Prior to the installation of the condensate return system, the facility discharged the condensate; make-up feed water was supplied by the municipal water supply, assumed to be at ground temperature. The condensate enters the evaporators at approximately 160 F. The savings stem from the use of this high temperature feed water versus the ground temperature feed water used previously for boiler make-up water.

2. Summary of the Ex Ante Calculations

The measure is a calculated measure. The ex ante calculations are not clearly described.

It appears that the ex ante calculations are as follows:

The ex ante calculations assume that all of the condensate coming from the second and third effect evaporators can be utilized by the boiler. The savings calculation is as follows:

$$\text{Gas Savings} = \dot{m} * h * \Delta h / \acute{\eta}_{boiler}$$

Where,

$\dot{m}$ = mass flow rate of the condensate (lbs/hr)
h = annual operating hours of the process (hrs/yr)
Δh = enthalpy difference in make up water source ($h_{condensate} - h_{groundwater}$)
$\acute{\eta}_{boiler}$ = boiler efficiency

The estimated condensate temperature was 160 F by plant personnel and the groundwater temperature was assumed to be 60 F. The process is assumed to operate 24 hours per day for 100 days a year. The boiler efficiency is 85%.

The ex ante impacts were calculated as follows:

- Condensate to boiler: 220,240,800 lbs/yr
- Condensate enthalpy difference: 108.5 Btu/lb

- Annual Energy savings: 281,213 therms/yr
- Hourly Savings: 11,717,208 Btu/hr

The incentive should have been calculated as follows:

- $1/therm: Incentive is $1/therm x 281,213 therms = $281,213.

3. Comments on the Ex Ante Calculations

The calculations assume the boiler is operating at nominal efficiency; the site may have regular efficiency tests/flue gas analysis that would show actual boiler operating efficiency, which should have been used in the analysis.

Similarly, the mass flow, condensate enthalpy, and groundwater enthalpy are all considered constant. These values should be verified and modifications to the calculation figures should be made as necessary.

The initial energy savings calculated on the spreadsheet provided in the application paperwork do not match with that listed on the final installation report. Therefore, there is some ambiguity as to which calculations and figures were used to arrive at the final ex ante savings reported in the Installation Report Review.

The reviewer provided clarification describing minor adjustments after the compilation of this report.

The total savings in the Installation Report Review are shown ass 281,213 therms/yr and the incentive was $273,600. The savings and incentive agree with the utility tracking system.

4. Measurement & Verification Plan

The facility where the measure is implemented is a 200,000 sf food processing plant. Annual natural gas use is recorded as 5,571,910 therms per year in the application paperwork. This measure reduces usage of natural gas in the facility's boilers. The savings is realized by returning the process condensate to the boilers as make-up water, reducing gas usage by the facility.

The fundamental premise in the development of the measurement and verification plan is to determine the amount of fuel required if the condensate was not used as make up boiler feed water. The M&V plan will be implemented in three basic steps:

1. On-site verification of installed condensate recovery system
2. Temperature measurement of the condensate to the boiler and baseline feed water temperature.

3. Collection of trend data/plant records (including prior make-up water requirements).
4. Collection of boiler data plate information

Relevant data to be gathered will include:

- Operational schedules of the process
- Condensate flow rate and annual condensate flow
- Boiler technical specifications
- Boiler flue gas analysis and combustion test efficiency results

On-site verification will attempt to determine the overall quality of the monitoring installation and to verify that the measurements are taken at the correct physical locations. The accuracy of the temperature readings will be verified by redundant spot measurements. Condensate mass flow will be obtained and estimated from plant data .No flow measurements are planned unless the site visit reveals an obvious instrumentation problem. Flow measurements will significantly increase the complexity of the analysis and for corrosive liquids such as condensate may be unreliable if utilizing non-invasive flow metering equipment. Using existing data streams may introduce some uncertainty: however, when a site is fully instrumented, it can be the most accurate and most cost effective way to proceed. If the spot measurements identify major discrepancies when compared to the operational data, an alternative M&V plan will be developed

Formulae and Approach

The natural gas savings at the facility after the installation of condensate recovery system will be calculated using the following equation.

$$E_p = [Q_{condensate}*(h_c - h_g)]/[\ 100{,}000\ \text{Btu/therm}*ή_{boiler}]$$

Where,

E_p = natural gas savings, therms/ yr
$Q_{condensate}$ = total condensate to the boiler (lbs/yr)
h_c = Enthalpy of post-installation condensate to the boilers (Btu/lb)
h_f = Enthalpy of water supply, assumed to be ground temperature (Btu/lb)
$ή_{boiler}$ = efficiency of the boiler

As the equation indicates, factors affecting the natural gas savings are: the enthalpy difference between condensate return and baseline feed water (which will be determined from the monitored temperature data), the mass flow of condensate to the boiler, and the efficiency of the boiler. An appropriate annual savings calculation strategy, depending on field findings, will be developed.

Estimates will be adjusted for annual production data, which will be collected from the site as possible.

Uncertainty for the savings estimate for the condenser recovery can be more fully understood by setting projected ranges on the primary variables.

Flow : $Q_{condensate}$ = Total annual condensate to the boiler (lbs/yr) = (85,644 + 44811)lbs/hr – 59 gpm x 8.337 lbs/ga x 60 min/hr = 100,942 lbs/hr

- 100,942 lbs/hr expected, 70,000 lbs/hr minimum, 131,000 lbs/hr maximum (+/-30 %, based upon assumption of continuous operation of 100 days and constant flow)

Enthalpy: Delta h = 127.96 Btu/lb – 28.06 Btu/lb = 99.9 Btu/lb

- 99.9 Btu/lb expected, 75 Btu/lb minimum, 115 Btu/lb maximum (+/-15 %)

Efficiency: Delta ή

- 85% expected, 78% minimum, 85% maximum (+ 0%, -10 %)

Accuracy and Equipment

Groundwater temperature and condensate temperatures will be verified with a Fluke 50D digital thermometers with type K thermocouples with instrumental accuracy of 0.1% of full scale i.e. +-1.3°F.

The condensate flow will be measured via the facility's permanently installed flow meter. The estimated instrumental accuracy is approximately 10% of flow rate.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The onsite survey was conducted on July 19, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the four stage evaporators and by interviewing the facility representative.

Installation Verification

We physically verified the installation of a condensate collection system for the second and third effects of two (2) four-effect evaporators at a tomato paste production facility The facility representative stated that the retrofit was completed in 2004.

This is the only measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 5 below.

	kW	kWh	Therm
SPC Tracking System			281,213
SPC Installation Report (ex ante)			281,213
Impact Evaluation (ex post)			256,245
Engineering Realization Rate			0.91

Scope of the Impact Assessment

The impact assessment scope is for the natural gas end use measure in the SPC application. This involves the installation of a condensate collection system from the second and third effects of two (2) four-effect evaporation systems. This is the only measure in this application.

Summary of Results

Ground water temperature and condensate water temperature were verified with a Fluke 50 D digital thermometer with a type K thermocouple. Additionally, weekly condensate mass flow rate was obtained from plant records. The facility personnel stated that the provided weekly condensate flow rate is a representative sample of their weekly operation. He stated that the facility has been running twenty-four hours a day since the 3rd of July and has shut down on the 15th of October, typically 105 operating days a year. The facility personnel also stated that these annual operating schedule are representative of a typical year.

The condensate water temperature was measured to be 159.2ºF, which agrees, within the instrumental uncertainty of 1.3 ºF, with the ex ante estimate of 160 ºF. The reported annual operating schedule was greater than the ex ante estimate. The average weekly condensate flow to the boiler from the 2nd and 3rd evaporator was 1,149,752 gallons per week from the facility monitoring system in the month of July. Information provided later in the report indicated that average condensate flow was higher for the 15 week processing period per year, and was approximately 1,741,072 gallons per week.

The ex post calculations were performed by using the same equations used in the ex-ante calculation. All the input variables to the equations were verified. These include facility operating schedule, the enthalpy difference between condensate water to the boiler and ground water temperature, condensate flow rate to the boiler and combustion efficiency of the boiler.

The ex post impacts are calculated as follows:

$$E_p = [Q_{condensate}*(h_c - h_g)]/[100{,}000 \text{ Btu/therm}*\eta_{boiler}] \times 15 \text{ weeks / year}$$

$$E_p = [1{,}741{,}072 \text{ gal/wk} * 8.34 \text{ \#/gal}*(160 - 60)]/[100{,}000 \text{ Btu/therm} *0.85] \times 15 \text{ weeks/yr}$$

$$E_p = 256{,}245 \text{ therms/year}$$

The engineering realization rate for this application is 0.91 for energy savings therms. The values shown in the tracking system are a slightly lower than with those shown in the installation report for this application. A summary of the realization rate is shown in Table 4.

Table 1 summarizes the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 2 is a summary of the percent of energy savings for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 129 % decrease in end use therms. The ex post results showed a 78 % decrease in end use therms.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Annual Therms
Total Meter	5,571,910
Baseline End Use	217,748
Ex Ante Savings	281,213
Ex Post Savings	256,245

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

Therms Reduction	Ex Ante Therms	Ex Post Therms
Total Meter %	5.0%	4.6%
Baseline End Use %	129.1%	78.1%

Baseline end use is for this process subsystem only

6. Additional Evaluation Findings

The ex post energy savings are less than the ex ante estimate as the ex ante savings used 2004 data which overestimated the condensate flow to the boiler (as compared to actual readings on site).

We were unable to physically verify the pre-retrofit system and hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $700,000 and a $273,000 incentive, the project had a 1.9 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 2.1 years. A summary of the economic parameters for the project is shown in Table 3.

The greatest uncertainty associated with the ex post estimate is the instrumentation error associated with the facility's flow meter, assumed to be +/-10%. Accepting this assumption, the savings estimate is also +/-10%, since the savings estimate is directly proportional to flow rate.

7. Impact Results

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.8/therms), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
(Ex Ante)	9/24/2004	$700,000			281,213	$224,970	$273,600	1.90	3.11
(Ex Post)	7/19/2007	$700,000			256,245	$204,996	$273,600	2.08	3.41

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System			281,213
SPC Installation Report (ex ante)			281,213
Impact Evaluation (ex post)			256,245
Engineering Realization Rate			0.91

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Notes	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Evaporator Condensate Collector	Boiler			Installation of a condensate collection system for the second and third effects of two (2) four-effect evaporators at a tomato paste production facility		NA	Condensate collection from T-120 and T-150 evaporators	Physically verified the collection of condensate from second and third effects of the two (2) evaporators and used it as boiler feed water.	1.0

Table 6: Projected Multi Year Ex ante and Ex post Savings

Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004					93,738	85,415
2	2005					281,213	256,245
3	2006					281,213	256,245
4	2007					281,213	256,245
5	2008					281,213	256,245
6	2009					281,213	256,245
7	2010					281,213	256,245
8	2011					281,213	256,245
9	2012					281,213	256,245
10	2013					281,213	256,245
11	2014					281,213	256,245
12	2015					281,213	256,245
13	2016					281,213	256,245
14	2017					281,213	256,245
15	2018					281,213	256,245
16	2019					187,475	170,830
17	2020						
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**					4,218,195	85,415

Custom SPC Measure – 15 year life.

FINAL REPORT

Site A010 IBxx IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: Other

Measure	Install Variable Frequency Drives (VFDs) on one (1) 25 hp chilled water pump and three (3) 40 hp cooling tower fans
Site Description	Research Center

1. Measure Description

The customer implemented three measures to reduce the energy usage used for AC&R for an office building.

Measure #1 is the installation of a VFD on 25 hp chilled water pump. Prior to the installation, the pump was modulated to the desired maximum flow. In the post-installation case, the VFD adjusted the flow to the amount that was required in a more efficient manner.

Measure #2 is the installation of VFDs on cooling tower fans. Two VFDs were installed on two 40 hp cooling tower fans.

Measure #3 is the installation of a VFD on another 40 hp cooling tower fan.

2. Summary of the Ex Ante Calculations

The measures were submitted as calculated measures.

The ex ante savings are:

Measure #1-Chilled Water Pump VFD:
Annual Savings - 32,719 kWh

Measure #2-Two VFDs on two cooling tower fans:
Annual Savings - 251,368 kWh

Measure #3-VFD on cooling tower fan:
Annual Savings - 133,610 kWh

Both Measures Combined:
Annual Savings - 417,697 kWh

The kW savings are 135.0 kW and the approved incentive amount is $33,415.

3. Comments on the Ex Ante Calculations

Preliminary ex ante savings numbers were provided in the Installation Report, and were 444,450 kWh with 0 kW of savings. The basis for the savings was not described.

According to the application, before the installation, the cooling tower fans and chilled water pumps fans operated at a constant speed and consumed 665,559 kWh. The measure summary information notes a proposed usage of 221,109 kWh.

Savings of 135.0 kW and 417,697 kWh as listed are found in the Operating Report Review. The kW savings of 135.0 kW are very high, considering that 145 hp (108 kW) of motor load is being controlled. The kWh savings may be reasonable for continuously operated motors.

The ex ante kWh savings agrees with the utility tracking system. However, the utility tracking system notes 0.0. kW for demand savings.

4. Measurement & Verification Plan

The facility is a 3 story research center, which was constructed in 1986. The building has a floor area of 542,000 sq. ft. The goal of the M&V plan is to estimate the actual kWh reduction due to the installation of VFDs on the cooling tower fans and the chilled water pumps.

The M&V plan would consist of monitoring the motors with kW or current data loggers and using weather data to extrapolate savings to a full year. However, the customer, after initially responding to evaluation efforts and site visit requests, was not able to provide access to the site. A post-installation verification was performed.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

No on-site survey was possible. Information on the retrofit equipment and operating conditions was collected through the application paperwork.

5.1. Installation Verification

A pre-installation inspection revealed that there were no VFD’s installed on the cooling tower fans or chilled water pumps. A post-installation inspection verified that the chilled water pump and cooling tower fans had VFDs installed on them. The retrofit was completed by June 2005.

These are the only measures in this application. A verification summary is shown in Table 1 below.

Table 1:Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Equipment Description	Installation Verified (Explain)
VFD on 25 hp chilled water pump	O	VFD HVAC	VFD on chilled water pumps	Installation of VFDs
VFD on three 40 hp cooling tower fan	O	VFD HVAC	VFDs on cooling tower fans	Installation of VFDs

5.2. Scope of the Impact Assessment

The impact assessment scope is for the VFD installations on one 25 hp chilled water and three 40 hp cooling tower fans. These are the only measures in this application.

5.3. Summary of Results

There was no measurement performed. However, an independent analysis was performed to simulate the effect of having all cooling tower fans in operation and running at lower speeds, utilizing all three cells of the cooling tower. This approach takes into account the interaction of the cells in maintaining proper condenser water temperatures. The results showed that kWh savings are 85% of ex ante savings. Thus, the ex ante savings are realistic and are accepted as the ex post savings, since measurement was not possible.

Demand savings are expected to be 0 kw, since the cooling tower fans and the chilled water pumps could be expected to operate at full load during the summer peak periods of 2 pm to 5 pm weekdays.

6. Impact Results

The values shown in the tracking system agree with those shown in the installation report for this application. We used the values from the tracking system. A summary of the realization rate is shown in Table 2.

Table 2: Realization Rate Summary

	kW	kWh
SPC Tracking System	0.0	417,697
SPC Installation Report (ex ante)	135.0	417,697
Impact Evaluation (ex post)	0.0	417,697
Engineering Realization Rate	1.00	1.00

Utility billing data for the site was reviewed. Annual usage prior to the retrofit was 30,500,000 kWh. Peak demand was 5,400 kW. Table 3 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 3: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	5,400.0	30,500,000
Baseline End Use	1,620.0	9,150,000
Ex Ante Savings	135.0	417,697
Ex Post Savings	0.0	417,697

Table 4 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations.

Table 4: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/ Demand Reduction	kW	kWh	kW	kWh
Total Meter %	2.5%	1.4%	0.0%	1.4%
Baseline End Use %	8.3%	4.6%	0.0%	4.6%

With a cost of $457,444 and a $147,784 incentive, the project had a 1.9 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is the same as the ex ante, and the estimated simple payback is also 1.9 years. A summary of the economic parameters for the project is shown in Table 5. Note that average rates were used to calculate the estimated annual cost savings, which can significantly affect savings and payback.

Table 5: Economic Information

	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	6/13/ 2005	$135,500	135.0	417,697	-	54,301	$33,416	1.88	2.50
SPC Program Review (Ex Post)	12/19/ 2007	$135,500	135.0	417,697	-	54,301	$33,416	1.88	2.50

It was determined that the VFD installation project was defined as an Adjustable Speed Drive measure in the California Public Utilities Commission *Energy Efficiency Policy Manual*. Therefore, the VFDs were assumed to have a useful life of fifteen (15) years. A summary of the multi-year reporting requirements is given in Table 6. Because this measure was installed in June of 2005 the energy savings in year #1 (2005) are assumed to be 50% of the expected annual savings for this measure.

Table 6: Multi-Year Reporting Requirements

Program ID:		Application # A010					
Program Name:		SPC 04-05 Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected kWh Savings	Ex-Post Gross Evaluation Confirmed kWh Savings	Ex-Ante Gross Program-Projected Peak kW Savings	Ex-Post Gross Evaluation Confirmed kW Savings	Ex-Ante Gross Program-Projected Therm Savings	Ex-Post Gross Evaluation Confirmed Therm Savings
1	2004						
2	2005	208,849	208,849	135.0	0		
3	2006	417,697	417,697	135.0	0		
4	2007	417,697	417,697	135.0	0		
5	2008	417,697	417,697	135.0	0		
6	2009	417,697	417,697	135.0	0		
7	2010	417,697	417,697	135.0	0		
8	2011	417,697	417,697	135.0	0		
9	2012	417,697	417,697	135.0	0		
10	2013	417,697	417,697	135.0	0		
11	2014	417,697	417,697	135.0	0		
12	2015	417,697	417,697	135.0	0		
13	2016	417,697	417,697	135.0	0		
14	2017	417,697	417,697	135.0	0		
15	2018	417,697	417,697	135.0	0		
16	2019	417,697	417,697	135.0	0		
17	2020	208,849	208,849				
18	2021						
19	2022						
20	2023						
TOTAL	2004-2023	6,265,455	6,265,455				

FINAL REPORT

SITE A011 (2005-xxx) HyaSFO IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: Other

Measure	Replace manual thermostats with occupancy based thermostats controls
Site Description	Hotel

1. Measure Description

Replace 827 manual guest room thermostats with occupancy-based programmable thermostats. The new thermostats control guest room temperatures based on occupancy and rental status.

2. Summary of the Ex Ante Calculations

The ex ante calculations identify the ex ante savings as 891,619 kWh/yr and 75.08 kW in the Installation Report Review. The ex ante savings were calculated by the installation reviewer for the utility. The project sponsor, an equipment vendor, initially submitted savings estimates of 25% of the baseline kWh and kW.

The ex ante savings calculations are based on monitoring data from guest room heating and cooling systems. A total of twenty-four in-room fan coil units (FCUs), were monitored from June 24, 2005 to July 12, 2005. Twelve guest rooms were identified as a baseline control group. These had occupancy-sensing and setback functions disabled. These rooms are referred to as "reference rooms". Another twelve guest rooms had the occupancy-sensing and setback functions enabled. These rooms are referred to as "test rooms" and were used to measure the impact of the energy efficiency measure.

The supply air temperatures for all 24 rooms were monitored in 5-minute intervals for the 19-day monitoring period. Supply air temperature readings were used to determine whether a room was in cooling or heating mode and whether the fan was running or not. In both test rooms and reference rooms, heating elements were considered to be in operation whenever the supply air temperature was greater than 77°F. In test rooms, the fan was considered to be on if the supply air temperature was less than 65°F or greater than 77°F, and in cooling mode whenever the room was not in heating mode and the fan was running. As stated in ex ante analysis spreadsheets, the reference room fans were assumed to be operating 75% of the time on average.

Using the monitored data, heating, cooling and fan run times were established for all of the reference and test rooms. The measured percent of time in heating mode and in cooling mode were regressed against the outside air dry-bulb temperature (OA_{db}). Equations for both reference and test room heating and cooling times were derived from the regressions. For test rooms, minimal association between the OA_{db} and percent heating and percent cooling was observed. Therefore, a constant linear relationship was used. The following equations were derived:

Reference rooms:

$$\%\ time\ cooling = 0.0302e^{0.0306xOA_{db}},\ R^2 = 0.7553 \quad \text{Eqn. 1}$$

$$\%\ time\ heating = -0.0033OA_{db} + 0.2848,\ R^2 = 0.36 \quad \text{Eqn. 2}$$

Test rooms:

$$\%\ time\ cooling = 0.04 \quad \text{Eqn. 3}$$

$$\%\ time\ heating = 0.129 \quad \text{Eqn. 4}$$

Cooling equations 1 and 3 were applied when OA_{db} was greater than 50°F. Heating equations 2 and 4 were applied when OA_{db} was less than 60°F. Hourly dry bulb outside air temperatures (OA_{db}) for local conditions were used to calculate the percent time heating and percent time cooling that occurs in guest rooms. However, the source of the weather data used is unknown. It does not correspond to typical meteorological year (TMY)[1] data for climate zone 3.

Heating Savings

Using equations 2 and 4, the typical annual post case reduction in heating was calculated to be 526.5 hours (527 hours in paperwork). The resistance heating capacity per FCU was estimated to be 1.22 kW, or 1,006.5 kW total for all guest rooms. The figure of 1,006.5 kW was also the total of the usage of guest room heating coils provided by the customer. The annual energy savings were calculated, as shown below, by multiplying the reduction in annual hours by the total heating capacity. This produced a savings of 529,939 kWh/yr.

$$kWh/yr_{savings} = (heating\ capacity)(annual\ hours)(ave\ annual\ heating\ \%) \quad \text{Eqn. 5}$$
$$= (1{,}006.5\ kW)(8{,}760 hr/yr)(9.6\% - 3.6\%) = 529{,}939\ kWh/yr$$

Note that the 9.6% and the 3.6% average annual heating figures were derived from equations 2 and 4 based on the OA_{db} temperature during the monitoring period. The entire calculation details were not provided for these factors.

A reduction in peak demand was not claimed for heating. It was assumed that heating occurred during nighttime and during off peak seasons.

Cooling Savings

The post case reduction in annual cooling hours was calculated in a manner similar to heating savings using equations 1 and 3. Each of the 827 FCUs is rated to deliver 300

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[1] TMY data are published by ASHRAE and use 30-year averages to represent typical weather data for specific locales. This method is appropriate for annualizing the savings since the savings will be anticipated for more than for the first year. The best weather data to use may be other typical weather data sets, however, such as the typical California climate zone data.

cfm of air flow. The chilled water system efficiency was assumed to be 0.9 kW/ton, based on customer supplied chiller operating data (no allowance was made for free cooling). A typical design cooling temperature difference (ΔT) of 15°F (70°F room temperature minus 55°F supply air temperature) was used for the cooling load on a typical FCU. The cooling energy savings was then calculated as follows:

$$kWh/yr_{savings} = (\#rooms)(hours\ reduced) \times \left[\frac{(\Delta T)(1.1)(FCU\ \text{flow}/room)(chiller\ eff)}{(12{,}000 Btu/ton)} \right] \quad \text{Eqn. 6}$$

$$= (827\ rooms)(371\ hours/yr) \times \left[\frac{(15°F)(1.1)(300CFM/room)(0.9kW/ton)}{(12{,}000 Btu/ton)} \right]$$

= 113,861 kWh/yr

The monitoring data also showed that the cooling load during the peak period was reduced from 26.5% in the base case to 11.3% in the post case. Therefore, the peak demand savings was calculated as:

$$kW_{savings} = (\#rooms)(avg\%\ reduction) \times \left[\frac{(\Delta T)(1.1)(FCU\ \text{flow}/room)(chiller\ eff)}{(12{,}000 Btu/ton)} \right] \quad \text{Eqn. 7}$$

$$= (827\ rooms)(26.5\% - 11.3\%) \times \left[\frac{(15°F)(1.1)(300CFM/room)(0.9kW/ton)}{(12{,}000 Btu/ton)} \right]$$

= 46.79 kW (46.8 kW in paperwork)

Fan Savings

It was assumed that the base case FCU fans operated 75% of the time in the reference rooms with the existing manual thermostats (when the room temperature set point was met and chilled-water valves were closed and heating coils were turned off). After installation of the programmable thermostats, monitoring results showed that the average post case fan operation time for cooling was 10.5%. The FCU fans were estimated to have an input power of 0.053 kW based on a 1/20-hp motor. The energy and demand savings are calculated by:

$$kWh/yr_{savings} = (\#\ of\ FCUs)(Fan\ power)(ave\ \%\ reduction)(annual\ hrs) \quad \text{Eqn. 8}$$

$$= (827)(0.053\ kW)(0.75 - 0.105)(8{,}760\ hrs/yr) = 247{,}819\ kWh/yr$$

$$kW_{savings} = (\#\ of\ FCUs)(Fan\ power)(ave\ \%\ peak\ reduction) \quad \text{Eqn. 9}$$

$$= (827)(0.053\ kW)(0.75 - 0.105) = 28.3\ kW/yr$$

A summary of the ex ante savings are provided below:

Table 1: Ex Ante Savings

Heating	
Baseline average on-time	9.6%
Baseline annual operating hours	841 hours
Post case average on-time	3.6%
Post case annual operating hours	314 hours
Total heating capacity	1,006.5 kW
Annual energy savings	529,939 kWh

Cooling	
Baseline average on-time	14.7%
Baseline annual operating hours	1,287 hours
Post case average on-time	10.5%
Post case annual operating hours	916 hours
Number of FCUs / hotel rooms	827 FCUS in 793 rooms
FCU volumetric flow	300 CFM
FCU ΔT	15°F
Chilled-water system efficiency	0.90 kW/ton
Annual energy savings	113,861 kWh
Baseline fan on during peak time	26.5%
Post fan on during peak time	11.3%
Peak Demand Savings	46.8 kW

Fan Energy	
Baseline average fan on	75.0%
Baseline annual operating hours	6,570 hours
Post case average fan on	10.5%
Post case annual operating hours	916 hours
Fan motor power	0.053 kW
Number of fans	827
Annual energy savings	247,819 kWh
Peak demand savings	28.3 kW

Total annual energy savings	**891,619kWh**
Total peak demand savings	**75.08 kW**
Incentive amount	**$71,329.50**

The project file also lists the total cost of this measure as $145,771.

3. Comments on the Ex Ante Calculations

The methodology for ex ante savings calculations is appropriate for this measure. Fan runtime, heating time, and cooling time were all based on monitoring data from guest rooms with occupancy-based controls both enabled and disabled. The sample of test rooms and reference rooms was selected to represent all sides of the building to prevent biasing the outcome. Regression analysis was completed for heating and cooling during the monitoring period. The monitoring period totaled 19 days and results were extrapolated to predict the typical annual performance based on weather data.

The monitoring period (June 24, 2005 to July 12, 2005) provided limited data for the yearly range of outside weather conditions. The outside dry-bulb air temperature (OA_{db}) during this period ranged from 55°F to 81°F. It is possible that supplemental monitoring would improve the correlation of post case heating values and OA_{db}. However, initial monitoring indicates that post case heating use is determined by factors other than the OA_{db} (as evidenced by the low r-squared value). It is possible that room occupancy is the main driver for post case heating use. If additional monitoring is conducted during the same time of year, it would likely capture similar conditions as the initial monitoring period with little additional benefit.

The ex ante analysis ignores the annual occupancy profile for the facility. The occupancy of the rooms are noted in the ex ante savings analysis, but not used in the analysis. After discussing the average occupancy rates with hotel staff, it was concluded that there are no seasonal fluctuations that need to be considered. Therefore, no adjustment will be made to the ex ante savings analysis for occupancy fluctuations.

The ex ante calculations neglect the free cooling capabilities of the cooling tower. When conditions allow, cooling will be provided at a higher efficiency then when the chillers are online. Free cooling is utilized from October through March. Free cooling will be considered in the ex post savings analysis.

The calculated fan savings appear to use an incorrect value for the post case average fan on time percentage, because this value seems to be taken from the average post case cooling runtime and does not include any heating fan runtime. The post case average fan on time percentage should be 14.1% (10.5% + 3.6%). However, the reduction in peak demand should use the post case fan on time percentage during peak hours (11.3%). With these changes, the fan energy and demand savings are reduced from 247,819 kWh to 233,831 kWh and from 28.3 kW to 27.9 kW, respectively.

The assumption of 75% fan on time for the pre-retrofit scenario is high compared to the reference rooms during the monitoring period, with a value of 27.6% fan on time. The reference rooms use programmable thermostats that are set to operate in the manual mode. However, when operated in this manner, this cannot simulate the baseline fan runtime since the reference room fans only run when the thermostat calls for cooling or heating. The manual thermostats also had a fan only option. Therefore, it is unknown how the fans operated prior to the retrofit; it is not possible to measure the correct value for the pre-retrofit fan run time. This will be a source of uncertainty for fan energy savings.

The heating and cooling equations were extrapolated to the entire year based on weather data. The source of the weather data used in the ex ante analysis is unknown, but it does not correspond to climate zone 3 TMY data as expected. This also introduces some uncertainty in the ex ante savings.

The application paperwork additionally indicated that the fans have a high and low speed for both the reference and test rooms. However, the ex ante savings were calculated with only one speed. The use of two fan speeds will likely change the fan savings and will be further explored in the ex post savings analysis.

The ex ante calculations identify the ex ante savings as 891,619 kWh/yr and 75.08 kW in the Installation Report Review. This agrees with the utility tracking system (except for rounding functions on the kW value).

4. Measurement & Verification Plan

The goal of the measurement and verification (M&V) plan is to determine the kW and kWh savings over the expected useful life of the measure by establishing the effect the occupancy based programmable thermostats have on heating, cooling and fan energy use in guest rooms. With some adjustments and additional data, the ex ante model and calculations can be utilized.

This facility is a hotel, with 827 FCUs in 793 guest rooms. The building contains a total of 650,000 sf with 492,332 sf of guest room space.

According to documentation provided by the customer, the FCUs are each rated at 300 CFM and 1/20-hp. The chilled water coil in each FCU is rated at 0.75 to 1-ton cooling capacity. Heating units are electric resistance heaters and are estimated to be 1.22 kW per FCU.

Cooling for the building is provided by a primary chilled water loop supplied from two 16 year old water-cooled chillers, with rated capacities of 416 tons and 465 tons. It is estimated that guest rooms represent about 70% of the total facility cooling load. According to the application paperwork and hotel staff, only one chiller operates at a time.

Two (2), two-stage, evaporative cooling towers with two 40-hp fans normally provide heat rejection for the central plant. The chillers are shut down from October through March, and the cooling towers provide cold water to cool the chilled water loop during this period (free cooling).

There are eight central exhaust fans and one main air handling unit. Operation of this equipment has no direct interaction with the occupancy based programmable thermostats.

Formulae and Approach

The ex ante analysis provides a good basis for the ex post analysis and a majority of the ex ante savings approach will be utilized. The M&V will attempt to target areas of uncertainty to improve the savings estimate. The primary areas of focus will be to better understand the baseline and new thermostat controls and setpoints, heating element capacity, central plant efficiency, fan capacity and speeds, and the effects of guest room rental status on HVAC equipment usage.

A variation of IPMVP M&V Option A (Partially Measured Retrofit Isolation) will be used.

Thermostat Controls and Setpoints

The control functions of the new occupancy-based thermostats are unclear. It is important to understand how the controls are actually operating and how the pre-retrofit, manual thermostats were functioning. Information regarding controls and setpoints will be determined from discussion with hotel staff, and examining the new occupancy-based programmable thermostats.

Heating Capacity

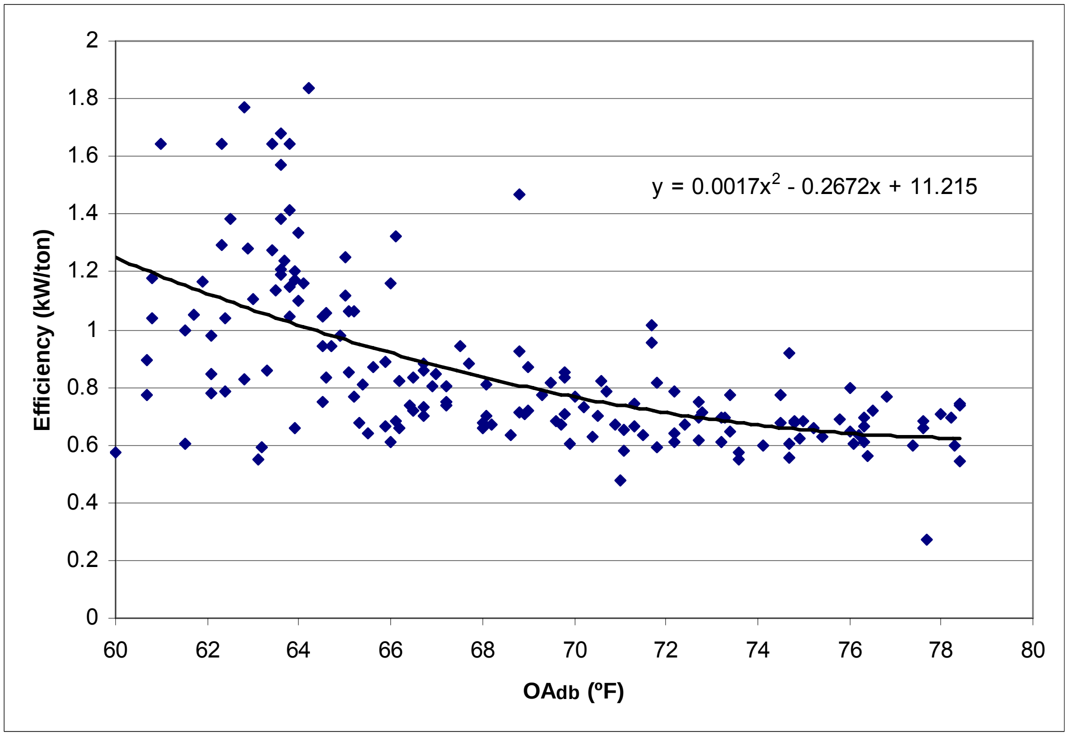
Heating is the largest component of ex ante savings. The value of 1.22 kW per heating element was used in ex ante calculations. The source of this value is not indicated in the provided documentation. Confirmation of this value would help improve the certainty of heating savings. It will be attempted to verify the heating element capacity of 1.22 kW per unit. Spot power checks or nameplate values will be used and verified with customer information; however, it is unclear if this can be collected. If new values are obtained, then they will be used in ex ante equation 5 to determine the ex post heating impact. As in the ex ante calculations, the energy savings from heating is:

$$kWh_{savings} = (heating\ capacity)(annual\ hours)(ave\ annual\ heating\ \%) \qquad \text{Eqn. 5}$$

Central Plant Efficiency

The ex ante analysis used an assumed average chiller plant efficiency of 0.9 kW/ton. The chiller plant was already monitored and analyzed. An average efficiency of 0.86 kW/ton was calculated for the monitoring period, based on chiller kW data and tons delivered. The load on the chiller plant is a function of OA_{db}, among other variables. The efficiency of the chiller plant is a function of the chiller plant load. Therefore, the efficiency can be plotted as a function of outside air temperature. Further analysis has provided more accurate, OA_{db}-dependent, chiller efficiency values. Using the monitoring data the chiller plant efficiency is given in equation 10.

Figure 1: Chiller Plant Efficiency



$$chiller\ \eta\ \ (kW/ton) = 0.0017OAT^2 - 0.2672OAT + 11.215 \qquad \text{Eqn. 10}$$

The cooling tower can provide cooling for either condenser water directly or chilled water indirectly through a heat exchanger. When ambient conditions are appropriate, the cooling tower can provide cooling of the chilled water loop directly without the use of the chillers. This is commonly known as free cooling. It is unclear how this feature is controlled, but a reduction in forecast cooling savings is expected due to the reduced power draw of the chilled water system in this period. When free cooling is utilized, central plant efficiency is estimated to be 0.4 kW/ton based on the type of equipment.

The ex post analysis will apply chiller plant efficiency equation, Eqn 10, when the chillers are in use, and the free cooling efficiency of 0.4 kW/ton when appropriate.

Fan Capacity and Speed

Fan savings also contribute to a significant portion of energy and demand savings. When onsite, fan power will be spot checked at all of the various speeds, as well as the control settings for the fan speed. Adjustments to the ex post analysis will be made if the findings dictate this change. The ex ante analysis uses a fan power of 0.053 kW and assumes only one speed. The customer documentation also indicates that the fan nameplate power is 1/20-hp; this will be verified. If changes in fan power are necessary, equations 8 and 9 will apply:

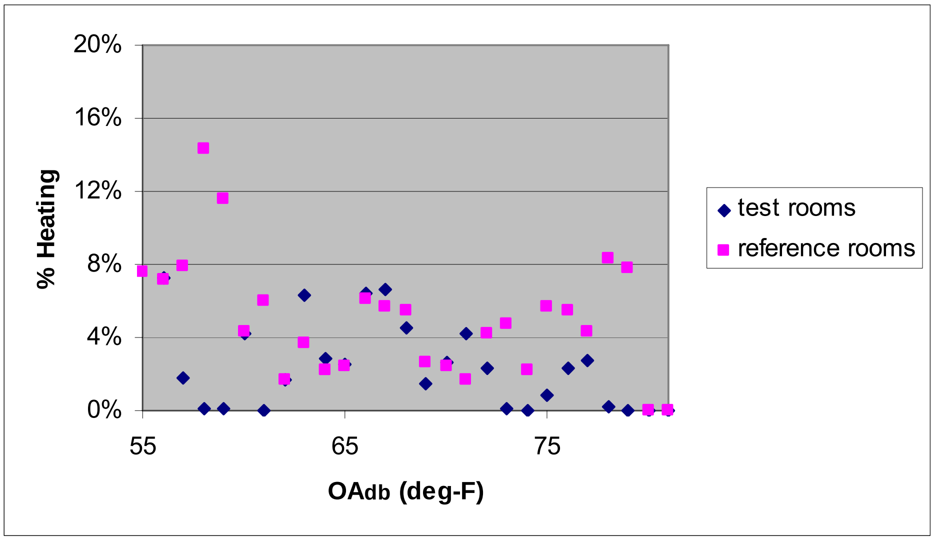
$$kWh_{savings} = (\#\ \ of\ \ FCUs)(Fan\ \ power)(ave\ \ \%\ \ reduction)(annual\ \ hrs) \qquad \text{Eqn. 8}$$

$$kW_{savings} = (\#\ \ of\ \ FCUs)(Fan\ \ power)(ave\ \ \%\ \ peak\ \ reduction) \qquad \text{Eqn. 9}$$

Effects of Guest Room Rental Status

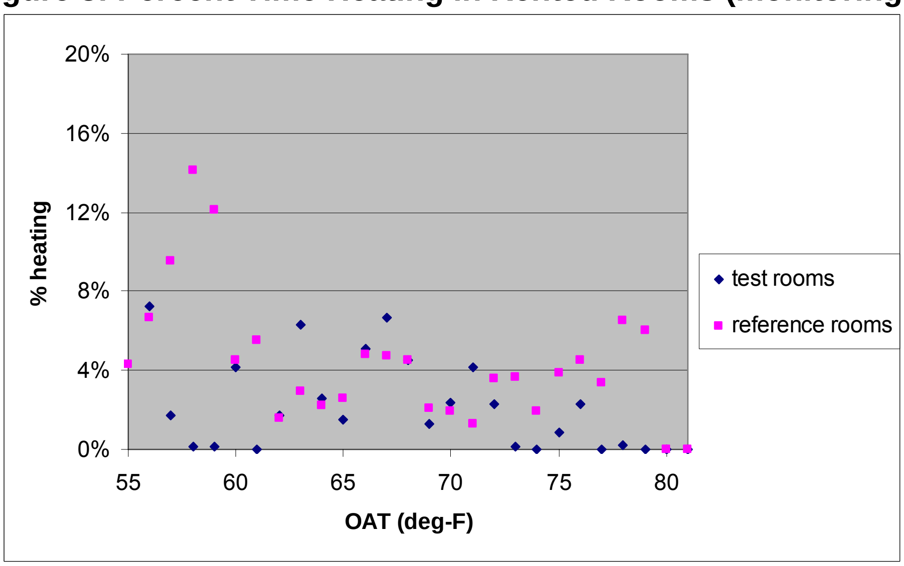
The programmable thermostats control FCU operation, based on occupancy and room rental status. Therefore, the rental status of a room affects the energy use of the FCU fan and the demand on the heating and cooling systems. Room occupancy was not a focus of the ex ante analysis. Further analysis was done on the ex ante data to establish rental status-dependant heating and cooling relationships. Figure 2 shows the ex ante values for heating savings with the guest room rental status neglected.

Figure 2: Average Percent Time Heating (based on monitoring data)



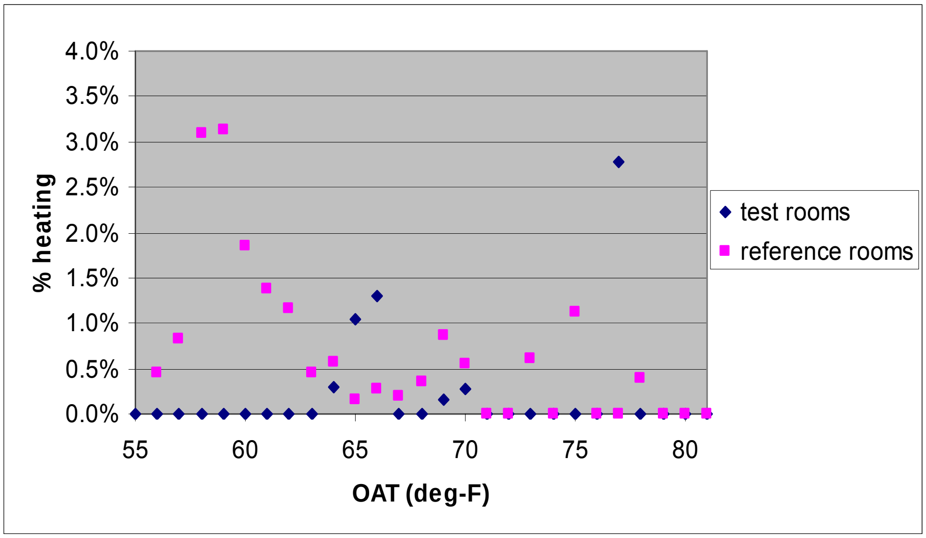
In figure 3, for rented rooms, the usage follows a similar pattern as shown in figure 2.

Figure 3: Percent Time Heating in Rented Rooms (monitoring data)



The figure for the post case heating scenario for vacant rooms, figure 4, shows that test room heating is substantially reduced (and entirely off in certain rooms).

Figure 4: Percent Time Heating in Vacant Rooms (monitoring data)



Although the correlation with temperature to the OA_{db} for post case heating is low, it is based on captured data. Moreover, the data indicates how the system is functioning, and the values produced are relevant. The revised heating equations become:

Rented:

$$\%\ time\ heating\ base_{rented} = (0.0001 \times OAT^2 - 0.0221 \times OA_{db} + 0.8569)(occupancy\ rate) \quad \text{Eqn. 11}$$

$$\%\ time\ heating\ post_{rented} = (0.033)(occupancy\ rate) \quad \text{Eqn. 12}$$

Vacant:

$$\%\ time\ heating\ base_{vacant} = (0.00001 \times OAT^2 - 0.0101 \times OA_{db} + 0.3798)(1 - occupancy\ rate) \quad \text{Eqn. 13}$$

$$\%\ time\ heating\ post_{vacant} = (0.022)(1 - occupancy\ rate) \quad \text{Eqn. 14}$$

These equations will be used in the same manner as ex ante equations 2 and 4, including the same temperature limits. The occupancy rate will be applied on either a monthly or annual basis depending on the information that is available.

Similar to heating, the cooling run time was analyzed based on rental status. The rented room equations were almost identical to the combined rented and vacancy analysis. The vacant room cooling data is insufficient, and cannot be used. There is not enough data to obtain viable results. Cooling accounts for 13% of the ex ante savings. The annual occupancy rate is relatively high, and it is difficult to capture data for vacant rooms. Considering the low number of vacant rooms and low percent of total ex ante savings attributed to cooling, the analysis will be used from the ex ante calculations. This is expected to introduce an error of less than 1% with respect to the overall ex post savings. Relative to the overall uncertainty in the heating and cooling system data, the effects of rental-status on % time cooling will be negligible.

A summary of equations that will be used in ex post savings analysis are:

Heating Savings

Rented:

$$\%\ time\ heating\ base_{rented} = (0.0001 \times OAT^2 - 0.0221 \times OA_{db} + 0.8569)(occupancy\ rate) \quad \text{Eqn. 11}$$

$$\%\ time\ heating\ post_{rented} = (0.033)(occupancy\ rate) \quad \text{Eqn. 12}$$

Vacant:

$$\%\ time\ heating\ base_{vacant} = (0.00001 \times OAT^2 - 0.0101 \times OA_{db} + 0.3798)(1 - occupancy\ rate) \quad \text{Eqn. 13}$$

$$\%\ time\ heating\ post_{vacant} = (0.022)(1 - occupancy\ rate) \quad \text{Eqn. 14}$$

Energy:

$$energy\ savings\ (kWh/\ yr) = (\%\ time\ heating\ base - \%\ time\ heating\ post) \times (8{,}760 hr/yr)(heating\ capacity)(827\ FCUs) \quad \text{Eqn. 5}$$

Cooling Savings

$$\%\ time\ cooling\ base = 0.0302 e^{0.0306 x OA_{db}} \quad \text{Eqn. 1}$$

$$\%\ time\ cooling\ post = 0.04 \quad \text{Eqn. 3}$$

$$Cooling\ Load_{per\ room}(kW) = \left[\frac{(\Delta T\ {}^\circ F)(1.1)(300 CFM/room)(central\ plant\ \eta\ kW/ton)}{(12{,}000 Btu/ton)} \right] \quad \text{Eqn. 7}$$

Where, equation 10 will be used if chillers are in operation, and equation 15 will be used while central chillers are offline and free cooling is utilized.

$$chiller\ \eta\ (kW/ton) = 0.0017 OAT^2 - 0.2672 OAT + 11.215 \quad \text{Eqn. 10}$$

$$free\ cooling\ \eta\ (kW/ton) = 0.4 kW/ton \quad \text{Eqn. 15}$$

Energy savings are based on 5 minute interval data that is averaged out over an entire year.

$$energy\ savings\ (kWh/yr) = (\%\ time\ cooling\ base - \%\ time\ cooling\ post) \times (cooling\ load)(annual\ hours)(827\ FCUs) \quad \text{Eqn. 16}$$

Peak Demand:

$$cooling\ peak\ demand\ reduction\ (kW) = \frac{(peak\ ave\ energy\ savings)}{(hours\ in\ peak\ period)} \quad \text{Eqn. 17}$$

Fan Savings

$$Annual\ kWh_{savings} = (\#\ of\ FCUs)(Fan\ power)(ave\ \%\ reduction)(annual\ hrs) \quad \text{Eqn. 8}$$

$$kW_{savings} = (\#\ of\ FCUs)(Fan\ power)(ave\ \%\ peak\ reduction\ ) \quad \text{Eqn. 9}$$

A site visit will be conducted to verify that thermostats are in place and functioning in a sample of the rooms.

The above approach will require the following data verification:

Table 2: Onsite Data Collection and Verification

Data Element	Proposed Means of Collecting Data
Current annual occupancy data (monthly if possible)	Confirm via customer interview and review of customer records.
Spot check heating element	Spot check kW, check nameplate, or customer confirmation.
Spot check fan power and number of speeds	Spot check kW at each speed. Check nameplate, or customer confirmation.
Thermostat setback inputs and temperature windows during unoccupied and un-rented periods	Review of thermostat settings and customer interview.
Free cooling operation	Confirm via customer interview and review of customer records.

Uncertainty for the savings estimates can be more fully understood by setting projected ranges on the primary variables.

Heating Savings

- Annual run time pre retrofit: 841 hrs/yr expected, 300 hrs/yr minimum, 2,000 hrs/yr maximum (+250% maximum , -70% minimum)
- Annual run time post retrofit: 314 hrs/yr expected, 200 hrs/yr minimum hours, 1,000 hrs/yr maximum hours (+300%, -50%) based on estimates of operation
- Capacity 1,006.5 kW expected, minimum 500 kW, maximum 2,000 kW (includes -50% and +100% for size of heating coil)
- 529,939 kWh/yr expected, minimum 260,000 kWh/yr, maximum 790,000 kWh/yr (+30% /- 50% based on extrapolation from summer run time percentages to the entire year)

Cooling Savings

- Annual run time pre retrofit: 1,287 hrs/yr expected; 1,000 hrs/yr minimum; 1,600 hrs/yr maximum (±25%)
- Annual run time post retrofit: 916 hrs/yr expected, 600 hrs/yr minimum hours, 1,200 hrs/yr maximum hours (±30 %) based on estimates of operation
- Temp difference: Average 12°F expected, minimum 6°F kW, maximum 15°F (includes -50% and +25%)

Fan Savings

- % time pre-retrofit: 25% expected, 8% minimum, 75% maximum (+300% / -70%)
- % time post-retrofit: 14.1% expected, 7% minimum hours, 28% maximum hours (±100%) based on expected operations
- Size: 827 units x 0.053 kW/unit; 48.3 kW expected, minimum 24 kW, maximum 827 units x 0.053 kW/unit (includes -50% for hi/low operation)
- 247,819 kWh/yr expected, minimum 200,000 kWh/yr, maximum 300,000 kWh/yr (based on ±20% from extrapolation from summer run time percentages to the entire year)

There may be other small potential sources of error introduced, for a variety of reasons, such as changes in occupancy rates and the average fan speed being unknown for both pre- and post-retrofit scenarios. The greatest source of error is from not measuring run times during the heating season. These smaller errors are estimated at a maximum of ±10% in aggregate. The larger error sources listed above, can very significantly affect savings. The ranges listed are to help better understand the errors and help guide M&V efforts.

Accuracy and Equipment

The spot electrical measurements are to be performed with a Wavetek Meterman AC38, digital multimeter with an accuracy of 1.2%.

Other collected data and reported data are considered to be 95% accurate where reviewed data is deemed reasonable.

Annualizing the cooling run time data and the fan run time data from a 17 day monitoring period is projected to result in a possible error in the final results of ±5%.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 12, 2007. Information was collected from equipment nameplate, spot power checks, and interviews with hotel staff. Several guest rooms were entered to examine FCUs and thermostat setpoints.

Installation Verification

All of the five guest rooms that were surveyed occupancy-sensor programmable thermostats installed. Door sensors and occupancy sensors are used to determine activity in guest rooms. When a guest room door is closed, the occupancy sensor looks for activity in the room. If there is room activity, the thermostat operates in its rented-occupied mode, in which the thermostat operates within a two-degree temperature range of the set target temperature. If the door is closed and the room has no activity for a period of 10 minutes, the thermostat reverts to its rented-unoccupied mode, during which the temperature is allowed to swing within five degrees of the target temperature setpoint. If there is no activity in the room for a period of 14 hours, the thermostat enters its un-rented mode. In this mode, the temperature is allowed to swing from 65°F to 80°F. While cleaning rooms, housekeeping staff resets the target temperature to 72°F.

The verification realization rate for this project is 1.0. A verification summary is shown in Table 8 below.

Summary of Results

As outlined in Section 4, the same approach as the ex ante savings calculations is being used for the ex post savings. Some modifications have been made based on information collected from the on-site survey. Savings are realized from three different sources: heating, cooling, and fan operation. Based on measured data, the baseline and post-retrofit runtimes for heating, cooling and fan run times are calculated.

Occupancy

From interviews with hotel staff it was determined that there are only minor fluctuations in the occupancy rates. There is an increase in occupancy around holiday periods, but on a monthly basis, changes in occupancy levels are negligible. The typical monthly occupancy rate is 75%.

Heating Savings

As discussed in Section 4, the ex ante monitoring data was analyzed to identify independent correlations in rental status and heating patterns. The occupancy rate is then applied to determine how many rooms will be in un-rented and rented status at any one time. This will improve the accuracy of heating savings compared to the ex ante approach.

The heating element capacity was assumed to be 1.2 kW in ex ante calculations, though the source was not sited. Spot measurements were taken and the nameplate was inspected during the on-site survey. The heating element rated capacity is 1.5 kW, and spot readings revealed that the heating elements operate in step mode at a power of 1.48 kW. This value is used in equation 5, replacing the ex ante value of 1.2 kW per FCU. The heating savings equations become:

Rented:

$$\%\ time\ heating\ base_{rented} = (0.0001 \times OAT^2 - 0.0221 \times OA_{db} + 0.8569)(occupancy\ rate) \qquad \text{Eqn. 11}$$

$$\%\ time\ heating\ post_{rented} = (0.033)(occupancy\ rate) \qquad \text{Eqn. 12}$$

Vacant:

$$\%\ time\ heating\ base_{vacant} = (0.00001 \times OAT^2 - 0.0101 \times OA_{db} + 0.3798)(1 - occupancy\ rate) \qquad \text{Eqn. 13}$$

$$\%\ time\ heating\ post_{vacant} = (0.022)(1 - occupancy\ rate) \quad \text{Eqn. 14}$$

Energy:

$$energy\ savings\ (kWh/\ yr) = (\%\ time\ heating\ base - \%\ time\ heating\ post) \times (8{,}760 hr/yr)(1.48 kW)(827\ FCUs) \quad \text{Eqn. 5}$$

Cooling Savings

The ex post analysis uses the same cooling percent time equation as the ex ante analysis. For ex ante calculations the central plant used an assumed efficiency of 0.9 kW/ton. Based on monitoring data, the temperature-dependant chiller efficiency was determined as described in equation 10, shown below. Also, free cooling was overlooked in the ex ante calculations. Based on interviews with hotel engineering staff, the chillers are typically shut down from October until April, and the cooling towers alone are used to meet cooling load requirements. Based on the cooling tower fan and system pump horsepower, it is assumed that during the free-cooling period the system will perform at an average efficiency of 0.4 kW/ton.

$$\%\ time\ cooling\ base = 0.0302 e^{0.0306 x OA_{db}} \quad \text{Eqn. 1}$$

$$\%\ time\ cooling\ post = 0.04 \quad \text{Eqn. 3}$$

$$Cooling\ Load_{per\ room}(kW) = \left[\frac{(\Delta T\ ^\circ F)(1.1)(300 CFM/room)(central\ plant\ \eta\ kW/ton)}{(12{,}000 Btu/ton)} \right] \quad \text{Eqn. 7}$$

$$chiller\ \eta\ (kW/ton) = 0.0017 OAT^2 - 0.2672 OAT + 11.215 \quad \text{Eqn. 10}$$

$$free\ cooling\ \eta\ (kW/ton) = 0.4 kW/ton \quad \text{Eqn. 15}$$

Equation 10 will be applied from April through September, and Equation 15 will be applied for October through March.

$$energy\ savings\ (kWh) = (\%\ time\ cooling\ base - \%\ time\ cooling\ post) x (cooling\ load)(annual\ hours)(827\ FCUs) \quad \text{Eqn. 16}$$

$$cooling\ peak\ demand\ reduction\ (kW) = \frac{(peak\ ave\ energy\ savings)}{(hours\ in\ peak\ period)} \quad \text{Eqn. 17}$$

Fan Savings

Ex ante calculations use an assumed FCU fan motor horsepower. This is a factor that was explored during the on-site visit. Ex ante savings utilized a nameplate capacity of 1/20 hp, and a demand of 0.053 kW for calculations. The on-site survey found that the nameplate capacity is 1/10 hp. The ex ante calculations assumed a single-speed fan for both base and post retrofit scenarios. The new thermostats control the fan motors at three speeds (high, medium, and low), spot readings were taken at all three speeds, providing 0.055 kW, 0.042 kW, 0.028 kW, respectively. The fan speed is determined by the thermostat set point and room temperature. The manual thermostats had a fan only control option. Therefore, it is not possible to simulate the manual thermostat fan speed, and determine the time spent at each particular speed. For ex post calculations, the medium speed power was used (0.042 kW), to minimize uncertainty. The base case fan run time is assumed to be 75% of the time for all guest rooms. This is taken from the ex ante analysis. The base case monitoring that was conducted simulated manual operation in the reference rooms, however, the fan runtime is unknown and could not be measured. Due to the lack of a better estimate, the ex ante value of 75% runtime is used. The post-retrofit runtime is a summation of the time the FCU is in heating mode and cooling mode.

$$kWh_{savings} = (827 \ \ FCUs)(0.042 \ \ kW)(ave \ \% \ \ reduction)(annual \ \ hrs) \qquad \text{Eqn. 8}$$

$$kW_{saving} = (827 \ \ FCUs)(0.042 \ \ kW)\frac{(peak \ ave \ energy \ savings)}{(hours \ in \ \ peak \ \ period)} \qquad \text{Eqn. 9}$$

$$ave \ \% \ \ reduction = (\% \ \ time \ \ heating + \% \ \ time \ \ cooling)_{post} - (75\%) \qquad \text{Eqn. 18}$$

Table 3 compares values from the ex ante calculations and ex post calculations.

The engineering realization rate for this application is 0.81 for demand kW reduction and 0.96 for energy savings kWh. A summary of the realization rate is shown in Table 7.

Table 3: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1,356.0	8,454,848
Baseline End Use	440.1	3,855,276
Ex Ante Savings	75.1	891,619
Ex Post Savings	60.7	852,821

Table 4: Percent Savings and Demand reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/ Demand Reduction	kW	kWh	kW	kWh
Total Meter %	5.5%	10.5%	4.5%	10.1%
Baseline End Use %	17.1%	23.1%	13.8%	22.1%

6. Additional Evaluation Findings

Ex post heating savings are higher then the ex ante values because the heating elements are larger than assumed in the ex ante calculations (1.48 kW versus 1.2 kW). Also, correlations between percent time heating were separated for rented and un-rented rooms.

This resulted in a higher baseline heating energy use and a slight reduction in post-retrofit heating energy use when compared to the ex ante analysis.

The largest discrepancy in ex post and ex ante values relating to cooling is in the average annual central plant efficiency. An assumed plant efficiency of 0.9 kW/ton was used throughout the entire year in ex ante savings. However, free cooling is utilized when conditions permit. After applying a higher, more appropriate efficiency for free cooling periods, cooling savings were reduced. The average annual central plant efficiency went from 0.9 kW/ton to 0.716 kW/ton in the ex post analysis. The cooling baseline hours also increased slightly. The only difference in baseline cooling is that the ex ante analysis used different weather data, and ex post used hourly TMY data for climate zone 3. Hourly data allowed for a more accurate demand reduction estimate. Ex post savings show a decrease in peak demand savings. This results from the central plant operating at a higher efficiency during peak periods (with high temperatures); consequently, savings are reduced.

Ex ante values in fan savings are reduced in the ex post analysis. This is due to higher post retrofit cooling time in the ex post analysis. An increase in post retrofit cooling will increase the post retrofit fan runtime. Also, the fan motor power is lower than ex ante assumptions (0.042 kW versus 0.053 kW).

There are some factors in the ex post analysis that contribute to the uncertainty of the savings. The best estimates were applied to minimize the propagation of uncertainty in ex post savings calculations. One of these factors is the time spent at a particular fan speed. This will relate to the weighted average fan power. The median value of 0.042 kW was used (with a possible range of ±50%). Other factors that cannot be accounted for are yearly fluctuations from TMY weather data and hotel occupancy. A summary of possible ranges of the primary variables is provided in Section 4.

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. With a cost of $145,771 and a $71,329.52 incentive, the project had a 7.7 month simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 8.1 months. A summary of the economic parameters for the project is shown in Table 6.

There are several positive, non-energy benefits from installing the occupancy based programmable thermostats. The existing thermostats were outdated in appearance, while the new units are considered attractive to hotel guests. Also, there is a better response time and smaller temperature swings with the new thermostats, thereby improving comfort.

7. Impact Results

Table 5: comparison of Ex Ante and Ex Post

Heating Savings	Ex Ante	Ex Post
Baseline average on-time in heating mode	9.6%	11.2%
Baseline annual operating time (hours/yr)	841	981
Post-retrofit average on-time in heating mode	3.6%	3%
Post-retrofit annual operating Time (hours/yr)	314	263
Heating capacity (kW)	1,006.5	1,224.0
Energy savings (kWh/yr)	529,939	548,904

Cooling Savings	Ex Ante	Ex Post
Baseline average on-time in cooling mode	14.7%	16.2%
Baseline annual operating time (hours/yr)	1,287	1,419
Post-retrofit average on-time in cooling mode	10.5%	10.9%
Post-retrofit annual operating time (hours/yr)	916	955
Number of hotel rooms	827	827
FCU air flow rate (cfm)	300	300
FCU ΔT (°F)	15	15
Annual average chilled-water system efficiency (kW/ton)	0.90	0.716
Energy savings (kWh/yr)	113,861	122,470
Peak demand savings (kW)	46.79	40.7

Fan Savings	Ex Ante	Ex Post
Baseline average fan on	75.0%	75%
Baseline operating time (hours/yr)	6,570	6,570
Post-retrofit average fan on	10.5%	14.0%
Post-retrofit operating time (hours/yr)	916	1,226
Fan motor power (kW)	0.053	0.041
Number of fans	827	827
Energy savings (kWh/yr)	247,819	181,447
Peak demand savings (kW)	28.3	20.0

Total Savings	Ex Ante	Ex Post
Energy savings (kWh/yr)	891,619	852,821
Peak demand savings (kW)	75.08	60.7

Table 6: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, Therms	Estimated Annual Cost Savings	SPC Incentive, $	Simple Payback w/ Incentive, Mo.	Simple Payback w/o Incentive, Mo.
Installation Approved Amount (Ex Ante)	10/5/2005	$145,771	75.08	891,619	0	115,910.47	71,329.52	7.7	15.1
SPC Program Review (Ex Post)	10/14/2007	$145,771	60.7	852,821	0	110,866.73	71,329.52	8.1	15.8

Table 7: Realization Rate Summary

	kWh	kW	Therm
SPC Tracking System	891,619	75.1	-
SPC Installation Report (ex ante)	891,619	75.08	-
Impact Evaluation (ex post)	852,821	60.7	-
Engineering Realization Rate	0.956	0.808	NA

Table 8: Installation Verification Summary

Measure Description	End-Use Category	Other Measure Description	Lighting Measure Description	AC&R Measure Description	Count	Equipment Description	Installation Verified	Verification Realization Rate
HVAC OCCUPANCY SENSOR	O - Other	Replace 827 hotel guest room thermostats with occupancy-based, programmable thermostats			827	INNCOM e4 Smart Digital Thermostat	Physically inspect several guest rooms, and made sure units were in use	1.0

Table 9: Multi Year Reporting Table

Program Name:		**SPC 04-05 Evaluation A011**					
Year	**Calendar Year**	**Ex-ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004						
2	2005	445,810	426,411	75.08	60.7		
3	2006	891,619	852,821	75.08	60.7		
4	2007	891,619	852,821	75.08	60.7		
5	2008	891,619	852,821	75.08	60.7		
6	2009	891,619	852,821	75.08	60.7		
7	2010	891,619	852,821	75.08	60.7		
8	2011	891,619	852,821	75.08	60.7		
9	2012	891,619	852,821	75.08	60.7		
10	2013	891,619	852,821	75.08	60.7		
11	2014	891,619	852,821	75.08	60.7		
12	2015	891,619	852,821	75.08	60.7		
13	2016	445,810	426,411				
14	2017						
15	2018						
16	2019						
17	2020						
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	9,807,809	9,381,031				

Setback thermostats with 11 year life.

Final Site Report

SITE A012 (2004-xxx) Lock1a IMPACT EVALUATION
SAMPLE CELL TIER: 3 END USE: AC&R

Measure	Chiller Replacement
Site Description	Multi-Use Campus

1. Measure Description

Replace one (1) 1,330-ton water-cooled constant speed chiller with one (1) 1,330-ton water-cooled variable speed chiller. The chiller is used primarily for trim in a 7,890 ton capacity central chilled water plant.

2. Summary of the Ex Ante Calculations

The ex ante calculations for the chiller replacement were performed by comparing a new constant speed chiller meeting Title 24 minimum efficiency standards with the specified variable speed replacement chiller. Assumptions were used for the number of run hours for the chiller at various loading conditions. Chiller efficiency (kW/ton) for each loading condition was taken from the chiller performance curve.

The back-up data provided does not clearly indicate the calculated value for energy savings. The application form gives an approved amount of 1,425,270 kWh/year and a submitted amount of 878,400 kWh/year. Various summaries of analyses were provided with one yielding 3,269,405 kWh/year and one with 1,260,355 kWh/year. A bin analysis was also provided that shows savings of 2,550,600 kWh/year between the existing chiller (not the Title 24 baseline chiller) and the new chiller.

No analysis was provided matching the tracking system energy savings (1,425,270 kWh/year) and the tracking system reported peak demand savings is 81.1 kW. These are used as the ex ante as well as the tracking system savings.

The report also lists a total measure cost of $800,000.The incentive was $ 199,537.80.

3. Comments on the Ex Ante Calculations

Analysis was not provided that supports the savings that were claimed. The utility reviewer was contacted but was not able to provide additional requested information. It appears that the SPC Calculator was used and the correct reviewer was not identified.

4. Measurement & Verification Plan

The goal of the measurement and verification (M&V) plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful life of the chiller through quantifying hours of operation and energy use during these hours.

The site is a multi-building campus that includes offices, clean rooms (primarily assembly, integration and test areas for specialty electronic equipment), machine shops, laboratories and computer server rooms. The offices are normally occupied Monday through Friday from 6:00 am to 6:00 pm. Computer server rooms, clean rooms and laboratories run continuously (24/7).

The customer utilizes what they refer to as a 9/80 weekday work schedule for most employees. On this schedule, employees work Monday to Thursday for 9 hours each day and work 8 hours on every other Friday.

Campus cooling and heating requirements are primarily served by a 7,890-ton central plant.

Formulae and Approach

The M&V plan proposed is a modified version of IPMVP Option A.

A performance curve for the new chiller will be obtained. An estimated performance curve will be used for the baseline chillers. This information will be used to model the annual electrical usage by the baseline and new chilled water plant equipment.

The actual cooling load for the chiller will be determined using chilled water supply and return temperatures and water flow. The actual kW demand of the chiller will be measured. Trend data from the customer may also be used if appropriate.

The size of the new chiller will be confirmed.

The proposed data collection will be chilled water supply and return temperatures and flow; chiller kW; and condenser water supply and return temperatures and flow.

The performance curve for the installed chiller will be established by plotting the kW vs. the percent of full load for all data points collected for the chillers' operation. The percent load will be determined by dividing the chiller full load amps by the trended amps during operation. The chiller efficiency (kW/ton) will be determined by dividing the trended kW draw by the calculated tonnage based on the temperature difference between chilled water supply and return (ΔT) and the chilled water flow. The tonnage will be calculated by the formula:

Tons = CHW gpm x 500 lb/hr/gpm x CHW ΔT x 1 Btu/lb °F/ 12,000 Btu/ton

With the chiller performance established, the new system can be modeled and the annual electrical usage determined. The post-retrofit energy usage will be compared to the baseline energy usage to determine the ex post savings using the following formula:

$$\text{kWh Savings} = \sum_{1}^{8,760} \text{Hours} \times \text{Average Tons} \times \left(\text{kW/ton}_{\text{w/o VSD}} - \text{kW/ton}_{\text{w/VSD}}\right).$$

The above approach will require the following data collection and verification:

Data Element	Proposed Means of Collecting Data
Base case equipment configuration	Confirm via customer interview and review of customer records.
Base case chiller duty	Confirm via customer records of chiller capacity rating. Interview customer to determine pre-retrofit control strategy.
Base case system operating hours	Confirm via customer interview and review of customer records and the planned maintenance schedule for each chiller and pump.
Base case control scheme	Confirm via customer records and interview, pre-retrofit chiller control. Verify manuals start/stop vs auto lead-lag.
Post case chiller duty	Obtain two weeks (or longer) of hourly customer trended data - chiller kW, ECHWT, LCHWT, ECDWT, LCDWT.
Post case equipment configuration	Confirm via site survey, customer interview, and review of customer records. Obtain manufacturers' data sheets for equipment and equipment nameplate information. Review control settings and sequence of operation for chiller and pump staging.
Post case system operating hours	Confirm via customer interview and review of customer records and the planned maintenance schedule for the chiller.

The greatest uncertainties in the ex ante savings estimate are the hourly chilled water loads, the extent to which the cooling loads are weather dependant, and, to a lesser extent, how the chillers' efficiencies (kW/ton) vary at different cooling loads.

Accuracy and Equipment

It is expected that water temperatures are being measured by the customer with either an RTD or thermocouple installed in a thermowell that is immersed in the flow. These devices are generally accurate to within ±2°F.

Power and readings will be obtained with the customer's installed monitoring equipment and supplemental short term monitoring equipment. The equipment includes local gauges and some ultrasonic flow meters used by an HVAC controls contractor for a central plant optimization study. All equipment used typically has accuracies to within ±2%.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

During the site visit, numerous issues were identified that invalidated several assumptions used to develop the M&V plan:

- There are seven chillers in the central plant and they are all manually staged. When the technician feels additional cooling capacity is required, an additional chiller is turned on and when he feels less capacity is needed, a chiller is shut off. Therefore, outside air temperature may not be a good indication of actual chiller load.

- The new VFD chiller was not operating during the evaluation period due to ongoing maintenance issues, so its performance could not be measured. The reliability of this unit has been poor ever since it was installed. The installation contractor has been recalled to the site to evaluate the issue (it is suspected that the motor starter for the VFD is not compatible with the actual VFD being used). The customer's run-time log for the chiller shows that it has operated for 728 hours during the past year out of the expected 8,760 hours/year. For most of those hours, the temperature differential (ΔT) between the chilled water (CHW) supply and return has only been 2 or 3° F. One chiller in the plant that was operating (Chiller #7) is the same make/model as the unit that was replaced. Monitoring was performed on that chiller to determine its performance under the ex post operation. These results were used to calculate how the VFD chiller would operate under the cooling loads expected once that chiller is operational.

The chilled water distribution piping may be suboptimal. It is currently set up in a primary/secondary loop arrangement but there are issues with certain zones not getting enough chilled water. The bypass valve was closed, removing the primary loop, and the chilled water supply temperature was set at 38° in an effort to satisfy all end use cooling demands. The current pumping configuration utilizes one distribution pump for each operating chiller to supply the distribution loop. Each building also has a booster pump that operates in series with the pumps at the central chiller plant. A pump curve was provided for the "primary" distribution pump for Chiller #7, but it does not match the motor horsepower being used. Also, since this pump is in series with other pumps, the curve cannot be used to determine chilled water flow.

- Data from the central plant is currently not trended through the facility EMS. Instead, chiller amps/volts and supply/return chilled and condenser water temperatures (among other chiller parameters) are manually logged two or three times a day by facility staff. Data from the manual logs is entered into a web-based program that flags potential maintenance issues (chillercheck.com). A building controls contractor is working with the customer on a central plant optimization study. The contractor has done some short-term monitoring of chilled water flow and chilled water ΔT's in the various buildings being served.

Despite all these issues, an impact evaluation could still be performed. Below is a summary of the data that was obtained and the analysis approach:

Table 1 gives a listing of all the chillers in the central plant.

Table 1: Central Plant Chillers

Designation	Make	Model	Serial	Refrigerant	Year	Tons	Volts	FLA
1	Carrier	19EX4141-756DP661	47325	R-134a	1994	1000	4160	116
2	York	YKQEQBJ1C2C	5BDM548250	R-134a	1995	1000	4160	94
3	York	YKQDQBJ1-C4C	SBDM-548350	R-134a	1995	900	4160	83
4	York	YKQEQBJ-1 C2C	SBDM 548150	R-134a	1995	1000	4160	94
5	Carrier	19EF83DP	35508	R-134a	1984	1330	4160	122
6	Carrier	19xr828502ekh68	4204Q70033	R-134a	2005	1330	4160	95
7	Carrier	19EF83DP	35510	R-134a	1984	1330	4160	122

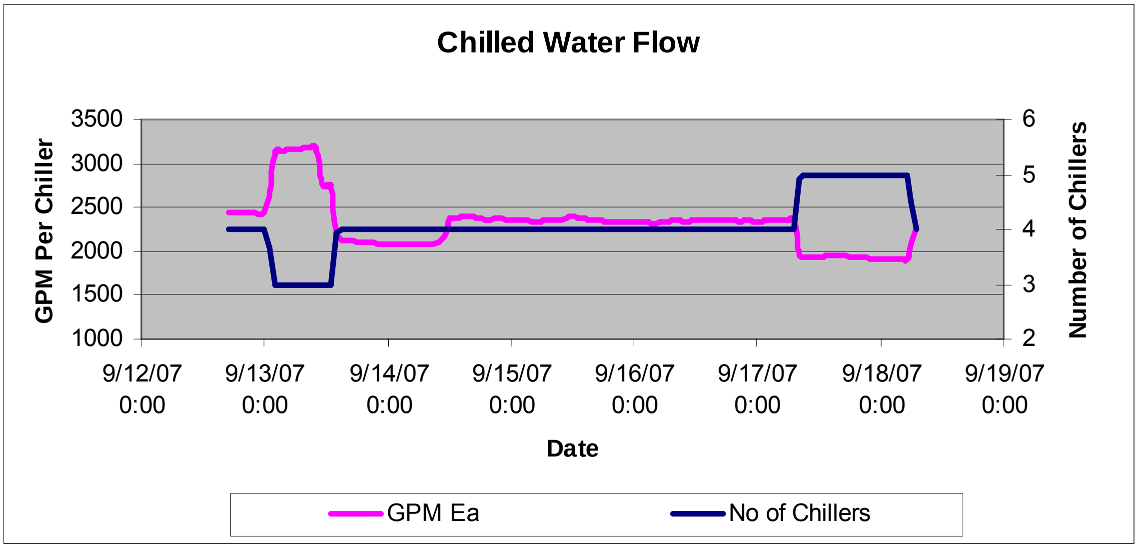
Chiller #6 is the new VFD unit. Chiller #7 is identical to the unit that was replaced. Performance data for Chiller #7 was used for much of the ex post impact evaluation.

From the short-term monitoring performed by the contractor, chilled water flow was obtained.

- The monitoring of chilled water flow through each building and chiller operation occurred simultaneously for approximately one week (9/12/07 through 9/18/07).
- Between 3 and 5 chillers were simultaneously operating during this time-frame.
- The sum of the chilled water flow through all the buildings was taken as the total chilled water flow in and out of the central plant.
- It is assumed that each chiller has an equal water flow rate.

Based on the above monitored data and assumptions, it was determined that the chilled water flow averages approximately 2,300 gallons per minute per chiller. This value was used in energy savings calculations. See Figure 1 for a graph of estimated chilled water flow per chiller and number of chillers in operation.

Figure 1: Chilled Water Flow per Chiller



The conclusion from Figure 1 is that chilled water flow through each chiller is driven primarily by the number of chillers in operation and not by the time of day or the day of the week.

Data was obtained from the web-based chiller log. Recorded values include amps, volts, and CHW as well as condenser water (CW) supply / return temperatures. For each chiller running, facility staff takes and records spot readings one to three times per day. One year of logged data was evaluated for Chiller #7, which included 419 data points. Table 2 shows a summary of the average parameters as logged for the chiller.

Table 2: Chiller #7 Average Annual Performance

Temp CW In °F	Temp CW Out °F	CW ΔT °F	Temp CHW In °F	Temp CHW Out °F	CHW ΔT °F	Run Hours	Amps	Volts	kW	% Full Load	Tons Cooling	kW/ton
68.6	72.0	3.4	44.1	38.3	5.8	6,274	61.0	4286	407	50.0%	559	0.728

The key parameters to note are as follows:

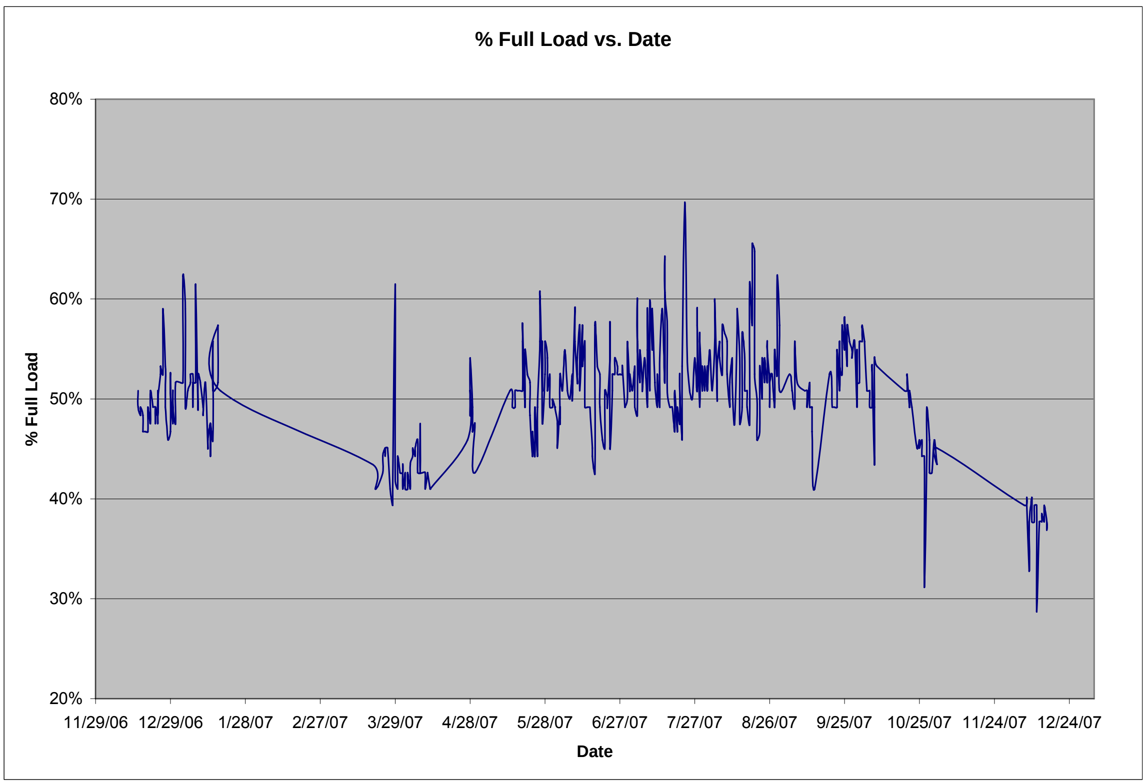
- The condenser water set-point is 68ºF. The actual average condenser water temperature was 68.6ºF.
- The average difference between condenser water inlet and outlet temperatures is 3.4ºF.
- The average difference between chilled water inlet and outlet temperatures is 5.8ºF.
- Total operating hours were 6,274 for the year.
- Average current draw is 61 amps. The full load current draw for this chiller is 122 amps.
- Average voltage is 4,286 volts
- Average kW was calculated through the following equation:

- kW=V x I x 1.73 x PF
- Power factor (PF) is assumed to be 0.9.

- Average load is 50% of full load. Figure 2 shows % full load for the entire year, which shows the chiller rarely operates above 60% or below 40% full load. Therefore using a straight average of 50% full load is acceptable for evaluation purposes.
- Assuming an average chilled water flow of 2,300 gpm, the chiller provided 559 tons/hour of cooling.
- Average chiller efficiency is 0.728 kW/ton.

Figure 2 shows Chiller #7 operation as a function of % full load throughout the year.

Figure 2: Chiller #7 Annual Operating Capacity

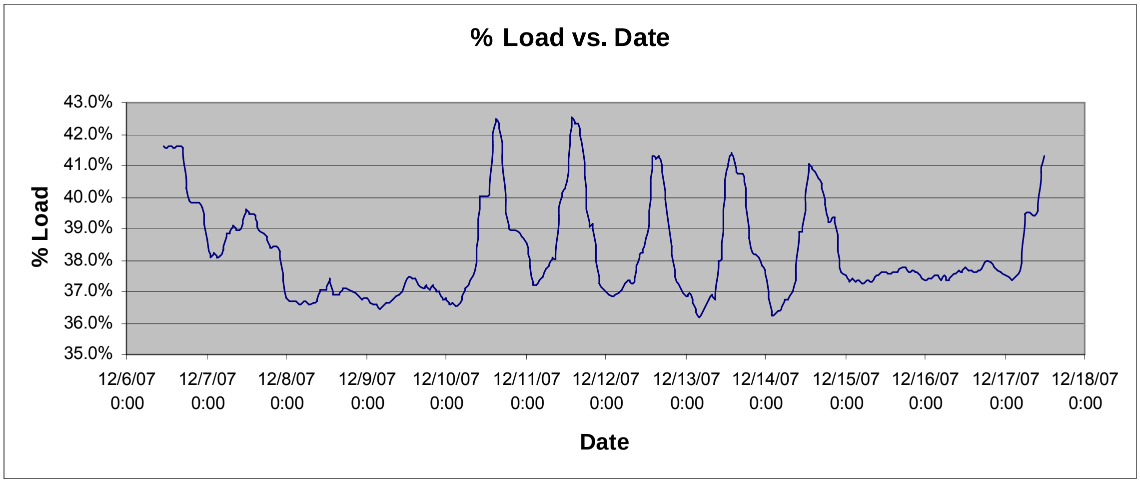


One thing to note about Figure 2 is the operation during December. For the evaluation, the evaluation team performed short term monitoring on Chiller #7. The monitored period represents the load below 40% full load. The facility didn't have Chiller #7 running at the time, but they agreed to operate it during the monitoring period. This data is inconsistent when compared to operation during the rest of the year. It is concluded that their normal pattern of central plant operation was disrupted based on the request to obtain short term monitored data.

Figure 3 shows the short term monitoring Chiller #7 output as a % of full load. The unit is a 4160 V chiller, so power or amperage was not monitored directly. The instrumentation wiring to the amp gauge was monitored. An amp logger with a 50 amp CT was installed and a multiplication factor was determined. The value for % full load was determined as follows:

% Full Load = Monitored Amperage / Rated Full Load Amperage

Figure 3: Chiller #7 Monitored % Load



Friday, 12/7, was an “off” Friday, where the majority of employees were off work. The period starting 12/10 through 12/15 is a typical work week. The load variation throughout the day can be seen, but that variation is only 5% of full load. As stated earlier, it appears the central plant was not in its normal operating mode due to the request of running this chiller for the purpose of short term monitoring, as seen by the operating load being lower than typically seen throughout the year. The variation in load throughout the day appears to be a very low percentage of full load.

6. Additional Evaluation Findings

The replaced chiller was 20 years old and at the end of its useful life. Therefore, the baseline Title 24 chiller was used and early retirement did not apply.

Based on the data obtained, an analysis was performed using the following data:

- The average chilled water flow through the chiller is 2,300 gpm.
- The average chiller load is 50% of full load.
- The average cooling output for the chiller is 559 tons/hr.
- The average efficiency of Chiller #7 is 0.728 kW/ton.
- The intended operating hours of the new VFD chiller is 8,760 hours/year.

- The average chilled water output temperature is 38.3º F.
- Average condenser water temperature is 68.6º F.
- At 50% load and 68.6ºF condenser water temperature, the efficiency of the VFD chiller is 0.287 kW/ton, interpolated from the chiller performance curve (Figure 5 in the Appendix).
- The minimum Title 24 (2001 standard) efficiency for water-cooled chillers operating in these temperature ranges is 0.433 kW/ton, calculated from Table 1-C10 in the 2001 Title 24 standard (Included as Figure 4 in the Appendix).

The Title 24 chiller efficiency formulas, from the 2001 Title 24 standard for centrifugal water-cooled chillers greater than 300 tons, are included below:

$COP_{std} = 6.1$

LIFT = Entering Condenser Water Temp – Leaving Chilled Water Temp

Condenser DT = Leaving Condenser Water Temp – Entering Condenser Water Temp

$K_{adj} = 6.1507 - 0.30244(X) + 0.0062692(X)^2 - 0.000045595(X)^3$

Where X = Condenser DT + LIFT

$COP_{adj} = K_{adj} \times COP_{std}$

A comparison was made between the Title 24 baseline energy use and the actual estimated energy use, with the difference being the annual savings. The results are included in Table 3.

Table 3:Chiller Replacement Energy Savings

Description	Hrs/yr	Cooling Output (tons/hr)	kW/ton	kW/yr
Old Chiller	8,760	559	0.728	3,564,900
Title 24 Chiller	8,760	559	0.433	2,120,332
VFD Chiller	8,760	559	0.287	1,405,393
Total Savings Compared to Title 24				**714,939**

The ex post savings are approximately 50% of the ex ante estimate. It is unclear as to why there is such a difference since there was limited documentation on how the ex ante estimate was determined. Through monitored data, it was determined the chiller is operating at 50% of full load. This may account for the difference in savings.

For peak kW savings, additional calculations were made. During summer afternoons, the condenser water temperature and the chiller load will both increase. This will affect overall efficiency of both the VFD and the Title 24 baseline chiller. The following information was used to perform the peak kW calculations:

- Average condenser water temperature was determined to be 70ºF.
- Average condenser water temperature differential in and out of the chiller was determined to be 4.8ºF.
- Average chilled water supply temperature was determined to be 38.4ºF.
- Average full load during the summer peak is 56%.
- Average cooling load during summer peak is 593 tons/hr.
- Under the above operating conditions, the Title 24 baseline chiller efficiency is determined to be 0.461 kW/ton.
- Under the above operating conditions, the efficiency of VFD chiller is determined to be 0.302 kW/ton.

Peak kW Savings = 593 tons x (0.461 kW/ton-0.302 kW/ton) = **94.9 kW**

The ex post peak kW savings is very similar to the ex ante peak kW estimate.

The above analysis is assuming a 24/7 operation of the new chiller, which is how this chiller is intended to be used. However, this machine has had poor reliability ever since it was installed (it was only run a total of 728 hours out of 8,760 hours over the past year). The installation contractor is being consulted to determine why the chiller continues to experience excessive failure rates.

7. Impact Results

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	12/7/2004	$800,000	81.1	1,425,270	0	$185,285	$199,538	3.24	4.32
SPC Program Review (Ex Post)	12/18/2007	$800,000	94.9	714,939	0	$92,942	$199,538	6.46	8.61

Table 5:Realization Rate Summary

	kW/yr	kWh/yr	Therm/yr
SPC Tracking System	81.1	1,425,270	-
SPC Installation Report (ex ante)	81.1	1,425,270	-
Impact Evaluation (ex post)	94.9	714,939	-
Engineering Realization Rate	1.17	0.50	0.00

Savings as a percentage of both baseline and energy use are small given the size of the plant and the size of the facility. Therefore, the tables for baseline end use and percentages of energy saved are not shown for this application.

Table 6: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
HVAC-OTHER	H	Replace 20 year old constant speed, 1,330-ton chiller with new 1,300-ton variable speed chiller	NA	VFD Chiller	Physically inspected facility, and made sure units were in use	1.00

Table 7:Multi Year Reporting Table

Program ID:		SPC 0405 A012					
Program Name:		SPC 04-05 Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	1,425,270	714,939	81.1	94.9	-	-
3	2006	1,425,270	714,939	81.1	94.9	-	-
4	2007	1,425,270	714,939	81.1	94.9	-	-
5	2008	1,425,270	714,939	81.1	94.9	-	-
6	2009	1,425,270	714,939	81.1	94.9	-	-
7	2010	1,425,270	714,939	81.1	94.9	-	-
8	2011	1,425,270	714,939	81.1	94.9	-	-
9	2012	1,425,270	714,939	81.1	94.9	-	-
10	2013	1,425,270	714,939	81.1	94.9	-	-
11	2014	1,425,270	714,939	81.1	94.9	-	-
12	2015	1,425,270	714,939	81.1	94.9	-	-
13	2016	1,425,270	714,939	81.1	94.9	-	-
14	2017	1,425,270	714,939	81.1	94.9	-	-
15	2018	1,425,270	714,939	81.1	94.9	-	-
16	2019	1,425,270	714,939	81.1	94.9	-	-
17	2020	1,425,270	714,939	81.1	94.9		
18	2021	1,425,270	714,939	81.1	94.9		
19	2022	1,425,270	714,939	81.1	94.9		
20	2023	1,425,270	714,939	81.1	94.9		
TOTAL	**2004-2023**	27,080,130	13,583,841				

Appendix A

Figure 4: Title 24 Chiller Efficiency Requirements

TABLE 1-C10 COPS AND IPLVS FOR NON-STANDARD CENTRIFUGAL CHILLERS > 300 TONS

Centrifugal Chillers > 300 Tons

$COP_{std} = 6.1$

Leaving Chilled Water Temperature (°F)	Entering Condenser Water Temperature (°F)	LIFT[a] (°F)	Condenser Flow Rate: 2 gpm/ton	2.5 gpm/ton	3 gpm/ton	4 gpm/ton	5 gpm/ton	6 gpm/ton
			Required COP and IPLV (IPLV=COP)					
46	75	29	6.80	7.11	7.35	7.71	7.97	8.16
45	75	30	6.71	6.99	7.21	7.55	7.78	7.96
44	75	31	6.61	6.89	7.09	7.40	7.61	7.77
43	75	32	6.52	6.79	6.98	7.26	7.45	7.60
42	75	33	6.43	6.69	6.87	7.13	7.31	7.44
41	75	34	6.33	6.60	6.77	7.02	7.18	7.30
40	75	35	6.23	6.50	6.68	6.91	7.06	7.17
46	80	34	6.33	6.60	6.77	7.02	7.18	7.30
45	80	35	6.23	6.50	6.68	6.91	7.06	7.17
44	80	36	6.13	6.41	6.58	6.81	6.95	7.05
43	80	37	6.02	6.31	6.49	6.71	6.85	6.94
42	80	38	5.90	6.21	6.40	6.61	6.75	6.84
41	80	39	5.77	6.11	6.30	6.52	6.65	6.74
40	80	40	5.63	6.00	6.20	6.43	6.56	6.65
46	85	39	5.77	6.11	6.30	6.52	6.65	6.74
45	85	40	5.63	6.00	6.20	6.43	6.56	6.65
44	85	41	5.47	5.87	6.10	6.33	6.47	6.55
43	85	42	5.30	5.74	5.98	6.24	6.37	6.46
42	85	43	5.11	5.60	5.86	6.13	6.28	6.37
41	85	44	4.90	5.44	5.72	6.02	6.17	6.27
40	85	45	4.68	5.26	5.58	5.90	6.07	6.17
Condenser DT[b]			14.04	11.23	9.36	7.02	5.62	4.68

[a] LIFT = Entering Condenser Water Temperature – Leaving Chilled Water Temperature

[b] Condenser DT = Leaving Condenser Water Temperature (°F) - Entering Condenser Water Temperature (°F)

$K_{adj} = 6.1507 - 0.30244(X) + 0.0062692(X)^2 - 0.000045595(X)^3$

where X = Condenser DT + LIFT

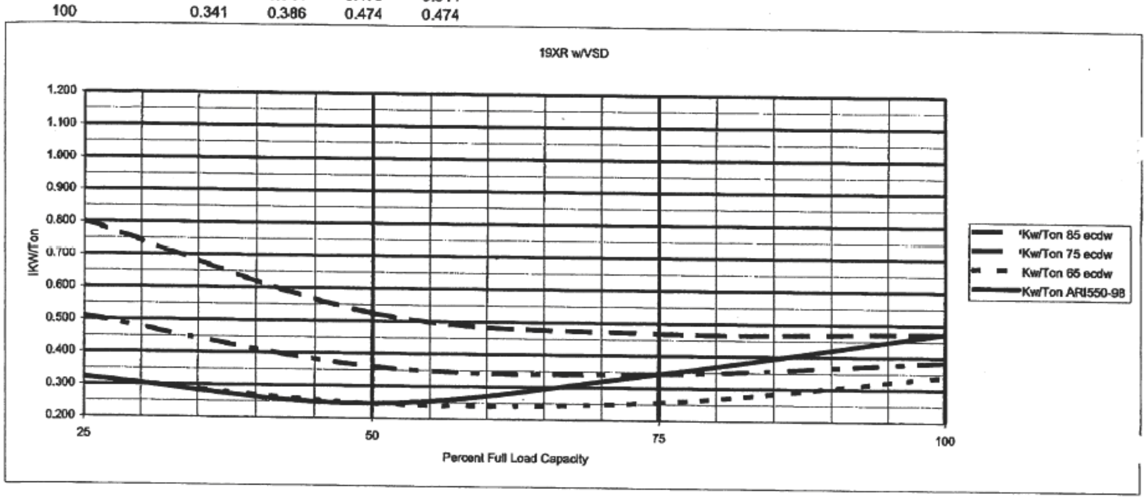
$COP_{adj} = K_{adj} * COP_{std}$

Figure 5: VFD Chiller Performance Curve

Full Load Tons **1330** Full Load IKW **648**

VSD PERFORMANCE DATA
19XR Chiller Part Load Performance Map Data
Values include 2.5% VSD losses

% Load	Kw/Ton 65 ecdw	Kw/Ton 75 ecdw	Kw/Ton 85 ecdw	Kw/Ton ARI550-98
25	0.322	0.511	0.801	0.322
50	0.246	0.361	0.524	0.246
75	0.255	0.344	0.470	0.344
100	0.341	0.386	0.474	0.474



Final Site Report

SITE A013a (2005-xxX) Coun   IMPACT EVALUATION
SAMPLE CELL: Backup   TIER: 3   END USE: AC&R

Measure(s)	Central Plant Upgrade
Site Description	Office Building (Large)

1. Measure Description

Install VFD on centrifugal chiller, install VAV boxes into existing constant volume air handling systems, and install VSDs on three 75-hp HVAC fan motors

2. Summary of the Ex Ante Calculations

<u>*Install VFD on Chiller*</u>

VFD control was installed on Chiller A, the smaller of the two centrifugal chillers that serve the main building. The savings associated with this measure were quantified with the SPC Calculator.

Project application inputs:

Equipment specification

- Equipment: Trane
- Cooling system type: Chillers, water cooled >300 tons – centrifugal
- Efficiency: 0.65 kW/ton
- Total tons: 400 tons
- Control method: On/Off
- Lifetime: 20 years

Building description

- Building type: Large Office
- Conditioned area: 91,636 sq ft (this was determined using the proportional square footage of total 252,000 sq ft served by Chiller A, compared with Chiller B, based on rated ton capacity)
- System operating hours: Mon – Fri, 4:00 am – 5:00 pm; Sat 12:00 pm – 12:00 am (2,937 run-time hours)

2004 SPC Energy Savings Calculator output:

- Baseline usage: 233.2 kW; 471,965 kWh
- Proposed usage: 231.2 kW; 307,233 kWh
- Savings of: 1.9 kW; 164,732 kWh

Incentive: $0.14/kWh; $23,062.48 for measure

Install VAV boxes (electric savings)

The building's constant volume HVAC system has been retrofitted with VAV boxes and additional EMS data points have been added. The electric savings associated with this measure were calculated using the Trane Trace 700 program.

Project application baseline assumptions:

- Load: 1,201 kW (Load calculation is from the Trane Trace 700 program. The load in kW is the entire building load, which takes into account operation of the chiller, fans, pumps, cooling towers, etc.; these are accumulated to forecast the total building HVAC load - which is then used to calculate VAV savings.)
- Operating hours: 4,423 hours/year (The baseline estimate for operating hours was calculated from Trane Trace 700 and from building operating profiles from the building operator.)

Project application proposed project assumptions:

- Load: 1,104 kW (Load calculations from Trane Trace 700, after installation of VAV boxes)
- Operating hours: 4,109 hours/year (Post installation estimate was calculated by the Trane Trace 700. Hours of operation changed since the contractor changed the fan schedule).

Estimated savings: 775,687 kWh; 97.0 kW

Incentive: $0.14/kWh; $108,596.18 for measure

Install VSDs on three (3) 75-hp HVAC fan motors

Three HVAC fan motors, each rated at 75-hp, have been retrofitted with VFDs and controls. As an itemized measure and using the Itemized approach, the estimated energy savings and energy incentive are based exclusively on the rated horsepower for each motor. The VFDs reflected in this measure serve a sum total of 225 hp. At an incentive rate of $80/hp, the total incentive for these measures is $18,000.

Operation: 47.5, 47.5 and 0 Hz
Estimated savings: 169,425 kWh
Incentive: $80/hp; $18,000 for measure

3. Comments on the Ex Ante Calculations

Install VFD on Chiller

Comments on VFD on chiller calculations: Because the ex ante calculations were performed using the SPC provided calculator, the general calculation methodology is assumed to be sound. However, the methodology to calculate conditioned area assumes that both chillers are operating simultaneously. This is an erroneous assumption, since interviews with the Maintenance Supervisor indicate that both chillers were not sequenced to run at the same time. Chiller A is typically used to cool the building until its capacity is exceeded. The larger Chiller B is then operated and Chiller A is shut down. Chiller A is also used to pre-cool the building and for cooling the ballroom area for special events in the evenings and on the weekends, when the rest of the building is not in use.

The interview with the Maintenance Supervisor also implies that Chiller A operating hours may be different from the overall system operating hours that were used in the ex ante calculation. There is thus potentially some error in the establishment of the baseline cooling load and proposed electrical usage. The ex ante baseline assumes a load profile, which is likely to be different from the actual load profile of the building.

Install VAV boxes (electric savings)

The interview with the Maintenance Supervisor indicated that the base case system had discharge dampers at the supply fans used to maintain static pressure in the ducts. Ex ante savings were calculated by modeling the building with the Trane Trace 700 software. Since it is unclear what was used as the basis of the cooling load (11 floors or 20 floors), there may be some error in the savings calculation.

Also, since the cooling load profile for the building is expected to be different from the profile used for the ex ante analysis for the chiller VFD installation (as stated above), the fan, chiller and pump savings from the VAV conversion are also expected to vary from the ex ante savings given for the VAV conversion.

Install VSDs on three (3) 75-hp HVAC fan motors

As an itemized measure, the savings from the VFD installation is prescribed. Savings of 753 kWh/hp are based upon the following, according to the Express Efficiency workpapers:

1.25 w/cfm x 746 w/hp x 0.75 cfm/sf x 1.33 savings coefficient x 0.81 deration factor due to variable inlet vane base case operation

Incomplete information was provided on how the savings were calculated in the application paperwork, since the VFDs were submitted as itemized measures. However, using the rated horsepower, fan speeds, EPRI fan performance data[1] and the associated 4,109 operating hours with other proposed HVAC retrofit measures, we infer that the following calculation was used:

Savings = (Fan energy x EPRI constant speed factor) – (Fan energy x EPRI VSD factor)

The 4,109 operating hours represent the assumptions related to the proposed projects. The savings calculation should have utilized the 4,423 operating hour base case for the pre retrofit

[1] Electric Power Research Institute, Adjustable Speed Drives Directory, 1991

condition. The operations of all three (3) fans, and whether the third fan is usually on standby (0 Hz), will be verified.

The tracking system notes that the VSD installations are in the HVAC (AC&R) category. Typically, VSDs are in the "Other" category. However, as a needed component for the VAV installation, the VSDs will remain in the AC&R category and be evaluated as part of this category.

4. Measurement & Verification Plan

The goal of the measurement and verification (M&V) plan is to estimate the actual annual kWh, peak kW, and therm savings over the useful life of the measure. This will be done by establishing a cooling load profile for the building and an associated performance curve for chiller A, and for the HVAC fans/pumps, in order to determine the energy savings attributed to the VFD installation on the chiller, to the VAV installation, and to the VFD installation on the air handler supply fans. In addition, we will also verify the installation of other non-AC&R measures installed at this customer site, if possible.

This site is a 20-story office building. The building contains 252,000 square feet of office space. The facility was built in 1963, and all floors above the 12th floor were part of a hotel before the present owner occupied them in 1982. All of the 12th floor is devoted to mechanical equipment and houses the chillers, pumps and air handlers.

The offices are occupied during normal office hours Monday through Friday. In addition to the offices, there is a server room on the top floor (about 2,500 square feet of 10,000 sf total area) and a radio/phone service center. There is also some use of the basement ballroom on Friday and Saturday evenings.

Cooling for the building is provided by two centrifugal chillers, Chiller A (400-ton water-cooled) and Chiller B (770-ton water-cooled). Chilled water from the chillers was previously supplied by constant speed primary/secondary chilled water pumps to constant volume air handling units. Conditioned air is now supplied to the office spaces by a variable air volume (VAV) distribution system to maintain a set point of 77°F. The secondary chilled water pump is now on variable speed control.

Formulae and Approach

The M&V plan proposed is a modified version of IPMVP Option A.

The actual cooling load for the building will be determined using chilled water supply and return temperatures and the water flow through the cooling loop. The actual kW demand of the chillers will be measured.

The greatest uncertainties in the ex ante savings estimate are the hourly chilled water loads, to what extent the cooling loads are weather dependant, and to a lesser extent, how the chiller efficiencies (kW/ton) vary at different cooling loads.

The size and sequencing of the chillers will be confirmed. Proposed data collection will include the chilled water supply and return temperatures, chiller amps or kW, chilled water flow rate, outside air temperature, VFD power use and fan speed.

The performance curve for the installed chillers will be established by plotting the kW vs. the percent of full load for all data points collected for the chillers' operation. The percent load will be determined by calculating the tonnage based on the temperature difference between chilled water supply and return (ΔT) and the chilled water flow (either a constant value or a measured varying value) and comparing it to the rated full load tonnage of the chiller. The tonnage will be calculated by the formula:

Tons = CHW gpm x 500 lb/hr/gpm x CHW ΔT x 1 Btu/lb °F / 12,000 Btu/ton

The measured kW will be regressed against measured cooling load to determine the performance curve. This formula will be used with climate zone temperature data to establish an annual demand profile.

The building cooling load profile will be determined using the same approach with outside temperature. The supplied tonnage will be plotted vs. outside air temperature and a curve will be fit to the plotted data. If the plotted data shows little or no correlation between chiller load and outside air temperature, then other variables affecting the chiller load will be evaluated. This formula will be used with climate zone temperature data to establish an annual cooling load profile.

With the building load and the chiller performance established, the new system can be modeled and the annual electrical usage determined. The post-retrofit energy usage will be compared to the baseline energy usage to determine the ex post savings using the following formula:

$$\text{kWh Savings} = \sum_{1}^{8{,}760} \text{Hours} \times \text{Average Tons} \times \left(\text{kW/ton}_{\text{w/o VSD}} - \text{kW/ton}_{\text{w/VSD}}\right).$$

Using the building cooling load profile, VAV savings will be calculated for the chiller, pumps and fans as the difference between the constant volume case and the variable volume case. Energy savings will be calculated using the following methods for each hour of the typical meteorological year.

Fan motor savings will be calculated by applying the baseline factors developed by EPRI for fans with discharge damper control to baseline flow data, arranged in bins to conform to the model as shown in the example analysis in the Appendix. Post case flow data will be developed from the cooling load profile.

Where:

Air Flow = cooling load (tons)/(ΔT*1.08)/ 12,000

ΔT is the temperature difference between the outside/recirculated air mixture and the supply air set point (°F)

VAV fan savings will be the difference between the annual kWh of constant volume system and the annual kWh of the variable volume system:

$$\text{kWh Savings} = \sum_{1}^{8,760} \text{kW}_{\text{constant volume}} - \text{kW}_{\text{variable volume}}$$

Chiller energy savings (from tons of cooling saved) = Volume x 1.08 x ΔT x (kW/ton) /12,000

Where:

Volume is the new air volume (compared with the constant volume case)

ΔT is the temperature difference between the outside/recirculated air mixture and the supply air set point (°F)

kW/ton is the chiller efficiency from the performance curve correlation at the specific cooling load

Pump savings will be calculated by applying the baseline factors developed by EPRI for pumps at constant flow with a VSD to baseline flow data arranged in bins to conform to the model as shown in the example analysis in the Appendix. Post case flow data will be developed from the cooling load profile.

Chilled Water Flow = cooling load (tons) x 2.4 gpm/ton

The above approach will require the following data collection and verification activities:

Data Element	Proposed Means of Collecting Data
Base case equipment configuration	Confirm via customer interview and review of customer records. Verify use of 2-way control valves.
Base case fan / pump power use	Confirm via customer interview, drawings and nameplate information.
Post case chiller duty	Obtain one month or longer of hourly customer EMS data of chiller kW, chilled water flow rate, and chilled water return and supply temperatures.
Post case equipment configuration	Confirm via site survey, customer interview, and review of customer records. Obtain manufacturers' data sheets for equipment and equipment nameplate information.
Post case system operating hours	Confirm via customer interview and review of customer records and the planned maintenance schedule for each chiller and pump.
Post case fan power use	Obtain from customer EMS data the VFD power use (kW and kWh) on each of the three fans.
Post case chilled water pump duty	Obtain one month or longer of hourly pump speed and kW demand

Accuracy and Equipment

It is expected that water temperatures are being measured with either an RTD or thermocouple installed in a thermowell that is immersed in the flow. These devices are generally accurate to within ±2 degrees.

Water flow, if being measured by existing instrumentation or the EMS, is most likely determined by measuring the pressure differential across a calibrated orifice plate installed in the fluid flow. These readings are typically = ±5% accurate.

Power and other measurements will be obtained either with the customer's installed monitoring equipment or with portable equipment. In the case of portable equipment, spot measurements will be taken with a hand held Fluke amp meter. For trending, current dataloggers and / or true RMS kW meters manufactured by Dent Instruments (with current transformers manufactured and calibrated by Dent Instruments) would be used. The hand held meters are generally accurate to within 1% and the Dent meters are accurate to within 1%.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 29, 2007 to collect information on the HVAC retrofits (including the VFD on Chiller A, VSDs on HVAC fans and VAV installation in the facility). Installations were visually verified, and data loggers were installed on Chiller A and HVAC fans. EMS setpoints were also verified, and the facility agreed to provide trend data for several operating parameters.

Installation Verification

The facility representative verified that there was no VFD on Chiller A or on HVAC fans before the retrofit. The facility representative also verified the configuration of chilled water pumps and sequencing of chillers A and B (rated 400-tons and 770-tons, respectively). As part of the VAV conversion, the cooling set point for the building was raised from 72°F to 78°F.

The verification realization rate for these measures is 1.0. A verification summary in shown below in Table.

Scope of the Impact Assessment

The impact assessment scope is for the AC&R end use measures in the SPC application, which included both AC&R and lighting retrofits.

Summary of Results

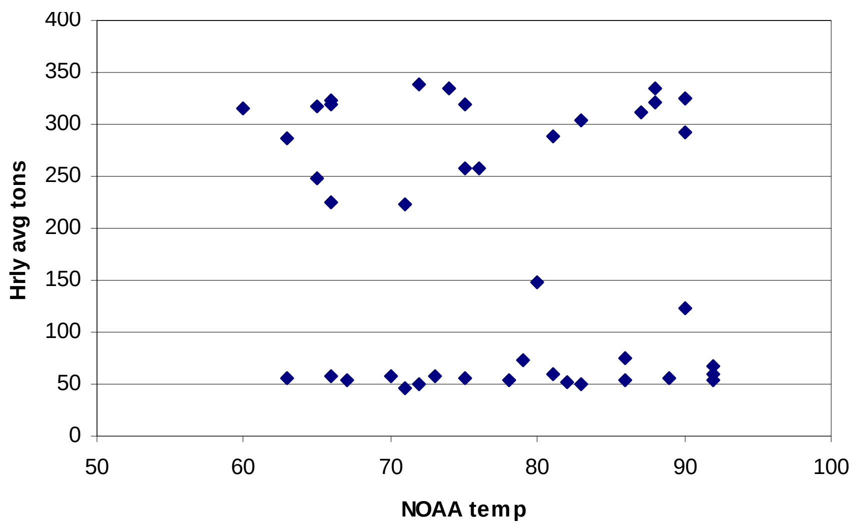
CT loggers were installed on the Chiller A VFD and Chiller B over a two week period to measure amps, voltage and the kW demand profile. Amp loggers were also installed for the same period of time on two supply fans (since the third did not run in the summer). The facility representative explained that Chiller A is programmed to start up in the morning, and if it can't meet the load within an hour, it shuts down and the larger Chiller B starts up and runs for the entire day. Typically, this occurs when outside air temperatures have risen to over 95°F. In the wintertime, the chillers are locked out when outside air temperatures are less than 55°F, with the chillers turned off for the entire months of November, December, January and February.

Since the monitoring period included many hot days, the data shows Chiller A starting up Tuesday through Friday at 5:15 a.m. and only running for about an hour until 6:15 or 6:30, when the system switched over to the larger Chiller B. On Mondays, Chiller A started up around 2:15a.m and seemed to run for the same one hour period until 3:15 am.

There were a few exceptions to this general schedule. On one Friday (9/7), Chiller A started up at 5:15a.m. as normal, and then ran most of the day until 17:00, when it switched over the Chiller B for one hour until about 18:00. Then on Saturday 9/8, Chiller A started up at 13:15 and ran until 1:00 a.m. the next day. The Saturday operation was due to an event in the building's ballroom facility, which the County of Fresno rents out for private functions from time to time.

The actual cooling load for the building was provided by the EMS system, and not calculated as suggested in the original M&V plan. The results of this data (**Error! Reference source not found.**Figure 1) show that the hourly chilled water loads were not found to be weather dependent.

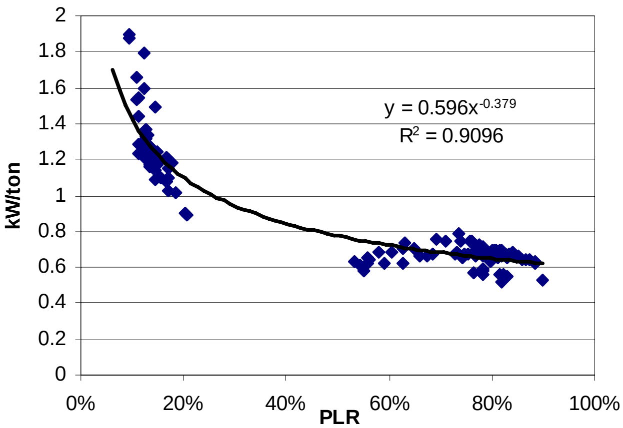
Figure 1: Chiller A Cooling Load

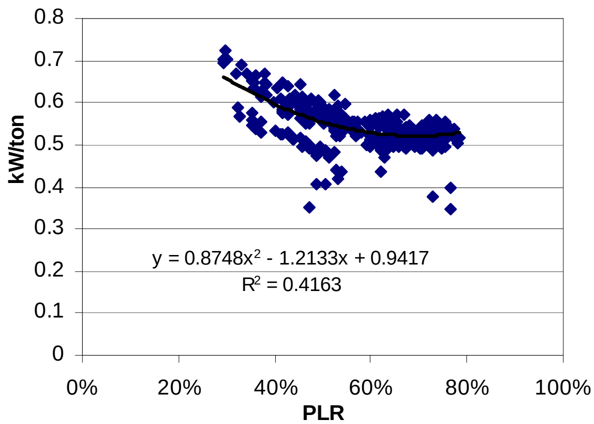


Since the cooling load is not closely correlated to outside air temperature, the cooling load is extrapolated across a typical meteorological year (TMY) based on the observed distribution of cooling load in the building during the monitoring period, as well as the HVAC system programming (lockout temperatures and months) and the temperature at which the system switches from Chiller A to B).

Performance curves for the chillers were calculated using the tons and kW data collected (see Figure 2). Combined with the extrapolated cooling load across the year, the expected kW consumption of the Chiller was estimated.

Figure 2: Measured Performance Curves for Chiller A (left) and Chiller B (right)





<u>VFD on Chiller A</u>

The savings for the Chiller A VSD installation is calculated by comparing the measured performance curve against a baseline ARI-rated curve adjusted for the building's set points (see **Error! Reference source not found.**). The kWh savings is the sum of the difference between the measured post case kWh consumption and the base case kWh use for each hour of the TMY.

$$\text{kWh Savings} = \sum_{1}^{8,760} \text{Hours} \times CoolingLoad\,(Tons) \times \left(\text{kW/ton}_{\text{base case}} - \text{kW/ton}_{\text{measured}}\right)$$

Table 1: Comparison of chiller performance before and after VSD installation

Part Load Ratio (PLR)	Cooling load (Tons)	Pre-1999 ARI Base Case (kW/ton)	Measured Efficiency of Chiller A (kW/ton)	kW/ton Savings at each PLR
25%	100	1.720	1.008	0.712
50%	200	1.158	0.775	0.383
75%	300	0.716	0.665	0.052
100%	400	0.558	0.596	-0.038

The resulting annual kWh savings is 115,548 kWh, and peak kW saved is 16.9 kW. During the monitoring period, Chiller A only operated once during a summer peak period (weekdays between 2 pm and 5 pm) and at approximately 75% PLR the entire time. Table 2 shows the cooling load (tons) for the peak periods monitored and the associated kW savings. Peak kW savings are calculated by averaging the kW savings during the peak period.

Table 2: Example of Peak kW Calculation for Chiller A

Date	Time	Tons	kW/ton saved	kW saved
9/7/07	15:00	323.75	0.052	16.7
9/7/07	15:15	332.5	0.052	17.1
9/7/07	15:30	327.5	0.052	16.9
9/7/07	15:45	326.25	0.052	16.8
9/7/07	16:00	316.25	0.052	16.3
9/7/07	16:15	330	0.052	17.0

VAV boxes

The VAV savings are calculated for four impacts: Chiller A, Chiller B, chilled water pump (Main CHWP), and HVAC fans.

Savings on Chiller A and B are calculated using the following equation:

$$\text{kWh Savings} = \sum_{1}^{8,760} \text{Hours} \times \left(\text{Volume}_{\text{new}} \times 1.08 \times \Delta T \times kW / ton\right) / 12,000$$

Where

Volume_{new} = (Average of measured usage, Hz)/60 x 500,000 cfm[2] = 459,717 cfm
ΔT = 78°F (old set point) – 72°F (new set point) = 6°F

kW/ton is the measured chiller efficiency from above (

Figure)
Operating hours are based on cooling load extrapolated across TMY

The resulting annual kWh savings is 496,839 kWh/yr for Chiller A and 45,999 kWh/yr for Chiller B. Although Chiller A did not operate for many hours during the monitoring period, the savings are significantly greater for Chiller A because across the year, it operates more than Chiller B. The system is designed to switch from Chiller A to Chiller B during days which are hotter than 95 °F, which occurred 8 out of the 9 weekdays that were monitored, but which across the year is not that frequent.

Peak kW savings are calculated by averaging the kW saved during the peak periods of the monitoring period (where kW = 459,717 cfm x 1.08 x 6 x (kW/ton)/12,000). For Chiller A and B, peak savings were calculated to be 166.3 and 135.3 kW, respectively.

Savings on the chilled water pump is calculated using a pump model, which takes into account VFD input kW for each percent of full flow (PFF) at which the pump operates. The post-retrofit PFF data for the monitoring period is binned into 5% increments, and a pivot table in Excel calculated the number of operating hours in each bin.

[2] Each supply fan is rated at 250,000 cfm

The pre-retrofit PFF is calculated based on the volume reduction (494,717/500,000 = 0.92) of the HVAC fans, according to the following equation:

Pre-retrofit PFF = (Post-retrofit PFF)/0.92

The assumed pre-retrofit PFF for the same monitoring period is also binned into 5% increments and using a pivot table; the number of operating hours in each bin is calculated.

The estimated pre-retrofit PFF hours and measured post-retrofit PFF hours are shown in Table Table 3 along with the kWh/year saved for each 5% bin of full flow. The total annual savings is calculated by taking the sum across all bins, which totals 6,161 kWh.

Table 3: Data Used For The Chilled Water Pump Savings Related to VAV Boxes

Percent of Full Flow	Pre-retrofit Operating Hours	Post-retrofit Operating Hours	VFD % Full Flow Power[3]	VFD Motor Input kW	Pre-retrofit Energy Use kWh/yr	Post-retrofit Energy Use kWh/yr
100%	1,369	574	105.0%	29.50	40,381	16,928
95%	7	678	90.0%	25.29	175	17,131
90%	69	118	78.0%	21.91	1,515	2,576
85%	311	28	66.0%	18.54	5,769	513
80%	55	69	57.0%	16.01	886	1,107
75%	41	325	48.0%	13.49	559	4,382
70%	7	55	41.0%	11.52	80	637
65%	35	14	35.0%	9.83	340	136
60%	62	35	30.0%	8.43	524	291
55%	69	76	25.0%	7.02	486	534
50%	7	55	21.0%	5.90	41	326
45%	-	7	17.0%	4.78	-	33
40%	297	297	14.0%	3.93	1,169	1,169
TOTAL	2330	2330			51,925	45,764

The peak kW calculation methodology uses the monitored data, and calculates what the pre-retrofit PFF is compared with the measured PFF, and taking the difference in kW consumption for each hour. The peak kW is calculated using an average of the kW saved during peak periods and equals 2.1 kW.

Savings on the HVAC fans is calculated using a fan model, with constant volume as the baseline and discharge dampers as the result of the VAV conversion. (The savings from discharge dampers to VFDs will be attributed to the VFD installation, see next section.) **Error! Reference source not found.** Table 4 shows how the logger data for the supply fans 1 and 2 was distributed into 5% bins and the total annual operating hours extrapolated across a typical meteorological year (TMY) based on fans operating from 5:15 am to 6 pm Tuesday through Friday, and 2:15 am to 6 pm on Mondays. Supply fans 1 and 2 operate March through October, and Supply fan 3

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[3] Electric Power Research Institute, Adjustable Speed Drives Directory, 1991

(hot deck) operates from October through March). A similar table to the one below was also developed for supply fan 3. Total kWh savings for all three supply fans are calculated to be 25,724 kwh/yr. Since the fans operate at 100% during summer peak periods, there are no peak kW savings.

Table 4: Data Used for HVAC Fans 1 and 2 Savings Related to VAV Boxes

Percent of Full Flow	Annual Operating Hours	Baseline % Full Flow Power	EEM % Full Flow Power[4]	Baseline Motor Input kW	EEM Motor Input kW	Power Savings kW	Baseline Energy Use kWh/yr	EEM Energy Use kWh/yr	Annual Energy Savings kWh/yr
100%	784	100.0%	100.0%	83.55	83.55	-	131,087	131,087	-
95%	409	100.0%	97.0%	83.55	81.04	5.01	68,409	66,356	2,052
90%	296	100.0%	95.0%	83.55	79.37	8.36	49,426	46,955	2,471
85%	409	100.0%	92.0%	83.55	76.87	13.37	68,409	62,937	5,473
80%	420	100.0%	88.0%	83.55	73.52	20.05	70,199	61,775	8,424
75%	9	100.0%	86.0%	83.55	71.85	23.39	1,434	1,233	201
70%	-	100.0%	83.0%	83.55	69.35	28.41	-	-	-
65%	-	100.0%	80.0%	83.55	66.84	33.42	-	-	-

In summary, Table 5Table presents the total VAV savings for annual kWh and peak kW. For peak kW, since Chiller A and Chiller B do not ever run at the same time, an average of both chillers' kW savings is used (166.3 + 135.3/2).

Table 5: Summary of VAV Ex Post Savings

VAV impact	Peak kW ex post	kWh ex post
Chiller A	150.8	496,839
Chiller B		45,999
Main CHWP	2.1	6,161
HVAC fans	0	25,724
TOTAL	152.9	574,723

<u>VFD on HVAC fans</u>

The savings related to the installation of VFDs on three HVAC fans is also calculated using a fan model. The model develops an associated kW consumption related to each 5% increment of full flow across the fans with VFD. The model also assumes a higher kW consumption related to each PFF bin in the baseline case of discharge dampers.

Using the same assumptions of operating hours, as detailed above, the distribution of PFF as observed in the monitored period is applied across the whole year to determine number of annual hours in each PFF bin. Table 6 shows the assumptions for kW usage in the baseline and VFD

[4] Electric Power Research Institute, <u>Adjustable Speed Drives Directory</u>, 1991

post-retrofit cases for each 5% bin, multiplied by the hours of operation in each bin to calculate total annual kWh savings. Table 7 shows the same information for supply fan 3.

Table 6: Data Used for HVAC Fans 1 and 2 Savings Related to VFD

Percent of Full Flow	Annual Operating Hours	Baseline % Full Flow Power	VFD % Full Flow Power	Baseline Motor Input kW	VFD Motor Input kW	Power Savings kW	Baseline Energy Use kWh/yr	VFD Energy Use kWh/yr	Annual Energy Savings kWh/yr
100%	784	100.0%	105.0%	83.55	87.73	(8.36)	131,087	137,642	(6,554)
95%	409	97.0%	92.0%	81.04	76.87	8.36	66,356	62,936	3,420
90%	296	95.0%	77.0%	79.37	64.33	30.08	46,955	38,058	8,897
85%	409	92.0%	64.0%	76.87	53.47	46.79	62,937	43,782	19,155
80%	420	88.0%	51.0%	73.52	42.61	61.83	61,775	35,801	25,973
75%	9	86.0%	42.0%	71.85	35.09	73.52	1,233	602	631
70%	-	83.0%	33.0%	69.35	27.57	83.55	-	-	-
65%	-	80.0%	27.0%	66.84	22.56	88.56	-	-	-
60%	-	77.0%	22.0%	64.33	18.38	91.91	-	-	-
55%	-	74.0%	18.0%	61.83	15.04	93.58	-	-	-
50%	-	71.0%	14.0%	59.32	11.70	95.25	-	-	-
45%	-	68.0%	11.0%	56.81	9.19	95.25	-	-	-
40%	-	64.0%	9.0%	53.47	7.52	91.91	-	-	-
35%	2	62.0%	7.0%	51.80	5.85	91.91	222	25	197

Table 7: Data Used for HVAC fan 3 Savings Related to VFD

Percent of Full Flow	Annual Operating Hours	Baseline % Full Flow Power	VFD % Full Flow Power	Baseline Motor Input kW	VFD Motor Input kW	Power Savings kW	Baseline Energy Use kWh/yr	VFD Energy Use kWh/yr	Annual Energy Savings kWh/yr
100%	583	100.0%	105.0%	83.55	87.73	(4.18)	48,690	51,124	(2,434)
95%	304	97.0%	92.0%	81.04	76.87	4.18	24,647	23,376	1,270
90%	220	95.0%	77.0%	79.37	64.33	15.04	17,440	14,136	3,305
85%	304	92.0%	64.0%	76.87	53.47	23.39	23,376	16,262	7,115
80%	312	88.0%	51.0%	73.52	42.61	30.91	22,945	13,298	9,647
75%	6	86.0%	42.0%	71.85	35.09	36.76	458	224	234
70%	-	83.0%	33.0%	69.35	27.57	41.78	-	-	-
65%	-	80.0%	27.0%	66.84	22.56	44.28	-	-	-
60%	-	77.0%	22.0%	64.33	18.38	45.95	-	-	-
55%	-	74.0%	18.0%	61.83	15.04	46.79	-	-	-
50%	-	71.0%	14.0%	59.32	11.70	47.62	-	-	-
45%	-	68.0%	11.0%	56.81	9.19	47.62	-	-	-
40%	-	64.0%	9.0%	53.47	7.52	45.95	-	-	-
35%	2	62.0%	7.0%	51.80	5.85	45.95	82	9	73

For the VFD on HVAC fans, the total kWh savings related to all three fans is 70,928 kWh per year. During the summer peak periods, the fans run at 100% PFF, and therefore, the peak kW savings are negative 8.36 kW, reflecting an increase in kW demand.

In summary, Table 8 shows the total meter use based on billing data included in the application, which spans from September 2003 through August 2004. The baseline end use is assumed to be 35% of the total meter, as the building is a typical office building. The below table also displays a summary of the ex post and ex ante kW and kWh estimates.

Table 8: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1,354	5,568,240
Baseline End Use	474	1,948,884
Ex ante Savings	99	1,109,844
Ex post Savings	161	761,200

Table 9 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. Overall, the ex post realization rate is 69% for kWh savings, and 163% for kW savings.

Table 9: Percent Savings and Demand Reduction, ex ante, ex post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	7.3%	19.9%	11.9%	13.7%
Baseline End Use %	20.9%	56.9%	34.0%	39.1%

As a supporting calculation, a billing analysis was completed to assess the first year savings related to the total project, including both AC&R and lighting measures. Table 9 shows the actual savings achieved, with no weather adjustment, based on PG&E bills. In the project application for both AC&R and lighting, the total ex ante savings were 1,447,994. Although these billing savings do not account for potential weather differences, with a "realization rate" of 66%, the billing analysis substantiates the general magnitude of savings calculated above.

Table 9: Results of billing analysis

	kWh usage
Base case (Dec. 2003 – Nov. 2004)	5,509,724
Post case (Dec. 2005 – Nov. 2006)	4,548,976
Difference	960,748

6. Additional Evaluation Findings

In general, the ex post kW demand reductions are found to be greater than the ex ante estimates, while annual kWh is found to be lower (see Table 10). This may be due to the fact that an incorrect conditioned area was used in the SPC Estimation Software (91,636 sq feet, as opposed to the entire building square footage of 252,000). One possible reason for the higher kW estimation, however, may be that the monitoring period included some very hot days, which may have resulted in higher kW savings than what may be observed across a typical summer. The actual load on the Chiller A when it operates during peak periods is observed to be around 75% PLR. The SPC Estimation Software is likely using a different kW/ton savings estimate than calculated here, and those assumptions are not known.

Table 10: Summary of ex ante and ex post results, by measure

	Peak kW Savings		kWh Savings	
	ex ante	ex post	ex ante	ex post
VFD on Chiller A	1.9	16.9	164,732	115,548
VAV boxes	97.0	152.9	775,687	574,723
VSD on HVAC fans	-	(8.4)	169,425	70,928
TOTAL	98.9	161.4	1,109,844	761,200

The ex post kWh results are also lower due to lower operating hours than assumed in the ex ante calculations. For the VFD on Chiller A, the annual savings may be lower because the chiller is found to operate often in the 75% PLR range, where savings related to the VFD are lower.

For VAV boxes, the Trane Trace program assumed 4,423 hours/year. Based on actual schedule, annual operating hours are found to be about 3,163 hrs/year. Therefore, part of the lower kWh results can be attributed to lower operating hours.

In general, a longer monitoring period would have assisted in identifying a more accurate cooling load profile for the building and better understanding of how the chillers operate in the shoulder seasons (October/November, March/April). Furthermore, since supply fan 3 was not operating during the monitoring period, additional data points would have helped to understand the savings related to this component.

The facility representative stated that he didn't know the source of the cost estimate. Therefore, it is unclear how accurate the cost estimate reflects the actual installation cost. However, given the size and the scope, the costs seem reasonable. In addition to saving energy, the project has increased comfort in the building, including less noise, and less disruption (such as papers being blown off tables previous to the VAV installation). There is also improved reliability for maintenance staff. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program has increased energy awareness in the facility, but they have not performed any additional large energy efficiency projects since then, nor have they participated in any further incentive programs.

With a cost of $888,516 and a $149,659 incentive, the HVAC measures had a 5.1 year simple payback based on the ex ante calculations, and a 7.4 year simple payback based on the ex post calculations.

7. Impact Results

Table 11: Economic information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, Therms	Estimated Annual Cost Savings	SPC Incentive, $	Simple Payback w/ Incentive	Simple Payback w/o Incentive
Installation Approved Amount (Ex Ante)	2/2/2004	$888,516	98.9	1,109,844	0	$144,280	$149,659	5.12	6.16
SPC Program Review (Ex Post)	10/10/2007	$888,516	161.4	761,200	0	$98,956	$149,659	7.47	8.98

Table 12: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	98.9	1,109,844	-
SPC Installation Report (ex ante)	98.9	1,109,844	-
Impact Evaluation (ex post)	161.4	761,200	-
Engineering Realization Rate	1.63	0.69	NA

Table 13: Installation Verification Summary

Measure Description	End-Use Category	AC&R Measure Description	Lighting Measure Description	Other / Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
HVAC-OTHER, ASD ON HVAC FAN, 100 HP MAX	A	VFD on Chiller and HVAC fans, VAV installation			n/a	VFD control on chiller, VAV boxes and VFD on three HVAC fans	Physically inspect facility, and made sure units were in use	1.0

Table 14: Multi Year Savings Table

Year	Calendar Year	Ex-ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
Program Name:		SPC 04-05 Evaluation Site A013a					
1	2004					0	0
2	2005	369,948	253,733			0	0
3	2006	1,109,844	761,200	98.90	161.36	0	0
4	2007	1,109,844	761,200	98.90	161.36	0	0
5	2008	1,109,844	761,200	98.90	161.36	0	0
6	2009	1,109,844	761,200	98.90	161.36	0	0
7	2010	1,109,844	761,200	98.90	161.36	0	0
8	2011	1,109,844	761,200	98.90	161.36	0	0
9	2012	1,109,844	761,200	98.90	161.36	0	0
10	2013	1,109,844	761,200	98.90	161.36	0	0
11	2014	1,109,844	761,200	98.90	161.36	0	0
12	2015	851,282	569,626	98.90	161.36	0	0
13	2016	334,157	186,477	1.90	8.50	0	0
14	2017	334,157	186,477	1.90	8.50	0	0
15	2018	334,157	186,477	1.90	8.50	0	0
16	2019	334,157	186,477	1.90	8.50	0	0
17	2020	277,682	162,834	1.90	8.50	0	0
18	2021	164,732	115,548	1.90	16.85	0	0
19	2022	164,732	115,548	1.90	16.85		
20	2023	164,732	115,548	1.90	16.85		
TOTAL	**2004-2023**	13,318,332	8,929,545				

NOTES FOR MULTIYEAR TABLE

	Measure	kWh savings Ex ante	kWh savings Ex post	kW savings Ex ante	kW savings Ex post	EUL
A	VFD for chiller A	164732.00	115,548.34	1.900	16.854	20
B	VAV conversion	775687.00	574,723.20	97.000	152.860	10
C	VSD for HVAC fans	169425.00	70,928.42	-	(8.355)	15

Measure believed not to be fully functional until late 2005.

Appendix A
Fan and Pump Energy Use Bin Models[5]

Exhaust Fans- VFD Annual Energy Savings

Given Data

Eqpt. Tag:	2PEA-001,002-3S		
Airflow	60,000	cfm	
Total Static Pressure	8.00	in WG	
Fan Efficiency	65.0%		
Motor Horsepower	150	hp	
Motor Enclosure Type	ODP		
Motor Speed	1,180	rpm	
Motor Efficiency	95.4%		
Fan Bhp	116.29	hp	Fan Bhp = Airflow * Static Pressure/(6,350 * Fan Efficiency)
Full Load Motor Input Power	90.94	kW	FL Motor Input Power = Fan Bhp * 0.746 kW/hp/(Motor Efficiency)
Annual Operating Hours	8,760	hrs/yr	
Use Factor	100%		
Baseline Control	Discharge Damper		

Annual Energy Savings

Percent of Full Flow	Number of Units	Use Factor	Annual Operating Hours	Baseline % Full Flow Power	EEM % Full Flow Power	Baseline Motor Input kW	EEM Motor Input kW	Power Savings kW	Baseline Energy Use kWh/yr	EEM Energy Use kWh/yr	Annual Energy Savings kWh/yr
100%				100.0%	105.0%	90.94	95.48	-	-	-	-
95%				97.0%	92.0%	88.21	83.66	-	-	-	-
90%				95.0%	77.0%	86.39	70.02	-	-	-	-
85%				92.0%	64.0%	83.66	58.20	-	-	-	-
80%				88.0%	51.0%	80.03	46.38	-	-	-	-
75%				86.0%	42.0%	78.21	38.19	-	-	-	-
70%				83.0%	33.0%	75.48	30.01	-	-	-	-
65%				80.0%	27.0%	72.75	24.55	-	-	-	-
60%				77.0%	22.0%	70.02	20.01	-	-	-	-
55%				74.0%	18.0%	67.29	16.37	-	-	-	-
50%	3	100%	7,618	71.0%	14.0%	64.57	12.73	155.50	1,475,588	290,961	1,184,627
45%				68.0%	11.0%	61.84	10.00	-	-	-	-
40%				64.0%	9.0%	58.20	8.18	-	-	-	-
35%				62.0%	7.0%	56.38	6.37	-	-	-	-
30%				58.0%	6.0%	52.74	5.46	-	-	-	-
25%				55.0%	4.0%	-	3.64	-	-	-	-
20%				52.0%	3.0%	-	2.73	-	-	-	-

Totals	155.50	1,475,588	290,961	1,184,627

[5] Electric Power Research Institute, Adjustable Speed Drives Directory, 1991

Water Distribution Pumps- VFD Annual Energy Savings

Given Data

Equipment Tag	2-HW-P-001 to 003 - UB	
Waterflow/ Pump	2,475	gpm
Total Static Pressure	84	ft
Efficiency	75.0%	
Motor Horsepower	75	hp
Motor Enclosure Type	TEFC	
Motor Speed	1,800	rpm
Motor Effciency	95.0%	
Pump Bhp	70.00	hp
Full Load Motor Input Power	54.97	kW
Annual Operating Hours	8,760	hrs/yr
Use Factor	100%	
Baseline Control	Throttling Valve	

Pump Bhp = Waterflow * Head/(3,960 * Pump Efficiency)

FL Motor Input Power = Pump Bhp * 0.746 kW/hp/(Motor Efficiency)

Annual Energy Savings

Percent of Full Flow	Number of Units	Use Factor	Annual Operating Hours	Baseline % Full Flow Power	EEM % Full Flow Power	Baseline Motor Input kW	EEM Motor Input kW	Power Savings kW	Baseline Energy Use kWh/yr	EEM Energy Use kWh/yr	Annual Energy Savings kWh/yr
100%				100.0%	105.0%	54.97	57.72	-	-	-	-
95%				98.0%	90.0%	53.87	49.47	-	-	-	-
90%				94.0%	78.0%	51.67	42.88	-	-	-	-
85%				93.0%	66.0%	51.12	36.28	-	-	-	-
80%	3	100%	6,669	88.0%	57.0%	48.37	31.33	51.12	967,783	626,859	340,923
75%				86.0%	48.0%	47.27	26.38	-	-	-	-
70%				83.0%	41.0%	45.62	22.54	-	-	-	-
65%				81.0%	35.0%	44.52	19.24	-	-	-	-
60%				79.0%	30.0%	43.43	16.49	-	-	-	-
55%				76.0%	25.0%	41.78	13.74	-	-	-	-
50%				74.0%	21.0%	40.68	11.54	-	-	-	-
45%				72.0%	17.0%	39.58	9.34	-	-	-	-
40%				71.0%	14.0%	39.03	7.70	-	-	-	-
35%					N/A	-	-	-	-	-	-
30%					N/A	-	-	-	-	-	-
25%					N/A	-	-	-	-	-	-
20%					N/A	-	-	-	-	-	-
							Totals	51.12	967,783	626,859	340,923

Final Site Report

SITE A014 (2004-xxx) Qwes IMPACT EVALUATION
SAMPLE CELL: TIER: 3 END USE: AC&R

Measure	Chiller Replacement
Site Description	Data Center

1. Measure Description

Replace four (4) 265-ton air-cooled chillers with three (3) new 550-ton water-cooled chillers with variable frequency drives (VFDs). One of the new units is designated as a standby unit.

2. Summary of the Ex Ante Calculations

Measure	Energy Savings (kWh)	Demand Savings (kW)	N. Gas Savings (therms)	Incentive Paid ($)
Chiller Replacement	22,429,006	117.0	0	$269,096.48
Other Measures	386,294	15.5	0	$30,903.52

The ex ante calculations for the chiller replacement were performed using the 2004 SPC Calculator. Other measures planned to be implemented in the project were also analyzed using 2004 SPC Calculator modules. These included VFDs on chilled water primary and secondary pumps and the cooling tower fans. Each calculation was performed separately, so the savings calculated for the chiller replacement are isolated from the other measures.

The equipment specification inputs to the calculator were as follows:

- Proposed Carrier model number
- Cooling system type: Chillers, Water Cooled>300 tons-Centrifugal
- Full load efficiency: 0.49 kW/ton
- Number of units: 2
- Size per unit: 530 tons (for a total tonnage of 1,060)
- Control method: on/off
- VSD on the chiller? Yes

The building description inputs included:

- Building type: Large office
- Conditioned area: 400,000 square feet
- Location: Sunnyvale
- System operating hours: 24 hours a day, 7 days per week

The only information supplied on the existing equipment is the year manufactured and the type, which was input as “Chillers Air Cooled > 150 tons-Rotary Screw”. The calculator asks for no other information on the existing equipment, and the report generated by the calculator lists only the year manufactured, not the equipment type.

The Measure Energy Savings Estimate provided by the calculator is shown in the following table:

Table 1: Ex Ante Calculation Summary

	kW	kWh
Baseline Usage	532.9	2,396,452
Current Minimum Standard (Title 24)	511.6	2,300,594
Proposed Usage	416.0	1,215,978
Annual Savings	116.8	1,180,474
Total Savings (19 year remaining useful life)		22,429,006
Estimated Annual Incentive		$165,266.36
Estimated Total Incentive		$3,140,060.84
Runtime Hours		3,251

The report also lists a total measure cost of $850,000.

3. Comments on the Ex Ante Calculations

Because the ex ante calculations were performed using the SPC provided calculator (the SPC Calculator), the general calculation methodology may be reasonable. No easily traceable documentation was provided as to the actual algorithms used in the SPC Calculator. The only inputs into the SPC Calculator for the existing equipment are the chiller type, size range, and age. Because the number and actual size of the existing chillers and how they are staged is not input into the SPC Calculator, and because the exact algorithms are not known to directly apply to this situation, there is potentially some error in the establishment of the baseline electrical usage.

For the new equipment, the chillers were input as Carrier centrifugal chillers at 530 tons, and the quantity was listed as two (2) units. According to the post installation inspection report, the units installed are York units, and there are three units (although one unit is designated as a standby unit). No capacity is given, and the model number does not give any indication of what the tonnage is, but does confirm that it is a centrifugal chiller.

The 2004 SPC Calculator does not ask for any information about the added load from the cooling tower fans and condenser water pumps that are necessary to support the water-cooled chillers. These components are not needed for the baseline air-cooled chillers. The SPC Calculator may not take these equipment items into account, which adds error to the calculation of energy savings.

The major problem with the ex ante savings is not with the calculation, but rather with how the output of the calculator was used. As shown in Table 1, the annual savings calculated was 1,180,474 kWh/yr. This appears to be a realistic number based upon a total tonnage of 1,030 tons, energy savings of 0.3 kW/ton, and 4,000 hours per year of use.

However, the SPC Calculator also calculated a total savings, based on an assumption of 19 years of remaining life on the existing chillers, which summed to 22,429,006 kWh. This larger number seems to have been used as the annual savings for the measure, and the unadjusted incentive was calculated based on this savings number. The site cap of $300,000 was applied, and the incentive adjusted to $ 269,096.48 due to the presence of other measures. This is still higher than the incentive calculated using the annual kWh savings and the incentive rate of $0.14/kWh ($165,266.36). **This was later corrected and total savings reported as the first year savings of 1,180,474 kWh/yr, which is also used as the ex ante savings figures.**

Demand kW savings are reported by the SPC Calculator as 116.8 kW. Based on the above savings figures, these estimates may be lower than actual achieved kW savings.

This measure is calculated as an early retirement measure, with a measure life of 23 years and remaining useful life of 19 years. The total savings per year can be better characterized as the annualized savings derived by combining the nineteen year savings using the existing chiller for the baseline energy use and the remaining four year savings using Title 24 as the baseline energy use, divided by the 23 year life of the chiller.

Under the CPUC Energy Efficiency Policy Manual (Version 2), the life of new chillers is 20 years. This would entail one year being compared to the Title 24 baseline energy use, and would reduce slightly the annual energy savings. Peak kW demand savings due to the new chiller would also be slightly lower in the last year of the 20 year life of the chiller.

In general, the savings figures in the Installation Report Review form would be expected to be identical to the utility tracking system savings figures. The total savings in the Installation Report Review were given as 22,429,006 kWh/yr and 117 kW and agree with the utility tracking system. However, as stated above, the lifetime kWh savings verses the annual kWh savings were used.

4. Measurement & Verification Plan

The goal of the measurement and verification (M&V) plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful life of the chiller, through quantifying hours of operation and energy use during these hours.

This site is primarily a large data center with a small amount of office space. The building is mainly single story, with an office area in the second story, and an equipment mezzanine that constitutes a second floor. The building is 90,000 square feet, which was estimated to be 5% office space and 95% data center. This data was provided by the customer during phone interview, and is in disagreement with information provided in the file as inputs to the SPC calculator, which says the facility is a 400,000 square feet large office. The offices are normally occupied Monday through Friday from 6:00 am to 5:00 pm. The data center runs 24 hours per day, 365 days per year.

It is noted that 78,000 sf was also listed as the building area.

Cooling for the office portion of the building is provided by a 30-ton DX package unit. Conditioned air is supplied to the office spaces by a variable air volume (VAV) distribution system to maintain a set point of 72°F.

Before the project was implemented, cooling for the data center was provided by four 285-ton air-cooled chillers, according to the customer. (This info also conflicts with information in the file, which said existing units were 265 tons). Chilled water from the chillers is supplied by constant speed primary/secondary chilled water pumps to 55 rooftop air handling units. Chilled water is also supplied to several recirculation air handling units in the data center.

Formulae and Approach

The M&V plan proposed is a modified version of IPMVP Option A.

A load profile for the building and a performance curve for the new chillers vs. actual building loads will be established. Originally it was planned that an estimated performance curve would be used for the baseline chillers. However, due to the eventual determination that the cooling load is fairly constant and the fact that the customer stated that the old chillers typically operated at full load, an overall assumed efficiency of 1.0 kW/ton was used for the existing chillers. This information will be input into an MS Excel based chiller modeling tool to determine the annual electrical usage by the baseline and new chilled water plant equipment.

The actual cooling load for the building will be determined using chilled water supply and return temperatures and the water flow through each cooling loop. The actual kW demand of the chillers will be measured at each building load. Measurements from the customer's EMS system may also be used if deemed accurate.

The size of the new chillers will be confirmed; it will also be confirmed that one of the three chillers is used as a standby unit only.

Originally, after initial review of the project file, there was another uncertainty about whether the chilled water pumps have VFDs installed. The other measures proposed with the measure being evaluated included installation of VFDs on both primary and secondary chilled water pumps. However, the post-installation inspection report states that there are no VFDs on either primary or secondary pumps. Based on the interview with the customer and the representative from the engineering firm that designed the project, there were no VFDs installed on the chilled water pumps because they were not economically justified, since the load does not vary enough to warrant modulating the chilled water flow. Because of this approach, a constant flow can be assumed, and will be determined based on review of design and/or balancing data.

All measures within the application will be verified for completeness.

The proposed data collection will be chilled water supply and return temperatures, chiller kW, outside air temperature, data center kW, and cooling tower fan motor frequency. The customer's designated representative has indicated that these data points can be (or already are) trended by the facility's EMS and can be exported to MS Excel. Cooling tower kW or amps would be preferable to frequency of the VFD on the tower fan; however, frequency is available as a trend-able point, and is adequate since tower usage is secondary in importance to the chiller use. Based on the information available by trending, no installation of any portable data logging equipment is planned; spot power measurements will be made during the site visit.

The customer stated that he does not believe the chiller load is very weather dependant. This will be confirmed by obtaining outside air temperature and analyzing the variation with other collected data. Internal heat load from the data center (kW) is one variable that may have more impact on chiller load than weather, and this point will be trended to test that correlation.

The performance curve for the installed chillers will be established by plotting in MS Excel the kW vs. the percent of full load for all data points collected for the chillers' operation. The percent load will be determined by calculating the tonnage based on the temperature difference between chilled water supply and return (ΔT) and the chilled water flow (either a constant value or a measured varying value) and comparing it to the rated full load tonnage of the chiller. The tonnage will be calculated by the formula:

$$\text{Tons} = \text{CHW gpm} \times 500\ \text{lb/hr/gpm} \times \Delta T_{CHW} \times 1\ \text{Btu/lb °F}/12{,}000\ \text{Btu/ton} \qquad \textbf{Eqn 1}$$

The measured kW will be regressed against measured cooling load to determine a performance curve fit.

The building cooling load profile will be determined using the same approach with outside temperature. The supplied tonnage will be plotted vs. outside air temperature and a curve will be fit to the plotted data. If the plotted data shows little correlation between chiller load and outside air temperature, then other variables affecting the chiller load, such as the data center heat load (kW) mentioned above, will be evaluated. If this variable has more effect on chiller load, then data center kW will be used to extrapolate the chiller plant usage to an annual amount.

With the building load and the chiller performance established the new system can be modeled and the annual electrical usage determined. The post-retrofit energy usage will be compared to the calculated baseline energy usage to determine the ex post savings using the following formula:

$$\text{kWh Savings} = \sum_{1}^{8,760} \text{Hours} \times \text{Average Tons} \times \left(\text{kW/ton}_{\text{old}} - \text{kW/ton}_{\text{new}}\right).$$

The greatest uncertainties in the ex ante savings estimate are the hourly chilled water loads, to what extent the cooling loads are weather dependant, and to a lesser extent, how the chillers' efficiencies (kW/ton) vary with different cooling loads. If the chiller loads do show a strong correlation with weather, California Climate Zone 4 will be used to extrapolate the monitored data to an annual kWh usage.

The above approach will require the data collection and verification, shown in the following table.

Table 2: Summary of Data Collection Plan

Data Element	Proposed Means of Collecting Data
Base case equipment configuration	Confirm via customer interview and review of customer records. Verify use of 3-way control valves.
Base case chiller duty	Confirm via customer records of chiller capacity rating. Interview customer to determine pre-retrofit control strategy.
Base case system operating hours	Confirm via customer interview and review of customer records and the planned maintenance schedule for each chiller and pump.
Base case control scheme	Confirm via customer records and interview, pre-retrofit chiller control. Verify manuals start/stop vs auto lead-lag.
Post case chiller duty	Obtain one shoulder month (or longer) of hourly customer EMS data - chiller kW, ECHWT, LCHWT, ECDWT, LCDWT.
Post case equipment configuration	Confirm via site survey, customer interview, and review of customer records. Obtain manufacturers' data sheets for equipment and equipment nameplate information. Review control settings and sequence of operation for chiller and pump staging.
Post case system operating hours	Confirm via customer interview and review of customer records and the planned maintenance schedule for each chiller and pump.
Post case pump and fan data	Obtain from customer design data or balancing data verifying the kW and flow for the primary and secondary chilled and condenser water pumps, and cooling tower full load kW. Also obtain from customer EMS one month (or longer) of hourly cooling tower fan frequency (hz).

Accuracy and Equipment

The primary variables are:

Chilled Water Flow (gpm), ±20%
Temperature (F), ±20 %
Accuracy of Chiller Curves, ±10%
Power Measured by Dent Elite Pro Loggers (kW), ±1%, exclusive of sensor accuracy;
Current Transformers (amperes), ±2.5%

It is expected that water temperatures are being measured by the customer with either an RTD or thermocouple installed in a thermowell that is immersed in the flow. These devices are generally accurate to within ±2°F. This can lead to 20% error based on a 10°F ΔT for each of the two sensors.

Power and readings will be obtained with the customer's installed monitoring equipment; the accuracy and calibration of such equipment will be ascertained during the site visit. Spot measurements will be taken during the site visit to provide additional verification of the information provided by the customer's EMS. As discussed below in Section 5, power measurements using portable datalogging equipment was required; Dent Elite Pro loggers were used for this purpose.

Data from customer's EMS will be provided in MS Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on July 17, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the new chiller plant equipment and by interviewing the facility representative.

The intent was that the customer would provide electronic data from the EMS in order to complete this evaluation. After several months of effort to collect this data, it was provided. An initial evaluation of this data indicated there was a problem with the kW/kWh data provided, since it showed the chiller efficiencies varying between ~1.0-1.1 kW/ton. These values are obviously too high for 2-3 year old water-cooled centrifugal chillers with VSD's installed. During the site visit, in meetings with the customer and design engineer, it was determined that the problem was with data output from the York chillers to the EMS and would require action from York to alleviate this problem. The customer expressed intent to get this problem resolved so that new trended data could be collected for analysis.

However, the chillers were out of warranty and York requested additional funds to resolve the issue. The customer still expressed intent to resolve the issue, but the need for additional funds resulted in a very slow movement to resolution. As a result, after approximately 6 weeks of waiting for the customer to initiate action it was decided to utilize portable datalogging equipment to monitor the kW of the chillers, and utilize other data that the customer's EMS could provide, including chilled water supply and return temperatures, cooling tower fan speed, and outside air dry bulb temperature. Consequently, three Dent Elite Pro dataloggers were installed; one on each chiller, and kW was recorded from September 14 through October 1, 2007. Temperatures and fan speed trend data was also obtained from the EMS for the period September 1 through September 30, 2007.

Installation Verification

The installation of equipment was physically verified. The three chillers are York model YKCHCHQ7CNF, with variable frequency drives. Chiller numbers 1 and 2 were operating and chiller number 3 was not. The three cooling towers are Evapco model 112-418. According to a cooling tower data sheet, the capacity of each tower is 568 tons and each tower has one (1) 30-hp motor. The speed of each tower fan motor is controlled by a Toshiba variable frequency drive (VFD). The VFDs on the two towers that were operating were each running the fans at full speed (60 Hz). The three condenser water pumps, each rated at 1,650 gpm and 79 feet of head, are each driven by a 50-hp 1,750 rpm motor at 94.5% efficiency. The three primary chilled water pumps, each rated at 1,320 gpm at 45 feet of head, are each driven by a 25-hp motor at 92.4% efficiency. The two secondary chilled water pumps, each rated at 2,640 gpm at 90 feet of head, are each driven by a 75-hp, 95.4% efficient motor. None of the pumps have VFD's.

Scope of the Impact Assessment

The impact assessment scope is for the chiller measure in the AC&R end use category in this SPC application. This is the only measure in this category.

The Other category also included VFD installation on the primary and secondary chilled water pumps and the cooling tower fans.

The customer chose not to install the VFDs on the chilled water pumps because they felt the relatively constant nature of the load would render the VFDs of minimal value. There were ten pumps which received incentives; the post installation review showed five pumps with no VSDs installed.

The customer did install the VFDs on the three (3) cooling tower fans, and as discussed below they operate at a fairly constant speed.

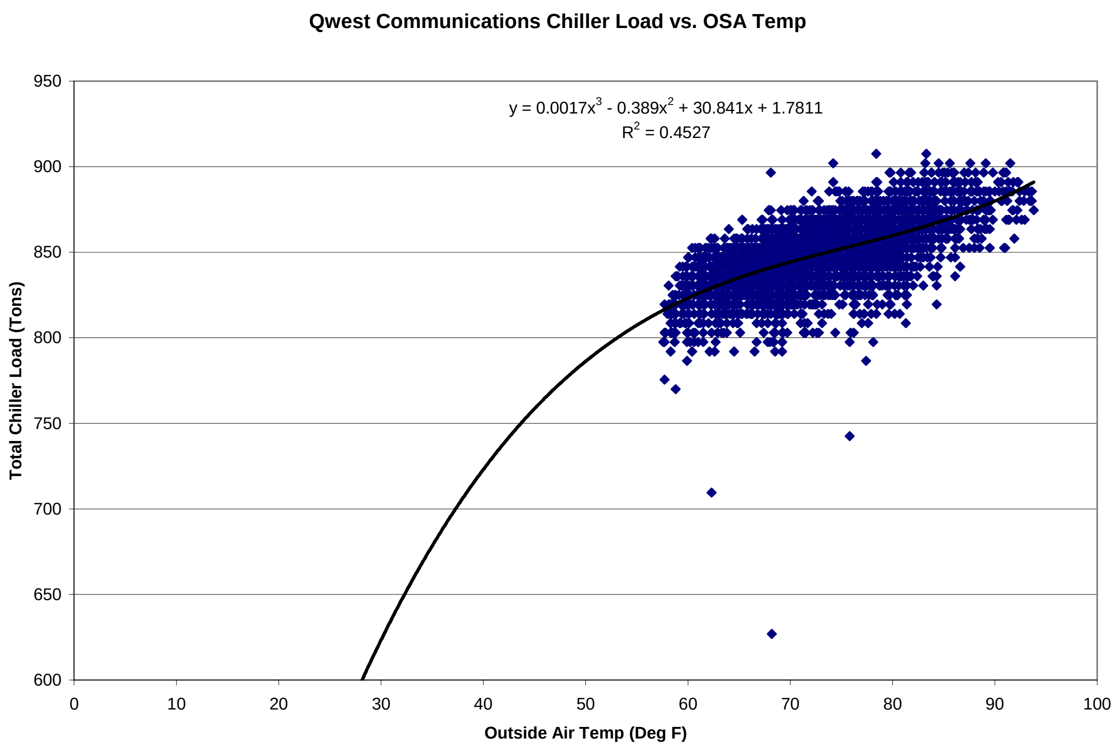
Summary of Results

Three (3) Dent Elite Pro kW Loggers were installed on each of the three chillers for 17 days (from September 14, 2007-October 1, 2007) to measure the power demand of the chillers, at 15 minute intervals. This data was supplemented with information from the customer's EMS that included chilled water supply and return temperatures for each chiller, cooling tower fan VFD speed for each tower, and outside air temperature for the period from September 1st through September 30th. The customer-supplied EMS data was collected at 8 minute intervals.

From the supply and return chilled water temperatures provided by the EMS, the difference between supply and return temperatures (ΔT) was calculated, and along with the constant volume flow of 1,320 gpm through each chiller a tonnage for each interval was calculated using Equation 1.

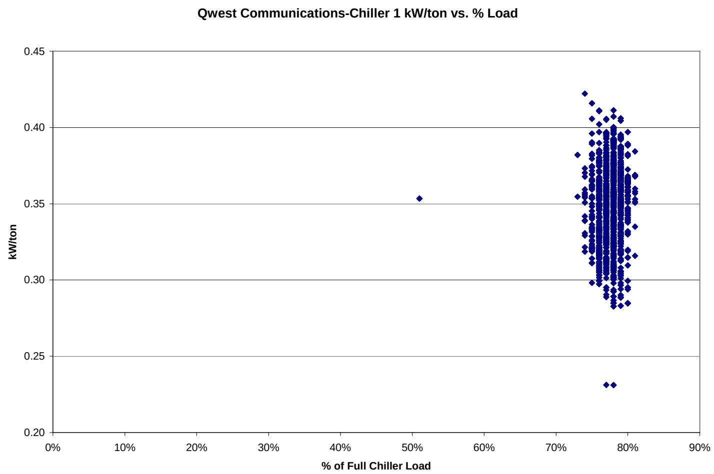
The total chilled water load was plotted vs. outside air temperature. This plotted data shows a mild correlation between cooling load and outside air temperature. The chiller load during the EMS data period was between 800 and 900 tons, the outside air temperature during this time varied between 58ºF and 94ºF. The trendline feature of MS Excel was used to apply a trendline to the plotted data; a 3rd order polynomial was selected. Although the R^2 factor of this trendline is fairly low (0.4527) for a regression, it does appear that the trendline represents a good average for the load in the temperatures where there is data. This chart is shown in Figure 1.

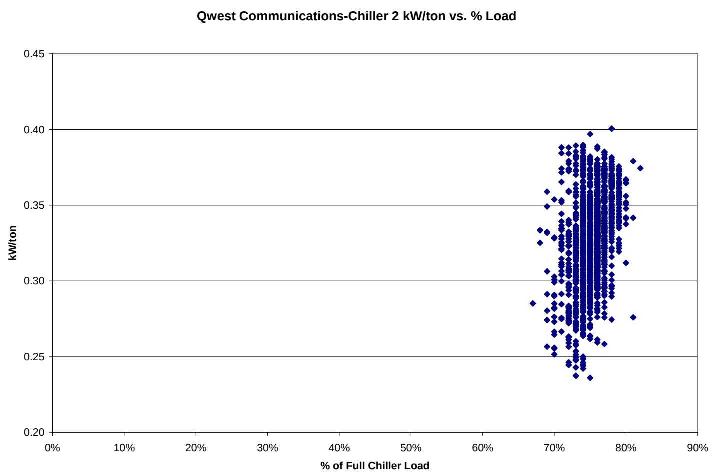
Figure 1: Chiller Load vs. Outside Air Temperature

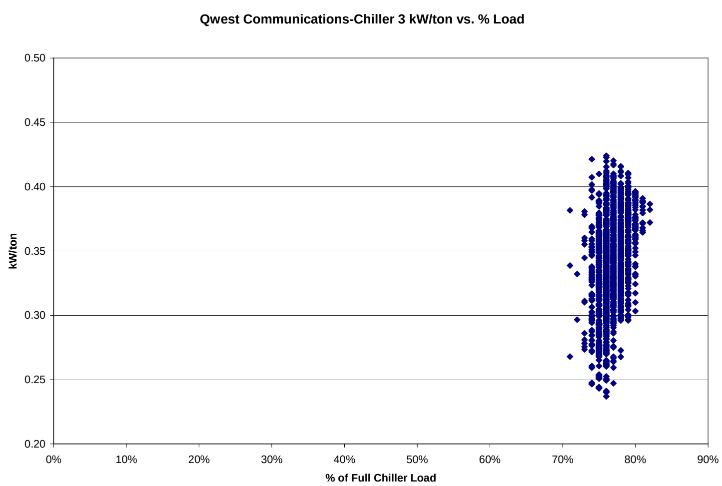


For each chiller the kW/ton was plotted vs. the percent load. As shown in Figure 2, the level of variation in the percent load was not great, and the kW/ton values varied between approximately 0.25 kW/ton and 0.4 kW/ton. From this data, it was not possible to establish a trendline of performance verses load. A conservative overall performance value of 0.35 kW/ton was used for the analysis of the current chiller annual kWh use.

Figure 2: Chiller kW/ton vs. Percent Load







The chilled water load from the trendline shown in Figure 1 was applied using weather data for California Climate Zone 4. For each of the 8,760 annual hours, the TMY[1] dry bulb temperature was used in the trendline equation to calculate the load for each of the 8,760 hours. An average chiller efficiency of 0.35 kW/ton was applied to determine a kW demand for each hour of the year. The sum of the hourly kW demands equals an annual kWh usage of 2,469,336 kWh for the new chillers. The average cooling load was 805.4 tons, creating an average demand of 281.9 kW.

The baseline kWh was re-calculated, since the ex ante savings were based on assumed run hours of 4,000 hrs/yr. An effort was made to determine the baseline kW/ton for the pre-retrofit air-cooled chillers. The customer was not able to provide any information on those chillers and no information could be found in the ex ante SPC calculation. The pre-inspection file showed the chillers to be Carrier model 30GX-265-Y-630 BA with capacity of 265 tons each. These chillers were installed in 2000. Carrier no longer shows an air-cooled chiller with a 30GX model number in its catalogue. Carrier does however currently manufacture an air-cooled screw chiller, model 30XA with a best full load EER of 10.7, (1.12 kW/ton), and a best IPLV of 15.2 (0.79 kW/ton). Also currently available is an air-cooled scroll chiller in this size, model 30RB with a best EER of 9.7 and IPLV of 14.2 (1.23 kW/ton and 0.84 kW/ton). Given that chillers purchased in 2000 were less efficient than those available in 2007, an efficiency of 1.0 kW/ton was assumed to represent a conservative value for calculating baseline usage. Therefore, the average demand kW based on an average cooling load of 805.4 tons, is 805.4 kW.

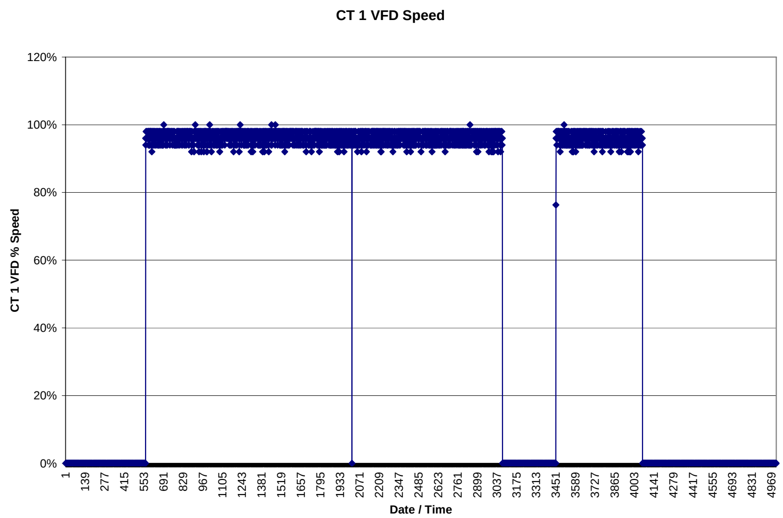
The electrical usage associated with the post-retrofit cooling towers and condenser water pumps was calculated. Baseline usage for these components was 0 kWh/yr as these components did not exist in the pre-retrofit case. The impact of the post-retrofit chilled water pumps was assumed to be 0 kWh since chilled water pumping should essentially be unchanged by the installation of the new chillers.

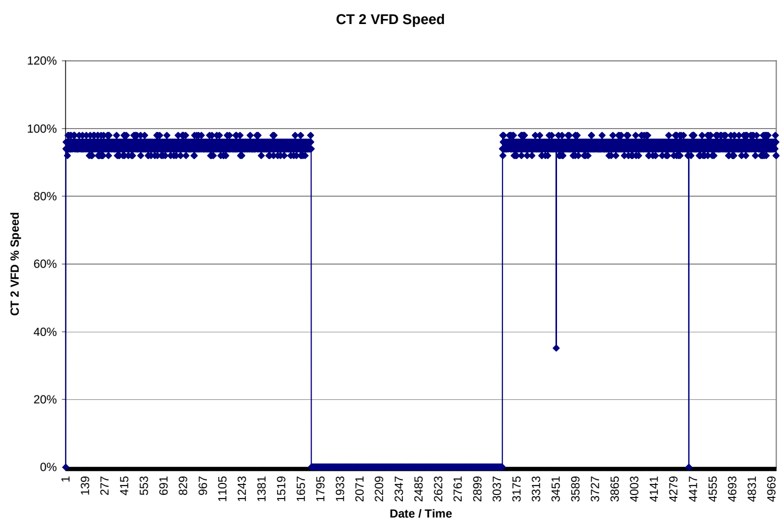
Condenser water pump energy usage is calculated using the motor rating, 50-hp, the rated motor efficiency, 94.5% and an assumed load factor of 85%, to determine the actual brake horsepower. Each condenser water (CW) pump has a demand of 33.6 kW, for a combined total for two of 67.1 kW, and an annual usage of 587,801 kWh.

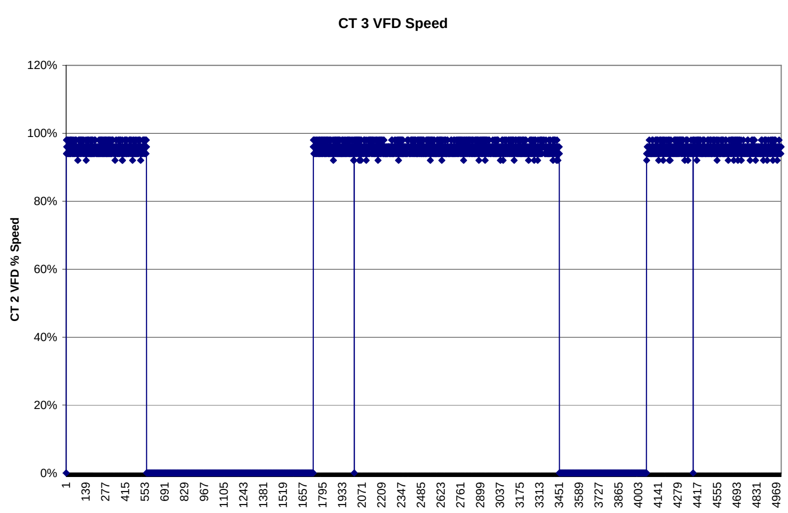
The cooling towers, even though they have VFD's installed on the fan motors, appear to have a fairly constant usage. The percent speed is shown for each of the three towers in Figure 3 plotted vs. date/time (although the date/times are not shown due to the high number of data points).

[1] TMY data are published by ASHRAE and use 30-year averages to represent typical weather data for specific locales. This is appropriate for annualizing the savings since the savings will be anticipated for more than for the first year.

Figure 3: Cooling Tower VFD Speed Percentages







The cooling tower average speeds are as follows in Table 3:

Table 3: Cooling Tower Average Speed

Cooling Tower	Average Percent Speed
1	96.2
2	95.0
3	95.5
Overall	95.5

Cooling tower fan energy usage is calculated using the rated motor horsepower, 30-hp, an assumed rate motor efficiency of 92.5%, and an assumed load factor of 85% to determine the actual brake horsepower. According to affinity laws for fans, changes in flow are proportional to changes in speed and changes in power are proportional to the cube of the change in speed. Thus the 95.5% average motor speed reduces the motor power requirement by the cube of the speed fraction. Each cooling tower fan has a demand of 17.9 kW, for a combined total for two of 35.8 kW, and an annual usage of 313,821 kWh.

The chiller replacement savings is calculated as an early retirement measure, with an old chiller being replaced 19 years before the end of its useful life by a new chiller with a useful life of 20 years. Therefore, the annual savings is calculated as a weighted average of the savings of the new chiller vs the old chiller for 19 years and the new chiller vs a Title 24 compliant chiller[2] for one year. The ex post impact savings calculations for each period are shown below in Tables 3A and 3B. A year by year look at the savings is shown in Table 3C, and then a combined weighted average in Table 3D.

As discussed in Section 3, according to the CPUC Energy Efficiency Policy Manual (Version 2), the life of new chillers is 20 years. The expected remaining life on the existing chillers was 19 years. The final ex post savings are calculated by using 19 years of the post-retrofit vs. pre-retrofit savings shown in Table 3A and one year of the post-retrofit vs. Title 24 savings as shown in Table 3B, combining them and dividing by 20 for each year of the expected life of the new chillers. These weighted average values are shown in Table 3D.

[2] California Title 24, 2001 Building Energy Standards, Table 1-C3 Chilling Packages-Minimum Efficiency Requirements, Water Cooled Rotary Screw and Scroll 4.90 COP, 4.95 IPLV

The ex post impacts are shown as follows:

Table 3A Ex Post Annual Savings Summary vs. Pre-Retrofit

System Component	Baseline		Post Retrofit		Savings	
	kW	kWh/yr	kW	kWh/yr	kW	kWh/yr
Chillers	805.4	7,055,246	281.9	2,469,336		
CW Pumps	0	0	67.1	587,801		
Cooling Tower Fans	0	0	35.8	313,820		
Total	805.4	7,055,246	384.8	3,370,957	420.6	3,684,289

Table 3B Ex Post Annual Savings Summary vs. Title 24

System Component	Baseline		Post Retrofit		Savings	
	kW	kWh/yr	kW	kWh/yr	kW	kWh/yr
Chillers	578.1	5,063,937	281.9	2,469,336		
CW Pumps	0	0	67.1	587,801		
Cooling Tower Fans	0	0	35.8	313,821		
Total	578.1	5,063,937	384.8	3,370,957	193.3	1,692,980

Table 3C: Multi Year Reporting Summary

Program		SPC 04-05 Evaluation A014					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	196,746	614,048	-	-		
3	2006	1,180,474	3,684,289	117	421		
4	2007	1,180,474	3,684,289	117	421		
5	2008	1,180,474	3,684,289	117	421		
6	2009	1,180,474	3,684,289	117	421		
7	2010	1,180,474	3,684,289	117	421		
8	2011	1,180,474	3,684,289	117	421		
9	2012	1,180,474	3,684,289	117	421		
10	2013	1,180,474	3,684,289	117	421		
11	2014	1,180,474	3,684,289	117	421		
12	2015	1,180,474	3,684,289	117	421		
13	2016	1,180,474	3,684,289	117	421		
14	2017	1,180,474	3,684,289	117	421		
15	2018	1,180,474	3,684,289	117	421		
16	2019	1,180,474	3,684,289	117	421		
17	2020	1,180,474	3,684,289	117	421		
18	2021	1,180,474	3,684,289	117	421		
19	2022	1,180,474	3,684,289	117	421		
20	2023	1,180,474	3,684,289	117	421		
TOTAL	**2004-2023**	21,445,278	66,931,250				

Table 3D: Ex Post Weighted Average Savings Summary

Years of Early Retirement	19
Remaining Useful Life	1
Weighted Average Savings	
Usage (kWh/yr)	3,584,723
Demand (kW)	409.2

The engineering realization rate for this application is 3.50 for demand kW reduction and 3.12 for energy savings kWh. A summary of the realization rate is shown in Table 5.

6. Additional Evaluation Findings

The ex post kW demand reduction is greater than the ex ante estimate because the ex ante estimate did not appear to be based on the actual plant load, unless the plant load has increased significantly since the project was complete. The ex post savings are greater than the ex ante because the ex ante savings demand reduction was based on 4,000 operating hours per year, when in fact the chilled water system operates 8,760 hours/year.

With a cost of $850,000 and a $269,096 incentive, the project had a 3.58 year simple payback based on the ex ante calculation of annual savings. The annual ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is revised to 1.15 years. A summary of the economic parameters for the project is shown in Table 4.

There were 3 other measures that were included in the original application, which were (1) VSDs on chilled water secondary pumps, (2) VSDs on chilled water primary pumps, and (3) VSDs on cooling tower fans. Items (1) and (2) were not completed as the customer decided that based on the relatively flat cooling load profile that VSDs on chilled water pumps would not have the desired energy savings. The impact calculations done for the chiller project largely support that conclusion. However, they remained in the Installation Report Review and the customer received an incentive for them.

Item (3), VSDs on cooling tower fans, was completed, as discussed in Section 5. The graphs in Figure 3 show that the impact of the VSDs on the tower fan operation is minimal. They may have more impact during the winter months, although the evaluator believes it will be minimal given the weak weather dependence of the overall load. The kWh usage of the tower fans was included in the impact calculations of the chiller project, since the pre-retrofit chilled water plant used air-cooled chillers and there were no cooling tower fans. The independent savings estimate for this measure was 157,739 kWh. The savings estimate was generated with the SPC calculator, using an input horsepower of 25 hp, rather than the actual 30-hp tower fans. The savings estimate divided the load on the tower in 10% increments between 50% of full speed and 95% full speed. An impact evaluation of the actual tower fan VSD savings would likely show a low realization rate.

There does not appear to be any carryover affect from this project in terms of other energy efficiency activity or awareness.

7. Impact Results

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	11/2/2005	$850,000	116.8	1,180,474	0	$153,462	$300,000	3.58	5.54
SPC Program Review (Ex Post)	10/25/2007	$850,000	420.6	3,684,289	0	$478,958	$300,000	1.15	1.77

Table 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System – **EEGA Update**	116.8	1,180,474	-
SPC Installation Report (ex ante **updated**)	116.8	1,180,474	-
Impact Evaluation (ex post)	420.6	3,684,289	-
Engineering Realization Rate	3.60	3.12	NA

Table 6: Verification Table

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
CHILLER REPLACEMENT	AC&R	Replace four (4) 265 ton air cooled chillers with three (3) new water cooled chillers with VFDs			1,239	York 550 ton water cooled centrifugal chillers with integral VFDs,Evapco cooling towers with 30-hp motor driven by Toshiba VFDs, 50-hp condenser water pumps, 25-hp primary chilled water pumps, 100-hp secondary chilled water pumps. All pumps constant speed.	Physically verified equipment described in the previous column. Verfication supplemented with submittals/data sheets for chillers and cooling towers.	0.16

Table 7: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	4170	31,705,200
Baseline End Use	805.4	7,055,246
Ex Ante Savings	116.8	1,180,474
Ex Post Savings	420.6	3,684,289

Table 8: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	2.8%	3.7%	10.1%	11.6%
Baseline End Use %	14.5%	16.7%	52.2%	52.2%

Final Site Report

SITE A015 (2004-xxx) Lock1 **IMPACT EVALUATION**
SAMPLE CELL: TIER: 2 **END USE: Other**

Measure	HVAC Controls
Site Description	Office / Data Center / Cafeteria

1. Measure Description

There are several measures included in this project. From the documentation provided, it is unclear exactly which measures were implemented. Through discussions with the facilities staff and the Engineer that performed the ex ante calculations, it was determined that the following energy conservation measures (ECMs) were installed:

ECM 1) Install new control valves in the air compressor system.
ECM 2) Chilled and hot water valve replacements (note: the SPC application calls this measure "adding new control system").
ECM 3) Implementing time of day schedules (from 24/7 to 13/5) for one (1) 30-hp and two (2) 50-hp supply fans, and for eighteen (18) 5-hp return fans.
ECM 4) Incentive provided on earlier project.
ECM 5) Economizer controls.
ECM 6) New temperature controls.

In actuality, the retrofit consists of adding economizers to most of their AHUs, replacing pneumatic with digital DDC controls and setting up the control sequences for proper operation of variable frequency drive (VFD) pumps and fans. For ECM 4, the "incentive provided on earlier project" refers to either replacing pneumatically controlled VAV boxes with DDC boxes or replacing constant chilled water (CHW) and hot water (HW) pump motors and AHU fan motors with new, VFD controlled units. A more detailed description of each measure is provided below.

2. Summary of the Ex Ante Calculations

The ex ante calculations for the control upgrades were all done manually using very broad assumptions. Some of the calculations are impossible to follow. Some can be followed, but the analyses are over-simplified.

The ex ante Measure Energy Savings Estimates are shown in the following table:

Number	Measure Description	kWh	Therms	Incentive
ECM 1	Air compressor control valves	14,258	0	$1,140.64
ECM 2	Chilled and hot water valve replacements	193,108	16,900	$32,348.64
ECM 3	Time of day schedules for (1) 30-hp and (2) 50-hp supply fans and (18) 5-hp return fans	1,171,226	0	$93,698.08
ECM 5	Economizer controls	959,855	0	$76,788.40
ECM 6	New temperature controls	36,103	1,232	$4,120.24
	Total	**2,374,550**	**18,132**	**$208,096**

Peak kW savings were not provided on the application. Based on the nature of these measures, the vast majority of the savings occur at night or during cooler outdoor air temperatures, so no peak kW savings is claimed.

The report also lists the total cost of all measures to be $421,990.

For this application, the cost, incentive and savings are not broken out separately for the 'Other' end use category and the 'Gas' end use category, as the electric and gas savings are due to the two of the ECMs interactive effects and cannot be partially implemented.

3. Comments on the Ex Ante Calculations

Based on discussions with the maintenance engineer, the controls engineer, and the contractor's engineer, the following clarifications were made for the ex ante calculations:

<u>ECM 1 - Air compressor control valves:</u>

The retrofit replaced the pneumatic system with DDC controls. Following the retrofit, the facility abandoned the air compressor; it is still in the building but not currently in use.

Ex ante calculations were savings estimates due to lower use of compressed air. It is unclear from the calculations whether the savings are assuming less run time or elimination of the air compressor altogether. Also the calculations assumed two 7.5-hp air compressors, but during the site survey, only one 7.5-hp air compressor was found.

<u>ECM 2 - Chilled and hot water valve replacements:</u>

The retrofit replaced 3-way pneumatically controlled valves with 2-way DDC controlled valves. The chilled and hot water pump motors were previously replaced with high efficiency units and VFDs; but no controls were in place to utilize the VFDs. Part of ECM 2 was to implement control of the VFDs.

Ex ante calculations are difficult to follow. It appears that an assumption of 75% less pumping power for the chilled water pump and 25% less pumping power of the hot water pump was used. It also appears that increased night-time shut-down of the pumps would be seen, thus contributing to the 75% and 25% figures.

ECM 3 - Time of day schedules for (1) 30-hp and (2) 50-hp supply fans and (18) 5-hp return fans:

The retrofit included implementing time-of-day schedules for the fans listed. The assumption is they all run 24/7 with the new operating schedule being 13/5 (13 hours per day, 5 days per week). There are several issues with these assumptions.

The (1) 30-hp and (2) 50-hp supply fans only represent one quadrant of the building. There are three additional quadrants with an identical supply fan arrangement. This was verified through inspection of HVAC drawings and the building EMS.

The supply fans in each quadrant were previously retrofitted with high efficiency motors and VFDs, but the controls were not in place to operate the VFDs. Part of this retrofit included the necessary controls to effectively utilize the VFDs.

There are 36 return fans (7.5-hp each) in use with these supply fans, as opposed to the (18) 5-hp assumed the ex ante calculations. There are also (16) 7.5-hp exhaust/relief fans in each quadrant.

In discussions with the engineer that compiled the ex ante calculations, he felt that time-of-day controls were already in place for the supply fans in three of the four quadrants; but the time-of-day schedules were not in place for the return fans in two of the four quadrants.

In discussion with the maintenance engineer, he mentioned that their previous control system was very unreliable, so they would tend to leave the AHUs running all the time rather than trying to schedule shut-downs.

The ex ante savings were based on the complete shutdown of specified motor horsepower for a certain length of time. This analysis will require reworking for the evaluation.

ECM 5 – Economizer Controls:

The baseline AHUs were equipped with fixed outside air dampers only. The retrofit included adding dry bulb economizers and the necessary controls to operate them.

The ex ante analysis included broad estimations of economizer operating hours, cooling load saved and subsequent kWh reductions. It is based on taking a percentage of the maximum design airflow of 336,000 CFM (total of the (8) 50-hp and (4) 30-hp supply fans). Actual design airflow of 594,000 CFM was determined from the HVAC drawings. Also, a cooling efficiency of 3.5 kW/ton was assumed, which is extraordinarily high for a chilled water plant of this size and type.

ECM 6 – New temperature controls:

This measure replaces pneumatically controlled thermostats with DDC units. Savings for this measure is very difficult to estimate accurately. The ex ante calculations assumed a 2ºF reduction can be achieved over a certain percentage of the time.

4. Measurement & Verification Plan

The goal of the measurement and verification (M&V) plan is to estimate the actual annual kWh savings.

The building is part of a large campus (approximately 3.5 million square ft), served by a central plant with approximately 8,000 tons of cooling. The building studied is a single 5-story building with a total floor area of 624,000 sq ft. The building is rectangular with a 90,000 sq ft atrium (the sum of all five floors). The roof over the atrium is covered with skylights. The atrium area is essentially unconditioned, but acts as the return plenum for the main HVAC units. The building is primarily used as office area, but it also includes the main campus cafeteria and some data centers/computer labs. The offices and the cafeteria are normally occupied Monday through Friday from 6:00 a.m. to 6:00 p.m. The data centers run 24 hours per day, 365 days per year.

The retrofit included adding economizers and DDC controls to most of the HVAC systems in the building. The main systems affected include four perimeter and core zone supply/return/exhaust fan systems. For the building, these include (8) 50-hp supply fans (core zones), (4) 30-hp supply fans (perimeter zones), (36) 7.5-hp return fans (feeding one common plenum for each quadrant) and (16) 7.5-hp exhaust/relief fans (four in each quadrant). These systems serve approximately 90% of the total building area.

Systems unaffected by the retrofit include four perimeter dual-duct multi-zone systems (serving a portion of floors 2 through 5), two VAV AHUs, each serving a portion of the 1st floor, cooling units serving the data centers/computer rooms, and the exhaust fans/make-up air (heating only) units serving the kitchen. These systems serve the remaining 10% of the building area. Retrofits for these systems (economizers, DDC controls) have been completed, but were not part of this SPC application.

Systems that share both the affected and unaffected systems are the chilled water pump (50-hp), hot water pump (7.5-hp) and air compressor (7.5-hp).

Formulae and Approach

The M&V plan proposed is a modified version of IPMVP Option A. Each measure will be discussed separately.

ECM 1 - Air compressor control valves:
The air compressor used for the old pneumatic control system was located. It has been tagged and locked-out as non-operational. It will be verified that it is not currently in use.

ECM 2 - Chilled and hot water valve replacements:

M&V for the energy savings of this measure is impossible to quantify directly. The prior configuration was reported to have had some percentage of malfunctioning pneumatic systems and valves. M&V actions included verifying that the pneumatic air compressor is not in use and the existence of two-way valves through the building EMS screens. The use of VFD control of the chilled and hot water pumps was verified through direct inspection of the pump room. The addition of VFDs is not directly included with this measure.

This ECM (along with ECM 6) allows the use of supply air reset controls, based on demand (or warmest zone) for their supply air systems. This control is in place as verified through inspection of the building EMS.

ECM 3 - Time of day schedules for (1) 30-hp and (2) 50-hp supply fans and (18) 5-hp return fans:

M&V includes determining the time of day schedules for the main air handler units in each quadrant and determining the annual energy consumption should the units be kept on during "off" hours. Through an interview with the Building Controls Maintenance Engineer and through short-term monitoring of a sampling of supply fans, the following time schedules were determined:

Perimeter Zones:

Summer:	Monday to Friday 0500 to 1800
Winter:	Sunday 2400 to Friday 2400

Core Zones:

All Year	Monday to Friday 0500 to 1800

Time schedules for the perimeter zones are variable. These are typically manually adjusted based on outside air temperature. Rather than running those zones 24 hours during the week for the six winter months, if the weather is warm, they are reset to run from 0400 or 0300 until 1800 and then adjusted back to 24 hours when the weather cools down. The purpose of operation prior to daily occupancy is to warm up the building. If the heating system is not operated on the weekend during cold weather, it takes several days of heating to restore the building temperature to the normal weekday set-points. The extended winter hours are for heating purposes only.

Each supply fan is VFD controlled, as determined through a building inspection and the building EMS. Short term monitoring of true power was performed on the supply fans in one quadrant, primarily to estimate the minimum power draw and to verify the time schedules. The addition of VFDs for these fans is not part of this retrofit measure (both the base case and post-retrofit case includes VFD controlled fans). A DOE 2 model of the building using eQuest software was completed to perform the detailed energy savings analysis.

ECM 5 – Economizer Controls:

The existence of economizers with controls was included through a building inspection and screen shots from the building EMS. Energy savings from this retrofit cannot be measured directly. A DOE 2 model of the building using eQuest software was completed to perform the annual energy savings analysis.

ECM 6 – New temperature controls:

Annual energy savings from this measure is impossible to measure directly. The pre-case included pneumatic thermostats. It is unclear how many thermostats did not work correctly or which zones may have had overlapping heating and cooling set-points with adjoining zones. Existence of DDC temperature controls for their various building zones was verified through inspection of the building EMS. Typical set-points are 70ºF for heating and 74ºF for cooling.

As noted before, ECM 2, along with this ECM, allows the use of supply air reset controls, based on demand (or warmest zone) for their supply air systems. This control is in place as verified through inspection of the building EMS.

The above approach will require the following data collection and verification:

Data Element	Proposed Means of Collecting Data
Base case equipment configuration	Confirm via customer interview and review of customer records.
Base case system operating hours	Confirm via customer interview and review of customer records.
Base case control scheme	Confirm via customer records and interview.
Post case equipment configuration	Confirm via site survey, customer interview, EMS settings and review of customer records. Perform short term monitoring of motors controlled by VFDs or spot measurement of motors not controlled by VFDs. Obtain supply air temperature reset settings from the customer's EMS.
Post case system operating hours	Confirm via customer interview, EMS settings and review of customer records.
Post case control scheme	Confirm via customer interview, review of facility EMS, and short-term monitoring of a sampling of supply fans for a minimum of two weeks.

The customer does not record any trends for any data points in this building. The primary focus for this facility's operations are the approximately 40 clean rooms on the campus, where they routinely trend operations and environmental conditions.

The greatest uncertainty may be in the load profile of the VFDs for the HVAC fans, which will reduce electrical energy consumption and heating / cooling needs.

Accuracy and Equipment

Spot measurements for power will be obtained by a hand held Fluke meter. Short term power monitoring will be performed with DENT Power Loggers with current transformers manufactured and calibrated by Dent Instruments. The hand held meters are generally accurate to within 1% and the Dent meters are accurate to within 1%.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on November 15, 2007 to collect information on the supply, return and exhaust fans. Power loggers were installed in a sampling of the supply fans to determine power draw and schedule, and spot measurements were taken for a sampling of exhaust fans. The return fans motors are the same model and horsepower as the exhaust fans, so power draw is assumed to be similar.

When the loggers were retrieved (December 3, 2007), the Building Controls Maintenance Engineer was interviewed concerning the details of the EMS controls. Strategies were determined and screen shots obtained of the EMS. The HVAC contractor that performed the initial analysis was also interviewed.

Installation Verification

It was determined the building previously had pneumatic controls that did not work very well. The old pneumatic air compressor was physically located, and it was tagged and locked out (not currently in operation).

It was also determined the building previously only had fixed outside air dampers (no economizers) and that time of day schedules are now in place. The baseline control system was very unreliable, so all air handlers were operated 24/7. To support this, the example of a Christmas shut-down of the air handlers was given. When the holiday had ended, the control system did not turn the units back on. When the staff finally got the AHUs running, it took several days to warm up the building.

The verification realization rate for these measures is 1.0. All measures are believed to be in place (including the air compressor valves which are not used). A verification summary is shown below in Table 7.

Scope of the Impact Assessment

<u>ECM 1 - Air compressor control valves:</u>

The air compressor used for the pneumatic control system is currently not in use. An estimation of the energy saved is through a simple horsepower conversion calculation:

Equation 1

$$kW = \frac{hp \times 0.746\ kW/hp \times Run\ Time \times Load\ Factor}{Motor\ Efficiency}$$

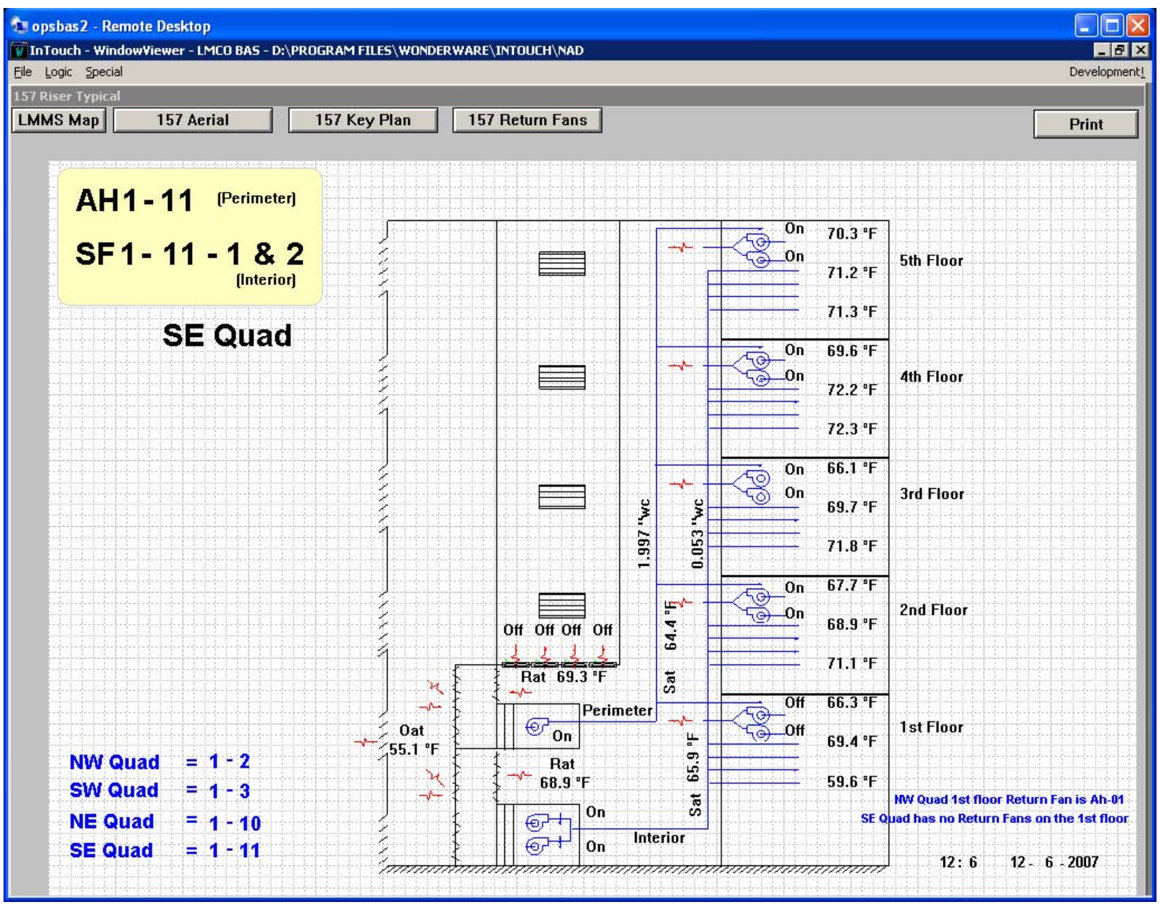
Assuming the ratio of load factor to motor efficiency is an average of 0.5, the following result is obtained:

kW = 7.5 hp x 0.746 kW/hp x 8760 hours/year x 0.5 = **24,506 kWh/year**

<u>ECM 3 - Time of day schedules for (1) 30-hp and (2) 50-hp supply fans and (18) 5-hp return fans:</u>

Design of the HVAC system consists of three supply fans and either eight or ten return fans in each quadrant. Figure 1 shows a typical riser diagram taken from the building EMS. There are a total of four risers in the building.

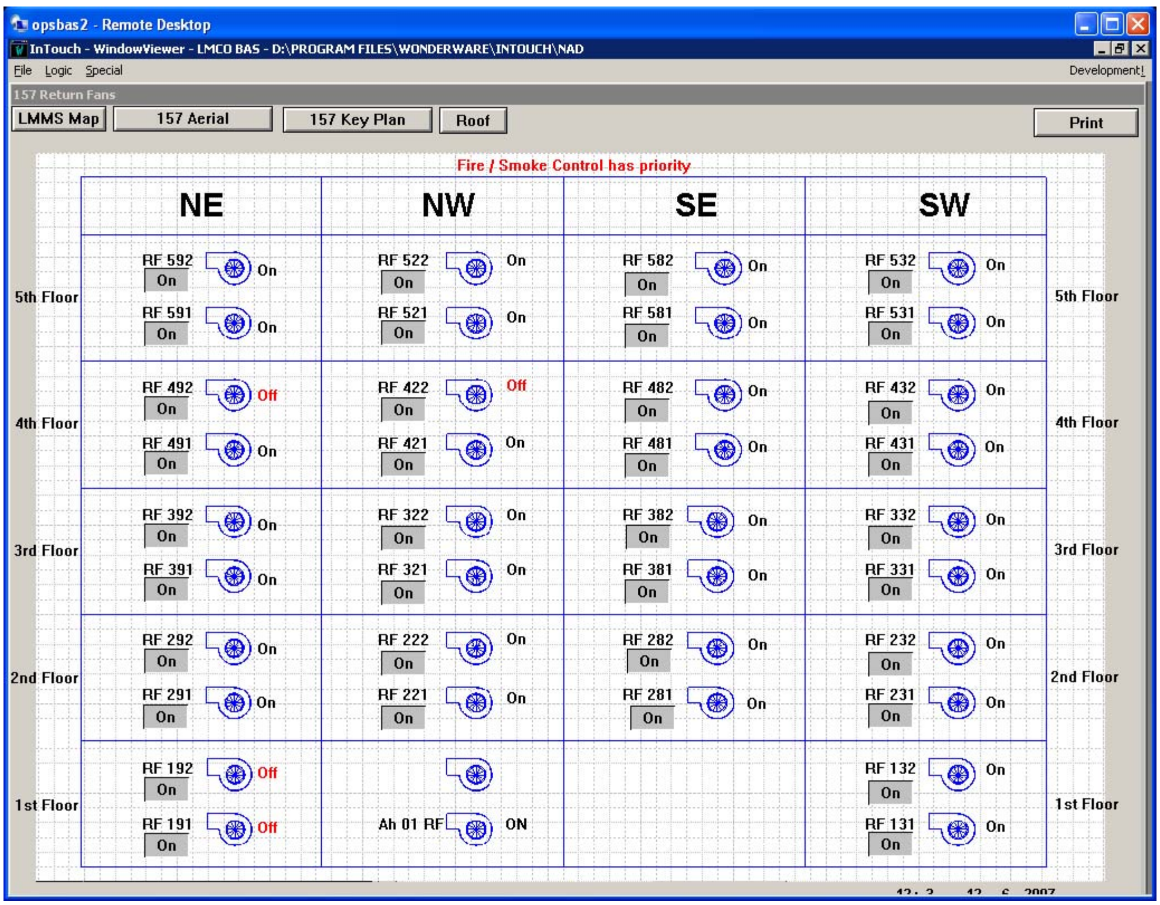
Figure 1: Typical Riser Diagram



Three supply fans and four exhaust/relief fans are in each fan room. The outside air dampers/economizers and the relief dampers are located throughout the entire elevation of the building. The exhaust/relief fans come on as needed based on static pressure. At the time this screen shot was taken, all exhaust/relief fans were off.

In general, two return fans are located on each floor. The return “plenum” feeds all three supply fans in the quadrant. The riser diagram is a bit misleading in that the return “plenum” is actually the central atrium area of the building. Return air from the supply fans in all quadrants feed the atrium. Return fans are staged based on maintaining static pressure requirements. Figure 2 shows the status of the return fans (total of 36 in the building). This screen shot was taken on a cold November day; four fans are off and 32 fans are running.

Figure 2: Return Fan Status



The original analysis assumed the implementation of time of day schedules for ¼ of the supply fans and ½ of the return fans. Through an interview with the Building Controls Maintenance Engineer, it was determined that time of day schedules were actually implemented for all units.

Dent power loggers were installed on three supply fan motor VFDs. The fans are controlled by VFDs, but the scope of this assessment does not include energy saved from VFDs. The logger data was used to verify time of day schedules and to help determine the power draw at lower speeds (the power draw the fans would see should they run at night or on weekends). The loggers were installed in the SE quadrant supply fans, at approximately 10:00 am, on a very warm day (even though it was in November). All the fans were running at 60 Hz. It was thought that in cooler weather the fans would slow down. However, throughout the monitoring period, the power draw was fairly constant, only slowing down by a few rpm during the coldest periods.

Supply fans SF-1-11-1 & 2 serve the core areas and SF-1-11-3 serve the perimeter. “Core” and “perimeter” areas are somewhat of a misnomer since most of the areas served are open cubicle office areas. Each quadrant has three supply fans, two designated for core areas (50-hp each) and one designated for perimeter areas (30-hp). The core and perimeter areas share much of the same floor space. Both core and perimeter units have heating coils, but the capacities of the perimeter heating coils are somewhat greater than those in the core units.

The core supply fans currently operate from 05:00 to 18:00, Monday through Friday. Figures 3 and 4 show the monitored data for SF-1-11-1 & 2 as operating under this schedule. Included in the monitored period is the Thanksgiving holiday, during which the supply fans were also shut off.

Figure 3: SF-1-11-1 Supply Fan Power

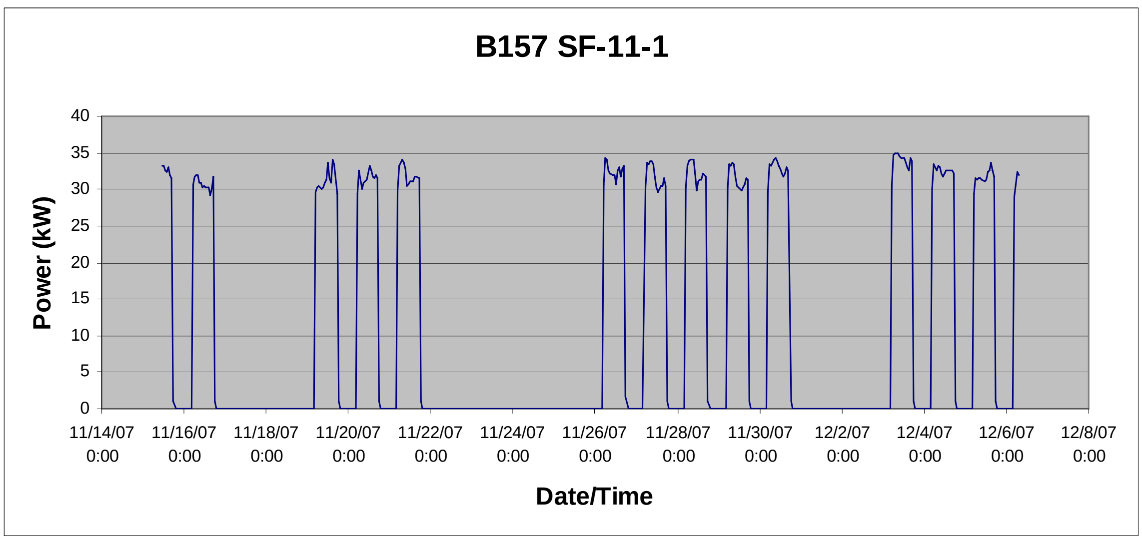
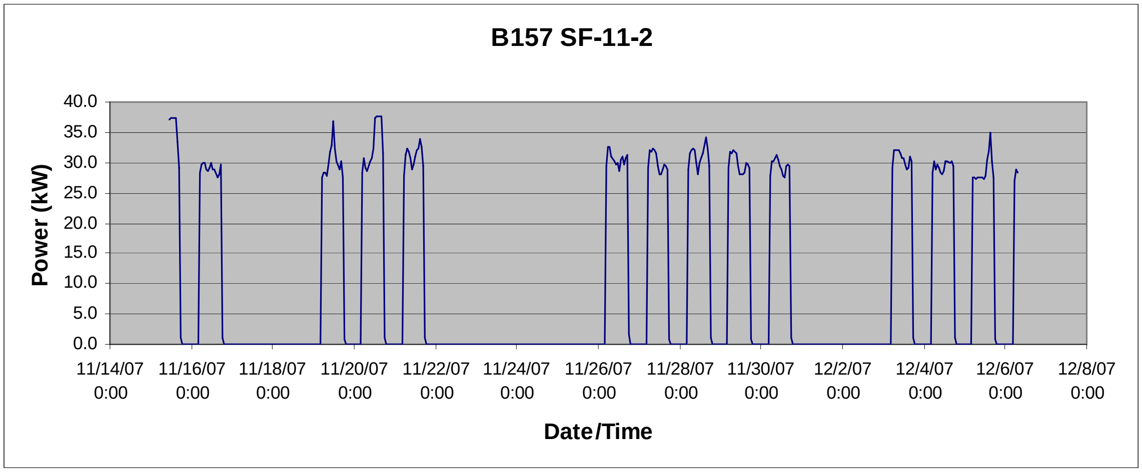


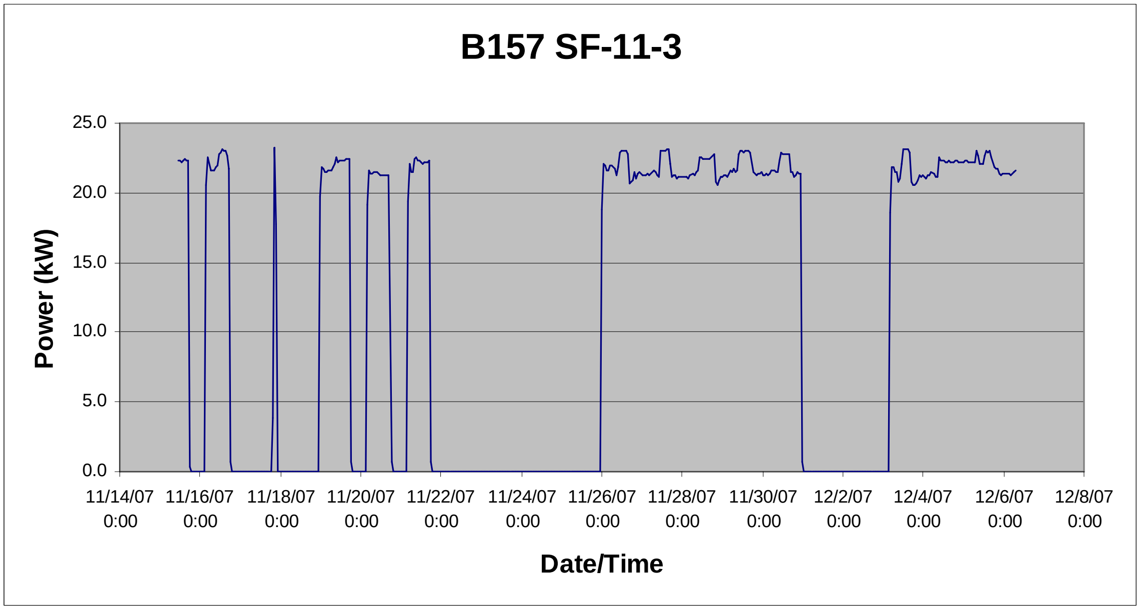
Figure 4: SF-1-11-2 Supply Fan Power



The schedule for the perimeter supply fans varies. In general, they operate 24/5 during the winter and 05:00 to 18:00 during the summer. Operating the perimeter fans 05:00 to 18:00 during the colder winter weather makes the building too cold during weekends which then keeps it from warming up enough until Wednesday. Consequently the Building Controls Maintenance Engineer typically adjusts this schedule depending on the actual weather expected. For example, during the week before Thanksgiving, it was unseasonably warm, so the perimeter fan schedule was adjusted to 04:00 to 18:00 on some days during the week. The unit was also scheduled to come on for a couple of hours late at night on at least one day. The week after Thanksgiving, the weather was very cold, so the fans were put back onto their normal schedule of 24/5.

Figure 5 shows the logger data for the perimeter fan in the SE quadrant. During the period after Thanksgiving, time schedules are 24/5, and during the period before Thanksgiving time schedules are 24 hours Monday and 04:00 to 18:00 on other week-days.

Figure 5: SF-1-11-3 Supply Fan Power



Through the power monitoring of the SE quadrant, the resulting frequency of the fan motors was determined by applying the cubed law. One supply fan in this quadrant slowed down to only a minimum of 54 Hz. On the day the loggers were installed (a very warm day), the supply fan VFDs in the NE and SW were inspected for fan speed. The electrician escort was not very familiar with the HVAC system and was unable to find the fan room for the NW quadrant. On the day the loggers were retrieved (a very cold day), the VFDs were inspected again for fan speed, with very little difference (within approximately 2 Hz) when compared to the previous inspection. This information was used to estimate the fan energy savings by implementing time of day schedules for these supply fans (Table 1). The resulting savings is 1,984,587 kWh/year.

Table 1: Fan Energy Savings from Time of Day Scheduling

SF Number	Fan HP	Quad	Area Served	Design CFM	Freq Read (Hz)	Min Freq (Hz)	Min Freq Determination Method	Min Airflow (CFM)	Min Airflow (%)	Full Power (kW)	PLF	Minimum SF Power (kW)	RF Power (kW)	Hours Off	SF Energy Saved (kWh/yr)	RF Energy Saved (kWh/yr)
SF-1-11-1	50	SE	Core	57,000	60.0	57.0	Recorded	54,150	95%	34.9	2.9	30.0	13.2	5486	164,714	72,415
SF-1-11-2	50	SE	Core	57,000	60.0	54.0	Recorded	51,300	90%	37.6	2.9	27.8	13.2	5486	152,523	72,415
SF-1-11-3	30	SE	Perimeter	34,500	60.0	58.0	Recorded	33,350	97%	23.2	3.0	21.0	13.2	4166	87,435	54,991
SF-1-10-1	50	NE	Core	57,000	60.0	54.0	Estimated	51,300	90%	36.3	2.9	26.8	13.2	5486	147,046	72,415
SF-1-10-2	50	NE	Core	57,000	59.9	53.9	Estimated	51,205	90%	36.3	2.9	26.7	13.2	5486	146,304	72,415
SF-1-10-3	30	NE	Perimeter	34,500	50.3	44.3	Estimated	25,473	74%	23.2	2.6	10.5	13.2	4166	43,544	54,991
SF-1-3-1	50	SW	Core	57,000	60.0	54.0	Estimated	51,300	90%	36.3	2.9	26.8	13.2	5486	147,046	72,415
SF-1-3-2	50	SW	Core	57,000	37.3	31.3	Estimated	29,735	52%	36.3	2.3	8.3	13.2	5486	45,727	72,415
SF-1-3-3	30	SW	Perimeter	34,500	42.5	36.5	Estimated	20,988	61%	23.2	2.4	7.0	13.2	4166	29,094	54,991
SF-1-2-1	50	NW	Core	57,000	60.0	54.0	Estimated	51,300	90%	36.3	2.9	26.8	13.2	5486	147,046	72,415
SF-1-2-2	50	NW	Core	57,000	37.3	31.3	Estimated	29,735	52%	36.3	2.3	8.3	13.2	5486	45,727	72,415
SF-1-2-3	30	NW	Perimeter	34,500	42.5	36.5	Estimated	20,988	61%	23.2	2.4	7.0	13.2	4166	29,094	54,991
TOTALS	**520**			**594,000**				**470,823**	**79%**	**382.8**		**227.0**	**158.4**		**1,185,301**	**799,286**

Since not all fans were monitored, and since the analysis must predict the fan power draw that would be seen if they had remained on during off hours, several assumptions were made:

- For the fans that were monitored, the slowest fan speed seen during the monitored period is assumed to be the fan speed that would typically be seen during off hours.
- For the fans that were not monitored, the fan speed will decrease by 6 Hz from the values recorded during the inspection.
- The fan room in the NW quadrant was not located so it is assumed that their fan speeds will be similar to those in the SW quadrant (the lowest fan speeds observed).
- Design airflow was taken from the building HVAC drawings.
- Airflow at slower speeds was calculated as a linear ratio of design airflow.
- In the SE quadrant, the two 50-hp fan motors showed a difference in full power of approximately 10%. For the 50-hp fan motors in the other quadrants, an average of these two full flow fan powers is assumed.
- Return fan power draw is assumed to be 4.4 kW each, which is an average of spot measurements taken for the exhaust/relief fans (they are the same type with the same hp per the HVAC drawings). Since access could not be provided to the return fans, it was assumed that they run at the same level and equal to the exhaust/relief fan power draw.
- Only 32 of the 36 return fans would normally be running during off hours. This estimate was taken by observing the return fan operation on a cold day.
- Potential savings from shutting down exhaust/relief fans were ignored for this analysis. There may be some reduced operation of these fans but it is impossible to predict due to the dynamics of changing static pressures from the supply/return fans and from wind loads on the building. The building is in a location where conditions can be very windy at times, and outside air as well as exhaust/relief dampers are located throughout the building's entire elevation. Savings from these fans were not included in the original analysis. Therefore, no attempt was made to quantify exhaust/relief fan energy savings.
- The hours off were calculated per the schedule explained earlier, in addition to 10 holidays per year when these fans would also be off.
- The minimum fan power draw was determined using a modified cube law (columns labeled "PLF" and "Minimum SF Power (kW)"). The "PLF" factor is the modification to the cube factor in the standard affinity law equation. Development of this factor and subsequent power draw is explained below.

The equations used are based on the following reference:

Jonathan B. Maxwell, "How to Avoid Overestimating Variable Speed Drive Savings", URL: https://txspace.tamu.edu/bitstream/1969.1/5621/1/ESL-IE-05-05-05.pdf

Equation 2

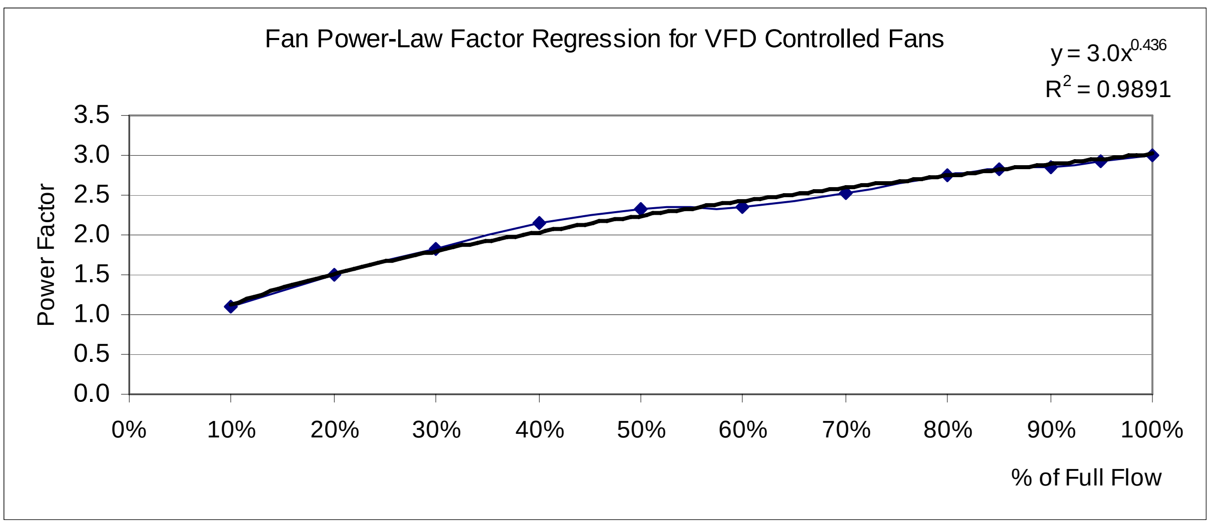
$$kW_{\text{part load}} = kW_{\text{full load}} \times (\text{Part Load Flow/Full Load Flow})^{PLF}$$

In Equation 2, the exponent 'PLF' is the fan power-law factor. For VFD controlled fans, the power-law factor is generally a variable in the range of 1.0 to 3.0 and is a function of the flow percentage. From the above reference, 'PLF' vs. % of full flow was plotted for VFD controlled fans (Figure 6) and an empirical function for 'PLF' was derived (Equation 3). A regression analysis was performed to determine the probability of the fit (R^2) of Equation 3 to the curve in Figure 6. Equation 3 will fit the curve 99% of the time, and so was used for fan motor calculations.

Equation 3

$$\mathrm{PLF} = 3.0 \times \mathrm{Percent\ of\ Full\ Flow}^{0.436}$$

Figure 6: The Regression Model of Fan Power Factor for VFD Controlled Fans



<u>Remaining Measures:</u>

Energy use for the following measures can only be analyzed as a group since there are many interactive effects in play:

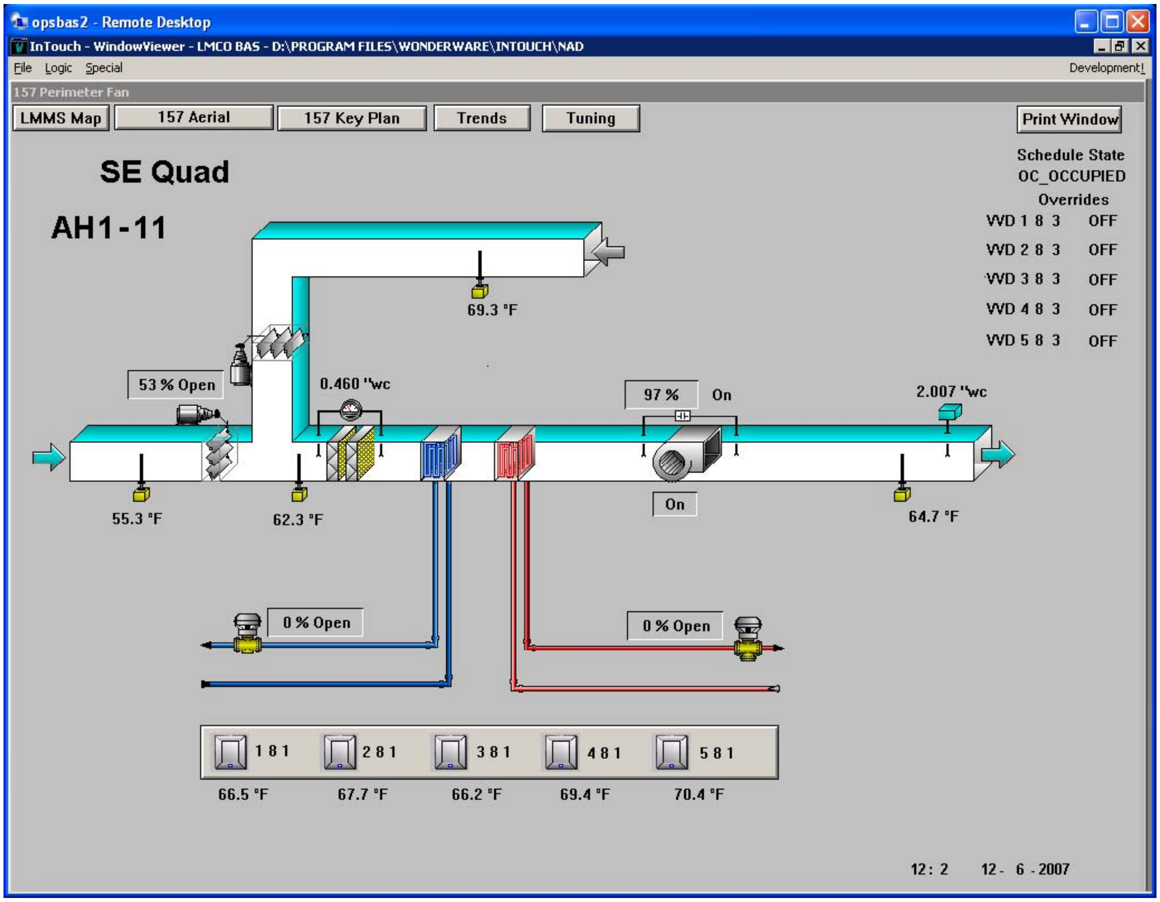
- ECM 2 - Chilled and hot water valve replacements
- ECM 5 - Economizer Controls
- ECM 6 - New temperature controls

The analysis includes new chilled/hot water valves under DDC controls (allowing the proper use of chilled/hot water pump VFD controls), new economizers with DDC controls and new space temperature controls. This combination of measures produces a very interesting dynamic.

The facility has implemented cold deck reset schedules based on building demand. This control strategy is demonstrated through Figure 7 (a screen shot of the perimeter air handler in the SE Quad).

- Return air temperature is 69ºF.
- Outside air temperature is 55ºF.
- Supply air temperature is reset to 65ºF based on building demand.
- The economizer is only 53% open since that's what's required to maintain the supply air temperature at 65ºF.
- Both hot water and chilled water valves are closed.

Figure 7: Supply Fan System



Chilled and hot water pumps controlled by VFDs slow down. Also the central plant includes a trim chiller with VFD controls on the compressor, so this unit will also slow down. With all these interactive effects, a DOE 2 model using eQuest software was created to capture the savings from these measures.

The model was created with the following key features:

- Design cfm was obtained from HVAC drawings.
- Minimum VAV flow was determined using the calculations from Table 1 (average 79% minimum VAV flow).
- Pumps, chiller and supply fans are on VFD controls.
- Condenser water temperature of the central plant is set at 68ºF.
- Time of day schedules were implemented in the "post" case, which capture some of the "non-fan energy" savings seen through implementing ECM 3.
- The building also includes computer rooms (cooled by the chilled water system), some dual duct multi-zone units serving some perimeter closed office areas, and the cafeteria. These other areas represent approximately 10% of the building area and are included in the model. No economizer, time of day schedules or temperature resets were included for these additional units.

The results of the eQuest simulation yields an energy savings of 1,106,844 kWh/year. Savings are from reduced heat rejection (cooling tower fans), pumping energy and space cooling (chiller energy). The results of each category and the total savings are all included in Table 2.

Table 2:Energy Savings from Economizer and Supply Air Temperature Reset Controls

MONTH	Heat Reject.		Pumps & Aux.		Space Cool		SAVINGS (kWh)
	Pre	Post	Pre	Post	Pre	Post	
Jan	1,335	23	53,167	46,205	104,637	37,742	75,169
Feb	2,775	365	50,018	42,211	106,777	38,605	78,388
Mar	3,137	528	55,363	47,283	126,352	47,107	89,935
Apr	5,051	1,276	55,372	46,409	130,014	52,714	90,038
May	14,793	9,309	62,628	53,543	166,315	93,443	87,441
Jun	20,409	14,005	63,719	53,626	188,014	106,837	97,674
Jul	25,313	17,709	69,274	56,913	220,387	125,799	114,553
Aug	26,871	18,483	69,667	56,979	218,774	129,359	110,491
Sep	24,202	15,947	65,935	53,293	190,631	104,674	106,854
Oct	13,705	8,504	63,054	52,772	166,376	86,940	94,919
Nov	2,193	194	53,217	45,197	116,677	42,828	83,869
Dec	1,451	39	53,286	46,174	107,081	38,091	77,513
TOTAL							**1,106,844**

Ex post savings were allocated to each of the 3 ECMs by multiplying the total ex post savings by the ex ante ratio of savings for each measure to the total ex ante savings for all 3 measures as shown in Table 3.

Table 3: Energy Savings from Economizer and Supply Air Temperature Reset Controls (By Measure)

Measure	Ex Ante Savings (kWh)	% Ex Ante	Ex Post Savings (kWh)
ECM 2	193,108	16%	179,755
ECM 5	959,855	81%	893,483
ECM 6	36,103	3%	33,607
Total	**1,189,066**	**100%**	**1,106,844**

There is also substantial gas savings from this retrofit. The two main drivers are the reduction in heating energy during evenings and weekends, and the reduced reheat required from implementing supply air temperature reset controls. The building has a large amount of single pane windows on the north and south faces; 18,000 sq ft of clear skylights in the atrium area; and very little insulation. Heat loss from the building is very high. The potential gas savings from these measures were completely ignored in the ex ante calculations. Instead, the ex ante savings simply claimed very broad estimates of a percentage of heating energy saved from replacing three-way pneumatic hot water valves with two-way DDC controlled units, and from replacing pneumatic thermostats with DDC units. The DOE 2 model was used to quantify the gas savings (Table 4).

Table 4: Ex Post Gas Savings

MONTH	Gas Use		SAVINGS (THERMS
	Pre	Post	
Jan	42,422	21,348	21,075
Feb	37,479	17,645	19,834
Mar	41,609	19,476	22,133
Apr	39,738	18,203	21,535
May	40,226	16,775	23,452
Jun	37,998	14,716	23,282
Jul	38,912	14,139	24,773
Aug	38,677	15,199	23,478
Sep	38,099	13,502	24,597
Oct	40,541	16,960	23,581
Nov	40,092	18,209	21,883
Dec	42,265	20,475	21,790
TOTAL			271,412

6. Additional Evaluation Findings

Overall the ex post annual energy savings (kWh/year) are found to be greater than the ex ante (Table 5). Some measures have higher savings and some have lower savings. The ex ante manual calculations where highly oversimplified, as discussed earlier, accounting for the differences.

Table 5: Summary of Ex Ante and Ex Post Results (By Measure)

Number	Measure Description	Ex Ante kWh/yr	Ex Post kWh/yr	Ex Ante therms/yr	Ex Post therms/yr
ECM 1	Air compressor control valves	14,258	24,506	0	0
ECM 2	Chilled and hot water valve replacements	193,108	179,775	16,900	22,199
ECM 3	Time of day schedules for (1) 30-hp and (2) 50-hp supply fans and (18) 5-hp return fans	1,171,226	1,984,587	0	245,063
ECM 5	Economizer controls	959,855	893,483	0	0
ECM 6	New temperature controls	36,103	33,607	1,232	4,150
Total		**2,374,550**	**3,115,958**	**18,132**	**271,412**

There is no peak kW savings claimed in the SPC application or in the ex post evaluation. Since the energy saved is during off hours and cooler weather only, the implementation of each of these measures ware not expected to reduce peak demand.

The air compressor control valve retrofit had initial calculation showing a control air reduction, not elimination. The particular retrofit involved outfitting 90% of the building with DDC controls, so the elimination of the air compressor was claimed under ex post savings.

ECM 2, 5 & 6 are all somewhat lower than the ex ante savings claimed. The cause is likely the oversimplification of the calculation methods. These measures are interactive, and, if analyzed independently, would yield higher combined energy savings. The ex post analysis takes into account their interactive effects.

The time of day schedules for the supply and return fans (ECM 3) yielded a much higher electrical savings (approximately 40%). This was determined through short-term monitoring data of a sampling of units. The assumptions the contractor used for the ex ante analysis did not match the initial use of this equipment. In addition, ECM 3 caused a significant gas savings, which were ignored in the ex ante calculation.

7. Impact Results

Table 6: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh, $1.10/therm), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	07/18/2005	$421,990	-	2,374,550	18,132	$328,637	$208,096	0.65	1.28
SPC Program Review (Ex Post)	12/18/2007	$421,990	-	3,115,958	271,412	$703,628	$208,096	0.30	0.60

Table 7: Realization Rate Summary

	kW/yr	kWh/yr	Therm/yr
SPC Tracking System	0	2,374,550	18,132
SPC Installation Report (ex ante)	0	2,374,550	18,132
Impact Evaluation (ex post)	0	3,115,958	271,412
Engineering Realization Rate	N/A	1.31	14.97

Table 8: Installation Verification Summary

Measure Description	End-Use Category	OTHER Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Controls / HVAC Valves	O	Replace pneumatic with DDC controls, economizers, time schedules, supply air temperature reset controls	NA	DDC controls, economizers	Physically inspect facility, and made sure units were in use	1.00

Table 9: Multi-Year Reporting Table

Program Name:		**SPC 04-05 Evaluation, Site A015**					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004						
2	2005	791,517	1,038,653	0	0	6,044	90,471
3	2006	2,374,550	3,115,958	0	0	18,132	271,412
4	2007	2,374,550	3,115,958	0	0	18,132	271,412
5	2008	2,374,550	3,115,958	0	0	18,132	271,412
6	2009	2,374,550	3,115,958	0	0	18,132	271,412
7	2010	2,374,550	3,115,958	0	0	18,132	271,412
8	2011	2,374,550	3,115,958	0	0	18,132	271,412
9	2012	2,374,550	3,115,958	0	0	18,132	271,412
10	2013	2,374,550	3,115,958	0	0	18,132	271,412
11	2014	2,374,550	3,115,958	0	0	18,132	271,412
12	2015	2,374,550	3,115,958	0	0	18,132	271,412
13	2016	2,374,550	3,115,958	0	0	18,132	271,412
14	2017	2,374,550	3,115,958	0	0	18,132	271,412
15	2018	2,374,550	3,115,958	0	0	18,132	271,412
16	2019	2,374,550	3,115,958	0	0	18,132	271,412
17	2020	1,583,033	2,077,305	0	0	12,088	180,941
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	35,618,250	46,739,370	0	0	271,980	4,071,180

Appendix A
VFD Power Law Factor Regression Analysis

In order to evaluate the fan part load power for VFD controlled fans, we referred to Jonathan Maxwell's research paper entitled "How to Avoid Overestimating Variable Speed Drive Savings". In this paper, a figure (Figure 1 in the first page of Mr. Maxwell's paper) shows a curve for the fan part load power as a function of percent flow for any VFD controlled fans. We read 12 data points from that curve and used these data to build a regression model. The regression model is based on the following fan power law formula:

Equation 4

$$\frac{\text{Fan Power}_{\text{part load}}}{\text{Fan Power}_{\text{full load}}} = \left(\frac{\text{Part Flow}}{\text{Full Flow}}\right)^{\text{PLF}} = \left(\frac{\text{Percent Flow}}{100\%}\right)^{\text{PLF}}$$

In Equation 4, PLF is the power-law factor, which is a variable value for VFD controlled fans and generally varies in the range of 1.0 (very low part load operation) to 3.0 (full load operation).

The regression model is shown in Equation 3 and the regression R^2 level is high, approximately 0.99. The 12 data points read from Mr. Maxwell's paper are shown in Table 8. The corresponding 12 PLF values calculated from the data points and calculated from the regression model (see Equation 1) are also presented in the table below.

Table 10: Fan Part Load Power to Part Load Flow

% of Full Flow Power – data points read from research paper	8%	9%	11%	14%	20%	30%	41%	54%	63%	74%	86%	100%
% of Full Flow – data points read from research paper	10%	20%	30%	40%	50%	60%	70%	80%	85%	90%	95%	100%
PLF – calculated from data points	1.10	1.50	1.83	2.15	2.32	2.36	2.53	2.76	2.82	2.86	2.92	3.00
PLF – calculated from regression model	1.10	1.49	1.77	2.01	2.22	2.40	2.57	2.72	2.79	2.87	2.93	3.00

FINAL REPORT

A016 SITE 20xx-04 Four IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: AC&R

Measure	Early Retirement of 480 Ton Chiller
Site Description	Hotel

1. Measure Description

A 480-ton centrifugal chiller was replaced as an early retirement measure under the 2004 SPC program. The pre-installation chiller was installed in 1991 and had an expected 10 years useful life remaining. The post-installation chiller was also a 480-ton centrifugal unit with an efficiency rating of 0.53 kW/ton. The post-installation chiller also includes a variable frequency drive (VFD) on the compressor.

2. Summary of the Ex Ante Calculations

The SPC Early Retirement-AC&R Cooling Units calculator was used to determine the annual savings. The SPC Early Retirement-AC&R Cooling Units calculator uses pre-defined building types along with building location, floor area, and hours of operation to determine a load profile for the chiller based on the ASHRAE simplified bin method. This load profile is then used, along with an industry standard performance curve for constant speed or VFD controlled chillers to determine the peak and part-load kW as well as annual kWh usage for the units.

The ex ante results determined by the 2004 SCP calculator are:

For the chiller early retirement:

Pre-Replacement Usage -	303.6 kW	1,038,778 kWh
Current Minimum Standard (Title 24) Usage -	273.2 kW	934,900 kWh
Post-Replacement Usage -	265.3 kW	579,239 kWh
Peak Summer Impact & Annual Savings -	38.3 kW	459,539 kWh
Total Savings (10 years remaining useful life) -	38.3 kW	4,595,390 kWh

3. Comments on the Ex Ante Calculations

The SPC Early Retirement-AC&R Cooling Units module was used to determine the annual savings utilizing information. The SPC Calculator uses information on chiller type, building type, building area, and location to determine a building factor and an average to peak kW ratio, which are then used to determine peak load and annual energy usage.

The SPC calculator calculates the building factor based on the building type and area. Based on a 350,000 square foot hotel facility, a building factor of 0.987 was used. For the baseline chiller, a constant speed chiller was input into the SPC Calculator. Therefore, a pre retrofit VFD efficiency of 100% was used. For the proposed chiller, the SPC calculator assumes a VFD efficiency of approximately 94.65%.

The hours of operation of the chiller and average to peak kW ratio are variables that would be determined based on site-specific information. The SPC calculator uses an ASHRAE simplified temperature bin analysis to determine a typical load profile, which is then coupled with a standard performance curve to determine full load and part load demand.

For constant speed chillers, the SPC calculator assumes an average to peak kW ratio of approximately 0.425. For VFD modulating chillers, the SPC calculator assumes an average to peak kW ratio of approximately 0.298. In both cases, it is expected that this chiller operates 7,337 hours per year.

The annual peak demand and energy usage of the chiller can be approximated using the formulae:

kW = chiller full load efficiency x chiller capacity x building factor / VFD efficiency

kWh = kW x hours of operation x average to peak kW ratio

As indicated, the ex ante savings were based upon the use of the SPC Calculator. The kWh savings appear lower than may be expected based upon a reasonable estimated efficiency increase of 0.3 kW/ton with newer variable speed modulating chillers. The kWh savings appear to be realistic based upon this efficiency increase and a 40% load factor.

The Installation Report Review and the Operating Report Review forms both list the correct identified kW savings of 38.3 kW. Both forms, however, list the total ten (10) year savings of 4,595,390 kWh (annual kWh savings of 459,539 kWh should have been entered). The utility tracking system correctly lists the kW and kWh savings.

The incentive was capped at 50% of the measure cost and was $140,850.00. If calculated at the correct rate of $0.14 / kWh, the incentive payment would have been $64,335.46.

4. Measurement & Verification Plan

The facility is a 5-story hotel with approximately 330,000 square feet of floor area. It was constructed in 1987. The building is expected to be occupied continuously. According to the application, before the installation, the facility utilized two 480-ton centrifugal chillers, which were installed in 1987. One chiller operated as a lead chiller, and operated approximately 24/7 throughout the year. The second chiller was utilized during periods when the lead chiller could not meet the required load. Per the customer, the second chiller operated approximately one month per year. After the installation, the new chiller became the lead chiller, which continued to operate approximately 24/7 throughout the year. In addition, the new chiller was modulated through the use of a VFD. The operation of the second chiller did not change with the installation of the new chiller.

The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction due to the early retirement and replacement of one 480 ton centrifugal chiller with a new centrifugal chiller with an efficiency of 0.53 kW/ton and modulating control via a VFD.

Formulae and Approach

For this application, it is proposed to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. The chiller in question is not expected to consume a large percentage of the facility's total energy consumption so billing analysis is not appropriate. Also, the usage of the chiller is not expected to remain consistent enough for single point measurements to be representative of the average usage.

Seasonal variation is expected to be predictable and two weeks should be sufficient for to calibrate an energy savings model; however, a longer period would more fully capture actual variations and the persistence of savings. Interval / trend data for only the chiller or chilled water system, on a 15-minute or less basis, preferably during the summer months of June to September, may be needed to accurately determine coincident peak period demand savings. However, the data collected during the hottest weekday periods between 2 pm and 5 pm can be used to forecast coincident peak load savings for this weather dependent measure.

Pre-retrofit and post-retrofit calculations of chiller load and energy use will be calculated using the following formulae:

<u>Post-installation</u>

kW = chiller full load efficiency x chiller capacity x building factor / VFD efficiency

kWh = kW x hours of operation x average kW load factor

<u>Pre-installation</u>

kW = chiller full load efficiency x chiller capacity x building factor

kWh = kW x hours of operation x average kW load factor

The most significant variables to be quantified are the pre-retrofit and post-retrofit average kW load factor values. Site personnel will be interviewed to more accurately determine the operating loads of the chiller. In addition, if possible, the full load efficiency of the pre-retrofit chiller will be determined from the identical backup chiller currently in place. Appropriate modifications for the savings calculations will be made to the pre-retrofit usage figures if required, in order to establish a more accurate baseline for energy use.

We will physically verify the installation of the 480-ton centrifugal chiller during the onsite visit. We will verify that the installed chiller is modulated by a VFD. We will verify the post-retrofit energy consumption by utilizing the customer's on-site EMS software to log the kW and kWh of the unit with a sampling delay of no greater than 2 minutes for a minimum of 14 days.

If the demand and energy consumption is not available from the EMS software, we will verify post-retrofit energy consumption by installing Hobo FlexSmart data loggers with WattNode WNA-3D-480-P Watt-hour transducers and Magnalab SCT-1250-200 current transformers on the power supplied to the VFD. The energy consumption of the chiller will be logged with a sampling delay of no greater than 1 minute, for a minimum of 14 days to verify the post-retrofit energy consumption.

In addition, the outdoor air temperature and relative humidity at the facility will be monitored using no less than two (2) Hobo H8 loggers. If possible, the daily occupancy level for the logged period will be verified with the customer representative. The logged kWh per unit output will then be used in conjunction with temperature and occupancy effects to determine the annual usage.

The greatest uncertainty in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit average kW load factor of the chiller. The average kW load factor is a representation of the chiller load profile and the performance curve throughout the course of the entire year.

The SPC calculator utilizes a standard load profile based on the type of facility, hours of operation, and building area, as well as a typical performance curve based on chiller type. In addition, the SPC calculator assumes a typical kW/ton for the baseline chiller; therefore, the actual baseline chiller kW/ton value cannot be used to calculate the savings in this program. The SPC Calculator will not be used for the ex post savings calculations.

Uncertainty for the savings estimate for the chiller replacement can be more fully understood by setting projected ranges on the primary variables.

<u>For the Pre-Retrofit Chiller</u>

- 303.6 kW expected, maximum of 324.5 kW, minimum of 273.2 kW (+7%, -10%, based on judgment of deviation from typical efficiency in SPC calculator, maximum load condition in SPC calculator, and period codes for chiller operation and efficiency)
- 0.466 average to peak kW ratio expected, maximum of 0.63, minimum of 0.30 (±35%, based on judgment of deviation from typical load profile and chiller standard performance curve in SPC calculator)

<u>For the Post-Retrofit Chiller</u>

- 265.3 kW expected, maximum of 291.8 kW, minimum of 238.8 kW (±10%, based on judgment of deviation from typical chiller efficiency in SPC calculator, deviation from typical VFD efficiency in SPC calculator, maximum load condition in SPC calculator, and period codes for chiller operation and efficiency)
- 0.298 average to peak kW ratio expected, maximum of 0.45, minimum of 0.19 (+50%, -35%, based on judgment of deviation from typical VFD chiller load profile and chiller standard performance curve in SPC calculator)

<u>For the Chiller Early Retirement</u>

- 459,539 kWh annual expected savings, minimum 21,283 kWh, maximum 938,572 kWh (-95.4%, +104.2%, based on pre-retrofit and post-retrofit chiller operation above)

- 7,337 running hours expected, maximum of 8,760 running hours, minimum of 6,236 running hours (+19%, -15%, based on judgment of deviation based on discussions with customer representative and typical operating conditions for similar facilities)

Accuracy

The Hobo FlexSmart loggers have a time accuracy of ±10 seconds. The WattNode Watt-Hour transducers have an accuracy of ±0.45%+0.05%FS, and the Magnelab SCT-1250-200 current transformers have an accuracy of ±1.5%. The Hobo H8 temperature and relative humidity loggers have an accuracy of ±1.3F (within the range of –4F to 104F) for temperature and ±5% for relative humidity.

The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to Microsoft Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on June 11, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the chillers and by interviewing the facility representative. During this site visit, the new chiller was not in operation due to equipment malfunction. The other existing chiller (same model as the retired chiller) was in operation. Data was obtained from the facility's energy management system (EMS) for both the old chiller and at a later date for the new chiller. Chiller compressor power, ambient temperature, and ambient relative humidity were obtained for 10 days for the old chiller and 15 days for the new chiller during June and July of 2007.

5.1. Installation Verification

The facility representative verified that chilled water was provided by two (2) 480 ton chillers before the retrofit One was the lead chiller, and the other was used only during peak summer periods to supplement the lead chiller.

The existing lead chiller was retired, and replaced with a new centrifugal chiller with a variable frequency drive. The existing supplemental chiller continued to operate as it did prior to the lead chiller replacement.

It was physically verified that the new centrifugal VFD chiller was installed.

This is the only measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in
Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	AC&R Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Chiller Replacement	A	Replacement of a chiller with a 480 ton VFD chiller - Early Retirement			1	480-ton centrifugal VFD chiller	Physically verified installed chiller	1.0

5.2. Scope of the Impact Assessment:

The impact assessment scope is for the AC&R end use category. The measure in the SPC application covers the early retirement of a chiller. This is the only measure in this application.

5.3. Summary of Results:

Data was collected from the EMS between the dates of June 11 and June 21, 2007 for the backup chiller, which was a duplicate model to the pre-retrofit chiller (the new chiller was down due to equipment malfunction). Data was also collected from the EMS between the dates of July 16 and July 30, 2007, for the new chiller. Ambient temperature and relative humidity was also collected from the EMS system for both these time periods.

It was determined from the EMS data that the demand of the chiller (both old and new) varies depending on ambient temperature. The EMS data collected is shown graphically in Figure 1 and Figure 2 below.

Figure 1: EMS Data – Old Chiller

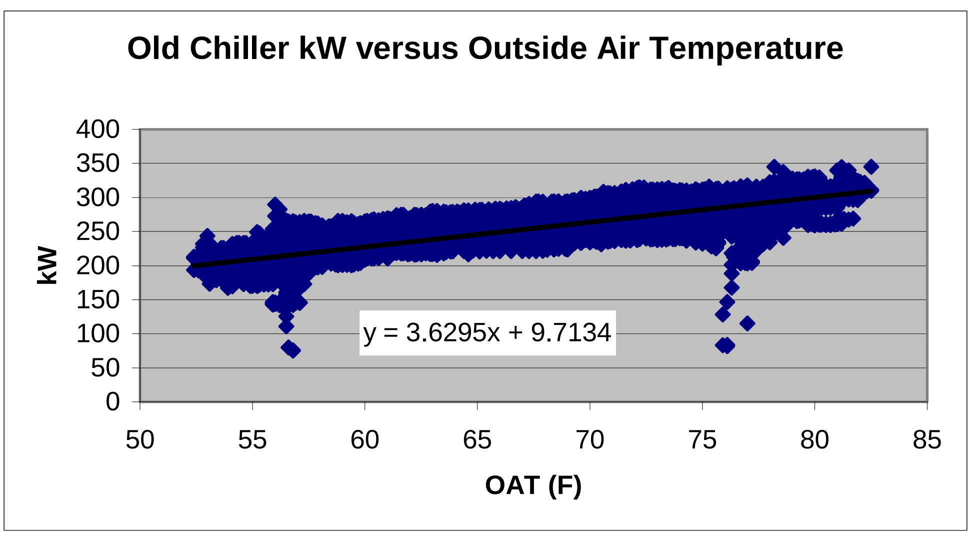
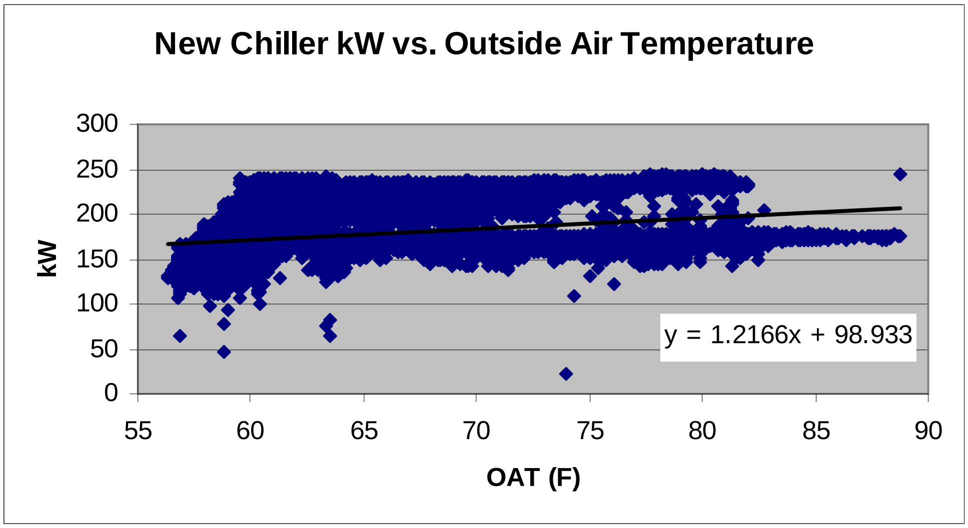


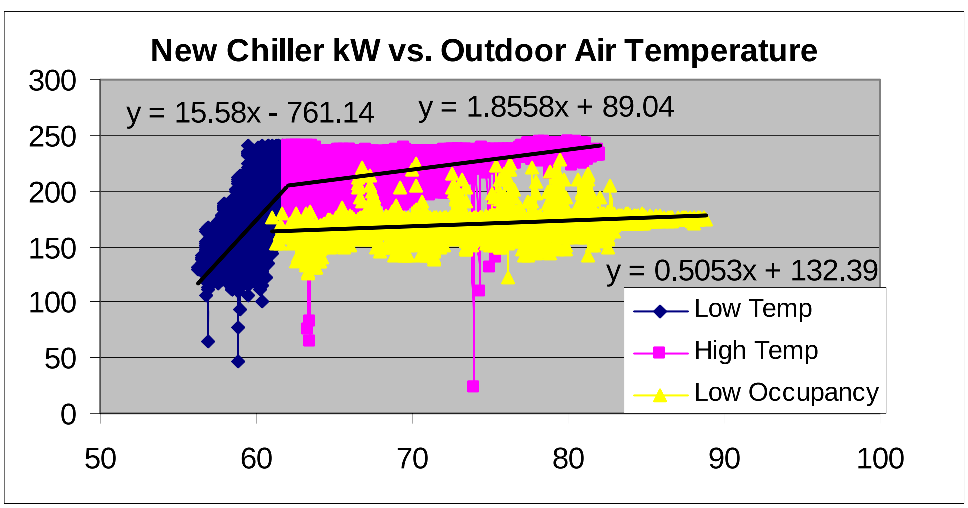
Figure 2: EMS Data – New VFD Chiller



The data above for the new chiller show two distinct patterns. Regression against only temperature leads to poor correlation. After reviewing the data, it appears that the chiller is responding to chilled water demand, which tracks occupancy patterns throughout the day. The building automation system shuts off fan coil units in unoccupied rooms, then restarts the fan coil units when the room is scheduled to be occupied. This is also illustrated when chiller demand is viewed as a function of time of day.

In order to produce better correlation, the data was separated in to three categories; low temperature operation, high temperature operation, and low occupancy operation. This data is presented in Figure 3 below.

Figure 3: EMS Data – New VFD Chiller



The hours of operation for this chiller are expected to cover nearly all hours of the year, according to the facility representative. The new chiller will operate during peak times in conjunction with the older existing chiller to meet the required demand. The new chiller will also operate during the remainder of the year when only one chiller is required. In addition, based on the metered data, the new chiller operates in the "low occupancy" condition for approximately 28% of the operating hours.

The ex post impacts are calculated using trend data from the EMS. Chiller demand is measured directly by the EMS and correlated to ambient outdoor air temperature. A weak linear relationship exists between chiller kW and ambient outdoor air temperature when the data is parsed into high temperature, low temperature, and low occupancy categories. The ex post impacts are shown in Figure 4 below. Note that the energy and demand were calculated at each bin temperature using the linear relationship. Bin hours for each temperature were obtained from NOAA weather data for the San Diego area.

Figure 4: Energy and Demand Formulae

Pre-Retrofit Demand kW	= Chiller kW from EMS data (at each Bin temperature)
Post-Retrofit Demand kW	= Chiller kW from EMS data (at each Bin temperature)
Peak Demand Savings	= Peak Pre-Retrofit Demand kW – Peak Post-Retrofit kW = 365.12 kW – 269.05 kW = 96.06 kW
Pre-Retrofit kWh	= $\sum$ (Pre-Retrofit Demand kW_{bin} x Pre-retrofit $Hours_{bin}$)
Post-Retrofit kWh	= $\sum$ (Post-Retrofit Demand kW_{bin} x Post-retrofit $Hours_{bin}$)
Energy Savings	= Pre-Retrofit kWh – Post-Retrofit kWh = 2,089,488 kWh/yr – 1,515,384 kWh/yr = 574,104 kWh/yr

The ex post kW demand reduction are greater than the ex ante estimate because the ex ante calculations overestimated the demand associated with the new chiller and underestimated the demand associated with the old chiller. The energy savings are greater than the ex ante estimate due to the underestimated demand savings and inaccurate assumptions for hours of operation and load profile. The SPC calculator uses an assumed 7,337 hours per year of operation,. However, based on the recorded data, the chiller is expected to operate over 8,500 hours per year. In addition, the data suggests that the chiller has a load factor of nearly 66%. This value is high for typical chiller loading, however, is not unreasonable for a base-loaded chiller with a second chiller operating a portion of the year.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. The customer did not give any drawbacks associated with the new equipment. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the

2004/2005 SPC Program has not encouraged them to perform any other energy efficiency projects for which they did not participate in an incentive program.

The pre-retrofit chiller operation was able to be substantiated to a relatively high degree, because an identical chiller remains in use as a back-up/supplemental chiller, and this chiller was operational during the on-site due to an equipment malfunction. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

7. Impact Results

Based on the ex ante savings of 38.3 kW and 459,539 kWh, the engineering realization rate for this application is 2.51 for kW reduction and 1.25 for energy savings kWh. The kwh values shown in the tracking system *do not* agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 2.

Table 2: Realization Rate Summary

	kW	KWh	Therm
SPC Tracking System	38.3	459,539	-
SPC Installation Report (ex ante)	38.3	4,595,390	-
Impact Evaluation (ex post) - First Year Savings	96.1	574,104	-
Engineering Realization Rate (First Year)	2.51	1.25	N/A
Impact Evaluation (ex post) - Average Savings	51.98	464,883	
Engineering Realization Rate (Average)	1.36	1.01	

Average engineering realization rate was based on average energy savings after ten remaining years of useful life over baseline Title 24 compliant equipment.

Utility billing data for the site was reviewed. In 2003 (pre-retrofit), the facility consumed 11,272,027 kWh. Peak demand was 2,254.8 kW in August/September 2003. Table 3 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 3: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	2,254.8	11,272,027
Baseline End Use	365.12	2,089,488
Ex ante Savings	38.3	459,539
Ex Post Savings	96.0642	574,104

Baseline end use for one existing chiller only.

Table 4 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations.

Table 4: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	1.70%	4.08%	4.26%	5.09%
Baseline End Use %	10.49%	21.99%	26.31%	27.48%

With a cost of $281,700 and a $140,850 incentive, the project had a 2.36 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 1.89 years. A summary of the economic parameters for the project is shown in Table 5.

Table 5: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), ($0.80/therm) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	7/15/2005	$281,700	38.3	459,539	0	$59,740	$140,850	2.36	4.72
SPC Program Review (Ex Post)	9/6/2007	$281,700	96.1	574,104	0	$74,634	$140,850	1.89	3.77

It was determined that the chiller retrofit project was defined as a Chiller – Variable Speed Drive in the California Public Utilities Commission *Energy Efficiency Policy Manual Version 2.* Therefore, the chiller was assumed to have a useful life of twenty (20) years. Note that the SPC Calculator uses 23 years as the useful life of the centrifugal chiller. A summary of the multi-year reporting requirements is given in Table 6.

Table 6: Multi-Year Reporting Requirements

Program Name:		SPC 04-05 Evaluation Site A016					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	229,770	287,052	38.3	96.1	0	0
2	2005	459,539	574,104	38.3	96.1	0	0
3	2006	459,539	574,104	38.3	96.1	0	0
4	2007	459,539	574,104	38.3	96.1	0	0
5	2008	459,539	574,104	38.3	96.1	0	0
6	2009	459,539	574,104	38.3	96.1	0	0
7	2010	459,539	574,104	38.3	96.1	0	0
8	2011	459,539	574,104	38.3	96.1	0	0
9	2012	459,539	574,104	38.3	96.1	0	0
10	2013	459,539	574,104	38.3	96.1	0	0
11	2014	407,600	509,217	7.9	19.8	0	0
12	2015	355,661	444,329	7.9	19.8	0	0
13	2016	355,661	444,329	7.9	19.8	0	0
14	2017	355,661	444,329	7.9	19.8	0	0
15	2018	355,661	444,329	7.9	19.8	0	0
16	2019	355,661	444,329	7.9	19.8	0	0
17	2020	355,661	444,329	7.9	19.8	0	0
18	2021	355,661	444,329	7.9	19.8	0	0
19	2022	355,661	444,329	7.9	19.8	0	0
20	2023	355,661	444,329	7.9	19.8	0	0
TOTAL	**2004-2023**	7,974,170	9,962,169			0	0

Extrapolation after 10 year useful life begins in July 2005. Baseline efficiency based on SPC Calculator results – savings are 77% for kWh and 21% for kW.

Note: The annual savings were correctly reported for the single year savings in the tracking system. The realization results for the evaluation results are the same as the results reported in the site reports (1.25). The Installation Report Review notes savings of 4,595,390 kWh (the full ten years of savings over the remaining useful life of the chiller over the existing equipment). This was a discrepancy in the paperwork only and did not affect the tracking system or claimed savings.

FINAL REPORT

SITE A017 2004-xxx Hilt IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 5 END USE: Other

Measure	Install Variable Frequency Drives (VFDs) and controls on two (2) 15 HP condenser water pumps and one (1) 15 HP chilled water (glycol) pump
Site Description	Hotel

1. Measure Description

Variable Frequency Drives (VFDs) were installed on two (2) 15-HP condenser water pumps and one (1) 15-HP chilled water (glycol) pump. Prior to the installation of the VFDs, flow was controlled through the use of throttle control valves.

2. Summary of the Ex Ante Calculations

The Variable Speed Drive for Process Motors portion of the SPC Calculation software was used to determine the annual savings. For the two (2) 15-HP condenser water pumps and the one (1) 15-HP chilled water pump, the savings are based on the retrofit of the controls from a throttling control valve to VFD. The SPC calculator determines the kW for each control scheme at 10% flow intervals using standardized unloading curves. The kWh savings are then determined by summing the kW savings at each interval multiplied by the hours at each interval.

The ex ante results determined by the 2004 SPC calculator are:

For the two (2) 15-HP condenser water pump VFDs:

Pre-Replacement Usage	21 kW	150,605 kWh
Post-Replacement Usage	12 kW	49,097 kWh
Peak Summer Impact & Annual Savings	9 kW	101,508 kWh

For the one (1) 15-HP chilled water pump VFD:

Pre-Replacement Usage	10 kW	76,157 kWh
Post-Replacement Usage	6 kW	24,827 kWh
Peak Summer Impact & Annual Savings	4 kW	51,330 kWh

For the three (3) pump VFDs combined:

Pre-Replacement Usage	31 kW	226,763 kWh
Post-Replacement Usage	18 kW	73,924 kWh
Peak Summer Impact & Annual Savings	13 kW	152,838 kWh

Although the 2004 SPC calculator gives a total of 13 kW savings for the retrofit, no credit was taken for these savings in the utility analysis.

3. Comments on the Ex Ante Calculations

The installation report review shows savings of 152,838 kWh/year and 0.0.kW. These figures agree with the utility tracking system figures.

The Variable Speed Drive for Process Motors portion of the SPC Calculator was used to determine the annual savings. In the pre-retrofit condition, the flow was considered, for both the condenser and the chilled water pumps, to be balanced with a throttling control valve. Based on customer feedback, the throttling valve was set to the nearly 50% closed position, which is expected to yield approximately 80% of full flow. In the post-retrofit condition, the two (2) 15-HP condenser pumps and the one (1) 15-hp chilled water pump are expected to operated for 20% of the time at each of the following conditions: 40% flow, 50% flow, 60% flow, 70% flow, and 80% flow. The two (2) condenser water pumps are expected to operate 20 hours per day, 365 days per year. The one (1) chilled water pump is expected to operate 20 hours per day, 365 days per year.

The following paragraphs highlight notable deficiencies regarding the ex ante calculations.

In the original calculations, a pre-retrofit control method of throttled control valve was selected in the SPC calculator. This is consistent with the description by the site representative in the project file stating that the pre-retrofit piping incorporated control valves throttled to about 50% position. The post-retrofit flow rate consists of 20% of the time period at 40%, 50%, 60%, 70%, and 80% levels. For the pre-retrofit condition, the ex ante calculations assume a constant flow of 100% for the entire operating time period. In the adjusted ex ante calculations, the throttle valve is considered to remain at a constant 80% flow condition, based on the customer description of operation provided in the original application.

In the original calculations, all three pumps are expected to operate 20 hours per day, 365 days per year. The customer provided total hours, running hours, and kWh values for all three post-retrofit VFDs and pumps, collected on 9/3/04. At this time, the post-retrofit VFDs had been in operation for approximately three (3) months. Condenser pump P1 had been in operation 2,178 hours, of which it ran 2,011 hours, or approximately 92% of the time. Condenser pump P2 had been in operation 2,197 hours, of which it ran 2,029 hours, also approximately 92% of the time. The chilled water pump, P7, had been in operation 2,174 hours, of which it ran 1,449 hours, or approximately 67% of the time. Because the operation of the condenser and chilled water pumps is expected to be temperature sensitive, and the period originally metered included the warmest months of the year, the daily hours of operation of the pumps is expected to be greater than average, therefore, the condenser pumps, at 22 hours per day, are not considered to deviate significantly from the expected 20 hours of operation. The chilled water pumps, however, at 16 hours per day, are operated significantly less than the 20 hours per day in the original calculations. Per discussion with the site representative, the chilled water pump operates in conjunction with an ice storage system, during off peak hours. Therefore, sixteen hours per day was used in commenting on the ex ante calculations.

The adjusted ex ante results determined by the 2004 SPC calculator are:

For the two (2) 15-HP condenser water pump VFDs:

Pre-Replacement Usage	18.4 kW	134,039 kWh
Post-Replacement Usage	11.8 kW	49,097 kWh
Peak Summer Impact & Annual Savings	6.6 kW	84,942 kWh

For the one (1) 15-HP chilled water pump VFD:

Pre-Replacement Usage	9.2 kW	54,224 kWh
Post-Replacement Usage	5.9 kW	19,862 kWh
Peak Summer Impact & Annual Savings	3.3 kW	34,362 kWh

For the three (3) pump VFDs combined:

Pre-Replacement Usage	27.7 kW	188,263 kWh
Post-Replacement Usage	17.7 kW	68,959 kWh
Peak Summer Impact & Annual Savings	10.0 kW	119,304 kWh

4. Measurement & Verification Plan

The facility is a 14-story hotel with approximately 350 rooms. It was constructed in 1987. The building is occupied continuously at varied occupancy levels. According to the application, before the retrofit, two (2) 15-HP condenser water pumps and one (1) 15-HP chilled water pump operated 20 hours per day, 7 days per week. The flow was controlled through the use of throttling control valves, which were closed to the approximately 50% position on all three pumps. After the retrofit, all three pumps were controlled through the use of variable frequency drives.

The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction due to the installation of the VFDs on the two (2) 15-HP condenser water pumps and one (1) 15-HP chilled water pump.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. The usage of the pumps is not expected to remain consistent enough for single point measurements to be representative of the average usage. Seasonal variation is expected to be somewhat variable and two weeks may yield reliable seasonal estimates; however, a longer period would more fully capture actual variations during different seasons and the persistence of savings. Interval data on a 15-minute or less basis, preferably during the summer months of June to September, would be needed to accurately determine utility peak period demand savings.

Pre-retrofit and post-retrofit calculations of condenser water and chilled water pump motor loads and energy use will be calculated using the following formulae:

Post-installation

Peak kW = kW_{bin} at maximum temperature bin

kWh = $\Sigma(kW_{bin} \times hours_{bin})$ where the kW_{bin} and $hours_{bin}$ values are determined from the metered data and local weather data

Pre-installation

Peak kW = kW_{bin} from adjusted ex ante calculations

$kWh = \Sigma(kW_{bin} \times hours_{bin})$ where the $hours_{bin}$ values are determined from the metered data and local weather data.

The most significant variables to be quantified are the pre-retrofit and post-retrofit hours of operation and the pre and post retrofit kW demand profiles of the pumps. Pre-retrofit hours will be confirmed with the site personnel to verify that the running hours listed in the application (7,300 hours per year) were valid. If required, appropriate modifications for the savings calculations will be made to the pre-retrofit usage figures, possibly based on post-retrofit monitoring, in order to establish a realistic baseline for energy use.

The installation of the three (3) VFDs will be physically verified during the onsite visit.

The post-retrofit energy consumption will be verified by installing Hobo FlexSmart data loggers with WattNode WNA-3D-480-P watt-hour transducers and Magnalab SCT-1250-200 current transformers on the power supplied to the VFD. The energy consumption of the pumps will be logged with a sampling delay of no greater than 1 minute, for a minimum of 14 days to verify the post-retrofit energy consumption. In addition, the outdoor air temperature and relative humidity at the facility will be monitored using no less than two (2) Hobo H8 loggers. If possible, the daily occupancy level for the logged period will be verified with the customer representative. The logged kWh per unit output will then be used in conjunction with temperature and occupancy effects to determine the annual usage.

The greatest uncertainty in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit hours of operation. The running hour data from the VFD controller screen recorded by the customer was inconsistent with the customer's original description of the operating hours. It may be possible to verify the accuracy of these run time figures, and attempts will be made to this effect. These numbers can provide valuable checks on annualized figures.

Uncertainty for the savings estimate for the pump VFD retrofit can be more fully understood by setting projected ranges on the primary variables.

<u>For the Pre-Retrofit Condenser Water and Chilled Water Pumps</u>

- Throttled condenser pumps average total kW of 18.4 kW, maximum of 23.0 kW, minimum of 13.8 kW (±25%, based on judgment of deviation from typical throttled condition pump unloading curve in the SPC calculator, deviation from judgment of pump brake horse power input to SPC calculator, and deviation from judgment of throttled flow rate)
- Throttled condenser pumps average total hours of operation of 2 pumps each operating 7,300 hours for a total running hours of 14,600 running hours expected, maximum of 16,800 running hours, minimum of 7,300 running hours (+15%, -50%, based on judgment of deviation from discussions with customer representative and typical operating conditions for similar facilities)
- Throttled chilled water pumps average total kW of 9.2 kW, maximum of 11.5 kW, minimum of 6.9 kW (±25%, based on judgment of deviation from typical throttled condition pump unloading curve in the SPC calculator, deviation from

judgment of pump brake horse power input to SPC calculator, and deviation from judgment of throttled flow rate)

- Throttled chilled water pump average hours of operation of 5,840 running hours expected, maximum of 8,176 running hours, minimum of 4,380 running hours (+40%, -25%, based on judgment of deviation based on discussions with customer representative and typical operating conditions for similar facilities)

For the Post-Retrofit Condenser Water and Chilled Water Pumps

- VFD controlled condenser pumps average total kW of 5.9 kW, maximum of 8.9 kW, minimum of 4.4 kW (+50%, -25% based on judgment of deviation from typical VFD pump unloading curve in the SPC calculator, deviation from judgment of pump brake horse power input to SPC calculator, and deviation from judgment of throttled flow rate)
- VFD controlled condenser pumps hours of operation are 7,300 hours expected for each pump, maximum of 8,400 running hours, minimum of 3,650 running hours (+15%, -50%, based on judgment of deviation based on discussions with customer representative and typical operating conditions for similar facilities)
- VFD controlled chilled water pump average total kW of 5.9 kW, maximum of 8.9 kW, minimum of 4.4 kW (+50%, -25% based on judgment of deviation from typical VFD pump unloading curve in the SPC calculator, deviation from judgment of pump brake horse power input to SPC calculator, and deviation from judgment of throttled flow rate)
- VFD controlled chilled water pump average hours of operation of 5,840 running hours expected, maximum of 8,176 running hours, minimum of 4,380 running hours (+40%, -25%, based on judgment of deviation based on discussions with customer representative and typical operating conditions for similar facilities)

For the Condenser Water and Chilled Water Pump Retrofit

- 119,304 kWh expected savings, minimum 69,811 kWh, maximum 179,066 kWh (-42.5%, +50.1%, based on pre-retrofit and post-retrofit pump operation above)
- 10.0 kW expected savings, minimum 3.9 kW, maximum 18.4 kW (-61.1%, +83.6%, based on pre-retrofit and post-retrofit pump operation above)

Accuracy and Equipment

The Hobo FlexSmart loggers have a resolution of ±10 seconds. The WattNode watt-hour transducers have an accuracy of ±0.50%, and the Magnelab SCT-075-050 current transformers have an accuracy of ±1.5%. The Hobo H8 temperature and relative humidity loggers have an accuracy of ±1% for temperature and ±3% for relative humidity.

Annualizing the data based on the reporting period is estimated to result in possible inaccuracies of +/- 20%.

The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to Microsoft Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on June 7, 2007. Information on the retrofit equipment and operating conditions was collected by inspection and by interviewing the facility representative. Three kW/kWh loggers were installed on the three pumps for the period of June 7 through August 9, 2007.

5.1. *Installation Verification*

The facility representative verified that the pre-retrofit chilled water pumps and condenser water pumps did not have VFDs and that the pumps were running at constant flow in a throttled condition.

It was physically verified that the chilled water pumps and condenser water pumps had VFDs installed on them. The facility representative stated that the retrofit was completed in May or June 2004.

These are the only measures in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	AC&R Measure Description	Lighting Measure Description	Other / Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
VFD on 2 CHW & 1 CDW Pumps	O			VFD HVAC	3	VFDs on HVAC Pump Motors	Physically verified installation of VFDs	1.00

5.2. *Scope of the Impact Assessment:*

The impact assessment scope is for the VFD installation on three (3) HVAC pump motors. These are the only measures in this application.

5.3. *Summary of Results:*

Three (3) Hobo Wattnodes were installed on the pumps from June 7 through August 9, 2007 to measure the operating hours and power consumption. The facility representative stated that the monitoring period had been representative of normal facility operation.

The two condenser pumps operate when the respective chillers are in operation. One of the chillers provides cooling directly to the facility, but only operates during the hottest times of the year (approximately 10% of the year, according to the facility representative). The other chiller is used to make ice during off-peak times, but also provides chilled water to the facility during evening and weekend off-peak times (the ice storage system appears to be bypassed during the weekend). The pump that circulates through the ice storage system operates all year, except during weekends, when the chillers are used directly to provide chilled water. A period of metered data for the three pumps during the non-summer time (June) is shown in Figure 1, and a period for the three pumps during the peak summer time (July/August) is shown in Figure 2.

Figure 1: Non-Summer Metered Data

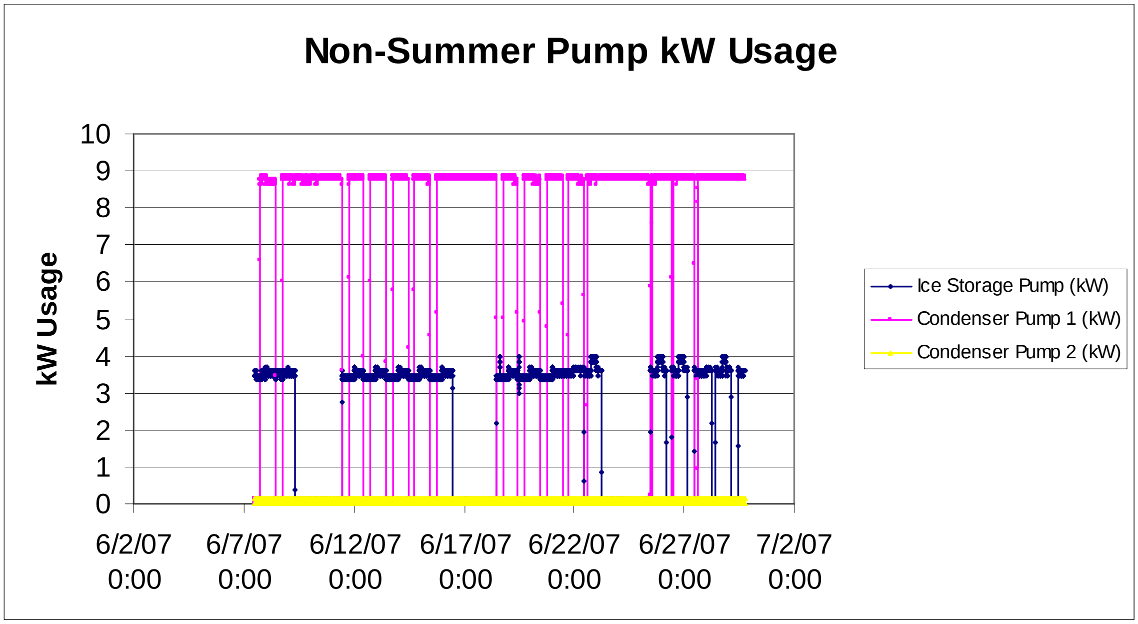
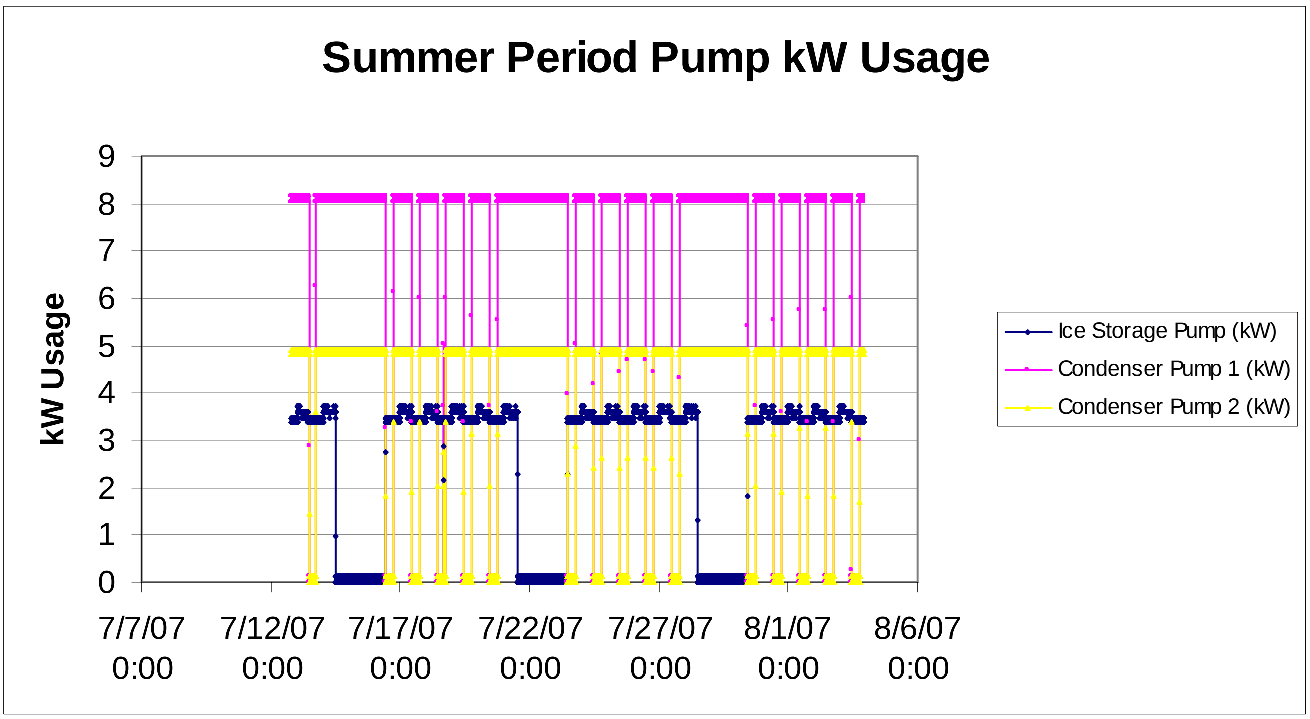


Figure 2: Peak Metered Data



Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load.

The ex post impacts are calculated in Figure 3 below:

Figure 3: Energy and Demand Formulae

The following formulas include all affected motors combined.

Pre-Retrofit Demand kW_{peak} = Adjusted Ex Ante kW
= 9.2 kW x 3 motors
= 27.6 kW

Post-Retrofit Demand kW_{peak} = Peak kW (from data logging)
= 3.5 kW + 8.1 kW + 4.8 kW
= 16.4 kW

Peak kW Savings = Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak}
= 27.6 kW – 16.4 kW = 11.2 kW

Pre-Retrofit kWh = Pre-Retrofit Demand x Sum of Hours
= 146,849 kWh/yr

Post-Retrofit kWh = Post-Retrofit Demand x Sum of Hours
= 87,539 kWh/yr

kWh Savings = Pre-Retrofit kWh – Post-Retrofit kWh
= 146,849 kWh/yr – 87,539 kWh/yr
= 59,310 kWh/yr

The ex ante calculations did not include demand savings.

In the original calculations, the hours of operation were estimated for all three pumps to be 7,280 per year. According to the facility representative, one of the condenser pumps only operates about 10% of the year. The other condenser pump would operate for the specified 7,280 hours per year. The chilled water pump (for the ice system) will likely operate less than 7,280 hours per year, as it is not used on the weekends. Based on the logging results, the hours are approximately 6,000 per year. These statements are corroborated by the logged data.

In addition, the chilled water pump (for the ice storage system) is running at a BHP of 73% nameplate HP, based on the logged data. The condenser water pumps are running at a BHP of 85% nameplate HP, based on the logged data. This was likely not accounted for in the original calculations.

The ex post energy savings is less than the ex ante energy savings because the ex ante calculations overestimated the pre-retrofit demand values as well as the hours of operation.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the vendor invoice for the work performed for the project and is an accurate reflection of the project cost. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program has not encouraged them to perform any other energy efficiency projects.

We were unable to physically verify the pre-retrofit equipment or hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

7. Impact Results

Based on the ex ante savings of 152,838 kWh, the engineering realization rate for this application is 0.39 for energy savings (kWh). A summary of the realization rate is shown in Table 1.

Table 1: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	-	152,838	-
SPC Installation Report (ex ante)	-	152,838	-
Impact Evaluation (ex post)	11.2	59,310	-
Engineering Realization Rate	N/A	0.39	NA

Utility billing data for the site was reviewed. Annual usage prior to the retrofit was 2,412,209 kWh. Peak demand was 362.0 kW. Table 2 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	362.0	2,412,209
Baseline End Use	27.60	146,849
Ex ante Savings	-	152,838
Ex Post Savings	11.2	59,310

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations.

Table 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	0.0%	6.3%	3.1%	2.5%
Baseline End Use %	0.0%	104.1%	40.4%	40.4%

With a cost of $32,000 and a $12,227 incentive, the project had a 1.00 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 2.56 years. A summary of the economic parameters for the project is shown in Table 4.

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	10/12/2004	$32,000	-	152,838	0	$19,869	$12,227	1.00	1.61
SPC Program Review (Ex Post)	9/24/2007	$32,000	11.2	59,310	0	$7,710	$12,227	2.56	4.15

It was determined that the VFD installation project was defined as an Adjustable Speed Drive measure in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the VFDs were assumed to have a useful life of fifteen (15) years. A summary of the multi-year reporting requirements is given in Table 5. Because this measure was installed in June 2004 the energy savings in year #1 (2004) are assumed to be 50% of the expected annual savings for this measure.

Table 5: Multi-Year Reporting Requirements

Program Name:		SPC 04-05 Evaluation Site A017					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	76,419	29,655			0	0
2	2005	152,838	59,310	0	11.16	0	0
3	2006	152,838	59,310	0	11.16	0	0
4	2007	152,838	59,310	0	11.16	0	0
5	2008	152,838	59,310	0	11.16	0	0
6	2009	152,838	59,310	0	11.16	0	0
7	2010	152,838	59,310	0	11.16	0	0
8	2011	152,838	59,310	0	11.16	0	0
9	2012	152,838	59,310	0	11.16	0	0
10	2013	152,838	59,310	0	11.16	0	0
11	2014	152,838	59,310	0	11.16	0	0
12	2015	152,838	59,310	0	11.16	0	0
13	2016	152,838	59,310	0	11.16	0	0
14	2017	152,838	59,310	0	11.16	0	0
15	2018	152,838	59,310	0	11.16	0	0
16	2019	76,419	29,655	0	11.16	0	0
17	2020					0	0
18	2021					0	0
19	2022						
20	2023						
TOTAL	2004-2023	2,292,570	889,647				

FINAL REPORT

SITE A018 (2050-04) Onea **IMPACT EVALUATION**
SAMPLE CELL: ORIGINAL TIER: 3 END USE: Other

Measure	1. Install VFDs on twenty three (23) 15 HP, five (5) 10 HP and one (1) 7.5 HP AHU Fans 2. Install VFDs and Controls on three (3) 200 HP Chilled Water Pumps and three (3)100 HP Condenser Water Pumps
Site Description	Office Tower

1. Measure Description

The customer implemented two measures to reduce the energy usage used for AC&R for an office building.

Measure #1 is the installation of VFDs on twenty-nine air handling units. VFDs were installed on twenty-three 15-HP fans, five 10-HP fans, and one 7.5-HP fan. Prior to the installation of the VFDs, the fans were modulated through the use of inlet vanes. In the post-installation case, the inlet vanes were locked in the wide-open position.

Measure #2 is the installation of VFDs on chilled water and condenser water pumps. VFDs were installed on three-200 HP chilled water loop pumps and three-100 hp condenser water pumps. Prior to the installation, the pumps were modulated to the desired maximum flow through the use of throttling valves, to approximately 90% full load flow condition. In both the pre-installation and post-installation case, only one of the three chilled water pumps and one of the three condenser water pumps operate at any given time.

2. Summary of the Ex Ante Calculations

The VFDs on HVAC fans used the itemized measure values to determine the ex ante impacts for measure #1. However, there were no demand savings. The energy savings in the tracking system were calculated using the estimate of 753.0 kWh/hp, using 402.5 hp).

For the second measure, the VFDs on the condenser water and chilled water pumps, the SPC Calculator Variable Speed Drive for Processes module was used to calculate the energy and demand savings. The SPC Calculator uses a user defined load profile for both the existing and proposed case to determine the savings.

The ex ante results from the Installation Report Review (IRR) anrd the utility tracking system, are:

Measure #1 - AHU VFDs:
Annual Savings - 179,790.3 kWh/ yr and 10.1 kW in the IRR (this value does not agree with the tracking system, which shows 303,083 kWh and 0 kW savings, and also incorrectly lists the end use category as H for HVACR or AC&R).

Measure #2a - Condenser Water Pump VFDs:

Pre-Replacement Usage -	600,759 kWh
Post-Replacement Usage -	114,847 kWh
Annual Savings -	485,912 kWh

Measure #2b - Chilled Water Pump VFDs:

Pre-Replacement Usage -	1,202,611 kWh
Post-Replacement Usage -	243,721 kWh
Annual Savings -	958,890 kWh

Measure 2 savings - 1,444,802 kWh (1,444,803 kWh in tracking system)

Both Measures Combined:

Annual Savings -	1,747,886 kWh, 0 kW tracking system
Annual Savings -	1,624,593.3 kWh, 10.1 kW ex ante (IRR)

3. Comments on the Ex Ante Calculations

The ex ante impacts for the condenser water and chilled water pumps were determined using the VFD on HVAC Fans program within the SPC Calculator. Within the SPC Calculator, VFDs on HVAC fans appear to be treated as an itemized or prescribed measure. The demand and energy savings seem to be determined from the utility workpapers based on an energy reduction of 753.0 kWh per year for each horsepower of HVAC fan motor. No credit is taken for any demand reduction due to the installation of the VFDs on the fan motors. This is a conservative assumption.

The energy and demand savings of the condenser water and chilled water pumps was determined using the VFD on Process Applications module within the SPC Calculator. The savings were calculated using motor information and a user defined loading profile. In both the condenser water pump and chilled water pump projects, the pre-retrofit operation is a 90% full flow condition for 8,736 hours per year. The post-retrofit condenser water pumps are expected to operate at 40% flow for 66% of the hours of operation. The remaining hours of operation are distributed within the range of 50% to 90% flow conditions. The post-retrofit chilled water pumps are expected to operate at 40% flow for 76% of the hours of operation. The remaining hours of operation are distributed within the range of 50% to 90% flow conditions. In both cases, no credit is taken in the utility work papers for the demand savings calculated by the SPC Calculator. Again, this is conservative, as there is likely over-sizing to cover any margin of error in the design. The pumps would probably not need to run at design flow under actual design conditions.

4. Measurement & Verification Plan

The facility is a 33 story, 506 ft tall office tower, which was constructed in 1991. The office tower has a floor area of 614,656 sq. ft. and is expected to be potentially occupied at any time during the week, with periods of peak occupancy occurring weekdays from 8:00 am to 5:00 pm. According to the application, before the installation, the HVAC fans were constant speed with inlet vanes to control flow. The condenser water pumps and chilled water pumps were also constant speed. The post-installation system includes the installation of VFDs on fan and pump motors, which reduces the energy consumption of the system.

The goal of the M&V plan is to estimate the actual kWh reduction due to the installation of VFDs on 29 AHU fans, three condenser water pumps, and three chilled water pumps, over the useful life of the new equipment.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. The AHU motors and pump motors in question are not expected to consume a large percentage of the facility's total usage. Also, the usage of the motors is not expected to remain consistent enough for single point measurements to be representative of the average usage.

Seasonal variation is expected to be predictable and two weeks should be sufficient to calibrate an energy savings model; however, a longer period would more fully capture actual variations and the persistence of savings. Interval data on a 15-minute or less basis, preferably during the summer months of June to September, would be needed to more accurately determine coincident peak period demand savings.

Pre-retrofit and post-retrofit calculations of demand and energy loads will be calculated using the following formulae:

For the AHU VFDs:

Peak coincident kW Savings = motor full load kW x load factor x (peak inlet vane kW load factor - peak VFD kW load factor)

Average kW Savings = motor full load kW x load factor x (average inlet vane kW load factor - average VFD kW load factor)

kWh Savings = Average kW Savings x hours of operation

For the Condenser Water Pump VFDs:

Peak coincident kW Savings = motor full load kW x load factor x (peak throttled kW load factor-peak VFD kW load factor)

Average kW Savings = motor full load kW x load factor x (average throttled kW load factor-average VFD kW load factor)

kWh Savings = Average kW Savings x hours of operation

For the Chilled Water Pump VFDs:

Peak coincident kW Savings = motor full load kW x load factor x (peak throttled kW load factor - peak VFD kW load factor)

kWh Savings = Σ (Pre-Retrofit $\text{Demand}_{\text{Bin}}$ x $\text{Hours}_{\text{Bin}}$)

The majority of the savings are from the chilled water pump VFD installation. Therefore, the evaluation will focus on this aspect of the project.

For the project, the most significant variables to be quantified are the decrease in kW load factor due to the improved part load energy consumption of the pump and fan motors with the VFDs. Site personnel will be interviewed to verify the pre-retrofit flow control method for the pump and fan motors. Care will be taken to determine any changes in flow characteristics due to installation. In addition, site personnel will be interviewed to attempt to more accurately determine annual variations and patterns in flow rates if possible.

The post-retrofit energy consumption for the chilled water and condenser water pump VFDs as well as the AHU VFDs will be verified by collecting no less than four weeks of collected data from the customer's EMS software package. The collected data from the EMS software will then be used in conjunction with local temperature data to determine annual usage.

If the customers EMS data is unavailable or incomplete, the post-retrofit energy consumption for the chilled water and condenser water pumps will be verified by installing Hobo FlexSmart data loggers with WattNode WNA-3D-480-P watt-hour transducers and Magnalab SCT-1250-200 current transformers on the power supplied to the VFD. The energy consumption of the pumps will be logged with a sampling delay of no greater than 1 minute, for a minimum of 14 days to verify the post-retrofit energy consumption. In addition, the consumption for the AHU fans will be verified by installing Hobo H8 4-channel external loggers with Onset CTV-B or CTV-C current transformers on the power supplied to the VFD for no less than eight (8) AHU fans. In addition, the outdoor air temperature (OAT) and relative humidity (RH) at the facility will be monitored using no less than one (1) Hobo H8 logger. The logged kWh per unit output will then be used in conjunction with temperature and occupancy effects to determine the annual usage.

Uncertainty for the savings estimate for this AHU fan and pump VFD project can be more fully understood by setting projected ranges on the primary variables.

<u>For the AHU VFDs</u>

- 179,790 kWh expected, maximum of 632,842 kWh, minimum of 82,300 kWh (+252.0%, -44.2 %, based on judgment of deviation from expected hours of operation, full load kW, and average kW load factors)

For the Chilled Water and Condenser Water Pump VFDs

- 485,912 kWh expected for the condenser water pump VFDs, maximum of 525,770 kWh, minimum of 184,938 kWh (+14.6%, -59.7 %, based on judgment of deviation from expected hours of operation, full load kW, and average kW load factors)
- 958,890 kWh expected for the chilled water pump VFDs, maximum of 1,090,747 kWh, minimum of 420,353 kWh (+13.8%, -56.2%, based on judgment of deviation from expected hours of operation, full load kW, and average kW load factors)
- 1,444,802 kWh expected for the condenser and chilled water pump VFDs combined, maximum of 1,616,517 kWh, minimum of 605,291 kWh (+11.9%, -58.1%, based on above information)

For the Two AC&R Improvements Combined

- 1,624,592 kWh expected for the AHU VFDs and the condenser and chilled water pump VFDs combined, maximum of 2,101,167 kWh, minimum of 1,012,486 kWh (+29.3%, -37.7%, based on above information)

Accuracy

The Hobo FlexSmart loggers have a resolution of ±10 seconds. The WattNode Watt-Hour transducers have an accuracy of ±0.45%+0.05%FS, and the Magnelab SCT-1250-200 current transformers have an accuracy of ±1.5%. The kWh loggers have a combined accuracy of ±2.0%+0.05%FS. The Onset current transformers have an accuracy of ±5%FS. The Hobo H8 current loggers have an accuracy of ±3%. The current loggers have a combined accuracy of ±8%. The Hobo H8 temperature and relative humidity loggers have an accuracy of ±1.3F (within the range of –4F to 104F) for temperature and ±5% for relative humidity.

The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to Microsoft Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on June 8, 2007. Information on the retrofit equipment and operating conditions was collected by inspection and by interviewing the facility representative. Trend data for all AHUs and pumps were obtained from the facilities EMS software.

5.1. Installation Verification

The facility representative verified that the pre-retrofit air handling units, chilled water pumps, and condenser water pumps did not have VFDs.

It was physically verified that the air handling units, chilled water pumps, and condenser water pumps had VFDs installed on them. The facility representative stated that the retrofit was completed prior to August 2005. A number of the AHUs were originally designed to have 10-hp motors on the fans. In order to standardize motor sizes at the facility, they have been replacing the 10-hp motors with 15-hp motors when replacement is necessary. Original motor counts were fourteen 15-hp motors, fourteen 10-hp motors and one 7.5-hp motor.

These are the only measures in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
VFD on 29 AHU Fans	O - Other	VFD HVAC			29	VFDs on HVAC Fan Motors	Physically verified installation of VFDs	1.00
VFD on 3 CHW & 3 CDW Pumps	O -Other	VFD HVAC			6	VFDs on HVAC Pump Motors	Physically verified installation of VFDs	1.00

5.2. Scope of the Impact Assessment:

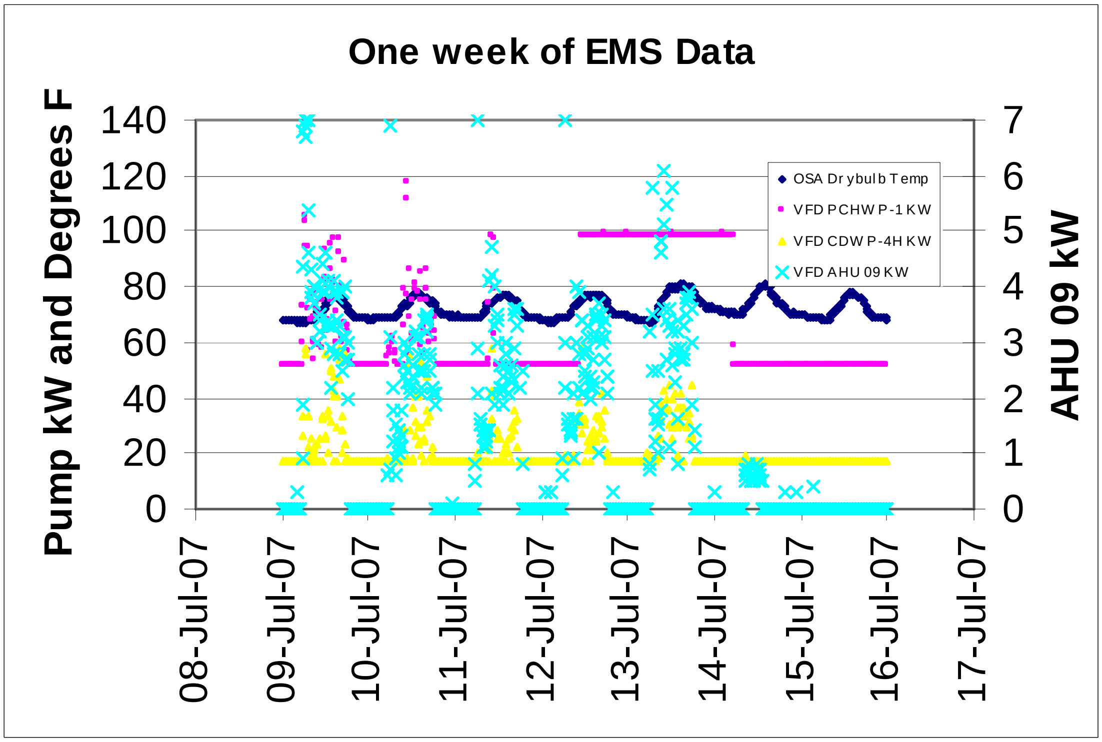
The impact assessment scope is for the VFD installation on twenty-nine (29) AHU fan motors and six (6) HVAC pump motors. These are the only measures in this application. Note that only two of the six HVAC pumps are in operation at any one time.

5.3. Summary of Results:

EMS data was obtained for the HVAC fans and pumps for 16 days (from July 7 to July 23, 2007) to measure the operating hours and power consumption. In addition, the OAT temperature was recorded using the facility EMS system. The facility representative stated that the monitoring period is representative of normal facility operation. The facility representative stated that this facility is predominantly occupied from approximately 8:00 a.m. to 6:00 p.m., 5 days per week. During the remainder of the week, the facility is expected to be generally unoccupied, with periods of very light occupancy occurring occasionally.

It was determined from the EMS data that only one each of the chilled water pumps and condenser water pumps are in operation at any one time. In general, the pump speed fluctuates as needed during the occupied time periods, and operates at a fixed minimum during unoccupied periods. The AHUs operate similarly according to the occupied period. However, the fans are in unoccupied mode during unoccupied periods, and only cycle on as needed to maintain temperature. Fan speed of the AHUs fluctuates during occupied periods as needed. A week of data from the EMS for the two pumps and one AHU are shown in Figure 1. While data was analyzed for all HVAC pumps and fans retrofit, only two pumps and one AHU are shown for purposes of clarity.

Figure 1: AHU and Pump EMS Data



Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load.

The ex post impacts are calculated in Figure 3 below:

Figure 3: Energy and Demand Formulae

This analysis includes the chilled water and condenser water pumps. The SPC calculator inputs for the pre retrofit condition were used for the ex post analysis.

Pre-Retrofit Demand kW_{peak} = Ex Ante Pre-Retrofit kW_{peak}
= 206.4 kW

Post-Retrofit Demand kW_{peak} = Metered Peak kW
= 189.1 kW

Peak kW Savings = Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak}
= 206.4 kW – 189.1 kW = 17.3 kW

Pre-Retrofit kWh = Σ ((Pre-Retrofit $Demand_{Bin\text{-}Occupied}$ x $Hours_{Bin}$ x Occupied Hours / Hours per week) + (Pre-Retrofit $Demand_{Bin\text{-}Un\text{-}Occupied}$ x $Hours_{Bin}$ x Un-Occupied Hours / Hours per week)
= 1,803,370 kWh/yr

Post-Retrofit kWh = Σ ((Post-Retrofit $Demand_{Bin\text{-}Occupied}$ x $Hours_{Bin}$ x Occupied Hours / Hours per week) + (Post-Retrofit

Demand$_{Bin-Un-Occupied}$ x Hours$_{Bin}$ x Un-Occupied Hours / Hours per week)
= 638,720 kWh/yr

kWh Savings = Pre-Retrofit kWh – Post-Retrofit kWh
= 1,803,370 kWh/yr – 638,720 kWh/yr
= 1,164,650 kWh/yr

kW Savings = 17.3 kW

The data logged by the EMS system was used to create a relation for average kW for each size fan vs. outdoor air temperature. Using affinity laws, a percent flow relation could then be determined as well. Assuming that the flow at each temperature did not change due to the retrofit, an average kW could be determined for each temperature bin, using a typical inlet vane modulation power curve. The average kW at each temperature bin was then used along with NOAA temperature bin hour information to predict energy usage for a typical meteorological year.

Total AHU kWh:	244,854	kWh	Summer peak kW:	136.9	kW
Initial kWh	807,903	kWh	Summer peak kW:	188.3	kW
Total AHU kWh:	563,049	kWh	Summer peak kW:	51.4	kW

Only the "Itemized" calculations (AHU fan VFDs) had demand savings recorded (10.1 kW).

The ex post energy savings is greater than the ex ante energy savings because the ex ante calculations overestimated the average demand associated with the variable frequency drive installation, and underestimated the pre-retrofit energy usage of the pumps and fans.

The uncertainty for this application is detailed in the Uncertainty Summary.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the vendor invoice for the work performed for the project and is an accurate reflection of the project cost. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program has not encouraged them to perform any other energy efficiency projects for which they did not participate in an incentive program.

We were unable to physically verify the pre-retrofit equipment or hours of operation. However, we are satisfied that the parameters have been accurately assessed and quantified based on discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine impacts of installed measures.

7. Impact Results

Based on the ex ante savings of 10.1 kW and 1,624,593 kWh, the engineering realization rate for this application is 6.80 for kW reduction (Based on the ex ante savings) and 0.99 for energy savings kWh (based on the utility tracking system). The values shown in the tracking system disagree with those shown in the installation report due to a discrepancy in the itemized measure savings. The values from the installation report were used to determine the realization rates. A summary of the realization rate is shown in Table 2.

Table 2: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	-	1,747,886	-
SPC Installation Report (ex ante)	10.1	1,624,593	-
Impact Evaluation (ex post)	68.7	1,727,699	-
Engineering Realization Rate	6.80	0.99	NA

Utility billing data for the site was reviewed. Annual usage prior to the retrofit was 9,918,374 kWh. Peak demand was 1,840.0 kW. Table 3 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 3: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1,840.0	9,918,374
Baseline End Use	394.7	2,611,273
Ex ante Savings	10.1	1,624,593
Ex Post Savings	68.7	1,727,699

Table 4 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations.

Table 4: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	0.5%	16.4%	3.7%	17.4%
Baseline End Use %	2.6%	62.2%	17.4%	66.2%

With a cost of $457,444 and a $147,784 incentive, the project had a 1.47 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 1.38 years. A summary of the economic parameters for the project is shown in Table 5. Note that average rates were used to calculate the estimated annual cost savings, which can significantly affect savings and payback.

Table 5: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	1/30/2006	$457,444	10.1	1,624,593	0	$211,197	$147,784	1.47	2.17
SPC Program Review (Ex Post)	9/21/2007	$457,444	68.7	1,727,699	0	$224,601	$147,784	1.38	2.04

It was determined that the VFD installation project was defined as an Adjustable Speed Drive measure in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the VFDs were assumed to have a useful life of fifteen (15) years. A summary of the multi-year reporting requirements is given in Table 6. Because this measure was installed prior to August of 2005, the energy savings in year #1 (2005) are assumed to be 42 % of the expected annual savings for this measure.

Table 6: Multi-Year Reporting Requirements

Program ID:		**Application # 20xx-04**					
Program Name:		**Site A018 SPC 04-05 Evaluation**					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings (1)**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings (2)**	**Ex-Ante Gross Program-Projected Peak Program kW Savings (1**)**	**Ex-Post Gross Evaluation Projected Peak kW Savings (2**)**	**Ex-Ante Gross Program-Projected Program Therm Savings (1)**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings (2)**
1	2004					0	0
2	2005	676,914	1,007,825	10.1	68.7	0	0
3	2006	1,624,593	1,727,699	10.1	68.7	0	0
4	2007	1,624,593	1,727,699	10.1	68.7	0	0
5	2008	1,624,593	1,727,699	10.1	68.7	0	0
6	2009	1,624,593	1,727,699	10.1	68.7	0	0
7	2010	1,624,593	1,727,699	10.1	68.7	0	0
8	2011	1,624,593	1,727,699	10.1	68.7	0	0
9	2012	1,624,593	1,727,699	10.1	68.7	0	0
10	2013	1,624,593	1,727,699	10.1	68.7	0	0
11	2014	1,624,593	1,727,699	10.1	68.7	0	0
12	2015	1,624,593	1,727,699	10.1	68.7	0	0
13	2016	1,624,593	1,727,699	10.1	68.7	0	0
14	2017	1,624,593	1,727,699	10.1	68.7	0	0
15	2018	1,624,593	1,727,699	10.1	68.7	0	0
16	2019	1,624,593	1,727,699	10.1	68.7	0	0
17	2020	947,679	719,875	10.1	68.7		
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	24,368,900	25,915,492				

FINAL SITE REPORT

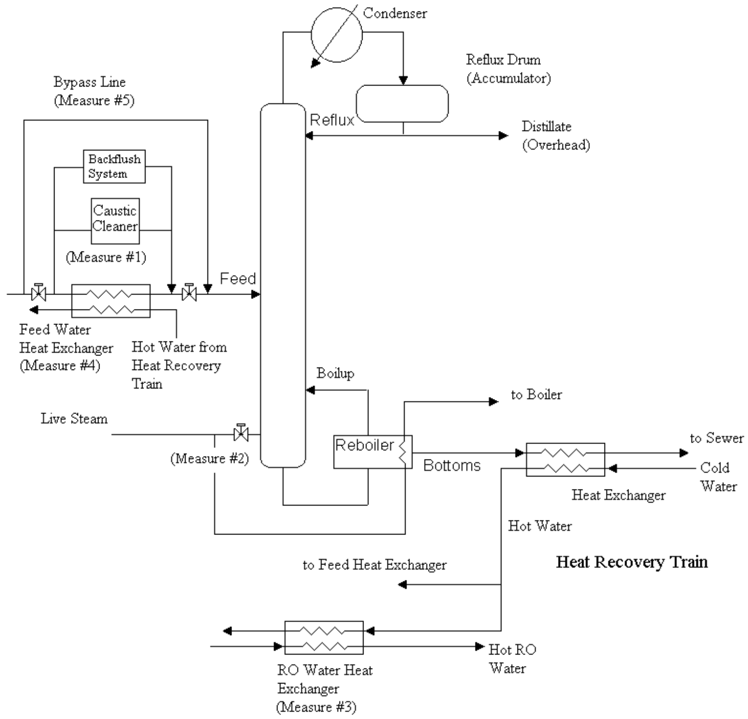
SITE A019 (2005-xxx) Cpke IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 1 END USE: Natural Gas Measures

Measure	Various Process Measures for Gas Conservation, Including: 1. Heat Exchanger Caustic Cleaning 2. Live Steam Injection Control Valve 3. Heat Recovery for Sterilizer Reverse-Osmosis Treated Water 4. Heat Exchanger Replacement for #2 Still 5. Feed Bypass for Improved Stills Back Flush System
Site Description	Chemical Process Facility

1. Measure Description

The customer implemented five measures to reduce the natural gas consumption for a distillation process and currently has three stills in operation. The feed for the stills is preheated by a heat exchanger from heat recovered from the still bottoms (liquid waste product rejected from the still) prior to being injected into the distillation column. Once in the distillation column the feed is boiled by heat input from a heat exchanger surface on the bottom of the still. As the heat exchanger becomes fouled, live steam is injected into the feed to maintain the process output. In addition, the heavies (non-vaporized product from the bottom of the still) are reheated through the use of a re-boiler to remove any remaining good product, which is then re-injected back into the distillation column. The remaining liquid is then rejected to the sewer as the still bottoms.

Figure 1: Diagram of Distillation Process with Incorporated Heat Recovery Measures



Measure #1 (M1) is the installation of a caustic cleaning system for the heat exchanger tubes on the feed heat exchanger. The heat exchangers are used to recover heat from the bottoms to preheat the feed to the towers. The feed also contains dissolved and suspended polysaccharides, which bake onto the heat exchanger surface, reducing the heat exchanger effectiveness. The pre-installation case, no caustic cleaning was implemented. In the post-installation case, caustic cleaning was used to remove the polysaccharide buildup and increase the heat exchanger effectiveness.

Measure #2 (M2) is a control valve to regulate the live steam injection process. In the pre-installation process, as the heat exchanger surfaces become fouled, to maintain temperature, live steam was injected into the distillation column and the condensate was not recovered. The post-installation injection process includes a control valve to direct a percentage of the steam through the re-boilers instead of the distillation column. The condensate there is then recovered, saving gas input to the boiler to heat makeup water.

Measure #3 (M3) is the utilization of heat recovered from the still bottoms to heat reverse-osmosis (RO) treated water for sterilizers. The sterilizers are sterilized with 200 F hot water to kill any bacteria on the heat exchanger. The pre-installation system heats cool (~70 F) RO water to 200 F. The post-installation system uses recovered heat from the still bottoms to heat the RO water to 200 F.

Measure #4 (M4) is the replacement of the feed heat exchanger for the #2 still. The pre-installation heat exchanger had a removable tube bundle. The removable tube bundle had less heat transfer surface area than a similar size fixed tube bundle. The post-installation heat exchanger, with a fixed tube bundle, allows an equivalent heat transfer at a lower feed temperature.

Measure #5 (M5) is an improved still back flush system. To reduce fouling, the feed heat exchanger is periodically (approximately once per week) flushed with water for 30 minutes, then back flushed to the sewer for 45 minutes. During this time, the stills continue to require steam input to maintain still temperature, however, the distillate produced is of an unacceptable quality, and therefore, it must be redistilled. The post-installation system includes a heat exchanger bypass, which will allow the distillation towers to continue to produce acceptable distillate while back flushing 30 minutes to the feed tanks.

2. Summary of the Ex Ante Calculations

For each measure the gas savings were calculated using a simple algorithm taking into account the existing steam usage and the expected change in steam required. Whenever possible, existing steam usage was provided from the customer's system monitoring software. The ex ante baseline utilized the existing system load and hours of operation, and is in accordance with the SPC Program guidelines.

The ex ante results are:

Measure #1-Heat Exchanger Caustic Cleaning:

Pre-Replacement Usage -	9,847,000 therms
Post-Replacement Usage -	9,635,440 therms
Annual Savings -	211,560 therms

Measure #2- Live Steam Injection Control Valve:

Pre-Replacement Usage -	2,182,680 therms
Post-Replacement Usage -	2,026,160 therms
Annual Savings -	156,520 therms

Measure #3-Heat Recovery for Sterilizer RO Water:

Pre-Replacement Usage -	28,380 therms
Post-Replacement Usage -	0 therms
Annual Savings -	28,380 therms

Measure #4-Heat Exchanger Replacement for #2 Still:

Pre-Replacement Usage -	316,480 therms
Post-Replacement Usage -	270,040 therms
Annual Savings -	46,440 therms

Measure #5-Improved Stills Back Flush System:

Pre-Replacement Usage -	184,900 therms
Post-Replacement Usage -	89,440 therms
Annual Savings -	95,460 therms

Total Project:

Annual Savings -	538,360 therms

3. Comments on the Ex Ante Calculations

The ex ante calculations were performed according to the SPC Program guidelines using customized worksheets provided by the customer.

One discrepancy noted in the ex ante calculations was found in measure #4, the heat exchanger replacement for #2 still. In this calculation, the gas load is calculated using the product of the flow rate, density, temperature differential, and the inverse of the boiler efficiency. However, no mention of the specific heat of the feed is included. If this factor is included, it decreases the savings of the measure from 46,440 therms to 42,725 therms.

4. Measurement & Verification Plan

The facility is a 28-acre chemical processing facility, which has been in operation since 1943. This facility includes a very large-scale isolation and distillation process of fermentation products, for the production of biogums. The facility is expected to be in production continuously, with five days plant-wide outages per year. According to the application, before the installation, the majority of the facility's steam was consumed in the distillation process. The post-installation system utilized recovered heat from the still bottoms as well as improved heat exchanger effectiveness to displace a portion of the steam required, and therefore reduced the therm usage.

The goal of the M&V plan is to estimate the actual therm reduction due to the implementation of the five stills heat recovery improvement projects.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. The gas usage is expected to be consistent and predictable based on instantaneous measurements as well as monthly and annual system reports.

Pre-retrofit and post-retrofit calculations of steam and gas loads will be calculated using the following formulae:

For M1, M3 and M4:

$$\text{Therm savings} = \frac{Q \times \rho \times \delta T \times C_p \times \text{hrs}}{\text{Eff}}$$

Where:

Q= fluid feed rate

ρ = density of fluid

δT = pre installation temperature difference– post installation temperature difference. (note that this represents one feed line through a heat exchanger).

C_p = specific heat of fluid

hrs = hours of operation

Eff = Boiler Efficiency

For M2 and M5:

$$\text{Therm savings} = \frac{\delta\text{lbs} \times \Delta H \times \text{hrs}}{\text{Eff}}$$

Where:

δlbs = M2: pre-installation pounds of condensate lost – post installation pounds of condensate lost; M5: pre-installation pounds steam used during back flush – post installation pounds of steam used during back flush

ΔH = System enthalpy

The majority of the savings are from the heat exchanger caustic cleaning, live steam injection control valve, and improved still back flush system (M1, M2, and M5). Therefore, the evaluation will focus on these three measures.

For M1, the heat exchanger caustic cleaning project, the most significant variables to be quantified are the increase in feed temperature due to the improved heat transfer resulting from the caustic cleaning and the feed rate. Site personnel will be interviewed to determine the increase in feed temperature resulting from the caustic cleaning. If possible, the temperature of the feed entering and leaving the heat exchanger will be measured. Site personnel will also be interviewed to determine variations in feed rates. In addition, monthly reports from the customer’s monitoring software, which include average feed rates, will be used to verify the feed rates.

For M2, the live steam injection control valve project, the most significant variable to be quantified is the decrease in steam usage due to the live steam injection control valve. Site personnel will be interviewed to determine the effect of the live steam injection control valve.

For M5, the improved still back flush project, the most significant variable to be quantified is the steam usage reduction due to the reduced back flush time. Site personnel will be interviewed to determine the time reduction resulting from the installation of the improved back flush system. In addition, monthly reports from the customer’s monitoring software, which include average steam usage during back flush periods, will be used to verify the steam usage reduction.

For the other two projects, M3 & M4, the sterilizer RO water flow rates and temperature before and after the heat exchanger will be verified as well as the feed rate for the #2 still heat exchanger.

The greatest uncertainty in the ex ante savings estimate is associated with the change in condensate return due to the live steam injection control valve (M2). This is the second largest portion of the savings, comprising nearly 30% of the total. In addition, no justification is given for the 7% reduction in condensate reheated.

The second largest uncertainty in the ex ante savings estimate is associated with the steam use reduction due to the improvements in the still back flush system (M5). In the original analysis, the time required for the back flush was expected to be reduced by half, resulting in half of the steam usage. However, according to the performance reports included in the original workpapers, the back flush pounds of steam per day was decreased by approximately 95%.

Uncertainty for the savings estimate for the still heat recovery improvement projects can be more fully understood by setting projected ranges on the primary variables.

<u>For the Heat Exchanger Caustic Cleaning (M1)</u>

- 211,560 therms expected, maximum of 350,648 therms, minimum of 72,313 therms (+65.7%, -65.8%, based on judgment of deviation from expected feed rates, density, temperature differential, specific heat, boiler efficiency, and hours of operation)

<u>For the Live Steam Injection Control Valve (M2)</u>

- 156,520 therms expected, maximum of 208,366 therms, minimum of 104,444 therms (+33.1%, -33.3%, based on judgment of deviation from expected condensate flow rates, specific heat, boiler efficiency, and hours of operation)

<u>For the Heat Recovery for Sterilizer RO Water (M3)</u>

- 28,380 therms expected, maximum of 35,030 therms, minimum of 18,129 therms (+23.4%, -36.1%, based on judgment of deviation from expected RO water feed rates, density, temperature differential, specific heat, boiler efficiency, and hours of operation)

<u>For the Heat Exchanger Replacement for #2 Still (M4)</u>

- 42,452 therms expected (46,440 in the original calculations), maximum of 70,851 therms, minimum of 14,021therms (+66.9%, -67.0%, based on judgment of deviation from expected feed rates, density, temperature differential, specific heat, boiler efficiency, and hours of operation)

For the Improved Still Back flush System (M5)

- 95,460 therms expected, maximum of 142,226 therms, minimum of 48,598 therms (+49.0%, -49.1%, based on judgment of deviation from expected steam usage rates, density, temperature differential, specific heat, boiler efficiency, and hours of operation)

For the Five Still Efficiency Improvements Combined

- 534,372 therms expected (538,360 therms in the original calculations), maximum of 807,121 therms, minimum of 257,505 therms (+51.0%, -51.8%, based on above information)

Accuracy

The Extech model 42540 IR thermometer has an accuracy of ±2%+2 F for temperatures less than 932 F.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on June 5, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the process and equipment and by interviewing the facility representative. Process fluid temperatures and flow rates were collected at various points throughout the process by use of the customer process monitoring software package and verified by use of the Extech IR thermometer.

Installation Verification

For M1, the heat exchanger caustic cleaning project, the heat exchanger in question was inspected. It was observed that caustic piping was connected to the inlet and outlet of the heat exchanger. The facility representative verified that prior to the installation of the caustic cleaning system, the heat exchangers were cleaned by sandblasting each year during the annual maintenance shutdown period.

For M2, a control valve modulating the steam flow was observed allowing a percentage of the steam to be redirected to the still re-boiler where the heat of the condensate could be recovered. This allows the condensate to be returned to the boiler system. The facility representative verified that prior to the installation of the live steam injection control valve, the steam level was controlled by workers manually adjusting the injection steam level.

For M3, the RO makeup water was preheated through the use of a heat exchanger and recovered heat from the still bottoms. This was observed and verified by the facility representative. The facility representative also verified that, prior to this retrofit, the water was heated through the boiler system.

For M4, the heat exchanger replacement project, the heat exchanger in question was observed. The facility representative verified that prior to the installation of the current heat exchanger, a heat exchanger with a removable tube bundle was in place.

For M5, the improved stills back flush project, the back flush piping in question was observed. The facility representative verified that prior to the installation of the improved stills back flush system, the still could not produce acceptable quality product during periods when the heat exchangers were being flushed.

A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
GAS - PROCESS	G			Heat Exchanger Caustic Cleaning System	1	Heat Exchanger, Piping for Caustic Flush System	Physically verified installation of heat exchanger and caustic cleaning piping	1.00
GAS - PROCESS	G			Live Steam Injection Control Valve	1	Steam Control Valve	Physically verified installataion of steam control valve	1.00
GAS - PROCESS	G			Heat Recovery for Sterilizer RO Water	1	Heat Exchanger, Piping for RO water	Physically verified installation of heat exchanger, RO water piping	1.00
GAS - PROCESS	G			Heat Exchanger Replacement	1	Heat Exchanger	Physically verified installation of heat exchanger	1.00
GAS - PROCESS	G			Improved Stills Backflush System	1	Heat Exchanger, Backfluch Piping	Physically verified installation of heat exchager, backflush piping	1.00

Scope of the Impact Assessment

All measures are a part of the natural gas end-use category also as defined by the SPC program.

Summary of Results

During the onsite visit temperature readings were taken for the flows into and out of each heat exchanger in question. In addition, the customer representative was able to provide EMS reports for one year of operation. In addition, temperature profiles and steam flow rates were collected when available for the same year of operation.

For M1, the heat exchanger caustic cleaning project the temperature profile for the feed leaving the heat exchanger was available for 2006, as well as a portion of the year prior to the installation. Per discussion with the site representative it was determined that the incoming feed temperature was not expected to change during the year prior to installation. By comparing the month prior to the installation of the caustic system to the month prior to the annual shutdown the next year (post installation, same month) it was observed that the feed exiting temperature for the pre-retrofit heat exchanger had dropped an average of 22 degrees more than the exiting temperature for the heat exchanger for the post-retrofit system. By assuming a linear profile, with the same exiting temperature immediately after cleaning in both the pre- and post-retrofit systems, the overall annual average decrease in temperature drop due to the installation of the caustic cleaning was determined to be 11 F.

For M2, the live steam injection system, trended data was used to determine the steam flow used in the direct injection processes. During 2006, it was determined that the average steam use for direct injection was 46,945 pounds per hour. It was not possible to verify the pre-retrofit steam usage due to direct injection because it was not metered at that time. Per discussion with the site representative, the 70,000 pounds per hour used in the original analysis was reasonable. In addition, it was determined that the condensate being returned from the reboiler was at 302F and the make up water was at 70F.

For M3, the sterilizer RO heat recovery system, trended data was used to determine the make up water flow rate. During 2006, it was determined that the average make up water flow rate was 1.46 gpm. In addition, the temperatures before and after the heat exchanger were verified using the IR thermometer as well as the facilities EMS system. During the on-site visit, the RO water was being heated from an initial temperature of 70 F to a leaving temperature of 174 F with recovered heat from the still bottoms. Prior to installation of the heat exchanger this feed was being heated using the boiler system.

For M4, the #2 still heat exchanger replacement project, it was discovered very shortly after the installation of this heat exchanger that another heat exchanger was installed upstream from this heat exchanger on the still feed line. This increased the temperature of the incoming feed compared to what was analyzed in the ex ante calculations. Based on the information presented in the original calculations and temperature and feed flow trends collected from the customers EMS system, a heat exchanger effectiveness value was developed for the old and the new heat exchangers. Based on this value, it was determined that the old heat exchanger would have raised the temperature of the feed from an incoming temperature of 234 F to a leaving temperature of 246.9 F. The installed heat exchanger, with the larger heat transfer surface area was found to raise the feed temperature from an incoming temperature of 234 F to a leaving temperature of 249 F. Therefore, it was determined that the installed heat exchanger raises the feed temperature an extra 2.1 F, when compared to the old heat exchanger.

Although there are interactions between this project and project M1, the heat exchanger caustic cleaning project, these interactions are disregarded. Based on the change in heat transfer effectiveness that was observed in project M1, the average difference in temperature rise through this heat exchanger in the heat exchanger train is only approximately 0.1 F. In addition, it is only expected to occur on the feed to still #2, while project M1 includes the flows for stills #1, #2, and #3.

For M5, the improved stills back flush project, the average steam usage per day during back flush cycles was collected from the customers EMS reports for a six month period before the retrofit and a one year period after the retrofit. The difference in steam usage during back flush cycles was then used to determine the annual savings. Based on the steam plant performance report, it was determined that a decrease in 90 pounds per hour of steam resulted in a decrease in 1 therm/hr of input gas. Therefore, each pound per hour reduction in steam usage was assumed to reduce the gas input by 1,111 BTU/hr.

The process stills are expected to operate 24 hours per day, seven days per week with the exception of five days for annual maintenance in July. At any time the stills are in operation, the equipment in this application is expected to be in operation as well.

The ex post impacts are calculated in Figure 2 below:

Figure 2: Energy Impact

$$\text{M1: Therm Savings} = \frac{Q \times \rho_{feed} \times \delta T \times C_p \times hrs}{Eff}$$

$$= \frac{496.6\text{gpm} \times 7.3 \text{ lb/gal} \times 0.889 \text{ BTU/lbF} \times 11 \text{ F} \times 60 \text{ min/hr} \times 8{,}600 \text{ hr/yr}}{90\% \times 100{,}000 \text{ BTU/therm}}$$

$$= 203{,}250 \text{ therms/yr}$$

$$\text{M2: Therm Savings} = \frac{\delta lbs \times \Delta H \times hrs}{Eff}$$

$$= \frac{(70{,}000 - 46{,}945) \text{ lbs/hr} \times (271.8-38.1) \text{ BTU/lb} \times 8{,}600 \text{ hrs}}{90\% \times 100{,}000 \text{ BTU/therm}}$$

$$= 514{,}843 \text{ therms/yr}$$

$$\text{M3: Therm Savings} = \frac{Q \times \rho_{feed} \times \delta T \times C_p \times hrs}{Eff}$$

$$= \frac{1.46 \text{ gpm} \times 8.34 \text{ lb/gal} \times 1 \text{ BTU/lbF} \times 104\text{F} \times 8{,}600 \text{ hrs/yr}}{90\% \times 100{,}000 \text{ BTU/therm})}$$

$$= 7{,}260 \text{ therms/yr}$$

$$\text{M4: Therm Savings} = \frac{Q \times \rho_{feed} \times \delta T \times C_p \times hrs}{Eff}$$

$$= \frac{170 \text{ gpm} \times 7.3 \text{ lb/gal} \times 2.1\text{F} \times 0.889 \text{ BTU/lbF} \times 60 \text{ min/hr} \times 8{,}600 \text{ hr/yr}}{90\% \times 100{,}000 \text{ BTU/therm}}$$

$$= 13{,}283 \text{ therms/yr}$$

$$\text{M5: Therm Savings} = \frac{\delta lbs \times \Delta H \times hrs}{Eff}$$

$$= \frac{(41{,}374 - 1{,}599)\ lbs/day \times 1{,}111\ BTU/lb \times 8{,}600\ hrs}{90\% \times 100{,}000\ BTU/therm \times 24\ hr/day}$$

$$= 158{,}360\ therms/yr$$

Total Project Annual Therm Savings = Σ Therm Savings$_{Mi}$ where i = 1 to 5

= Therm Savings$_{M1}$ + Therm Savings$_{M2}$ + Therm Savings$_{M3}$ + Therm Savings$_{M4}$ Therm Savings$_{M5}$

= 896,997 therms/yr

The ex post therm reduction is greater than the ex ante therm reduction. This is primarily due to the underestimated savings attributed to the live steam injection control valve project (M2) as well as the back flush system project (M5). In the ex ante calculations, it was assumed that the installation of the live steam injection control valve would reduce the steam usage by 5,000 pounds of steam per hour.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. The customer did not identify any non-energy benefits or drawbacks associated with the new equipment. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future.

The customer provided still reports and several data strings from the EMS system. However, we were unable to physically verify the pre-retrofit heat exchanger characteristics, still operation and hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

7. Impact Results

Based on the ex ante savings of 538,360 therms, the engineering realization rate for this application is 1.67 for therms reduction. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 2.

Table 2: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	-	-	538,360
SPC Installation Report (ex ante)	-	-	538,360
Impact Evaluation (ex post)	-	-	896,997
Engineering Realization Rate	N/A	N/A	1.67

Utility billing data for the site was reviewed. In the 12-month period from July 2003 - June 2004 (pre-retrofit), the facility consumed 30,692,664 therms. Table 3 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 3: Total Meter, Ex Ante, Ex Post Results

	Annual Therms
Total Meter	30,692,664
Baseline End Use	8,787,004
Ex ante Savings	538,360
Ex Post Savings	896,997

Table 4 is a summary of the percent of therm savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 1.8% decrease in total meter therms and a 6.1% decrease in process end use therms. The ex post results showed a 2.9% decrease in total meter therms and a 10.2% decrease in process end use therms.

Table 4: Percent Savings, Ex Ante, Ex Post

	Ex Ante	Ex Post
Therm Reduction	Therms	Therms
Total Meter %	1.8%	2.9%
Baseline End Use %	6.1%	10.2%

With a cost of $932,989 and a $400,960 incentive, the project had a 1.24 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 0.74 years. A summary of the economic parameters for the project is shown in Table 5.

Table 5: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), ($0.80/therm) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	8/13/2005	$932,989	-	-	538,360	$430,688	$400,960	1.24	2.17
SPC Program Review (Ex Post)	9/1/2007	$932,989	-	-	896,997	$717,598	$400,960	0.74	1.30

It was determined that the heat recovery projects were defined as a Custom Project under the SPC program according to the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the heat exchangers, steam control valve, caustic cleaning system, and back flush system, are assumed to have a useful life of fifteen (15) years.

A summary of the multi-year reporting requirements is given in Table 6. Because this measure was installed approximately July of 2005, the energy savings in year #1 (2005) are assumed to be 1/2 of the expected annual savings for this measure.

Table 6: Multi-Year Reporting Requirements

Program Name:		SPC 04-05 Evaluation A019					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	-	-	-	-	269,180	448,499
2	2005	-	-	-	-	538,360	896,997
3	2006	-	-	-	-	538,360	896,997
4	2007	-	-	-	-	538,360	896,997
5	2008	-	-	-	-	538,360	896,997
6	2009	-	-	-	-	538,360	896,997
7	2010	-	-	-	-	538,360	896,997
8	2011	-	-	-	-	538,360	896,997
9	2012	-	-	-	-	538,360	896,997
10	2013	-	-	-	-	538,360	896,997
11	2014	-	-	-	-	538,360	896,997
12	2015	-	-	-	-	538,360	896,997
13	2016	-	-	-	-	538,360	896,997
14	2017	-	-	-	-	538,360	896,997
15	2018	-	-	-	-	538,360	896,997
16	2019	-	-	-	-	269,180	448,499
17	2020	-	-	-	-	-	-
18	2021	-	-	-	-	-	-
19	2022	-	-	-	-	-	-
20	2023	-	-	-	-	-	-
TOTAL	2004-2023	-	-			8,075,400	13,454,956

FINAL REPORT

SITE A020 (2046-04) BDSh IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 5 END USE: Other

Measure	New 1,100 ton Injection Molder with Variable Volume Hydraulic Pump Installation
Site Description	Plastics Manufacturing Facility

1. Measure Description

A new 1,100-ton plastic injection molder was installed. The new molder was manufactured by Cincinnati Milacron and is a model Maxima MG 1100. The energy efficient feature of this unit is the variable volume hydraulic pump. A variable volume pump automatically reduces the flow of hydraulic fluid whenever demand is reduced during the injection cycle.

The new injection molder replaced an existing Engel 400 ton unit with standard hydraulic pump and operating controls. A typical hydraulically operated injection molder has a pump with bypass valve to redirect any unused capacity back to the reservoir. Full flow and power is required at all times with bypass control.

2. Summary of the Ex Ante Calculations

The SPC High Efficiency Injection Molder calculator was used to determine the annual savings. The SPC High Efficiency Injection Molder Calculator provides estimates of the energy and demand of the pre-installation and post-installation equipment, using equations that are based on energy use per pound of plastic. The energy use per pound of plastic is based, per the 2004 SPC Procedures Manual, on measured performance data which accounts for the type of machine, variations in part size, production rates, and cycle time.

The existing injection-molding machine was used as the baseline, which is consistent with the SPC Guidelines. In both the pre-retrofit and post-retrofit replacement cases, the pre-retrofit production rate was used.

Notable inputs and parameters used by the calculator are:

<u>Pre-Retrofit Existing Equipment and Production</u>
Manufacturer and Size – Engle 400 ton standard hydraulic machine
Average Production Rate – 101 lbs/hr
Annual Operating Hours – 7,452
Production Rate - 0.253 lbs/ton (101/400)
Specific Energy Use – 0.91 kWh/kg

<u>Post-Retrofit Equipment and Production</u>
Manufacturer and Size – Maxima 1,100 ton variable volume machine
Average Production Rate – 101 lbs/hr
Annual Operating Hours – 7,452

Production Rate - 0.092 lbs/ton (101/1,100)
Specific Energy Use – 0.55 kWh/kg

The ex ante results determined by the 2004 SCP calculator are:

Pre-Replacement Usage -	42.6 kW	285,701 kWh
Post-Replacement Usage -	24.3 kW	187,395 kWh
Peak Summer Impact & Annual Savings -	18.3 kW	98,306 kWh

3. Comments on the Ex Ante Calculations

The ex ante calculations were performed using the SPC Calculator. The energy saving results are in agreement with values generated using the formula outlined in the SPC manual based on the equipment size and production rates provided.

Energy Savings = [(0.91 – 0.55) kWh/kg x 101 lbs/hr x 7,452 hrs/yr / 2.2 lb/kg)] x (1-0.20)
(20% reduction factor for molders with low production rates)

The ex-ante calculated energy savings results were adjusted correctly for the lower baseline equipment production rate (equating in this case to the efficiency of the machine).

Additionally, the pre-retrofit and post-retrofit calculated energy usage of the injection molders is consistent with the formulae:

Pre-Retrofit kWh = 0.3796 kWh/lb x 101 lb/hr x 7,452 hrs/yr

Post-Retrofit kWh = 0.2490 kWh/lb x 101 lb/hr x 7,452 hrs/yr

The SPC Guidelines do not provide a method for calculating demand savings. However, the pre-retrofit and post-retrofit calculated demand for the injection molders is consistent with the formulae:

Pre-Retrofit kW = 0.421 kW/(lb/hr) x 101 lbs/hr

Post-Retrofit kW = 0.240 kW/(lb/hr) x 101 lbs/hr

An alternative appropriate method to determine demand savings is below and results is an estimated savings of 16.53 kW or 90.3% of the SCP calculated amount.

Demand Savings = [(0.91 – 0.55) kWh/kg / 2.2 lbs/kg] x 101 lb/hr

The reported savings from the Installation Report agree with the savings reported in the utility tracking system. (18.3 kW: 98,306 kWh)

4. Measurement & Verification Plan

The customer operates a facility for the manufacturing of uniquely designed sharps collectors for the medical industry. Many of its products are made of plastic collectors manufactured using injection molding machines. The facility floor area is approximately

40,000 square feet and is heated and cooled. In normal operation, the facility is expected to be in operation for three shifts per day, for approximately 355 days per year.

According to the application, the pre-retrofit production rate was 101 lb/hr. After the retrofit, the production rate remained 101 lb/hr.

The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction due to the installation of the 1,100 ton injection molder with variable volume hydraulic pump.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. The injection molder in question is not expected to consume a large percentage of the facility's total usage. Also, the usage of the injection molder is not expected to remain consistent enough for single point measurements to be representative of the average usage. There is not expected to be significant seasonal variation and two weeks should be sufficient for comparison; however, a longer period would more fully capture actual variations and the persistence of savings. Interval data on a 15-minute or less basis, preferably during the summer months of June to September, would be needed to accurately determine coincident peak period demand savings.

To estimate peak demand kW for the new machine, the metered kWh logged during continuous weekday afternoon periods will be used to determine an average production kW. The average kW should be appropriate because cycle times should be short compared to the typical 15-minute period over which billing demand is determined. These operating kW data points will then be adjusted based on any differences in pre-retrofit and post-retrofit production levels.

Pre-retrofit and post-retrofit calculations of injection molder loads and energy use will be calculated using the following formulae:

Post-installation

kW = kWh / hours (during a continuous production run on a weekday afternoon)

$$\text{kWh} = \frac{\text{metered kWh x production weeks per year x pre-installation production}}{\text{metered weeks x metered production}}$$

Pre-installation

kW = ex ante kW

kWh = ex ante kWh = ex ante kW x ex ante hours of operation

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit production rate and equipment information. The original equipment has been removed and cannot be observed nor metered, and focus will be placed on this equipment during the interview with the customer representative. A typical method for determining the energy and demand associated with an injection molder with a standard hydraulic pump would be:

kW = motor hp x motor load factor x 0.746 kW/hp / motor efficiency

kWh = kW x Operating hours

The most significant variables to be quantified are the pre-retrofit and post-retrofit hours of operation. Pre-retrofit hours will be confirmed with the site personnel to verify that the production hours listed in the application (7,452 hours per year) were valid. Appropriate modifications for the savings calculations will be made to the pre-retrofit usage figures if required, in order to establish a realistic baseline for energy use.

We will physically verify the installation of the variable volume hydraulic pump during the onsite visit. We will verify post-retrofit energy consumption by installing Hobo FlexSmart data loggers with WattNode WNA-3D-480-P watt-hour transducers and Magnalab SCT-1250-200 current transformers on the motor. The energy consumption of the injection molder will be logged with a sampling delay of no greater than 2 minutes, for a minimum of 14 days to verify the post-retrofit energy consumption. In addition, the production level for the logged period will be verified with the customer representative. Preferably, production levels by hour will be logged. If this is not feasible for the customer, daily production rates will be obtained. The logged kWh per unit output will then be used to make any adjustments to post installation usage, as appropriate.

The ex ante savings estimate has several areas of significant uncertainty. The SPC calculator uses scaling factors to determine the kW/(lb/hr) and kWh/(lb/yr) values. Per the 2004 SPC Procedures Manual, these values are determined to be "typical" values based on compiled information from a large variety of injection molders. A large uncertainty is associated with comparing the pre-retrofit and post-retrofit injection molders to an unknown "typical" injection molder. Additional uncertainty is associated with the hours of operation and production level of the injection molders.

Uncertainty for the savings estimate for the injection molder retrofit can be more fully understood by setting projected ranges on the primary variables.

<u>For the Pre-Retrofit Injection Molder</u>

- Standard hydraulic injection molder kW/(lb/hr) of 0.421 kW/(lb/hr), maximum of 0.526 kW/(lb/hr), minimum of 0.316 kW/(lb/hr) (±25%, based on judgment of deviation from typical standard hydraulic injection molder in SPC calculator)
- Standard hydraulic injection molder kWh/lb of 0.3800 kWh/lb, maximum of 0.474 kWh/lb, minimum of 0.285 kWh/lb (±25%, based on judgment of deviation from typical standard hydraulic injection molder in SPC calculator)
- Production rate of 101 lb/hr, minimum 90.1 lb/hr, maximum of 111.1 lb/hr (±10%, based on judgment of use for production method)

For the Post-Retrofit Injection Molder

- Variable volume hydraulic injection molder kW/(lb/hr) of 0.240 kW/(lb/hr), maximum of 0.3000 kW/(lb/hr), minimum of 0.180 kW/(lb/hr) (±25%, based on judgment of deviation from typical standard hydraulic injection molder in SPC calculator)
- Variable volume hydraulic injection molder kWh/lb of 0.249 kWh/lb, maximum of 0.311 kWh/lb, minimum of 0.187 kWh/lb (±25%, based on judgment of deviation from typical standard hydraulic injection molder in SPC calculator)
- Production rate of 101 lb/hr, minimum 90.1 lb/hr, maximum of 111.1 lb/hr (±10%, based on judgment of use for production method)

For the Injection Molder Retrofit

- 7,452 hours post-retrofit expected operation, minimum of 5,600 hours, maximum of 8,500 hours (-25%, +14%, based on judgment of use for site type)
- Production rate of 101 lb/hr, minimum 90.1 lb/hr, maximum of 111.1 lb/hr (±10%, based on judgment of use for production method)
- 18.3 kW expected savings, minimum 5.93 kW, maximum 30.67 (±67.6%, based on pre-retrofit injection molder expected deviation, post-retrofit injection molder expected deviation, and propagation of error method)
- 98,306 kWh expected savings, minimum 8,880 kWh, maximum 185,383 kWh (-91.0%, +88.6%, based pre-retrofit injection molder expected deviation, post-retrofit injection molder expected deviation, and propagation of error method)

Accuracy

For the Hobo data logger, the kWh loggers have a resolution of ±10 seconds, the transducers have an accuracy of ±0.45%, and the transformer has an accuracy of ±1%.

Annualizing from a short monitoring period is expected to result in an inaccuracy of + / - 5% for the kW and kWh savings estimates.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on June 9, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the injection molder and by interviewing the facility representative. One set of 600A current loggers were installed on the input phases for the injection molder with a sampling frequency of five (5) seconds.

In addition, kWh loggers were installed on the input phases for the hydraulic motor and the extruder screw motor.

5.1. Installation Verification

The facility representative verified that the pre-retrofit injection molder was an Engel 400 ton unit. He also verified that the pre-retrofit unit had a standard hydraulic drive.

It was physically verified that the new unit was a Cincinnati Milacron Maxima MG1100. It was determined that the machine installed was a hybrid machine as opposed to the variable volume drive unit specified in the application. For the installed hybrid machine, the platen end of the machine was controlled by a hydraulic system, which included a 100 AC HP motor connected to a variable volume pump. A separate 200 HP motor with a VFD controlled the extruder screw. The facility representative stated that the retrofit was completed in May 2004.

This is the only measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
PROCESS-INJECTION MOLDER	O			Replace one 400T standard hydraulic drive injection molder with one 1100T variable volume injection molder	1	1100T Variable Volume Injection Molder	Physically verified installation of 1100T variable volume injection molder	1.00

5.2. Scope of the Impact Assessment:

The impact assessment scope is for the injection molder retrofit measure in the SPC application. This is the only measure in this application.

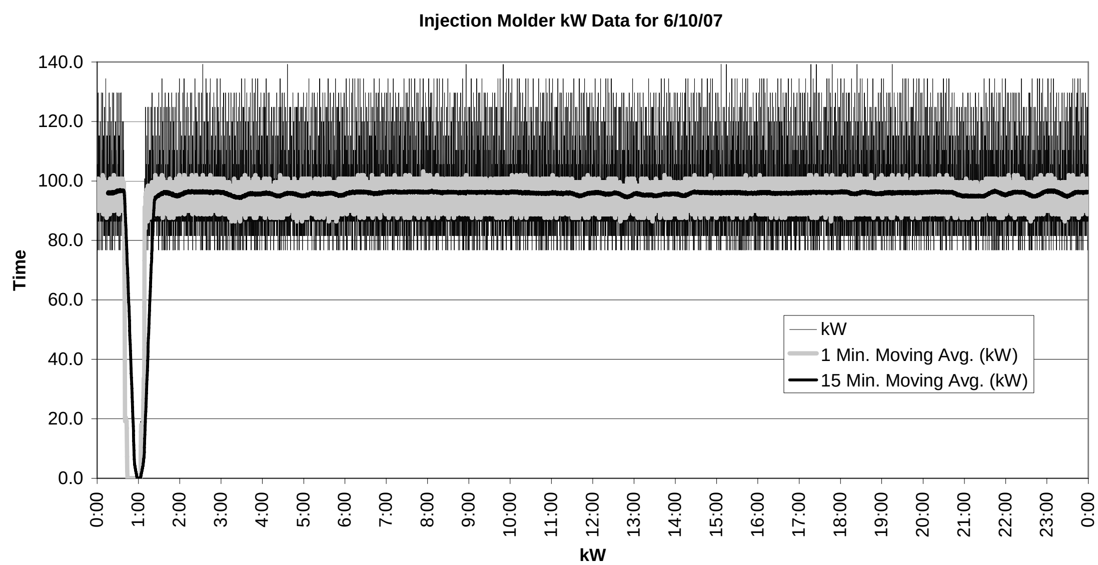
5.3. Summary of Results:

Two (2) Hobo Wattnodes were installed in the warehouse for 21 days (from June 9, 2006-June 30) to measure the operating hours and power consumption of the retrofit injection molder. The facility representative stated that the 21-day period had been representative of normal facility operation. It was found that on average, the injection molder operated 89.0% of the time for an expected 7,561 hours per year compared to the 7,452 hours per year assumed in the ex ante calculations. There was no distinction in operating conditions for weekday or weekend hours.

The facility representative stated that this facility operates 24 hours per day. In addition, this facility is in production throughout the year except for 11 holidays. The facility representative stated that the 21-day period had been representative of normal facility operation.

It was determined from the Hobo kWh logger and the Hobo 600A current logger that the demand of the injection molder varies significantly over time, even if production level is held relatively constant. For the time period from 2:00 AM to 12:00 AM on June 10, 2007, the 15-second average demand of the injection molder varied from 76.8 kW to 139.2 kW. However, this fluctuation smoothes out very quickly as the sampling period is increased. If a one-minute average kW is used to determine the demand of this injection molder, the range is only 86.4kW to 103.2 kW. With a 15-minute average kW, the range is reduced further to 91.8kW to 96.8kW. The instantaneous, 1-minute average, and 15-minute averages are shown in Figure 1.

Figure 1: Hobo kWh Logger Results



To accurately represent the kWh/lb and kW/(lb/hr) the customer tracked the production level throughout the metering process. This was then used on a daily basis to determine an average kW/(lb/hr). In addition, the total production during the metered time period and total energy usage during the metered time period was used to determine an overall average kWh/lb. These values are presented in Table 2. The kW/(lb/hr) and kWh/lb values were then used to determine an adjusted peak kW and annual kWh based on the pre-retrofit production rate.

Table 2: Daily Production and Usage Values

Part #	Date	Qty	kg/day	Average lb/hr	kWh	Average kW	Average kW-h/lb
1056	9-Jun	8760	4730	433.62	2,285.9	95.24	0.22
1056	10-Jun	9540	5152	472.23	2,258.2	94.09	0.20
1056	11-Jun	9340	5044	462.33	2,275.2	94.8	0.21
1056	12-Jun	9560	5162	473.22	2,302.7	95.95	0.20
1056	13-Jun	9000	4860	445.50	2,266.4	94.43	0.21
1056	14-Jun	360	194	17.82	743.0	30.96	1.74
1056	15-Jun	-	-	-	-	-	N/A
1056	16-Jun	7800	4212	386.10	1,354.7	56.45	0.15
1056	17-Jun	9480	5119	469.26	2,287.0	95.29	0.20
1056	18-Jun	8970	4844	444.02	2,313.1	96.38	0.22
1056	19-Jun	9320	5033	461.34	2,237.9	93.25	0.20
1056	20-Jun	9480	5119	469.26	2,299.8	95.83	0.20
1056	21-Jun	9840	5314	487.08	2,317.8	96.58	0.20
1056	22-Jun	9520	5141	471.24	2,313.2	96.38	0.20
1056	23-Jun	9800	5292	485.10	2,302.4	95.87	0.20
1056	24-Jun	9780	5281	484.11	2,263.7	94.32	0.19
1056	25-Jun	9690	5233	479.66	2,278.9	94.95	0.20
1056	26-Jun	8310	4487	411.35	2,093.6	87.23	0.21
1055	27-Jun	1800	707	64.85	826.0	34.45	0.53
1055	28-Jun	4860	1910	175.08	1,232.0	51.36	0.29
1055	29-Jun	4860	1910	175.08	1,234.0	51.24	0.29
Total		**160,070**	**84,744**		**39,485**		
Average							0.2118

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load, with an adjustment for the pre-retrofit production level of 101 lb/hr. The average kW of the machine was used to account for the probability of the peak occurring during the system peak.

The ex post impacts are calculated in Figure 2 below:

Figure 2: Energy and Demand Formulae

Pre-Retrofit Demand kW_{peak} = Pre-Retrofit Demand Rate x Pre-retrofit Production
= 0.4218 kW/ (lb/hr) x 101 lb/hr
= 42.6 kW (ex ante calculations)

Post-Retrofit Demand kW_{peak} = Post-Retrofit Demand Rate x Pre-retrofit Production
= 0.2118 kW/ (lb/hr) x 101 lb/hr
= 21.4 kW

Peak kW Savings = Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak}
= 42.6 kW – 21.4 kW
= 21.2 kW

Pre-Retrofit kWh = Pre-Retrofit Energy Rate x Pre-Retrofit Production x Prost-retrofit Hours
= 0.3796 kWh/lb x 101 lb/hr x 7,561 hours/yr
= 289,903 kWh/yr

Post-Retrofit kWh = Post-Retrofit Energy Rate x Pre-Retrofit Production x Post-retrofit Hours
= 0.2118 kWh/lb x 101 lb/hr x 7,561 hours/yr
= 161,743 kWh/yr

kWh Savings = Pre-Retrofit kWh – Post-Retrofit kWh
= 289,903 kWh/yr – 161,743 kWh/yr
= 128,160 kWh/yr

The ex post kW demand reduction is greater than the ex ante estimate because the ex ante calculations overestimated the demand associated with the new injection molder.

The ex post energy savings is greater than the ex ante energy savings because the ex ante calculations overestimated the average demand associated with the new injection molder and underestimated the annual hours of operation.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the vendor invoice for the work performed for the project and is an accurate reflection of the project cost. In addition to saving energy, the primary benefit of the project is increased production capacity, which was the primary motivation for this project. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer’s participation in the 2004/2005 SPC Program has not encouraged them to perform any other energy efficiency projects for which they did not participate in an incentive program. Other energy efficiency projects implemented at this facility under the SPC program included installation of T8 fixtures with occupancy sensors.

We were unable to physically verify the pre-retrofit injection molder type, production level, or hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

7. Impact Results

Based on the ex ante savings of 18.3 kW and 98,306 kWh the engineering realization rate for this application is 1.16 for kW reduction and 1.30 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 3.

Table 3: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	18.3	98,306	-
SPC Installation Report (ex ante)	18.3	98,306	-
Impact Evaluation (ex post)	21.2	128,160	-
Engineering Realization Rate	1.16	1.30	N/A

Utility billing data for the site was reviewed. In the 12-month period from February 2004 – January 2005 (includes retrofit), the facility consumed 773,800 kWh. Peak demand was 120.8 kW in March 2004. Table 4 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 4: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	120.8	773,800
Baseline End Use	42.6	285,701
Ex Ante Savings	18.3	98,306
Ex Post Savings	21.2	128,160

Table 5 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 15.1% decrease in total meter kW, a 43.0% decrease in the injection molder end use kW, a 12.7% decrease in total meter kWh, and a 34.4% decrease in the injection molder end use kWh. The ex post results showed a 17.5% decrease in total meter kW, a 49.8% decrease in the injection molder end use kW, a 16.6% decrease in total meter kWh, and a 44.9% decrease in the injection molder end use kWh.

Table 5: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/ Demand Reduction	kW	kWh	kW	kWh
Total Meter %	15.1%	12.7%	17.5%	16.6%
Baseline End Use %	43.0%	34.4%	49.8%	44.9%

With a cost of $550,000 and a $7,864 incentive, the project had a 42.4 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 32.5 years. A summary of the economic parameters for the project is shown in Table 6.

Table 6: Economic Information

	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	10/18/04	$550,000	18.3	98,306	0	$ 12,780	$ 7,864	42.4	43.0
SPC Program Review (Ex Post)	7/27/07	$550,000	21.2	128,160	0	$ 16,661	$ 7,864	32.5	33.0

It was determined that the injection molder replacement project was defined as a Miscellaneous Measure-Extrusion Equipment in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the injection molders were assumed to have a useful life of fifteen (15) years. A summary of the multi-year reporting requirements is given in Table 7. Because this measure was installed in May of 2004, the energy savings in year #1 (2004) are assumed to be 58.3% of the expected annual savings for this measure. In addition, because the 15-year life expires before the expected summer peak, no peak savings are included for 2019.

Table 7: Multi-Year Reporting Requirements

Program	001 Application # A020						
Program	SPC 04-05 Evaluation						
Year	Calen dar Year	Ex-Ante Gross Program-Projected kWh Savings	Ex-Post Gross Evaluation Confirmed kWh	Ex-Ante Gross Program-Projected Peak kW Savings	Ex-Post Gross Evaluation Confirmed kW Savings	Ex-Ante Gross Program-Projected Therm Savings	Ex-Post Gross Evaluation Confirmed Therm Savings
1	2004	57,345	74,760	18.3	21.2	0	0
2	2005	98,306	128,160	18.3	21.2	0	0
3	2006	98,306	128,160	18.3	21.2	0	0
4	2007	98,306	128,160	18.3	21.2	0	0
5	2008	98,306	128,160	18.3	21.2	0	0
6	2009	98,306	128,160	18.3	21.2	0	0
7	2010	98,306	128,160	18.3	21.2	0	0
8	2011	98,306	128,160	18.3	21.2	0	0
9	2012	98,306	128,160	18.3	21.2	0	0
10	2013	98,306	128,160	18.3	21.2	0	0
11	2014	98,306	128,160	18.3	21.2	0	0
12	2015	98,306	128,160	18.3	21.2	0	0
13	2016	98,306	128,160	18.3	21.2	0	0
14	2017	98,306	128,160	18.3	21.2	0	0
15	2018	98,306	128,160	18.3	21.2	0	0
16	2019	40,961	53,400	0	0	0	0
17	2020	0	0	0	0	0	0
18	2021	0	0	0	0	0	0
19	2022	0	0	0	0	0	0
20	2023	0	0	0	0	0	0
TOTAL	2004-2023	1,474,590	1,922,400			0	0

Final Report

SITE A021 (2004-xxx) Call IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 3 END USE: Other

Measure	Replace Three (3) Large Dust Collection Systems with Seventeen (17) Smaller Dust Collectors
Site Description	Manufacturing Facility

1. Measure Description

Seventeen (17) new dust collection units were installed. The new units utilize 10 hp fan motors for each unit. The energy savings result from the use of the new units with lower total horsepower.

The seventeen 10 hp dust collection units replaced three (3) 400 hp dust collectors (scrubbers). During production hours, two of the three scrubbers were in use. Each scrubber included one (1) 400 hp fan motor and one (1) ½ hp sludge motor.

2. Summary of the Ex Ante Calculations

The ex ante calculations for the dust collector retrofit are based on information provided in the sheet entitled "SPC 2094-04 Review of Dust Collector Data and Annual Energy Savings". This sheet included summaries of short-term metering performed on the pre-retrofit scrubbers and the post retrofit dust collectors.

Notable inputs and parameters used are as follows:

Pre-Replacement Existing Equipment and Operation

Equipment – Three 400 hp dust collection systems (scrubbers)
Typical operating conditions – 2 operating
Hours of operation – 6005 hours per year
Average baseline power consumption – 417.12 kW (for two operating units, based on metered amps and estimated power factor)

Post-Replacement Equipment and Production

Equipment – Seventeen 10 hp dust collectors
Typical operating conditions – 17 operating
Hours of operation – 6000 hours per year (6005 hours in original analysis)
Average power consumption – 160.88 kW

The ex ante results determined are:

Pre-Replacement Usage -	417.12 kW
Post-Replacement Usage -	160.88 kW
Peak Summer Impact -	256.24 kW

The resulting kWh savings is (417.12-160.88) kW x 6005 hours/year = 1,538,721 kWh/year (1,538,798 kWh/yr in original analysis). The discrepancy appears to be in rounding figures.

3. Comments on the Ex Ante Calculations

The ex ante calculations were formulated using pre-retrofit and post retrofit metered data as the basis for the values. The baseline for the savings calculation was calculated based on the original scrubbers. Since there is no standard or energy code for dust collection systems, this baseline is reasonable.

The savings calculated agree with the tracking system savings.

The ex ante calculations used current measurements from the customer's EMS software to estimate the power consumption of each pre-replacement scrubber. The current measurements were then used to calculate the peak kW when two scrubbers were operating using the formula:

$$kW_{pre} = \frac{(\text{measured amps \#1} + \text{measured amps \#2}) \times 1.732 * 466 \text{ Volts} * 0.85}{1000 \text{ W / kW}}$$

The 1.732 figure is a three-phase power conversion factor and the 0.85 figure is an assumed power factor for the dust collector motors.

The operation of two of the three pre-replacement scrubbers, operating for 6,005 hours per year (based on metered data), was used to determine the energy usage. This value is consistent with the description of the hours of operation described by the customer representative during a phone interview. However, this is inconsistent with the operating schedule described in the San Diego Gas & Electric 2004 Standard Performance Contract Program Application Review. In the application review, it is indicated that one of the original scrubbers operated for 6,864 hours per year. In this review, the second scrubber and the post-retrofit dust collectors operated for 5,720 hours per year.

For the post-installation demand, three of the seventeen installed dust collection units were monitored for demand and hours of operation. An average demand value was determined from the metered data for each metered dust collector. The average demand of each dust collector was then averaged to determine a typical demand of each of the seventeen dust collectors. The average hours of operation for the three metered units was also applied to the seventeen total units using the formula:

$$kW_{post} = \frac{(\text{measured kW \#1} + \text{measured kW \#2} + \text{measured kW \#3}) \times 17 \text{ units}}{3 \text{ metered units}}$$

The ex ante calculations were performed according to the SPC Program guidelines using customized spreadsheets. No basis was given for the assumed 85% power factor used in the pre-installation kW calculation. However, based on MotorMaster version 4.0.6, this power factor is reasonable. No support was provided to verify that the three monitored post-installation dust collectors are typical of all seventeen installed units. In addition, the metered kW values were not provided, so the consistency of the values could not be determined.

Pre- retrofit and post-retrofit dust collector loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Peak demand period savings = kW_{pre} – kW_{post}

4. Measurement & Verification Plan

The participant operates an approximately 100,000 square foot heated and cooled facility for the manufacture of sporting equipment. The facility is expected to be in operation for 20 hours per day, 6 days per week, for approximately 50 weeks per year. During production, approximately 500 people occupy this facility, 300 of which occupy the manufacturing areas. During production periods, the manufacturing process requires the removal and collection of dust material. According to the application, before the retrofit, this was accomplished through the use of two (2) centralized 400 hp scrubbers, with one standby scrubber. After the retrofit, the dust collection was accomplished through seventeen (17) localized 10 hp dust collection systems. This project saves energy through reduced fan brake horsepower requirements and consequent connected load.

The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction due to the replacement of the three (3) 400 hp scrubbers with the seventeen (17) 10 hp dust collectors, over the expected useful life of this equipment.

Formulae and Approach

For this application, we propose to use IPMVP Option A, Partially Measured Retrofit Isolation. The installed dust collection units are all of the same make and model number and expected to operate in a similar manner. In addition, the operation of the units is not expected to change significantly over the course of the operating period. There is not expected to be significant seasonal variation. Based on these conditions, one to two weeks is a sufficient monitoring period for evaluation.

Instantaneous demand readings will be taken for a minimum of eight (8) dust collectors, as described in subsequent paragraphs. In addition, site personnel will be interviewed to verify the pre-retrofit scrubber and post-retrofit dust collector hours of operation. Pre-retrofit scrubber and post-retrofit dust collector demand and energy use will be calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Average peak demand period savings (kW) = kW_{pre} – kW_{post} during the hours from 2 pm to 5 pm, Monday to Friday, during the three hottest contiguous weekdays in June, July, August, and September

Peak demand period savings = kW_{pre} – kW_{post}

The most significant variables to be quantified are the pre-retrofit and post-retrofit dust collector hours of operation and the usage on the new and old units. The focus will be on verifying that, prior to the retrofit, two scrubbers were operating during hours listed (6,005 hours/year) and that the listed hours/year were valid.

The post-retrofit hours of operation of the new units will be verified through the use of motor on/off sensors. Motor on/off sensors will be placed on a minimum of eight units to verify hours of operation. Discussions with the customer and on-site observations will be used to verify the units metered are representative of the entire seventeen units. The motor on/off sensors would be left in place for a period of 7 to 14 days. Attention will be given to the time period for monitoring, in order to avoid periods of irregular usage patterns (e.g., during holidays or breaks). The use of eight sampling points is consistent with SPC program documentation from March 2001 (Appendix E, Sampling), which suggests guidelines for determining sampling point requirements necessary to achieve an 80% confidence interval with 20% precision (using a coefficient of variation of 0.5).

The demand of the post-retrofit dust collectors will be measured, on a minimum of eight (8) units, using a Fluke 41B handheld kW meter. If, based on on-site observations or discussions with the customer, it is determined that the demand of the post retrofit dust collectors is not constant, a Hobo FlexSmart data logger with WattNode WNA-3D-480-P Watt-hour transducers and Magnalab SCT-750-050 current transformers will be installed on the motor of one (1) 10 hp dust collection unit. The energy consumption of the fan motor will be logged, with a sampling delay of no greater than 1 to 2 minutes, for a minimum of 14 days, in order to verify the post-retrofit energy consumption.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit dust collector hours of operation. The pre-retrofit and post retrofit demand seems to be well established to within 5% to 10%, based on metered data provided in the Application Review.

Uncertainty for the savings estimate for the dust collector retrofit can be more fully understood by setting projected ranges on the primary variables.

For the Pre-Retrofit Scrubbers

- 417.12 kW expected, minimum 396.3 kW, maximum 438.0 (+/- 5%, based on metered data provided in Application review)

- 6,005 hours pre retrofit expected/reported, minimum 4804 hours, maximum 7206 hours (based on judgment of deviation from stated operating schedule for type of facility)

For the post retrofit dust collectors

- 9.46 kW expected per unit, minimum 8.5 kW, maximum 10.4 kW (+/- 10%, based on summary of metered data provided in the Application review)
- 17 units expected operating, maximum 17, minimum 15 (based on quantity purchased and expected machine use)

For the dust collector retrofit

- 6,005 hours pre retrofit expected/reported, minimum 5000 hours, maximum 7000 hours (+/- 17% based on judgment of use for site type;
- 256.23 kW expected, 282.6 maximum, 229.9 minimum (+/- 10%, based on pre-retrofit scrubbers and post retrofit dust collector information above)

Accuracy and Equipment

For the Hobo data logger, the kWh loggers have a resolution of ±10 seconds, the transducers have an accuracy of ±0.45%, and the transformer has an accuracy of ±1%. The motor on/off sensors have an accuracy of 100% and a resolution of ±2.0 minutes. The Fluke power meter (including probe) has an accuracy ± 0.5% for voltage, ± 5.5% for current, ± 6% for power, and ± 2% full scale for power factor.

Annualizing from a short monitoring period is expected to result in an inaccuracy of + / - 5% for the kW and kWh savings estimates.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on June 4, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the dust collectors and by interviewing the facility representative. Eight (8) motor on/off loggers and one (1) kW/kWh logger were installed on dust collectors throughout the facility.

Installation Verification

The facility representative verified that the dust collection was provided by two (2) 400 HP wet scrubbers before the retrofit two dust collectors were required for first and second shift hours of operation, with only one dust collector was required during the third shift hours of operation.

It was physically verified that there are seventeen (17) new Filter1 Hydrotron wet dust collectors. All installed dust collectors are similar 10 HP models. The facility representative stated that the retrofit began in November 2004 and was completed in December 2004.

This is the only measures in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Other-Process	O			Replace 2-400HP dust collectors with 17-10HP dust collectors	17	17-10HP dust collectors	Physically verified dust collector quantity and HP	1.0

Scope of the Impact Assessment

The impact assessment scope is for the Other-Process end use measure in the SPC application covering the dust collection retrofit. This was the only measure in this application.

Summary of Results

Eight Hobo motor on/off loggers were installed on dust collection units for 14 days (from June 4, 2007-June 18, 2007) to measure the operating hours of a representative sample of the retrofit dust collectors. One (1) Amprobe DM-II was installed for 4 days (from June 4, 2007-June 8, 2007) to measure the operating kW of a representative unit dust collector. Instantaneous kW recordings were recorded for an additional eight (8) dust collectors using a Fluke 41B power meter.

The facility representative stated that this facility operates on an increased production schedule for approximately six months of the year, with production occurring 24 hours per day, six days per week. The remaining six months of the year the facility operates on a reduced production schedule, with production occurring 16 hours per day, five days per week. The months of increased production generally occur from December to May. The facility representative stated that the 14-day period had been representative of normal facility operation during the transition from the increased hour period to the reduced hour period.

It was determined from the Amprobe kW logger that the demand of the dust collectors is relatively constant and does not vary significantly over time. The Amprobe data collected is given in Figure 1 below. Table 2 gives the kW readings taken using a Fluke 41B meter for eight dust collection units. It was shown that the dust collector's demand varied from 8.0 to 9.2 kW with and average of 8.55 kW.

Figure 1: Amprobe Logger Results

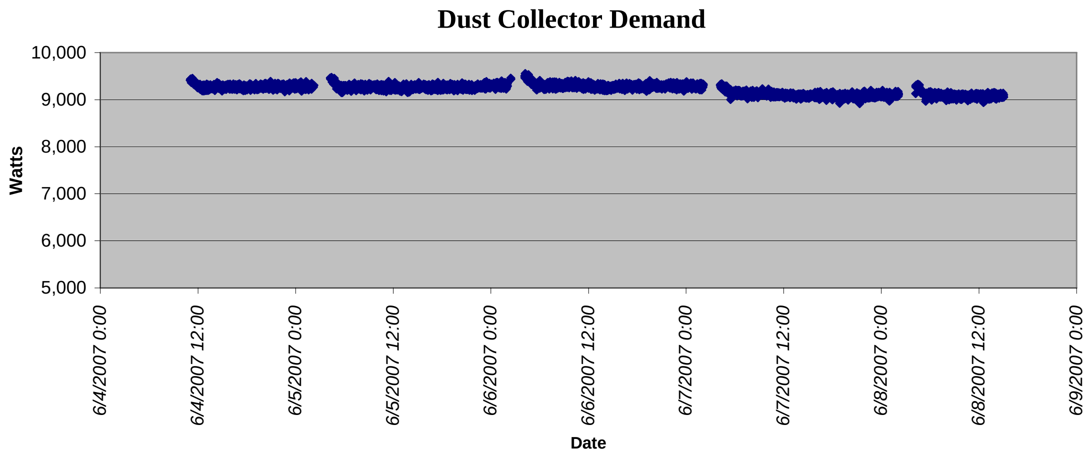


Table 2: Fluke 41B Power Measurements

Dust Collector	kW	Dust Collector	kW
MO-5309	8.3	MO-5305	8.7
MO-5307	8.0	MO-5302	8.6
MO-5308	9.1	MO-5312	9.2
MO-5317	8.5	MO-5303	8.0
Average			**8.55**

To accurately represent the hours of operation the dust collectors must be broken down into two categories: custom and standard. The majority of the dust collectors are on a standard schedule, with generally three units operating on a custom schedule. These three units can vary as needed but generally are the dust collectors for the special order, custom iron or custom wood areas of the facility. For the custom schedule dust collectors, one was metered and was found to operate 100% of the time the meter was in place. The facility representative stated this is not typical. Generally, the custom dust collectors operate 24 hours per day, six days per week during the months of increased production. During the hours of decreased production, the custom dust collectors are expected to operate 16 hours per day, five days per week. The remaining seven dust collectors metered were on the standard schedule. They were found on average to operate 63.1% of the time, operating from approximately 22 hours per day on Monday through Thursdays and 20 hours per day on Fridays. According to the site representative, during the months of increased production hours, the Friday shift would generally work 22 hours, with a Saturday shift working from 20 hours. If these hours are added to the logged hours, the dust collectors are expected to operate 130 hours per week, or 77.4% of the time. During the six months of decreased production, the standard dust collectors are also expected to operate 16 hours per day, five days per week. A description of the operating hours can be found in Table 3 and Table 4.

Table 3: Dust Collector Operating Hours

Dust Collectors	Qty	Weekly Hours Running (Logged)	Dec-May Expected Weekly Run Hours	Jun-Nov Expected Weekly Run Hours	Annual Average Expected Weekly Run Hours
Custom	3	168*	144	80	112
Standard	14	108	130	80	105
Weighted Average			132.5	80	106.2

*The dust collector logger for the custom location showed the unit running throughout the logging process, however, the facility representative stated this was not typical for these units.

Table 4: Hobo Motor On/Off Logger Results

Standard		Custom	
Dust Collector	**%Time Running**	**Dust Collector**	**%Time Running**
custom woods	64.86%	custom irons	99.97%
Irons	61.24%		
Protour	51.69%		
Putters	61.03%		
special order	91.96%*		
woods 1	69.87%		
woods 2	69.84%		
Average	**63.1%**		**99.97%**

*The special order dust collector logger %Time Running data was determined from the kW logger. This logger only operated for five days, the weekend hours were not included in this interval. Therefore, this logger was disregarded when determining the average standard schedule operating hours.

During daytime hours it was found that all units operated: therefore, at the summer peak hours, between 2 pm and 5 pm on weekdays, all seventeen (17) dust collectors are expected to be in operation.

The ex post impacts are calculated in Table 7 below:

Table 5: Energy and Demand Formulae

Hours per year based on 52.17 wks per year and 11 holidays: 5,459 hrs/year pre retrofit / 5,319 hrs/year post retrofit

Pre-Retrofit Demand kW_{peak} = Pre-Retr Scrubber Wattage x Pre-retr Scrubber Qty
= 208.56 kW/Scrubber x 2 Scrubbers
= 417.12 kW

Post-Retrofit Demand kW_{peak} = Post-Retr Scrubber Wattage x Post-retr Scrubber Qty
= 8.55 kW/Scrubber x 17 Scrubbers
= 145.35 kW

Peak kW Savings = Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak}
= 417.12 kW – 145.35 kW
= 271.77 kW

Pre-Retrofit kWh = Pre-Retrofit Demand kW_{peak} x Pre-retrofit Hours
= 417.12 kW x 5,458.7 hours/year
= 2,276,933 kWh/yr

Post-Retrofit kWh = Post-Retrofit Demand kW_{peak} x Post-retrofit Hours
= 145.35 kW x 5,318.837hours/year
= 773,093 kWh/yr

kWh Savings = Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak}
= 2,276,9330 kWh/yr – 773,093 kWh/yr
= 1,503,840 kWh/yr

The ex post kW demand reduction is greater than the ex ante estimate because the ex ante calculations overestimated the demand associated with the new dust collectors. The ex post energy savings are less than the ex ante energy savings because we found that the ex ante savings overestimated the hours of operation of the dust collectors by extrapolating hours of operation measured during the busy season throughout the year.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. In addition to saving energy, the benefit of the project is diversity. The maintenance of a dust collection unit no longer requires the stopping of production for approximately half of the employees. The customer did not give any drawbacks associated with the new equipment. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program has not encouraged them to perform any other energy efficiency projects for which they did not participate in an incentive program.

We were unable to physically verify the pre-retrofit dust collector type, quantity and hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

7. Impact Results

Based on the ex ante savings of 256.24 kW and 1,538,721 kWh the engineering realization rate for this application is 1.06 for kW reduction and 0.98 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 6.

Table 6: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	256.24	1,538,798	-
SPC Installation Report (ex ante)	256.24	1,538,798	-
Impact Evaluation (ex post)	271.77	1,503,840	-
Engineering Realization Rate	1.06	0.98	N/A

Utility billing data for the site was reviewed. In the 12-month period from April 2003 - March 2004 (pre-retrofit), the facility consumed 9,401,719 kWh. Peak demand was 1,974.2 kW in July 2003. Table 7 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 7: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1,974.2	9,478,300
Baseline End Use	417.1	2,504,806
Ex Ante Savings	256.2	1,538,798
Ex Post Savings	271.8	1,503,840

Table 8 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 13.0% decrease in total meter kW, a 61.4% decrease in dust collection end use kW, a 16.4% decrease in total meter kWh, and a 61.4% decrease in dust collection end use kWh. The ex post results showed a 13.8% decrease in total meter kW, a 65.2% decrease in dust collection end use kW, a 15.9% decrease in total meter kWh, and a 60.0% decrease in dust collection end use kWh.

Table 8: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/ Demand Reduction	kW	kWh	Kw	kWh
Total Meter %	13.0%	16.2%	13.8%	15.9%
Baseline End Use %	61.4%	61.4%	65.2%	60.0%

With a cost of $515,000 and a $123,104 incentive, the project had a 1.96 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 2.00 years. A summary of the economic parameters for the project is shown in Table 9.

Table 9: Economic Information

	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	3/23/07	$515,000	256.24	1,538,721	0	$ 200,034	$ 123,104	1.96	2.57
SPC Program Review (Ex Post)	7/9/07	$515,000	272.62	1,503,840	0	$ 195,499	$ 123,104	2.00	2.63

It was determined that the dust collector retrofit project was defined as a Custom Measure-SPC in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the dust collectors were assumed to have a useful life of fifteen (15) years. A summary of the multi-year reporting requirements is given in Table 10. Because this measure was installed by December 2004, the energy savings in year #1 (2004) are assumed to be 1/12 of the expected annual savings for this measure. In addition, no peak savings are assumed to occur in that year.

Table 10: Multi-Year Reporting Requirements

Program		001 Application # A021					
Program		SPC 04-05 Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected kWh Savings	Ex-Post Gross Evaluation Confirmed kWh Savings	Ex-Ante Gross Program-Projected Peak kW Savings	Ex-Post Gross Evaluation Confirmed kW Savings	Ex-Ante Gross Program-Projected Therm Savings	Ex-Post Gross Evaluation Confirmed Therm Savings
1	2004	128,233	125,320	-	-	0	0
2	2005	1,538,798	1,503,840	256.2	271.8	0	0
3	2006	1,538,798	1,503,840	256.2	271.8	0	0
4	2007	1,538,798	1,503,840	256.2	271.8	0	0
5	2008	1,538,798	1,503,840	256.2	271.8	0	0
6	2009	1,538,798	1,503,840	256.2	271.8	0	0
7	2010	1,538,798	1,503,840	256.2	271.8	0	0
8	2011	1,538,798	1,503,840	256.2	271.8	0	0
9	2012	1,538,798	1,503,840	256.2	271.8	0	0
10	2013	1,538,798	1,503,840	256.2	271.8	0	0
11	2014	1,538,798	1,503,840	256.2	271.8	0	0
12	2015	1,538,798	1,503,840	256.2	271.8	0	0
13	2016	1,538,798	1,503,840	256.2	271.8	0	0
14	2017	1,538,798	1,503,840	256.2	271.8	0	0
15	2018	1,538,798	1,503,840	256.2	271.8	0	0
16	2019	1,410,565	1,378,520	256.2	271.8	0	0
17	2020	-	-	-	-	0	0
18	2021	-	-	-	-	0	0
19	2022	-	-	-	-	0	0
20	2023	-	-	-	-	0	0
TOTAL	2004-2023	23,081,970	22,557,606			0	0

Final Site Report

SITE A022 All IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: Lighting

Measure	High Bay T8 Lighting Retrofit
Site Description	Warehouse

1. Measure Description

Replace 336 high pressure sodium fixtures and 276 metal halide fixtures with 612 six lamp, high output fluorescent fixtures using T8 lamps.

2. Summary of the Ex Ante Calculations

The installation was submitted as an itemized measure (Measure L-Hb1). No kW or kWh savings calculations were provided. The basis of the incentive payment was the itemized incentive rate in the Measure Savings Worksheet.

According to the Installation Report Review, the ex ante savings are 683,138 kWh annually and demand reduction is 122.8 kW.

However, handwritten notes on the Project Application Review by the program administrator revise the savings to 515,860.92 kWh and 125.5177 kW. No justification for revising the energy savings and demand reduction estimate is included in the application.

The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. The workpapers note that a conversion from metal halide fixtures to four lamp high output (HO) T5 fixtures results in a wattage reduction from 0.458 kW to 0.234 kW, for a non-coincident peak reduction of 0.224 kW. Coincident peak reduction is noted as 0.205 kW and kWh savings is noted as 843 kWh/year. The hours of operation for a warehouse are fixed in the work papers at 3,550 hours/year.

3. Comments on the Ex Ante Calculations

The Express Efficiency work papers are not directly applicable since they are based only on four lamp T5 fixtures converted from metal halide fixtures. There was no work paper available for six lamp T8 fixtures or for high pressure sodium replacements. Examination of the lighting wattage fixture tables indicates that a 6 lamp high output T-8 fixture (fixture code: F46ILL/2-V (G2)) consumes 226 watts, which is approximately the same as the 234 watts used in the Express Efficiency work papers for four lamp high output fixtures using T5 lamps.

For the 612 fixtures replaced, using 0.234 kW for a four lamp fixture and using 0.458 kW for all HID lamps, along with 3,550 hrs per year from the work paper, the 486,662 kWh and 137.1 kW savings, while not identical, are similar to the savings reported in the utility tracking system.

The project description in the Installation Report Review states that the new fixtures consume 276 watts each. The source of the 276 watt figure is not cited.

Our estimates of the pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post}

The savings estimates in the Installation Report Review would be expected to be identical to the utility tracking system savings figures. The total savings in the Installation Report Review were given as 683,138 kWh/yr and 122.8 kW. The project Application Review and the utility tracking system note a total savings of 515,861 yr and 125.52 kW. The utility tracking system figures will be used to calculate the realization rate.

4. Measurement & Verification Plan

The building is a single level 368,000 sf warehouse. The facility was reported to be approximately 11 years old. According to the application, before the retrofit there were 336 high pressure sodium fixtures and 276 metal halide fixtures. All fixtures had 400 watt lamps. After the retrofit, there are 612 six-lamp T-8 high output fluorescent fixtures. The project saves energy through the installation of lighting fixtures with lower power draw. According to documentation in the application, all lighting fixtures are energized continuously.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture quantities and hours of operation. The pre-retrofit and post-retrofit connected loads associated with various fixture types are adequately quantified in the SPC lighting wattage tables. However, for this application, if lighting hours are fixed (i.e., operating continuously or on a known schedule), then lighting wattages may be able to be confirmed.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures, through quantifying hours of operation, fixture quantities, and fixture wattages.

Formulae and Approach

The M&V plan proposed is a modified version of IPMVP Option A.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture quantities, wattage draw, and hours of operation. The pre-retrofit and post-retrofit connected loads associated with various fixture types may be adequately quantified in the SPC lighting wattage tables.

However, since hours of operation and quantities may be fixed and accurately known, the fixture wattages will be measured if possible.

The pre-retrofit fixture types, quantities and hours of operation will be verified with the facility representative. Variances due to burned out bulbs, maintenance, and/or schedules will be addressed to the extent possible. The post-retrofit fixture quantities and fixture types will be physically verified during the site visit. Holiday periods will be considered.

If the customer states that lighting operation is not presently energized continuously or does not have a regular schedule, lighting Dent TOU loggers will be installed throughout the warehouse in representative areas for a minimum of 7 days to verify the post retrofit hours of operation. These optically triggered loggers record lighting status (on or off).

Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Summer coincident peak demand period savings = kW_{pre} – kW_{post} during the hottest periods between 2 pm to 5 pm, Monday to Friday, in June, July, August, September

Monitoring with light loggers if conducted, may require fifteen (15) loggers. However, additional loggers may be required, based on usage and traffic patterns. The use of fifteen sampling points is generally consistent with SPC program documentation from March 2001 (Appendix E, Sampling); this document suggests guidelines for determining sampling point requirements necessary to achieve an 80% confidence interval with 20% precision (using a coefficient of variation of 0.5). Random sampling may be employed, labeling fixtures sequentially according to their location, and randomly selecting from the total number of fixtures using a random number generator. The light loggers would be placed so as to be unaffected by fixtures not on motion sensors or by ambient outside light.

If the light loggers cannot be placed in suitable locations, it was considered that, where the lighting circuits can be isolated and it can be determined that only lighting loads for the warehouse fixtures are controlled by that lighting circuit, a current or power meter could be used to track multiple fixtures. The total current / power would be determined by activating all fixtures and by confirming loads using the electrical drawings. Between three and six current/power meters are expected to be needed, to capture a representative sample of the lighting fixtures.

The lighting loggers or current / power sensors would be left in place for a period of 7 to 14 days. Attention will be given to the time period for monitoring, in order to avoid periods of irregular usage patterns (e.g., during holidays or breaks). While longer periods might be preferable, these periods are appropriate given the scope of the evaluation and reported usage characteristics.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture hours of operation. The lighting fixture quantities seem to be well established and were counted to within 5% in utility post-installation inspection visits. The pre-retrofit and post-retrofit connected loads associated with various fixture types may be adequately quantified in the SPC lighting wattage tables. The advantage of using current or power sensors is that the use of these devices will assist in verifying the actual wattage draw of the new fixtures.

Uncertainty for the savings estimate for the warehouse fixture retrofit can be more fully understood by establishing projected ranges on the primary variables shown in Exhibit 1 below.

- 612 fixtures expected, minimum 582, maximum 642 (+/- 5%)
- 8,760 hours pre retrofit expected/reported, minimum 8,000 hours, maximum 8,760 hours
- 0.226 kW draw per fixture expected, minimum 0.208 kW, maximum 0.244 kW (+/- 8%)

If lighting hours are not constant, there may be a small potential source of error introduced by annualizing estimates from short monitoring periods. This error is estimated at a maximum of + /- 5% for this facility and is not included in the analysis of uncertainty due to its size.

Accuracy and Equipment

The light loggers, if used, will be Dent TOU-L Lighting Smart*logger* data loggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Power meters may also be used to verify fixture wattages. The power meter to be used, if this M&V technique is selected, would be a model manufactured by Nanovip. The accuracy range is expected to be +/- 8 %.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on April 17, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Lighting fixture quantities and hours of operation were verified. Lighting fixture power consumption was measured on a circuit serving 10 fixtures.

The building is occupied continuously except for 12 hours between 5 p.m. Saturday and 5 a.m. Sunday. Most activity occurs between 4 a.m. and 11 p.m. Monday to Friday. Maximum occupancy is approximately 400 employees at any given time. The facility is closed 3 holidays annually.

Installation Verification

The facility representative verified that the high pressure sodium fixtures and metal halide fixtures were replaced on a one for one basis. It was physically verified that there are 608 six-lamp T-8 fluorescent fixtures. The facility representative stated that the retrofit was completed in December 2004. For purposes of the ex post calculations, it is assumed that there were 334 high pressure sodium lamp fixtures and 274 metal halide fixtures prior to the retrofit.

This is the only measure in this application. The verification realization rate for this project is 0.99 (608/612). A verification summary is shown in Exhibit 5 below.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measure in the SPC application covering the lighting efficiency retrofit. This is the only measure in this application.

Summary of Results

Lighting power consumption was measured on one circuit in a lighting power panel. It was verified that the circuit measured serves 10 lighting fixtures by de-energizing the circuit and observing the number of deenergized fixtures. Power was measured on the energized circuit with the Nanovip power meter and found to be 2.044 kW or 204 watts per fixture.

The facility representative stated that the building is occupied continuously except for 12 hours between 5 p.m. Saturday and 5 a.m. Sunday. All lights are on when the building is occupied. The shift supervisor and security personnel are responsible for turning lights off during the unoccupied 12 hour period between 5 p.m. and Saturday and 5 a.m. Sunday. It is assumed the lights are off during all of these weekly periods.

Very few burned out lights were observed during the site visit and the facility has a five year service contract on the lighting system. Burned out lights are regularly replaced. Therefore, there was no adjustment to the lighting energy consumption due to burned out lamps.

All lights are expected to be operating during the peak demand period defined as the three contiguous hottest weekdays between 2 pm to 5 pm, Monday to Friday, in June, July, August, and September.

The ex post impacts were calculated as follows:

- Pre and post retrofit hours of operation are 8,062 hrs/year.
  (52.14 weeks/year x (168-12) hours/week)- 24 hours x 3 holidays/year
- Pre-retrofit wattage was 280.8 kW.

  0.465 kW per 400 watt HPS fixture x 334 fixtures
  + 0.458 kW per 400 watt MH fixture x 274 fixtures

  Annual kWh usage is 280.8 kW x 8,062 hrs/yr = 2,263,810 kWh/yr
- Post-retrofit wattage is 124.0.

  0.204 kW per six-lamp fixture x 608 fixtures

  Annual kWh usage is 124.0 kW x 8,062 hrs/yr = 999,688 kWh/yr
- The resulting annual kWh savings is 2,263,810 kWh/yr – 999,688 kWh/yr = 1,264,122 kWh/yr

Summer peak demand reduction impacts were estimated by subtracting post-retrofit from pre-retrofit connected load.

Peak kW savings is 280.8 kW – 124.0 kW = 156.8 kW

The engineering realization rate for this application is 1.25 for demand kW reduction and 2.45 for energy savings kWh. According to the Installation Report Review, the ex ante savings are 683,138 kWh annually and demand reduction is 122.8 kW. However, handwritten notes on the Project Application Review by the program administrator revise savings to 515,860.9 kWh and 115.5 kW. The handwritten revised figures matching the tracking system will be used as the ex ante savings and to calculate the realization rates.. A summary of the realization rate is shown in Exhibit 5.

Utility billing data for the site was provided in the application. Pre-retrofit annual consumption was listed as 4,650,300 kWh. Peak demand was 1,263 kW. However, actual kWh consumption was 7,709,854 kWh from billing records for the pre retrofit period. Exhibit 1 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility provided numbers.

Exhibit 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 9.9% decrease in total meter kW, a 44.7% decrease in baseline lighting end use kW from the existing fixtures, a 6.7% decrease in total meter kWh, and a 22.8% decrease in lighting end use kWh. The ex post results showed a 12.4% decrease in total meter kW, a 55.8% decrease in lighting end use kW, a 16.4% decrease in total meter kWh, and a 55.8% decrease in lighting end use kWh.

Exhibit 1 Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1,263	7,709,854
Baseline End Use	280.8	2,263,810
Ex ante Savings	125.5	515,861
Ex Post Savings	156.8	1,264,122

Exhibit 2 Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	9.9%	6.7%	12.4%	16.4%
Baseline End Use %	44.7%	22.8%	55.8%	55.8%

6. Additional Evaluation Findings

The ex post kW demand reduction is greater than the ex ante estimate because the ex ante savings estimated may have been based on a post retrofit fixture consuming a higher number of watts versus the 204 watts measured. The ex post energy savings are greater than the ex ante energy savings because the hours of operation were much greater than those assumed in the Express Efficiency work papers and presumably used for the ex ante calculations.

The facility representative stated that the cost estimate provided in the application ($265,330) is from the invoice for the work performed for the project and is an accurate reflection of the project cost.

In addition to saving energy, the benefits of the project are better quality of lighting and increased light levels in some areas. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer is currently investigating the installation of occupancy sensors on the high bay fixtures and they will likely participate in the offered energy efficiency programs if they proceed with this project. Participation in the 2004/2005 SPC Program has not encouraged them to perform any other energy efficiency projects without participating in an incentive program.

The pre-retrofit lighting fixture type, quantities and hours of operation were unable to physically verified. However, these parameters have been accurately assessed and quantified based on discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $265,330 and a $45,900 incentive, the project had a 4.0 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 1.6 years. A summary of the economic parameters for the project is shown in Exhibit 3.

7. Impact Results

Impact results are presented in the following tables.

Exhibit 3 Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	2/3/2005	$265,330	125.5	515,861	0	$67,062	$45,900	3.27	3.96
SPC Program Review (Ex Post)	4/20/2007	$265,330	156.8	1,264,122	0	$164,336	$45,900	1.34	1.61

Exhibit 4 Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	125.5	515,861	-
SPC Installation Report (ex ante)	122.8	683,138	-
Impact Evaluation (ex post)	156.8	1,264,122	-
Engineering Realization Rate	1.25	2.45	NA

Tracking System values used for economic information and realization rate calculations

Exhibit 5 Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Replace 336 high pressure sodium lamp fixtures and 276 metal halide fixtures with 612 six lamp high output T8 fluorescent lamp fixtures		608	6 lamp T-8 HO fixtures	Physically verified fixture quantity and lamp type.	0.99

Exhibit 6 Multi Year Reporting Table

Site ID:	001 Application # A022
Program Name:	SPC 04-05 Evaluation

Year	Calendar Year	Ex-ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	42,988	105,344				
2	2005	515,861	1,264,122	125.5	156.8		
3	2006	515,861	1,264,122	125.5	156.8		
4	2007	515,861	1,264,122	125.5	156.8		
5	2008	515,861	1,264,122	125.5	156.8		
6	2009	515,861	1,264,122	125.5	156.8		
7	2010	515,861	1,264,122	125.5	156.8		
8	2011	515,861	1,264,122	125.5	156.8		
9	2012	515,861	1,264,122	125.5	156.8		
10	2013	515,861	1,264,122	125.5	156.8		
11	2014	515,861	1,264,122	125.5	156.8		
12	2015	515,861	1,264,122	125.5	156.8		
13	2016	515,861	1,264,122	125.5	156.8		
14	2017	515,861	1,264,122	125.5	156.8		
15	2018	515,861	1,264,122	125.5	156.8		
16	2019	515,861	1,264,122	125.5	156.8		
17	2020	472,873	1,158,779	125.5	156.8		
18	2021						
19	2022						
20	2023						
TOTAL	2004-2023	8,253,776	20,225,952				

Based upon implementation in December 2004 with a 16 year life.

FINAL SITE REPORT

SITE A023 (2004-xxx) USP IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 2 END USE: Lighting

Measure	Lighting and Lighting Controls Retrofit
Site Description	Distribution Facility

1. Measure Description

The application documents numerous lighting measures including:

- Replacing high bay 400 watt high pressure sodium fixtures with 8 lamp, high output T-8 fluorescent lamp fixtures.
- Replacing high bay 250 watt high pressure sodium fixtures with 4 lamp, high output fluorescent lamp fixtures.
- Installing occupancy sensors on the high bay fixtures to reduce lighting hours of operation.
- Retrofitting “first generation” T8 lamps and electronic ballasts with “third generation” T8 lamps and electronic ballasts.
- Installing hard wired compact fluorescent lights.
- Retrofitting exit signs.
- Installing occupancy sensors for selected T8 lighting.
- Delamping selected fixtures.

2. Summary of the Ex Ante Calculations

There are a total of eleven lighting sub measures. Five of the measures use a calculated approach and six of the measures are itemized.

The calculated measures use a simple pre-retrofit and post-retrofit algorithm using fixture connected loads and hours of operation for the ex ante calculations. The calculations were originally performed by the energy efficiency service provider. The reviewer made several adjustments to the calculations including changing fixture counts, changing fixture wattage, moving a sub measure from the calculated to the itemized subset, and making adjustments to the annual hours of operation.

For the calculated measures, the ex ante baseline is the existing system connected load and hours of operation, and is in accordance with the SPC Program guidelines. Pre-retrofit and post-retrofit calculations of lighting loads and energy use were performed using the following formulae:

kW = fixture watts / 1,000 watts / kW x fixture quantity

kWh = kW x hours

The ex ante calculations for the itemized measures are typically based on the Express Efficiency work papers.

According to the installation report, the approved ex ante savings are 2,186,523.6 kWh and demand reduction is 492.8 kW. The utility tracking data, however, shows 2,318,322 kWh and 522.75 kW demand reduction. The incentive is given as $122,370.85 in both the installation report review and in the tracking system.

Approximately 75% of the ex ante energy savings and 80% of the demand reduction are associated with the retrofit of 765 high bay 400 watt high pressure sodium lamp fixtures with 8 lamp, high output, T8 fluorescent lamp fixtures and occupancy sensors. The evaluation will focus on these measures.

The reviewer noted that the 8 lamp, high output, T8 fluorescent lamp fixture is not included in the SPC lighting fixture wattage tables. The reviewer notes indicate that manufacturer's data for the fixture was provided with the installation report showing that the fixture wattage is 294 watts. This submittal was not included in the application paperwork provided. A lighting manufacturer was contacted and sent a specification for an 8 lamp, high output T8 fluorescent lamp fixture confirming that the fixture wattage is 294 watts.

The occupancy sensor is an itemized measure. The ex ante calculations for the itemized measures are typically based on the Express Efficiency work papers.

The ex ante impacts were calculated as follows:

- Lighting Efficiency:
  Pre-retrofit hours of operation were 8,760 hrs/year.
  Pre-retrofit wattage was 465 watts per fixture
  Post-retrofit wattage was 294 watts per fixture
  Lighting demand reduction is :
  (0.465 kW-0.294 kW) x 765 fixtures = 130.815 kW
  Lighting efficiency savings are:
  130.815 kW x 8,760 hours = 1,145,939 kWh
  This calculation agrees with the figure shown in the installation report.

- Occupancy Sensors:
  Connected load for the 765 eight lamp, high output T8 fluorescent lamp fixtures is:
  0.294 kW x 765 fixtures = 224.9 kW
  The installation report "Summary of Approved Measures" shows 291.6 kW demand reduction for the occupancy sensor installation and 603,308 kWh energy savings. The demand reduction stated (291.6 kW) exceeds the total connected load calculated (224.9 kW). The kwh savings are approximately

25% based on the assumed connected load. [(630,308 kWh/291.6 kW)/8,760 hours].

- Total energy savings and demand reduction for the high bay lighting retrofit and occupancy sensors only:
  422.4 kW and 1,749,247 kWh / year

3. Comments on the Ex Ante Calculations

The ex ante calculations were performed according the SPC Program guidelines using the lighting fixture wattages from the SPC lighting wattage tables for the 400 watt HPS fixtures and manufacturer's data for the 8 lamp, high output T8 fluorescent lamp fixtures which are not included in the SPC lighting wattage tables. The calculation shows 8,760 hours of operation for the lighting fixtures before the retrofit. There appears to be an discrepancy between the expected savings and the ex ante savings reported for the occupancy sensor installation, and the discrepancy was not able to be resolved from the information provided, but is most likely related to the savings estimates used in the Express Efficiency workpapers.

4. Measurement & Verification Plan

There are numerous lighting measures documented in the application. Approximately 75% of the ex ante energy savings and 80% of the demand reduction are associated with the retrofit of 765 high bay 400 watt high pressure sodium lamp fixtures with 8 lamp, high output, T8 fluorescent lamp fixtures and occupancy sensors. The evaluation will focus on these measures.

The area with the high-bay lighting is a single level 300,000 ft^2 conditioned space that sorts goods for distribution. The building has few windows. There are skylights on the roof. The building is occupied continuously, however most activity occurs between 3 p.m. and 8 a.m. Monday-Friday. Maximum occupancy is approximately 500 employees at any given time. The facility does not close and always remains occupied, although occupancy may be lower during major holiday periods.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture quantities and hours of operation. The pre-retrofit and post-retrofit connected loads associated with various fixture types are adequately quantified in the SPC lighting wattage tables and were supplemented with manufacturer's data for the new 8 lamp, high output T8 fluorescent lamp fixtures.

According to the application, 765 fixtures with 400-watt high pressure sodium lamps were replaced with 765 fixtures with 8 lamp, high output T8 fluorescent lamp fixtures. The post-retrofit fixtures were equipped with occupancy sensors. The project saves energy through the installation of lighting fixtures with lower power draw and by controlling the lighting with occupancy sensors to reduce hours of operation.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures, through quantifying hours of operation, fixture quantities, and fixture wattages.

Formulae and Approach

The M&V plan proposed is a modified version of IPMVP Option A. For this application, the pre-retrofit fixture types, quantities and hours of operation will be verified with the facility representative. Variances due to burned out bulbs, maintenance, and/or schedules will be addressed to the extent possible. The post-retrofit fixture quantities and fixture types will be physically verified during the site visit.

Hobo lighting loggers will be installed throughout the warehouse in representative areas for a minimum of 7 days to verify the post retrofit hours of operation. These loggers measure light intensity and will be used to record lighting status (on or off). The loggers will be set to record light intensity every 90 seconds.

Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x ((energized $hours_{pre}$ - energized $hours_{post}$) / energized $hours_{pre}$) during the hottest periods between 2 pm to 5 pm, Monday to Friday in June, July, August, or September.

Thus, to estimate peak demand kW reduction, the reduction in connected kW due to the increased lighting efficiency will be added to the post-retrofit connected load multiplied by the percent of energized time according to the above formulae. The derivation or extrapolation of the average percent of time energized used in the above formula for both the coincident peak demand periods will be described.

Monitoring with light loggers may require twelve (12) sensors. However, additional sensors may be required, based on usage and traffic patterns. The use of twelve sampling points is generally consistent with SPC program documentation from March 2001 (Appendix E, Sampling); this document suggests guidelines for determining sampling point requirements necessary to achieve an 80% confidence interval with 20% precision (using a coefficient of variation of 0.5). Random sampling may also be able to be employed, labeling fixtures sequentially according to their location, and randomly selecting from the total number of fixtures using a random number generator. The light loggers would be placed so as to be unaffected by fixtures not on motion sensors or by ambient outside light.

The lighting loggers would be left in place for a period of 7 to 14 days. Attention will be given to the time period for monitoring, in order to avoid periods of irregular usage patterns (e.g., during holidays or breaks). While longer periods might be preferable, these periods are appropriate given the scope of the evaluation and reported usage characteristics.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture hours of operation. The lighting fixture quantities seem to be well established and were counted to within 5% in utility post-installation inspection visits. The pre-retrofit and post-retrofit connected loads associated with various fixture types are also adequately quantified in the SPC lighting wattage tables.

Uncertainty for the savings estimate for the high bay fixture retrofit can be more fully understood by establishing projected ranges on the primary variables, as follows:

- 765 fixtures expected, minimum 727, maximum 803 (+/- 5%)
- 8,760 hours pre retrofit expected/reported, minimum 7,884 hours, maximum 8,760 hours (-10%)
- 6,570 hours post retrofit expected/reported, minimum 4,600 hours, maximum 8,541 hours (+/- 30%)

If lighting hours are not constant, there may be a small potential source of error introduced by annualizing estimates from short monitoring periods. This error is estimated at a maximum of + /- 5% and is not included in the analysis of uncertainty due to its size.

Accuracy and Equipment
The light loggers to be used are Hobo data loggers. The logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers will be set to sample light intensity every 90 seconds and for the purposes of the evaluation are considered to be 95% accurate for light levels where reviewed data is deemed reasonable. However, greater accuracy is expected if only light fixture energization is required.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on April 26, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representatives. Twelve (12) lighting loggers were installed throughout the floor area.

Installation Verification

The facility representative verified that all 400 watt high-bay fixtures were replaced on a one-for-one basis. We physically verified that there are 760 eight-lamp T-8 fluorescent fixtures. All lamps are high output (HO). All post-retrofit fixtures are equipped with occupancy sensors. Several hours were spent at the facility during the initial site visit and while retrieving light loggers on a subsequent visit. Very few lights were de-energized during those periods, and the only lamps observed off were the 4 inboard lamps on the 8 lamp fixtures. In a few instances, we did observe the lamps coming on or going off indicating that the occupancy sensors were functioning.

The facility representative confirmed that the occupancy sensors only control the 4 inboard lamps, and that the outboard lamps remain on continuously. Further discussion confirmed that the large open area has a significant amount of foot traffic through most areas. The facility representative did not know the time delay setting on the occupancy sensors, but it appears that the lights remain on a significant amount of time.

We reviewed the complete list of lighting measures with the facility representative and verified that the type of measures listed had actually been installed. We did not however verify the quantities listed in the application.. Based on the installed high-bay fixtures with occupancy sensors, the verification realization rate for this project is 0.99 (760/765). A verification summary is shown in Table 5 below.

Scope of the Impact Assessment

The impact assessment scope is for the high-bay lighting end use measures in the SPC application covering both lighting efficiency and controls retrofits. These are the only measures evaluated in this application.

Summary of Results

Random numbers were generated and used to determine which fixtures would be monitored. Twelve (12) Hobo lighting loggers were installed in the facility for 7 days. Data was collected from April 27, 2007 through May 3, 2007 to measure the operating hours of a representative sample of the retrofit lighting fixtures. We determined during the site visit that only 4 of the 8 lamps are controlled by the occupancy sensors. The remaining four lamps remain on continuously.

The facility representative stated that the 7 day period had been representative of normal facility operation. It was found that on average, the controlled lamps were on 93.8% of the time compared to the 75% that was representative in the ex ante calculations. Table 7 shows the percent of time the controlled lamps were on for the fixtures monitored during the period from April 27, 2007 - May 3, 2007.

During the period between 2 p.m. to 5 p.m., Monday to Friday, the controlled lamps were measured to be on an average 98.1% of the time.

Very few burned out lights were observed during the site visit. The facility has a maintenance department and burned out lights are regularly replaced. Therefore, there was no adjustment to the lighting energy consumption due to burned out lamps.

The ex ante calculations were performed using the verified operating schedule and lighting fixture wattage from the SPC tables and data obtained from a lighting manufacturer for the eight (8) lamp T-8 fixtures.

The ex post impacts are calculated as follows:

- Pre-retrofit hours of operation were 8,760 hrs/year.
  Pre-retrofit wattage was 465 watts per lamp x 760 fixtures = 353.4 kW
  Annual kWh usage was 353.4 kW x 8,760 hrs/yr = 3,095,784 kWh/yr
- Based on lighting logger data, post-retrofit hours of operation are 8,217 hrs/year (93.8% x 8,760 hrs/yr) for the controlled lamps,
  and 8,760 hrs/year for the uncontrolled lamps.
  Post-retrofit controlled wattage is (294 watts per eight-lamp fixture/2) x 760 fixtures = 111.72 kW
  Post-retrofit uncontrolled wattage is (294 watts per eight-lamp fixture/2) x 760 fixtures = 111.72 kW

  Annual post retrofit kWh usage is 111.72 kW x 8,217 hrs/yr + 111.72 kW x 8,760 hrs/yr = 1,896,670 kWh/yr
- The resulting annual kWh savings is 3,095,784 kwh/yr – 1,896,670 kwh/yr = 1,199,113 kWh/yr.

Summer peak kW impacts were estimated by subtracting post-retrofit from pre-retrofit connected load, with an adjustment for the weekday 2 pm to 5 pm average measured post-retrofit percent on value of 98.1% for the controlled lamps.

- Peak kW demand reduction is 353.4 kW – (111.72 kW+111.72 kW x 98.1%) = 132.1 kW.
- The engineering realization rates for this application are 0.31 for demand kW reduction and 0.69 for energy savings kWh.
  132.1 kW/422.4 kW= 0.31
  1,199,113 kWh/ 1,749,247 kWh = 0.69

The realization rates are applied to the ex ante energy savings and demand reduction for all lighting end use measures in the application. The values from the utility tracking system are used as the basis of the evaluation.

- Applying the engineering realization rates for this application of 0.31 for demand kW reduction and 0.69 for energy savings kWh to the total lighting project yields a demand reduction of 162 kW and an annual energy savings of

1,599,642 kWh

- 0.31 x 522.75 kW = 162.0 kW
  0.69 x 2,318,322 kWh = 1,599,642 kWh

The values shown in the tracking system do not agree with those shown in the installation report for this application. The values shown in the Tracking System are used for the realization rate calculations. A summary of the realization rate is shown in Table 5.

Utility billing data for the site is shown in the Project Site Summary Section of the Application. The summary indicates that the site annual energy use was 14,900,000 kWh and peak demand was 2,677 kW. Table 1 summarizes the total metered use and the baseline end use energy, the ex ante savings and the ex post calculation results for the high bay lighting retrofit with occupancy sensors.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use for the high bay lighting retrofit with occupancy sensors, for both the ex ante and ex post savings calculations. The ex ante results estimated a 15.8% decrease in total meter kW, a 120% decrease in lighting end use kW, an 11.7% decrease in total meter kWh, and a 56.5% decrease in lighting end use kWh. The ex post results showed a 4.9% decrease in total meter kW, a 37.4% decrease in lighting end use kW, an 8% decrease in total meter kWh, and a 38.7% decrease in lighting end use kWh.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	2,677	14,900,000
Baseline End Use	353.4	3,095,784
Ex ante Savings	422.4	1,749,247
Ex Post Savings	132.1	1,199,113

Baseline end use, ex ante and ex post savings are for the high-bay lighting retrofit with occupancy sensors only, not the entire lighting project.

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	15.8%	11.7%	4.9%	8.0%
Baseline End Use %	119.5%	56.5%	37.4%	38.7%

Baseline end use % and total meter %, ex ante and ex post savings are for the high-bay lighting retrofit with occupancy sensors only, not the entire lighting project.

6. Additional Evaluation Findings

The ex post kW demand reduction is less than the ex ante estimate because the ex ante estimate was based upon itemized savings measures which did not reflect the actual situation. The installation report "Summary of Approved Measures" shows 291.6 kW demand reduction for the occupancy sensor installation and 603,308 kWh energy savings. The demand reduction stated (291.6 kW) exceeds the total connected load calculated (224.9 kW). Additionally, during the site visit, we determined that the occupancy sensors only control 4 of the 8 lamps in each fixture, and loggers indicate that the controlled lamps are seldom off during the peak demand period. The ex post energy savings are less than the ex ante energy savings because we found that the ex ante savings over-estimated the amount of time the lights would be turned off by the occupancy sensors.

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. In addition to saving energy, the benefits of the project are better quality of lighting and increased light levels in some areas. One drawback of the project has been an increase in maintenance associated with the need to replace fluorescent lamps and ballasts. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program has not encouraged them to perform any other energy efficiency projects for which they did not participate in an incentive program.

We were unable to physically verify the pre-retrofit lighting fixture type, quantities and hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $724,370 and a $122,371 incentive, the project had a 2.0 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 2.9 years. A summary of the economic parameters for the project is shown in Table 3.

7. Impact Results

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	2/3/2005	$724,370	522.8	2,318,322	0	$301,382	$122,371	2.00	2.40
SPC Program Review (Ex Post)	4/20/2007	$724,370	162.1	1,599,642	0	$207,953	$122,371	2.89	3.48

Tracking system savings used in this table.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	522.8	2,318,322	-
SPC Installation Report (ex ante)	492.8	2,186,524	-
Impact Evaluation (ex post)	162.1	1,599,642	-
Engineering Realization Rate	0.31	0.69	NA

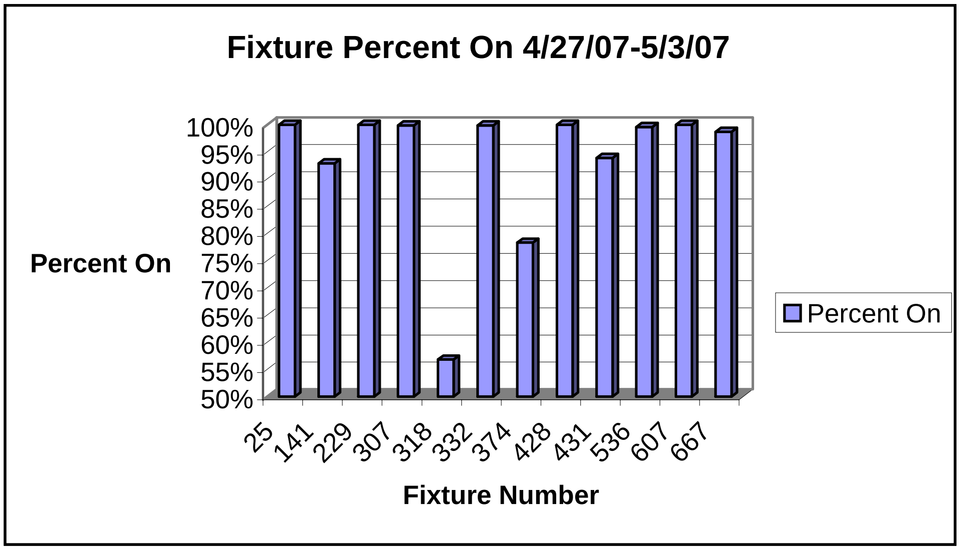
Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Replace 765 high pressure sodium lamp fixtures with 765 eight lamp high output T8 fluorescent lamp fixtures with occupancy sensors.		760	8 lamp T-8 HO fixtures with occupancy sensors.	Physically verified fixture quantity, lamp type and occupancy sensors.	0.99

Table 6: Multi Year Reporting Table

Program Name:		SPC 04-05 Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	2,186,524	1,599,642	492.8	162.1		
3	2006	2,186,524	1,599,642	492.8	162.1		
4	2007	2,186,524	1,599,642	492.8	162.1		
5	2008	2,186,524	1,599,642	492.8	162.1		
6	2009	2,186,524	1,599,642	492.8	162.1		
7	2010	2,186,524	1,599,642	492.8	162.1		
8	2011	2,186,524	1,599,642	492.8	162.1		
9	2012	2,186,524	1,599,642	492.8	162.1		
10	2013	2,186,524	1,599,642	492.8	162.1		
11	2014	2,186,524	1,599,642	492.8	162.1		
12	2015	2,186,524	1,599,642	492.8	162.1		
13	2016	2,186,524	1,599,642	492.8	162.1		
14	2017	2,186,524	1,599,642	492.8	162.1		
15	2018	2,186,524	1,599,642	492.8	162.1		
16	2019	2,186,524	1,599,642	492.8	162.1		
17	2020	2,186,524	1,599,642	492.8	162.1		
18	2021						
19	2022						
20	2023						
TOTAL	2004-2023	34,984,384	25,594,272				

Table 7: Fixture Percent On 4/27/07-5/3/07



FINAL SITE REPORT

SITE A024 (2004L-xxx) USP2 IMPACT EVALUATION
SAMPLE CELL: ORIGINAL   TIER: 1   END USE: AC&R

Measure	Early Retirement of Centrifugal Chillers
Site Description	Distribution Facility

1. Measure Description

This project involved the early retirement of two 450 ton centrifugal chillers. The new chillers are VFD driven. The savings were documented under the early retirement feature of the SPC Program.

VFDs were also installed on eight air handlers, three chilled water pumps, and three heating water pumps. The compressed air system was upgraded to include an intermediate pressure controller and a sequencing controller for five air compressors. Evaluation of the VFD measures and the compressed air system upgrade impacts is not performed as these measures are in other end use categories.

2. Summary of the Ex Ante Calculations

The SPC calculator was used for the ex ante savings estimates. The SPC calculator required inputs for the measure involving the early retirement of the chillers include: existing and proposed cooling system type, number of units and capacity, building type, location, conditioned area, whether or not the chillers run with the economizer, and annual hours of operation. The proposed system efficiency at full load is input. Also required is the year of manufacture. The existing chillers are shown to have 450 tons capacity each and to have been manufactured in 1991. During the post installation inspection, the reviewer observed that the customer had installed VFD driven chillers. The original application documents had not shown the proposed chillers to be VFD driven. The reviewer recalculated the ex ante impacts for the measure using the SPC calculation software.

The Installation Review Report (IRR) states that the ex ante savings for the early retirement of the chillers are 3,801,660 kWh with a demand reduction of 46.0 kW. These values agree with the utility tracking system.

3. Comments on the Ex Ante Calculations

The AC&R measure evaluated involves the early retirement of two 450 ton chillers. The application states that the chillers were manufactured in 1991, and this date is the basis of the early retirement claim.

Review of the SPC calculator results for this measure has revealed a significant error. The annual savings result has been multiplied by the remaining years of useful life and the result has been reported as the annual savings. The calculator output sheet indicates an annual savings of 380,166 kWh, a demand reduction of 46.0 kW and an incentive of $53,223, with 10 years remaining useful life. The reported savings for the measure are 3,801,660 kWh, a demand reduction of 46 kW with an adjusted incentive of $116,624.15 (adjusted for 50% measure cap and $300,000 site cap). This error has created a gross over-reporting of the ex ante kWh impacts. This error was not found for the demand reduction impacts. Based on the SPC calculator results, the correct ex ante savings for the measure are 380,166 kWh, a demand reduction of 46 kW and an incentive of $53,223.

4. Measurement & Verification Plan

Meteorological data will be used, in conjunction with customer reported operating hours (as verified by energy management system data as available), to determine the reasonableness of reported savings from the early retirement of the centrifugal chillers.

The savings are calculated using the pre retrofit equipment as a baseline for the expected remaining useful life of the pre retrofit equipment, then using Title 24 minimum efficiency for the remainder of the expected equipment life.

For example, the expected useful life of a centrifugal chiller is 23 years. The chillers were manufactured in 1991 and replaced in 2004. According to the program guidelines, the chillers would have 10 more years of useful life when they were replaced. The first 10 years of savings are calculated using the pre-retrofit equipment efficiency as a baseline. The remaining 13 years of savings are calculated using Title 24 minimum equipment efficiency as a baseline. The ex post impact is the average annual kWh savings and average peak demand reduction over the 23 year expected useful life of the new equipment.

The ex post impacts will be calculated using a simplified temperature bin analysis comparing the efficiency of the new units to the pre retrofit equipment efficiency and Title 24 minimum equipment efficiency. Annual hours of operation will be determined from the customer interview (and verified by energy management system data as available). System load will be estimated and energy consumption at various outdoor conditions will be calculated. The baseline equipment performance will be compared to the new equipment performance.

The project saves energy by the installation of more efficient heat pumps serving school buildings.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit hours of operation and the pre-retrofit chiller energy consumption.

The goal of the M&V plan is to verify the peak demand kW and annual kWh savings over the useful life of the equipment.

Formulae and Approach

The M&V plan is a modified version of IPMVP Option A.

The application contains the post retrofit efficiency of the chillers, the date the chillers were manufactured and the annual hours of operation for the facility.

The approach will entail the verification of the installed equipment full load efficiency and the annual hours of operation for each unit.

To determine pre and post retrofit chiller kW and kWh

For each temperature bin we will calculate kW and kWh as follows:

kW= tons x kW/ton
kWh= kW x annual hours

The annual kWh and peak demand will be calculated for each scenario - existing pre retrofit equipment, Title 24 pre retrofit equipment, and installed equipment. The average impact will be calculated as described above, with consideration for the expected useful life of the equipment and the manufacture date shown in the application.

To estimate peak demand kW reduction, the expected reduction in connected kW due to the higher efficiency units during the three expected contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in the week with the hottest weekday in June, July, August, September will be determined by calculating the expected kW reduction during the hottest periods in the hours from 2 pm to 5 pm, Monday to Friday, in June, July, August, September.

The post retrofit kW demand savings as determined above will be subtracted from the pre retrofit kW demand and the peak demand reduction will be calculated.

Peak demand reduction kW= maximum kW_{pre} – maximum kW_{post}

Uncertainty for the savings estimate can be more fully understood by setting projected ranges on the primary variables.

For the Chiller Replacement

- 550 kW pre-retrofit expected maximum demand, +/- 15% (468 to 633 kW)
- 6,700 hours/yr pre retrofit expected, +/- 20% (5,360 to 8,040 hrs/yr)

Accuracy and Equipment

Using the manufacturer's nameplate data for equipment efficiency is expected to have a error of 10-15%. Utilizing the modified bin analysis is expected to be +/- 15% accurate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on April 26, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the energy management system and centrifugal chiller units and by interviewing the facility representatives. Chiller unit make, model, quantities and hours of operation were verified. Temperature bin weather data was obtained from the National Climatic Data Center for an airport located in close proximity to the facility. The data contains 23 year averaged observations. This data was used for the ex post analysis.

The chillers are enabled by the energy management and control system to operate when the outside air temperature is above 62 ºF. The facility is continuously occupied.

Installation Verification

The installation of the new VFD driven centrifugal chillers was physically verified. The facility representative verified that two 450 ton chillers had been replaced with the two new 450 ton chillers.

This is the only AC&R end use measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 6 below.

Scope of the Impact Assessment

The impact assessment scope is for the AC & R end use measure in the SPC application covering the early retirement of the centrifugal chillers. This is the only AC & R end use measure in this application.

Summary of Results

To determine the reasonableness of reported savings from the early retirement of the chillers, meteorological data was used, in conjunction with customer reported operating hours (as verified by energy management system data) to calculate the impacts of the chiller installation. Full load chiller efficiency was obtained from the documents in the application for the pre and post retrofit chillers. We utilized chiller performance curves for the baseline and VFD chillers obtained from a chiller manufacturer's representative for similar capacity chillers. During the site visit we determined that the chillers are enabled when the outside air is above 62 ºF and that all of the air handling units have air side economizers. Using this data, we calculated the impact of the new chillers to be an annual savings of 220,677 kWh annually with a demand reduction of 45 kW versus the ex ante reported savings of 3,801,660 kWh and 46 kW demand reduction. Table 1 is a summary of the ex post analysis.

It should be noted while the ex ante first year savings seem to be 380,166 kWh, the application paperwork includes several calculator runs. One of these runs shows 74.1 kW and 227, 845 kWh of first year savings.

Table 1: Summary of the Ex Post Analysis for the Early Retirement of Centrifugal Chillers

	kW	kWh
Pre Retrofit	549	671,637
Post Retrofit	504	450,960
Ex Post Impacts	45	220,677

We were not able to obtain information on the pre retrofit equipment efficiency during the site visit. We accepted the efficiency value of 0.61 kW/ton at full load shown in the application documents. The Title 24 Standards in effect at the time of the Project installation (2001 version) indicate a minimum COP of 5.5 (0.64 kW/ton) for centrifugal chillers with a capacity greater than 300 tons. The pre retrofit chiller efficiency (0.61 kW/ton) was better than the 2001 Title 24 baseline (0.64 kW/ton) so there is no adjustment to the ex post impacts over the useful life of the chillers.

The engineering realization rate for this application is 0.98 for demand kW reduction and 0.06 for energy savings kWh. A summary of the realization rate is shown in Table 5.

Utility billing data for the site is shown in the Project Site Summary Section of the Application. The summary indicates that the site annual energy use was 14,900,000 kWh and peak demand was 2,677 kW. Table 2 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility provided numbers.

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 1.7% decrease in total meter kW, a 8.4% decrease in chiller end use kW, a 25.5% decrease in total meter kWh, and a 566% decrease in chiller end use kWh. The ex post results showed a 1.7% decrease in total meter kW, an 8.2% decrease in chiller end use kW, a 1.5% decrease in total meter kWh, and a 32.9% decrease in chiller end use kWh.

Table 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	2,677	14,900,000
Baseline End Use	549	671,637
Ex ante Savings	46	3,801,660
Ex Post Savings	45	220,677

Table 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	1.7%	25.5%	1.7%	1.5%
Baseline End Use %	8.4%	566.0%	8.2%	32.9%

6. Additional Evaluation Findings

The ex post kW demand reduction is essentially equal the ex ante estimate because we utilized the same full load efficiency for the pre and post retrofit chillers. The ex post energy savings are less than the ex ante energy savings because we determined that the early retirement measure has a calculation error (described above) and that the ex ante analysis did not account for the impacts of the air side economizers.

The facility representative stated that the cost estimate provided in the application ($233,248) is an approximation of the cost for the work performed for the project and may not be an accurate reflection of the true project cost. In addition to saving energy, the benefits of the project are more reliable equipment operation and reduced maintenance costs. Participation in the 2004/2005 SPC Program has not encouraged the customer to perform any other energy efficiency projects without participating in an incentive program.

With a cost of $233,248 and a $116,624 incentive, the project had a 0.24 year simple payback based on the ex ante calculations. The costs appear reasonable and possibly low for these application given the chiller size. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 8.1 years. A summary of the economic parameters for the project is shown in Table 5. The customer stated that they have no reason to believe that the operation of the equipment will change in the future, therefore the multi-year impacts, shown in Table 7 below, are expected to remain constant over the life of the equipment.

7. Impact Results

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	6/9/2005	$233,248	46.0	3,801,660	0	$494,216	$116,624	0.24	0.47
SPC Program Review (Ex Post)	10/12/2007	$233,248	45.0	220,677	0	$28,688	$116,624	4.07	8.13

Table 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	46.0	3,801,660	-
SPC Installation Report (ex ante)	46.0	3,801,660	-
Average Impact Evaluation (ex post)	45.0	220,677	-
Average Engineering Realization Rate	0.98	0.06	NA
First Year Impact Evaluation (ex post)	45.0	220,677	-
First Year Engineering Realization Rate	0.98	0.06	NA

Table 7: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Early retirement of centrifugal chillers	AC&R	Replace two 450 ton units with new 450 ton VFD driven units.			2	York Model YKCF CFQ7CMFS	Physically verified chiller quantity and installation. Two 450 ton VFD driven units were installed as stated in the documentation.	1.0

Table 8: Multi Year Reporting Table

	Program Name:	A024 SPC 04-05 Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004					0	0
2	2005	1,900,830	110,338	46	45	0	0
3	2006	3,801,660	220,677	46	45	0	0
4	2007	3,801,660	220,677	46	45	0	0
5	2008	3,801,660	220,677	46	45	0	0
6	2009	3,801,660	220,677	46	45	0	0
7	2010	3,801,660	220,677	46	45	0	0
8	2011	3,801,660	220,677	46	45	0	0
9	2012	3,801,660	220,677	46	45	0	0
10	2013	3,801,660	220,677	46	45	0	0
11	2014	3,801,660	220,677	46	45	0	0
12	2015	3,801,660	220,677	46	45	0	0
13	2016	3,801,660	220,677	46	45	0	0
14	2017	3,801,660	220,677	46	45	0	0
15	2018	3,801,660	220,677	46	45	0	0
16	2019	3,801,660	220,677	46	45	0	0
17	2020	3,801,660	220,677	46	45	0	0
18	2021	3,801,660	220,677	46	45	0	0
19	2022	3,801,660	220,677	46	45		
20	2023	3,801,660	220,677	46	45		
TOTAL	**2004-2023**	70,330,710	4,082,524				

Note: If the multi year ex ante savings of 3,801,660 kWh are replaced with first year savings of 380,166 kWh in the realization rate calculations, the kWh realization rate is increased from 0.06 to 0.58 (6% to 58%). The kW realization rate is not affected.

FINAL SITE REPORT

SITE A025 Kind (2004-xxx) IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 1 END USE: Other

Measure	Replace Pipeline
Site Description	Petroleum Product Distribution

1. Measure Description

Replace 61 miles of 14” diameter pipeline with 69 miles of 20” diameter pipeline. Install a drag reduction agent (DRA) injection system, and eliminate the use of some pumps.

The pipeline begins at site A. Site A is also the beginning of three other pipelines. Site A is served by a single electric meter. The pre-retrofit 14” pipeline was served by two 1,250 HP pumps and a surge pump unit. At the completion of the project it was expected that only one 1,250 HP pump and one surge pump would be needed for the new pipeline.

Site B was a booster pump station serving this pipeline only. The new pipeline does not go through Site B. According to the application the 1,500 HP booster pump at Site B has been decommissioned. Site B is served by a single electric meter.

Site C was also a booster pump station on the pipeline. The new 20” pipeline goes to Site C, but the route is approximately 9 miles longer than the old 14” pipeline route. According to the application, the 1,500 HP pump at Site C would no longer be needed when the 20” pipeline is installed. Site C is served by a single electric meter. Some product is taken out of the pipeline at Site C. The pipeline continues from Site C to Site D, but the pipeline is 12.75” for this section, and has not been replaced.

The application also shows that a drag reduction agent injection system will be installed at Site A. According to the customer, DRA is a polymer that absorbs turbulence in the fluid reducing pressure losses in the pipeline.

2. Summary of the Ex Ante Calculations

The application includes detailed engineering calculations prepared by the customer. The calculations utilize pump performance data, pressure drop at loaded and unloaded conditions and product throughput for the savings estimates. At the completion of the project, the customer was required to provide 6 months of data from the SCADA system at Site A and billing data from Sites B and C. The ex ante calculations were based on 2 months post installation data from Site A SCADA system, 8 months post installation utility bill data from Site B, and 6 months post installation utility bill data from Site C. The reviewer noted that the post installation savings kWh data were within 0.2% of the predicted savings.

The Installation Report states that the ex ante savings are 19,364,419 kWh annually and demand reduction is 4,107 kW. These values agree with the Tracking System data.

3. Comments on the Ex Ante Calculations

The ex ante calculations were based on data from the SCADA system at Site A and billing data from Sites B and C. Data collected from the SCADA system is not included in the application file. The ex ante analysis did not normalize the energy usage to the product throughput; it is a gross energy consumption analysis for the pre and post retrofit cases only.

4. Measurement & Verification Plan

According to the application, prior to the retrofit there was one surge pump, two 1,250 HP pumps, and three 1,500 HP pumps serving the 61 mile section of 14" pipeline and 24 miles of 12.75" pipeline. After the installation of the DRA injection system, and the 14" pipeline is replaced with 70 miles of 20" pipeline and the 24 miles of 12.75" pipeline are reused, a single surge pump and one 1,250 HP pump will be adequate to pump the product from Site A to Site D. According to the customer, the pipeline does not operate continuously, and there is some seasonal variation in the throughput.

The project saves energy through the installation of a larger diameter pipeline and a DRA injection system which reduces pressure loss in the pipeline and decreases pumping energy.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit hours of pipeline operation, product throughput, and the pump energy consumption.

The goal of the M&V plan is to verify the peak demand kW and annual kWh consumed, which will be derived from the customer's SCADA system for Site A and the utility bills for sites B and C. The analysis will normalize the data to pipeline throughput and adjust for changes in throughput if necessary.

Formulae and Approach

The M&V plan is a modified version of IPMVP Options A and C.

Four pipelines and their associated equipment are served by a single electric meter at Site A. For Site A, we will obtain data from the customer's SCADA system to evaluate the demand kW and energy consumption of the pumps serving the pipeline documented in the application. Based on preliminary discussions with customer, we believe that the SCADA system measures and trends system throughput, individual pump amps, volts and possibly power factor on a 15 minute basis. System throughput is measured in barrels (Bbl) at Site A. One barrel is 42 gallons.

To determine pre and post-retrofit pump kW and kWh Site A

Obtain SCADA system data on system throughput, individual pump amps, volts and power factor (if available) on a 15 minute basis. If power factor is not measured, use the average power factor from the utility bills. Calculate kW, kWh in 15 minute intervals for one year pre and one year post retrofit.

kW= (amps x volts x power factor x sq. root of three)/(1,000 watts/kW)
For each 15 minute period (1/4 hour):
kWh = kW/4

To determine pre and post-retrofit pump kW and kWh Sites B and C

According to documentation in the application, the primary energy consumption at Sites B and C was associated with the pumps. We will verify this during the site inspection, and, if true, we will use pre and post retrofit energy bills for the analysis. If we find this is not accurate, we will obtain data from the customer's SCADA system for this portion of the analysis. (Available SCADA data may be more limited from Sites B and C).

Obtain utility billing data for one year pre and one year post retrofit (use the same periods as used for Site A). According to the application, the new pipeline no longer passes through Site B. We will verify from the SCADA data or billing data that the pumps at Site C are no longer used.

To determine the pre –retrofit usage attributed to the pumps at each site, subtract the post retrofit usage from the pre retrofit usage This will yield the pre retrofit usage attributed to the pumps.
kW_{pre}-kW_{post} = kW_{pre} attributed to the pumps
kWh_{pre}-kWh_{post} = kWh_{pre} attributed to the pumps

To determine pre-retrofit pump kWh/Bbl

Sum the kWh for the pre-retrofit periods from each Site. Divide by the throughput for the pre-retrofit period.

kWh_{pre}= kWh Site A_{pre} +kWh Site B_{pre} + kWh Site C_{pre}
kWh/Bbl_{pre}= kWh_{pre}/Bbl_{pre}

To determine post-retrofit pump kWh/Bbl

Sum the kWh for the post-retrofit periods from each Site. Divide by the throughput for the post-retrofit period. The expected value for the kWh post attributed to the pumps at Sites B and C is zero.

kWh_{post}= kWh Site A_{post} +kWh Site B_{post} + kWh Site C_{post}
kWh/Bbl_{post}= kWh_{post}/Bbl_{post}

To determine post-retrofit pump energy savings kWh/Bbl

Subtract the pre-retrofit kWh/Bbl from the post-retrofit kWh/Bbl

kWh/Bbl savings= kWh/Bbl_{pre}- kWh/Bbl_{post}

To determine post-retrofit annual energy savings kWh associated with pumping energy

Annual kWh savings/Bbl are multiplied by the pre-retrofit throughput to calculate the annual savings in energy consumption.

Annual kWh Savings= kWh/Bbl savings x $Throughput_{pre}$

To determine ex post demand kW reduction

The energy consumption of this measure is not greatly affected by the outside air temperature. To estimate peak demand kW reduction, the expected reduction in connected kW due to the reduced pumping energy during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in the week with the hottest weekday in June, July, August, September will be determined by calculating the average kW reduction from 2 pm to 5 pm, Monday to Friday in June, July, August, September.

kW during this period for Sites A, B and C will be determined as described above. The kW will be summed for all three sites for the pre retrofit and post retrofit periods. The average post retrofit kW will be subtracted from the pre retrofit kW and the peak demand reduction will be calculated.

kW_{pre}= kW Site A_{pre} +kW Site B_{pre} + kW Site C_{pre}
kW_{post}= kW Site A_{post} +kW Site B_{post} + kW Site C_{post}

Peak demand reduction kW= Average kW_{pre} – Average kW_{post}

Uncertainty for the savings estimate can be more fully understood by setting projected ranges on the primary variables.

<u>Pipeline Replacement</u>

- 5,500 kW pre-retrofit expected maximum demand, +/- 15% (4,675-6,325 kW)
- 0.85 kWh/Bbl pre retrofit expected, +/- 30% (0.60-1.10 kWh/Bbl)
- 25,000,000 Bbl pre retrofit expected, +/- 30% (17,500,000-32,500,000 Bbl)

Accuracy and Equipment

The customer's SCADA system is expected to have a measurement error of less than 3%. The current transducers (CTs) and voltage reference are expected to have a measurement error of 2 to 5 %. Flow measurement are expected to have a measurement error of 2 to 5 %.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on June 6, 2007. Information on the pipeline replacement and operating conditions was collected by inspection of sites A, B and C and by interviewing the facility representative. Pump horsepower was verified at all sites. The customer provided data from the SCADA system for Site A. Utility billing and 15 minute kW interval data was obtained for Sites B and C.

The pipeline is designed to operate continuously, however there are periods when the pipeline is shut down for maintenance or other reasons. The facility does not close for holidays.

Installation Verification

The pipeline is buried but pipe diameter was visible at Sites A and C where it comes above ground adjacent to the pumps. The pipe was verified to be 20 inch diameter. We verified that a drag reduction agent is injected into the pipeline at Site A.

This is the only measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 8 below.

Scope of the Impact Assessment

The impact assessment scope is for the process/other end use measures in the SPC application covering the pipeline replacement. This is the only measure in this application.

Summary of Results

The customer provided data from the SCADA system for Site A. We verified that before the pipeline was replaced, the primary users of electricity at sites B and C were the pipeline pumps. Utility billing and 15 minute kW interval data was obtained for Sites B and C. Pre-retrofit data was analyzed for one year, from October 1, 2003-September 30, 2004. Post-retrofit data was analyzed for one year, from July 1, 2005-June 30, 2006. As shown in Table 3, system throughput was approximately equal during the pre and post retrofit periods. Review of the utility bill data indicates that the pumps at Sites B and C do not operate in the post retrofit period.

During the site visits, we determined that before the retrofit, the customer's SCADA system only measured pump amps. It did not measure volts or power factor. Part of the retrofit project included upgrading the SCADA system at site A. The post retrofit SCADA system measures pump kW and pump amps.

For Site A, we converted the pre-retrofit pump amps provided by the customer to kW by evaluating the post retrofit relationship between amps and kW. In the post retrofit period, the average ratio of kW to amps was 3.62. We multiplied the pre retrofit amps by this ratio to determine pre retrofit kW. We verified the reasonableness of this ratio. The pump nominal voltage is 2,300 volts. A kW to amp ratio of 3.62 equates to a power factor of 0.91 which is reasonable for this system.

3.62 = 2.3 kV x 1.73 x Power factor
0.91 = Power factor

Pre retrofit kW and kWh for Site A were calculated as follows:
kW= (amps x 3.62)
For each 15 minute period (1/4 hour):
kWh = kW/4

Tables 1, 2 and 3 show the results of the energy and kW demand analysis. Before the pipeline replacement system throughput was 25,480,842 barrels, 27,788,558 kWh were used, the average demand was 3,475 kW and the system averaged 1.091 kWh/barrel. After the pipeline replacement system throughput was 25,117,980 barrels, 11,222,651 kWh were used, the average demand was 1,338 kW and the system averaged 0.447 kWh/barrel.

Table 1: Energy and Demand Results, Pre-Retrofit

Site	kWh	kW
A	14,068,058	1,566
B	10,093,131	1,451
C	3,627,369	458
Total	27,788,558	3,475

Table 2: Energy and Demand Results, Post-Retrofit

Site	kWh	kW
A	10,977,290	1,309
B	76,821	9
C	168,540	21
Total	11,222,651	1,338

Table 3: Normalized System Throughput, Pre and Post Retrofit

Period	Barrells	kWh	kWh/barrel
Pre retrofit	25,480,842	27,788,558	1.091
Post retrofit	25,117,980	11,222,651	0.447
Difference	362,862	16,565,907	0.644

Annual kWh savings/Bbl are multiplied by the pre-retrofit throughput to calculate the annual savings in energy consumption.

Annual kWh Savings= kWh/Bbl savings x Throughput_{pre}
Annual kWh Savings= (1.091-0.447) kWh/Bbl x 25,480,842 bbl
Annual kWh Savings= 16,409,662 kWh

Summer peak demand reduction impacts were estimated by averaging the demand reduction for the time period 2 pm to 5 pm, Monday to Friday, June-September.
Peak demand reduction kW= Average kW_{pre} – Average kW_{post}
Peak demand reduction kW= 3,475 kW -1,338 kW
Peak demand reduction kW= 2,137 kW

The engineering realization rate for this application is 0.52 for demand kW reduction and 0.85 for energy savings kWh. A summary of the realization rate is shown in Table 7.

Utility billing data for the three sites was reviewed. For the period October 2003 to September 2004, pre-retrofit annual consumption was 67,049,922 kWh. Peak demand was 11,482 kW. Table 4 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility provided data.

Table 5 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 35.8% decrease in total meter kW, a 118% decrease in pump end use kW, a 28.9% decrease in total meter kWh, and a 69.7% decrease in pump end use kWh. The ex post results showed a 18.6% decrease in total meter kW, a 61.5% decrease in pump end use kW, a 24.5% decrease in total meter kWh, and a 59.1% decrease in pump end use kWh.

Table 4: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	11,482	67,049,922
Baseline End Use	3,475	27,788,558
Ex ante Savings	4,107	19,364,419
Ex Post Savings	2,136	16,409,662

Table 5: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	35.8%	28.9%	18.6%	24.5%
Baseline End Use %	118.2%	69.7%	61.5%	59.1%

6. Additional Evaluation Findings

The ex post kW demand reduction is less than the ex ante estimate because we determined that the customer occasionally operates two 1,250 HP pumps at Site A. The ex ante analysis expected that only one pump would be required to operate after the pipeline replacement. Additionally, the ex post analysis evaluated the average kW demand reduction for the time period 2 pm to 5 pm, Monday to Friday, June-September. The ex ante analysis involved evaluating the maximum reduction. Similarly, we found that the ex post energy savings are less than the ex ante energy savings because the customer occasionally operates two 1,250 HP pumps at Site A. The customer and reviewer did an admirable job in attempting to estimate the impacts of this complex project.

The facility representative stated that the cost estimate provided in the application ($68,145,500) is from the contractor's bid for the work performed for the project and is an accurate reflection of the project cost. In addition to saving energy, the benefits of the project are increased pipeline reliability and capacity for future use. At this time, the customer does not anticipate any changes to operation that will affect energy consumption. Participation in the 2004/2005 SPC Program has not encouraged the customer to perform any other energy efficiency projects without participating in an incentive program.

All of the pre retrofit pumps remain on-site and the pre-retrofit pump HP and quantities were physically verified. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measure.

With a cost of $68,145,500 and a $1,251,621 incentive, the project had a 34.5 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 40.8 years. A summary of the economic parameters for the project is shown in Table 6. The customer stated that they have no reason to believe that the operation of the facility will change in the foreseeable future, therefore the multi-year impacts, shown in Table 9 below, are expected to remain constant over the life of the equipment.

7. Impact Results

Table 6: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.10/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	10/3/2005	$68,145,500	4,107.0	19,364,419	0	$1,936,442	$1,251,622	34.54	35.19
SPC Program Review (Ex Post)	7/17/2007	$68,145,500	2,136.1	16,409,662	0	$1,640,966	$1,251,622	40.76	41.53

Table 7: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	4,107	19,364,419	-
SPC Installation Report (ex ante)	4,107	19,364,419	-
Impact Evaluation (ex post)	2,136	16,409,662	-
Engineering Realization Rate	0.52	0.85	NA

Table 8: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Process- OTHER	O			Replace Pipeline	1	Replace 61 miles of 14" diameter pipeline with 69 miles of 20" diameter pipeline	Physically verified 20" diameter pipe where visible above ground.	1.0

Table 9: Multi Year Reporting Table

Program Name:		A025 SPC 04-05 Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	0	0	0	0	0	0
2	2005	9,682,210	8,204,831	4,107	2,136	0	0
3	2006	19,364,419	16,409,662	4,107	2,136	0	0
4	2007	19,364,419	16,409,662	4,107	2,136	0	0
5	2008	19,364,419	16,409,662	4,107	2,136	0	0
6	2009	19,364,419	16,409,662	4,107	2,136	0	0
7	2010	19,364,419	16,409,662	4,107	2,136	0	0
8	2011	19,364,419	16,409,662	4,107	2,136	0	0
9	2012	19,364,419	16,409,662	4,107	2,136	0	0
10	2013	19,364,419	16,409,662	4,107	2,136	0	0
11	2014	19,364,419	16,409,662	4,107	2,136	0	0
12	2015	19,364,419	16,409,662	4,107	2,136	0	0
13	2016	19,364,419	16,409,662	4,107	2,136	0	0
14	2017	19,364,419	16,409,662	4,107	2,136	0	0
15	2018	19,364,419	16,409,662	4,107	2,136	0	0
16	2019	19,364,419	16,409,662	4,107	2,136	0	0
17	2020	9,682,210	8,204,831			0	0
18	2021					0	0
19	2022					0	0
20	2023					0	0
TOTAL	2004-2023	290466285	246144934				

FINAL SITE REPORT

SITE A026 (2005-xxx) A&BD IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 5 END USE: Process/Other

Measure	Install VFD Driven Air Compressor
Site Description	Manufacturing

1. Measure Description

Replace single stage lubricant injected rotary screw air compressor with new single stage lubricant injected VFD driven rotary screw air compressor.

2. Summary of the Ex Ante Calculations

The ex ante calculations were performed using the SPC calculator. The equipment vendor prepared the application for the customer. Detailed information concerning the existing and proposed compressor systems are input to the calculator. Required inputs include compressor type, full load BHP, operating pressure, rated acfm at full capacity, control method, no load power, motor HP and motor efficiency. A seven (7) day air usage load profile is also input into the calculator. The reviewer changed some of the input data to match field verified data.

The Installation Report states that the ex ante savings are 170,308 kWh annually and demand reduction is 21.6 kW. This agrees with the utility tracking system.

3. Comments on the Ex Ante Calculations

The ex ante calculations were performed according the SPC Program guidelines using the SPC calculator. The reviewer made a good effort to verify the pre-retrofit and post-retrofit conditions and ensure that the calculator was used correctly.

Some information was provided to support the SPC Calculator development for the compressed air system savings. However, it was not certain how this data was used. Lacking detailed documentation for the SPC calculator, we are unable to determine the assumptions used in the ex ante calculations for this measure.

The documentation revealed that there were two compressors, each with a rating of 69 BHP (brake horsepower). Air demands were continuous on one compressor and for about 50% of the time on the second compressor. A 60% load for approximately 70% of the time with an 80% power factor yields a demand and usage of 77 kW and 473,000 kWh. Site measurements of 55 kW on the new compressor and a 70% factor for both load and time yield 22 kW of demand reduction and 137,000 kWh of usage reduction. The savings may be overstated and the previous demand may be better qualified; the demand reduction and savings projections do appear reasonable, however.

4. Measurement & Verification Plan

According to the application, prior to the retrofit there were two compressors with a capacity of 245 acfm each. The new compressor has a capacity of 337 acfm. The documentation indicates that the new compressor has adequate capacity for the peak plant load. The application provides an estimated air usage profile that shows the compressed air plant operating 24 hours per day 5 days per week, 52 weeks annually. The air usage profile is the same for each day.

The project saves energy through the installation of a VFD driven compressor that has better part load performance than the pre retrofit compressor system.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit hours of operation, air usage profile, and the compressor performance curves used by the SPC calculator.

The goal of the M&V plan is to verify the kW and kWh consumed, which may be able to be derived from the air usage profile and pre-retrofit and post-retrofit hours of operation. Compressor unloading curves for the pre-retrofit and post-retrofit compressors will be used to estimate annual energy consumption and peak demand reduction from the air usage profiles.

Formulae and Approach

The M&V plan is a modified version of IPMVP Option A.

For this application, the pre-retrofit compressor usage and characteristics will be verified with the facility representative. It will be determined from interviews, hourly records and production records if there were any changes in the operating hours or equipment served, and how these affected hours of usage and air usage profiles. It will be determined if these changes were tied to production increases or decreases, and regression techniques will be considered if appropriate.

Power monitoring equipment will be installed on the new compressor for a minimum of 7 days, in order to verify the post retrofit hours of operation and power usage. Power will be measured in 5 minute intervals (or less) and averaged for each hour to determine average hourly kW.

Power measurements for the new compressor will be annualized to determine the annual kWh.

Using the measured average hourly kW, we will calculate the average hourly air usage profile of the new compressor for seven days using performance data for the VFD compressor (% of compressor capacity vs. % full load power, based on data available from the manufacturer and / or from the DOE Compressed Air Challenge).

The air usage profile determined for the new VFD compressor will be adjusted if necessary based on changes in production or equipment served as described above. The pre-retrofit kW and kWh will be calculated based on performance data for the pre-retrofit compressor, which used inlet modulation control, utilizing the performance data (% of compressor capacity vs. % full load power) from the DOE Compressed Air Challenge.

The air compressor is water cooled. The energy consumption of this measure is not greatly affected by the outside air temperature. To estimate peak demand kW reduction, the expected reduction in connected kW due to the increased compressor efficiency during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in June, July, August, and September will be determined by calculating the average kW reduction from 2 pm to 5 pm, Monday to Friday during the 7 day period.

If kW measurements cannot be taken, we will request that the customer log readings from the compressor control panel on an hourly basis showing the air flow and air compressor kW for a 24 hour period. We will then use this data to annualize compressor performance.

The formulae and methodology for the calculations are summarized as follows:

To determine post-retrofit compressor kW and kWh

Measure kW in 5 minute (or less) intervals.

Calculate average kW for each hour for 168 hours (7 days):
Average the kW readings over the one hour period.

Calculate the average kWh for each hour in the 168 hour period:
Hourly kWh= Average hourly kW x 1 hour

Calculate kWh for the 168 hour period:
Sum the 168 hourly results

Estimate the annual kWh:
Multiply the 168 hour result x 52.14 weeks/year to obtain annual kWh (accounting for holidays if appropriate).

Calculate the average peak kW from the monitoring results between 2 p.m. to 5 p.m., Monday to Friday during the monitoring period.

To determine pre-retrofit compressor kW, kWh

Obtain the maximum capacity of the new air compressor and maximum input power from the manufacturer’s representative. Determine the average hourly acfm from VFD compressor performance data (% capacity versus % power) and adjust for changes in equipment/production/schedules if necessary.

Utilizing performance data from the DOE Compressed Air Challenge (CAC) and manufacturer's data (maximum capacity of the old air compressors and maximum input power) stated in the application, determine the average hourly kW for 168 hours for the pre-retrofit compressor. This will be determined from CAC performance data and based on the hourly air usage profile developed above.

Calculate the average kWh for each hour in the 168 hour period:
Hourly kWh= Average hourly kW x 1 hour

Calculate kWh for the 168 hour period:
Sum the hourly results

Estimate the annual kWh:
Multiply the 168 hour result x 52.14 weeks/year to obtain annual kWh (accounting for holidays if appropriate).

Calculate the average peak kW from the CAC performance data based on the hourly air usage profile developed above, between 2 p.m. to 5 p.m., Monday to Friday during the monitoring period.

The average peak kW and the kWh figures from the post-retrofit analysis will be subtracted from the pre-retrofit analysis and the result will be the ex post impact (kW and kWh savings).

Uncertainty for the savings estimate can be more fully understood by setting projected ranges on the primary variables.

Air Compressor Retrofit

- 90 kW pre-retrofit expected maximum demand, + 20% / - 20% (81-99 kW)
- 6,257 operating hours pre retrofit expected, +/- 10% (5,631-6,883 hours)
- Air usage: 0- 337 acfm

Accuracy and Equipment

The Dent Elite Pro power monitors have a measurement error of less than 1%. The accompanying current transducers (CTs) have a measurement error of 2 to 5 % depending on the size needed for the compressor and the CT manufacturer. The compressor performance data is estimated to be +/- 5% accurate. Annualizing the seven day measurement period is estimated to be +/- 10% accurate.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on April 11, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the air compressor system and by interviewing the facility representative. Air compressor make, model, quantities and hours of operation were verified. Power consumption was measured on the new VFD driven air compressor in 2 minute intervals over a 168 hour period.

The building is occupied continuously from 7 p.m. Sunday to 2 a.m. Saturday. According to the facility representative, the new VFD driven air compressor generally operates from 3 a.m. Monday-2 a.m. Saturday. One of the old compressors is used at other times during the occupied periods. Maximum occupancy is approximately 40 employees at any given time. The facility is closed 10 holidays annually.

Installation Verification

The facility representative verified that there were two Quincy QSI1245 air compressors installed before the retrofit. One of the compressors remains and is used as described above. The Quincy QSI1245 is rated at 245 CFM at 125 psig and 45.5 kW. The new compressor is a Sullair V160-75 H/A, rated at 337 CFM at 125 psig and 67.4 kW. The new compressor is water cooled and VFD driven.

This is the only measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 7 below.

Scope of the Impact Assessment

The impact assessment scope is for the process/other end use measure in the SPC application covering the air compressor retrofit. This is the only measure in this application.

Summary of Results

Compressor power consumption was measured in 2 minute intervals with the Dent Elite logger. Data was analyzed for 168 hours, from April 14, 2007-April 20, 2007. Input power ranged from zero to 70 kW, with an average of 30 kW and a median of 35.5 kW. The new compressor operated for 118 hours out of the 168 hour period analyzed.

The facility representative stated that the period monitored was reflective of average operation and that the operation of the facility had not changed in any significant way since the new compressor was installed. Therefore, there was no adjustment to the energy consumption due to an un-representative monitoring period.

The following is an example of the ex post impact calculations for a one hour period:

The pre-retrofit system had two Quincy QSI1245 compressors. According to documentation provided by the reviewer in the application, the Quincy QSI1245 is rated at 245 CFM at 125 psig and 45.2 kW. The new compressor is a Sullair V160-75 H/A, rated at 337 CFM at 125 psig and 67.4 kW. Input power to the new VFD driven compressor was measured in 2 minute intervals and averaged for each hour. Table 1 shows the data for the hour of 6 p.m. on 4/16/2007.

- The average was 35.1 kW for this hour.
- The energy consumption is 35.1 kWh

Table 1: Compressor Input kW for 6 p.m. 4/16/2007

Monitored Data		
Date	Time	kW
4/16/2007	18:00:00	33.8
4/16/2007	18:02:00	30.9
4/16/2007	18:04:00	32.0
4/16/2007	18:06:00	31.8
4/16/2007	18:08:00	32.0
4/16/2007	18:10:00	32.7
4/16/2007	18:12:00	31.2
4/16/2007	18:14:00	30.4
4/16/2007	18:16:00	30.7
4/16/2007	18:18:00	31.4
4/16/2007	18:20:00	31.8
4/16/2007	18:22:00	30.6
4/16/2007	18:24:00	33.9
4/16/2007	18:26:00	37.9
4/16/2007	18:28:00	41.1
4/16/2007	18:30:00	40.3
4/16/2007	18:32:00	35.9
4/16/2007	18:34:00	34.7
4/16/2007	18:36:00	35.3
4/16/2007	18:38:00	32.9
4/16/2007	18:40:00	35.3
4/16/2007	18:42:00	32.8
4/16/2007	18:44:00	35.7
4/16/2007	18:46:00	38.0
4/16/2007	18:48:00	40.1
4/16/2007	18:50:00	36.9
4/16/2007	18:52:00	41.1
4/16/2007	18:54:00	41.6
4/16/2007	18:56:00	43.2
4/16/2007	18:58:00	38.1
Average		**35.1**

Performance data from the manufacturer lists the full load input power as 67.4 kW at 125 psig and 337 acfm.

- For this hour, the compressor is operating at an average 52% of full load power 35.1 kW/67.4 kW = 52%

- Table 2 is an Air Compressor Control Comparison from the DOE Compressed Air Challenge. A VFD driven compressor operating at 52% of full load power is operating at 50% of full load capacity.

Table 2: Air Compressor Control Comparison

% of Compressor Capacity	Modulation (Inlet Valve) % FL Power	Variable Frequency Drive % FL Power
100	100.0	100.0
95	98.5	95.2
90	97.0	90.4
85	95.5	85.6
80	94.0	80.8
75	92.5	76.0
70	91.0	71.2
65	89.5	66.4
60	88.0	61.6
55	86.5	56.8
50	85.0	52.0
45	83.5	47.2
40	82.0	42.4
35	80.5	37.6
30	79.0	32.8
25	77.5	28.0
20	76.0	23.2
15	74.5	18.4
10	73.0	13.6
5	71.5	8.8
0	70.0	4.0

Values from the Compressed Air Challenge Workshop Sponsored by the US Department of Energy

- The average airflow for this hour is 169 acfm
  337 acfm x 50%= 169 acfm

- The average % capacity for this hour for the pre-retrofit compressor 72.6%
  169 acfm/245 acfm= 69%

Performance data from the manufacturer lists the full load input power as 45.2 kW at 125 psig and 245 acfm. The pre-retrofit compressor was “inlet valve modulated”.

- Table 2 from the DOE Compressed Air Challenge is used to determine the average input power to the pre-retrofit compressor. At 70% of compressor capacity, the inlet modulated compressor is operating at 91% of full load power. At 65% of capacity, the compressor is operating at 89.5% of full load power.

Values from Table 2 are interpolated. An inlet valve modulated compressor operating at 69% of full load capacity is operating at 90.7% of full load power.
91% - (70%-69%)/(70%-65%) x (91%-89.5%)= 90.7%

- The average power for this hour is 41 kW
  45.2 kW x 90.7% =41 kW

- The energy consumption for this hour is 41 kWh
  41 kW x 1 hour= 41 kWh

- The ex post impacts for this hour are 5.9 kW, 5.9 kWh
  41 kW -35.1 kW= 5.9 kW
  41 kWh -35.1 kWh= 5.9 kWh

Using this methodology for the 168 hour period, we determined that the pre-retrofit energy consumption was 5,949.3 kWh and the post retrofit energy consumption was 5,014.1 kWh. The new VFD driven compressor reduced energy consumption by 935.2 kWh for the 168 hour (one week) period from April 14, 2007-April 20, 2007.

- Pre and post retrofit weeks of compressor operation are 50.14 weeks/year.
  52.14 weeks/year –(10 holidays/year)/(5 days/week)= 50.14 weeks/year
- Pre-retrofit energy consumption is 298,298 kWh/yr.

  Weekly usage 5,949.3 kWh /week x 50.14 weeks/yr.= 298,298 kWh/yr
- Post-retrofit energy consumption is 251,407 kWh/yr.

  Weekly usage 5,014.1 kWh /week x 50.14 weeks/yr.= 251,407 kWh/yr
- The resulting annual kWh savings is 298,298 kWh/yr – 251,407 kWh/yr = 46,891 kWh/yr

Summer peak demand reduction impacts were estimated by averaging the demand reduction for the time period 2 pm to 5 pm, Monday to Friday. Average demand reduction is 6.7 kW. The 168 hour analysis is shown in Table 9.

The engineering realization rate for this application is 0.31 for demand kW reduction and 0.28 for energy savings kWh. A summary of the realization rate is shown in Table 6.

Utility billing data for the site was provided in the application. For the period May 2004 to June 2005, pre-retrofit annual consumption was 2,353,800 kWh. Peak demand was 777 kW. Table 3 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility provided numbers.

Table 4 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 2.8% decrease in total meter kW, a 26.8% decrease in compressor end use kW, a 7.2% decrease in total meter kWh, and a 57.1% decrease in compressor end use kWh. The ex post results showed a 0.9% decrease in total meter kW, a 8.3% decrease in compressor end use kW, a 2.0% decrease in total meter kWh, and a 15.7% decrease in compressor end use kWh.

Table 3: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	777	2,353,800
Baseline End Use	80.6	298,298
Ex ante Savings	21.6	170,308
Ex Post Savings	6.7	46,891

Table 4: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	2.8%	7.2%	0.9%	2.0%
Baseline End Use %	26.8%	57.1%	8.3%	15.7%

6. Additional Evaluation Findings

The ex post kW demand reduction is less than the ex ante estimate because we determined that the air usage was lower than that used in the ex ante savings. The ex ante analysis assumed that, in the pre-retrofit scenario, the second compressor would operate 95 hours out of each 168 hour period. Based on our measurements, we estimate that the second compressor would operate 25 hours out of a 168 hour period. The ex post energy savings are less than the ex ante energy savings because we found that the ex ante analysis over estimated air usage.

The facility representative stated that the cost estimate provided in the application ($34,050) is from the invoice for the work performed for the project and is an accurate reflection of the project cost. In addition to saving energy, the benefits of the project are quieter compressor operation and a more constant pressure in the compressed air line. The customer does not anticipate any changes to operation that will affect energy. Participation in the 2004/2005 SPC Program has not encouraged the customer to perform any other energy efficiency projects without participating in an incentive program.

One of the old compressors remains on-site and the pre-retrofit compressor type and quantities were physically verified. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measure.

With a cost of $34,050 and a $13,264 incentive, the project had a 0.9 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 3.4 years. A summary of the economic parameters for the project is shown in Table 5. The customer stated that they have no reason to believe that the operation of the facility will change in the foreseeable future, therefore the multi-year impacts, shown in Table 8 below, are expected to remain constant over the life of the equipment.

7. Impact Results

Table 5: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	12/30/2005	$34,050	21.6	170,308	0	$22,140	$13,264	0.94	1.54
SPC Program Review (Ex Post)	5/16/2007	$34,050	6.7	46,891	0	$6,096	$13,264	3.41	5.59

Table 6: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	21.6	170,308	-
SPC Installation Report (ex ante)	21.6	170,308	-
Impact Evaluation (ex post)	6.7	46,891	-
Engineering Realization Rate	0.31	0.28	NA

Table 7: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Process- OTHER	O			Replace 60 HP rotary screw air compressor with VFD driven 75 HP rotary screw air compressor.	1	Sullair V160 75H	Physically verified compressor quantity and model.	1.0

Table 8: Multi Year Reporting Table

SPC 0405 Evaluation Site A026

Year	Calendar Year	Ex-Ante Gross Program Projected kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program Projected Peak kW Reduction	Ex-Post Gross Evaluastion Projected Peak kW Reduction	Ex-Ante Gross Program Projected Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	0	0	0	0		
2	2005	0	0	0	0		
3	2006	170,308	46,891	21.6	6.7		
4	2007	170,308	46,891	21.6	6.7		
5	2008	170,308	46,891	21.6	6.7		
6	2009	170,308	46,891	21.6	6.7		
7	2010	170,308	46,891	21.6	6.7		
8	2011	170,308	46,891	21.6	6.7		
9	2012	170,308	46,891	21.6	6.7		
10	2013	170,308	46,891	21.6	6.7		
11	2014	170,308	46,891	21.6	6.7		
12	2015	170,308	46,891	21.6	6.7		
13	2016	170,308	46,891	21.6	6.7		
14	2017	170,308	46,891	21.6	6.7		
15	2018	170,308	46,891	21.6	6.7		
16	2019	170,308	46,891	21.6	6.7		
17	2020	170,308	46,891	21.6	6.7		
18	2021						
19	2022						
20	2023						
Totals	2004-2023	2,554,620	703,365				

Table 9: 168 Hour Analysis

Post Retrofit	
Max kW	67.4
Max CFM	337.0
Full Load psig	125.0

Pre Retrofit	Compressor 1
Max kW	45.2
Max CFM	245.0
Full Load psig	125.0

Pre Retrofit	Compressor 2
Max kW	45.2
Max CFM	245.0
Full Load psig	125.0

		Post Retrofit Hourly Average				Pre retrofit Compressor 1			Pre retrofit Compressor 2			Savings	
Date		kW	% Max kW	% Max ACFM	ACFM	% max CFM	% max kW	kW	% max CFM	% max kW	kW	kW	kWh
4/14/2007	0:00	22.9	33.9%	37%	123.3	50%	85%	38.4	0.0	0.0	0.0	15.6	15.6
	1:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	2:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	3:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	4:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	5:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	6:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	7:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	8:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	9:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	10:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	11:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	12:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	13:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	14:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	15:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	16:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	17:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	18:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	19:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	20:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	21:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	22:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	23:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
4/15/2007	0:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	1:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	2:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	3:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	4:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	5:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	6:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	7:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	8:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	9:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	10:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	11:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	12:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	13:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	14:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	15:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	16:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	17:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	18:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	19:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	20:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	21:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	22:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	23:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0

4/16/2007	0:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	1:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	2:00	0.0	0.0%	0%	0.0	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0
	3:00	2.0	3.0%	6%	20.2	8%	72%	32.5	0.0	0.0	0.0	30.5	30.5
	4:00	20.3	30.1%	27%	91.0	37%	81%	36.7	0.0	0.0	0.0	16.4	16.4
	5:00	20.4	30.2%	27%	91.0	37%	81%	36.7	0.0	0.0	0.0	16.3	16.3
	6:00	39.0	57.9%	56%	188.7	77%	93%	42.1	0.0	0.0	0.0	3.1	3.1
	7:00	54.9	81.5%	81%	273.0	56%	87%	39.2	56%	87%	39.2	23.5	23.5
	8:00	51.6	76.5%	76%	254.4	52%	86%	38.7	52%	86%	38.7	25.8	25.8
	9:00	53.4	79.3%	79%	264.5	54%	86%	39.0	54%	86%	39.0	24.5	24.5
	10:00	46.7	69.3%	68%	229.2	94%	98%	44.4	0.0	0.0	0.0	-2.3	-2.3
	11:00	48.6	72.0%	71%	239.3	98%	99%	44.9	0.0	0.0	0.0	-3.6	-3.6
	12:00	44.5	66.1%	65%	219.1	89%	97%	43.7	0.0	0.0	0.0	-0.8	-0.8
	13:00	33.5	49.7%	48%	160.1	65%	90%	40.5	0.0	0.0	0.0	6.9	6.9
	14:00	47.6	70.6%	70%	234.2	96%	99%	44.7	0.0	0.0	0.0	-2.9	-2.9
	15:00	44.1	65.5%	64%	215.7	88%	96%	43.6	0.0	0.0	0.0	-0.5	-0.5
	16:00	35.5	52.6%	51%	170.2	69%	91%	41.0	0.0	0.0	0.0	5.5	5.5
	17:00	33.1	49.1%	47%	158.4	65%	90%	40.5	0.0	0.0	0.0	7.4	7.4
	18:00	35.1	52.1%	50%	168.5	69%	91%	41.0	0.0	0.0	0.0	5.9	5.9
	19:00	40.6	60.3%	59%	198.8	81%	94%	42.6	0.0	0.0	0.0	2.0	2.0
	20:00	39.5	58.6%	57%	192.1	78%	93%	42.2	0.0	0.0	0.0	2.7	2.7
	21:00	34.4	51.0%	49%	165.1	67%	98%	44.1	0.0	0.0	0.0	9.7	9.7
	22:00	40.2	59.6%	58%	195.5	80%	94%	42.5	0.0	0.0	0.0	2.3	2.3
	23:00	34.1	50.7%	49%	163.4	67%	90%	40.7	0.0	0.0	0.0	6.6	6.6
4/17/2007	0:00	37.4	55.5%	54%	182.0	74%	92%	41.7	0.0	0.0	0.0	4.3	4.3
	1:00	39.3	58.3%	57%	190.4	78%	93%	42.2	0.0	0.0	0.0	3.0	3.0
	2:00	31.3	46.5%	44%	148.3	61%	88%	39.9	0.0	0.0	0.0	8.6	8.6
	3:00	34.4	51.0%	49%	165.1	67%	90%	40.7	0.0	0.0	0.0	6.4	6.4
	4:00	35.1	52.1%	50%	168.5	69%	91%	41.0	0.0	0.0	0.0	5.9	5.9
	5:00	32.6	48.3%	46%	155.0	63%	89%	40.2	0.0	0.0	0.0	7.6	7.6
	6:00	50.5	74.9%	74%	249.4	51%	85%	38.6	51%	85%	38.6	26.6	26.6
	7:00	50.6	75.1%	74%	249.4	51%	85%	38.6	51%	85%	38.6	26.5	26.5
	8:00	49.9	74.0%	73%	246.0	100%	100%	45.2	0.0	0.0	0.0	-4.7	-4.7
	9:00	58.4	86.6%	86%	289.8	59%	88%	39.6	59%	88%	39.6	20.9	20.9
	10:00	50.5	74.9%	74%	249.4	51%	85%	38.6	51%	85%	38.6	26.7	26.7
	11:00	65.6	97.3%	97%	326.9	67%	90%	40.7	67%	90%	40.7	15.9	15.9
	12:00	59.8	88.8%	89%	298.2	61%	88%	39.9	61%	88%	39.9	20.0	20.0
	13:00	40.6	60.2%	59%	197.1	80%	94%	42.5	0.0	0.0	0.0	1.9	1.9
	14:00	61.1	90.7%	90%	303.3	62%	89%	40.1	62%	89%	40.1	19.0	19.0
	15:00	49.7	73.8%	73%	246.0	100%	100%	45.2	0.0	0.0	0.0	-4.5	-4.5
	16:00	45.6	67.7%	67%	224.1	91%	97%	44.0	0.0	0.0	0.0	-1.6	-1.6
	17:00	53.2	78.9%	78%	262.9	54%	86%	39.0	54%	86%	39.0	24.8	24.8
	18:00	42.7	63.4%	62%	208.9	85%	96%	43.2	0.0	0.0	0.0	0.4	0.4
	19:00	56.8	84.2%	84%	281.4	57%	87%	39.4	57%	87%	39.4	22.0	22.0
	20:00	53.2	78.9%	78%	262.9	54%	86%	39.0	54%	86%	39.0	24.8	24.8
	21:00	35.9	53.3%	52%	173.6	71%	91%	41.3	0.0	0.0	0.0	5.4	5.4
	22:00	49.8	73.8%	73%	246.0	100%	100%	45.2	0.0	0.0	0.0	-4.5	-4.5
	23:00	43.1	63.9%	63%	210.6	86%	96%	43.3	0.0	0.0	0.0	0.2	0.2

4/18/2007	0:00	40.1	59.4%	58%	195.5	80%	94%	42.5	0.0	0.0	0.0	2.4	2.4
	1:00	46.8	69.5%	68%	229.2	94%	98%	44.4	0.0	0.0	0.0	-2.4	-2.4
	2:00	40.2	59.6%	58%	195.5	80%	94%	42.5	0.0	0.0	0.0	2.3	2.3
	3:00	31.4	46.6%	45%	150.0	61%	88%	39.9	0.0	0.0	0.0	8.5	8.5
	4:00	30.7	45.6%	44%	146.6	60%	88%	39.8	0.0	0.0	0.0	9.1	9.1
	5:00	33.9	50.2%	48%	161.8	66%	90%	40.6	0.0	0.0	0.0	6.7	6.7
	6:00	45.4	67.4%	66%	222.4	91%	97%	44.0	0.0	0.0	0.0	-1.5	-1.5
	7:00	55.5	82.4%	82%	276.3	56%	87%	39.2	56%	87%	39.2	22.9	22.9
	8:00	53.8	79.8%	79%	266.2	54%	86%	39.0	54%	86%	39.0	24.1	24.1
	9:00	53.3	79.0%	78%	262.9	54%	86%	39.0	54%	86%	39.0	24.7	24.7
	10:00	48.4	71.9%	71%	237.6	48%	84%	38.2	48%	84%	38.2	27.9	27.9
	11:00	60.3	89.5%	89%	299.9	61%	88%	39.9	61%	88%	39.9	19.5	19.5
	12:00	57.3	85.0%	85%	284.8	58%	87%	39.5	58%	87%	39.5	21.7	21.7
	13:00	40.9	60.6%	59%	198.8	81%	94%	42.6	0.0	0.0	0.0	1.8	1.8
	14:00	63.0	93.5%	93%	313.4	64%	89%	40.3	64%	89%	40.3	17.6	17.6
	15:00	55.4	82.2%	82%	274.7	56%	87%	39.2	56%	87%	39.2	23.1	23.1
	16:00	44.0	65.3%	64%	215.7	88%	96%	43.6	0.0	0.0	0.0	-0.5	-0.5
	17:00	46.5	68.9%	68%	229.2	94%	98%	44.4	0.0	0.0	0.0	-2.1	-2.1
	18:00	35.4	52.5%	51%	170.2	69%	91%	41.0	0.0	0.0	0.0	5.6	5.6
	19:00	36.7	54.4%	53%	176.9	72%	92%	41.4	0.0	0.0	0.0	4.7	4.7
	20:00	39.9	59.3%	58%	195.5	80%	94%	42.5	0.0	0.0	0.0	2.6	2.6
	21:00	37.8	56.0%	54%	182.0	74%	92%	41.7	0.0	0.0	0.0	3.9	3.9
	22:00	47.3	70.2%	69%	232.5	95%	99%	44.5	0.0	0.0	0.0	-2.8	-2.8
	23:00	40.0	59.4%	58%	195.5	80%	94%	42.5	0.0	0.0	0.0	2.5	2.5
4/19/2007	0:00	46.0	68.3%	67%	225.8	92%	98%	44.1	0.0	0.0	0.0	-1.9	-1.9
	1:00	47.4	70.4%	69%	232.5	95%	99%	44.5	0.0	0.0	0.0	-2.9	-2.9
	2:00	36.7	54.4%	53%	178.6	73%	92%	41.5	0.0	0.0	0.0	4.9	4.9
	3:00	35.2	52.2%	50%	168.5	69%	91%	41.0	0.0	0.0	0.0	5.8	5.8
	4:00	36.3	53.8%	52%	175.2	72%	92%	41.4	0.0	0.0	0.0	5.1	5.1
	5:00	33.8	50.1%	48%	161.8	66%	90%	40.6	0.0	0.0	0.0	6.8	6.8
	6:00	40.4	59.9%	58%	195.5	80%	94%	42.5	0.0	0.0	0.0	2.1	2.1
	7:00	51.4	76.2%	75%	252.8	52%	86%	38.7	52%	86%	38.7	26.0	26.0
	8:00	54.0	80.1%	80%	269.6	55%	87%	39.1	55%	87%	39.1	24.2	24.2
	9:00	61.7	91.5%	91%	306.7	63%	89%	40.2	63%	89%	40.2	18.7	18.7
	10:00	46.1	68.4%	67%	225.8	92%	98%	44.1	0.0	0.0	0.0	-2.0	-2.0
	11:00	53.4	79.2%	79%	264.5	54%	86%	39.0	54%	86%	39.0	24.6	24.6
	12:00	50.2	74.4%	74%	247.7	51%	85%	38.6	51%	85%	38.6	27.0	27.0
	13:00	35.6	52.8%	51%	171.9	70%	91%	41.1	0.0	0.0	0.0	5.6	5.6
	14:00	52.2	77.4%	77%	257.8	53%	86%	38.8	53%	86%	38.8	25.5	25.5
	15:00	44.2	65.6%	64%	215.7	88%	96%	43.6	0.0	0.0	0.0	-0.6	-0.6
	16:00	40.1	59.5%	58%	195.5	80%	94%	42.5	0.0	0.0	0.0	2.4	2.4
	17:00	40.6	60.3%	59%	197.1	80%	94%	42.5	0.0	0.0	0.0	1.9	1.9
	18:00	37.5	55.6%	54%	182.0	74%	92%	41.7	0.0	0.0	0.0	4.2	4.2
	19:00	40.6	60.3%	59%	197.1	80%	94%	42.5	0.0	0.0	0.0	1.8	1.8
	20:00	41.2	61.1%	60%	200.5	82%	95%	42.8	0.0	0.0	0.0	1.6	1.6
	21:00	34.7	51.4%	49%	163.4	67%	90%	40.7	0.0	0.0	0.0	6.1	6.1
	22:00	38.5	57.1%	55%	185.4	76%	93%	42.0	0.0	0.0	0.0	3.5	3.5
	23:00	34.8	51.6%	50%	166.8	68%	90%	40.9	0.0	0.0	0.0	6.1	6.1

4/20/2007	0:00	37.0	54.9%	53%	178.6		73%	92%	41.5	0.0	0.0	0.0	4.5	4.5
	1:00	36.1	53.6%	52%	175.2		72%	92%	41.4	0.0	0.0	0.0	5.3	5.3
	2:00	30.4	45.2%	43%	144.9		59%	88%	39.7	0.0	0.0	0.0	9.3	9.3
	3:00	29.1	43.2%	41%	138.2		56%	87%	39.2	0.0	0.0	0.0	10.2	10.2
	4:00	29.9	44.4%	42%	141.5		58%	87%	39.5	0.0	0.0	0.0	9.6	9.6
	5:00	41.4	61.5%	60%	202.2		83%	95%	42.9	0.0	0.0	0.0	1.5	1.5
	6:00	49.3	73.1%	72%	242.6		99%	100%	45.1	0.0	0.0	0.0	-4.2	-4.2
	7:00	49.2	73.0%	72%	242.6		99%	100%	45.1	0.0	0.0	0.0	-4.1	-4.1
	8:00	43.2	64.1%	63%	210.6		86%	96%	43.3	0.0	0.0	0.0	0.1	0.1
	9:00	47.8	70.9%	70%	234.2		96%	99%	44.7	0.0	0.0	0.0	-3.1	-3.1
	10:00	48.6	72.1%	71%	239.3		98%	99%	44.9	0.0	0.0	0.0	-3.6	-3.6
	11:00	43.2	64.1%	63%	210.6		86%	96%	43.3	0.0	0.0	0.0	0.1	0.1
	12:00	46.5	69.0%	68%	229.2		94%	98%	44.4	0.0	0.0	0.0	-2.1	-2.1
	13:00	36.8	54.6%	53%	178.6		73%	92%	41.5	0.0	0.0	0.0	4.8	4.8
	14:00	39.5	58.6%	57%	192.1		78%	93%	42.2	0.0	0.0	0.0	2.8	2.8
	15:00	34.5	51.2%	49%	165.1		67%	90%	40.7	0.0	0.0	0.0	6.2	6.2
	16:00	34.5	51.2%	49%	165.1		67%	90%	40.7	0.0	0.0	0.0	6.2	6.2
	17:00	36.8	54.6%	53%	178.6		73%	92%	41.5	0.0	0.0	0.0	4.7	4.7
	18:00	39.2	58.1%	57%	190.4		78%	93%	42.2	0.0	0.0	0.0	3.1	3.1
	19:00	40.2	59.6%	58%	195.5		80%	94%	42.5	0.0	0.0	0.0	2.3	2.3
	20:00	37.7	55.9%	54%	182.0		74%	92%	41.7	0.0	0.0	0.0	4.0	4.0
	21:00	33.0	48.9%	47%	158.4		65%	90%	40.5	0.0	0.0	0.0	7.5	7.5
	22:00	43.3	64.3%	63%	212.3		87%	96%	43.4	0.0	0.0	0.0	0.1	0.1
	23:00	41.7	61.9%	60%	202.2		83%	95%	42.9	0.0	0.0	0.0	1.2	1.2
168 hour kWh		5,014							4,890			1,059		935
8,760 hour kWh		251,408							245,201			53,095		46,889

Final Report

SITE AO27 Clar IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: AC&R

Measure	Chiller Replacement (80 ton)
Site Description	Hotel

1. Measure Description

Replace an older 80 ton air cooled chiller with a newer, more efficient 80 ton chiller.

2. Summary of the Ex Ante Calculations

The ex ante savings for the measure are 34,986 kWh and 13.7 kW, as identified in the updated Installation Report Review (IRR) and in the utility tracking system. The SPC incentive is identified in handwritten notes in the IRR and in the utility tracking system as $30,347.50 and is based on the 50% measure cap applied to the total capital costs. The savings were submitted as a calculated measure using the SPC Calculator with figures adjusted on review by utility staff. The reviewer did not show any basis for these calculations. The ex ante savings figures are significantly lower than the 2,148,048 kWh submitted by the customer (according to the application paperwork). This number appears as the Total Savings (12 years remaining useful life) in the SPC Calculator output. The ex ante kWh savings are significantly higher, however, than the annual savings listed in the SPC Calculator. The ex ante kW savings are slightly lower than the output from the SPC Calculator.

3. Comments on the Ex Ante Calculations

The utility reviewer calculated an energy savings of 419,832 kWh for 12 years of savings, a demand savings of 13.7 kW, and an estimated incentive of $30,817; these figures are significantly lower than the applicant's original submittal. The reviewer stated that the savings figures were corrected. No calculations were provided.

The ex ante savings are significantly lower than the 2,148,048 kWh calculated as the total savings by the SPC Calculator and incorrectly submitted by the project applicant. The SPC calculator documentation supplied in the application paperwork shows the following:

Baseline Usage – 106.3 kW; 268,266 kWh
Current Minimum Standard – 97.8 kW; 246,804 kWh
Proposed Usage - 91.7 kW; 89,626 kWh
Annual Savings - 14.7 kW; 179,004 kWh
Remaining Useful Life – 12 years
Runtime Hours - 2,352

Total Savings (12 years remaining life) - 2,148,048 kWh

(A review of the report indicated that another SPC Calculator run was performed and these parameters changed; savings were then consistent with the tracking system.)

A check calculation was performed using information from the proposed equipment specifications and the replaced equipment specifications. This calculation was based on operating hours of 8,760 hours per year and an assumed load factor of 40% over the entire year (note that this factor equates to about 50% more run time than used in the SPC calculator). According to a manufacturer's representative, the baseline energy usage of the original chiller was 106 kW (1.325 kW/ton).The proposed chiller's energy usage is 85 kW (1.06 kW/ton); this figure is lower than the figures used for the post retrofit chiller in the SPC Calculator (which used an EER of 10.2, corresponding to 1.18 kW/ton). The maximum energy use of a chiller of this size and type conforming to Title 24 efficiency standards is 97.8 kW at the time of the retrofit (according to the SPC Calculator).

Pre- retrofit and post-retrofit energy use were calculated using the following formulae:

$kWh_{pre=}$ 106 kW x 40% x 8,760 hours/years = 371,424 kWh/year

$kWh_{post=}$ 85 kW x 40% x 8,760 hours/years = 297,840 kWh/year

kWh savings =($kW_{pre} - kW_{post}$) x operating hours x load factor

(106 kW – 85 kW) x 8,760 x 0.4 = 73,584 kWh

These check calculations shows that the ex ante first year kWh savings may be significantly overstated.

The energy savings that can be realized from replacing the original chiller with a chiller that exceeds the Title 24 standard efficient chiller is given by the following formulae:

($kW_{Title24} - kW_{post}$) x operating hours x load factor = kWh savings

(97.8 kW – 85 kW) x 8,760 x 0.4 = 44,851 kWh

The typical useful life for a reciprocating chiller is 20 years. The original chiller had been in operation since November 1993, which indicates a remaining useful life of 9 years at the time of the application, which was submitted in May 2004. The replacement chiller then would have a remaining useful life of 11 years after the original chiller would have needed to have been replaced. Therefore, in order to calculate the average annual energy usage saved by replacing the original chiller with the proposed chiller, the following formula is used:

(9 years x 73,584 kWh/year) + (11 years x 44,851 kWh/year)/ 20 years = 57,781 kWh/year

This amount is significantly lower than the ex ante savings figures submitted or shown in the calculations from the SPC Calculator. Although it is not known how the ex ante savings were determined, the reviewer may have made some assumptions that were based on the customer's original application. The ex ante kWh savings are larger than the baseline energy use in the SPC calculator or as calculated above with a higher usage factor.

The SPC Calculator notes annual savings (the difference from the pre retrofit, baseline to the post retrofit chiller) of 179,004 kWh/year. A significant amount of these savings are believed to come from economizer operation on the post retrofit chiller (verses no economy cycle on the pre retrofit chiller). The presence of economy cycles before and after the retrofit can be significant and should be verified.

An assumption in the original application was that the chiller was a centrifugal type which has a useful life of 23 years, as opposed to a screw type which has a useful life of 20 years. This resulted in stating that the remaining useful life was twelve years.

4. Measurement & Verification Plan

The building is a ten story 400,000 square foot hotel that is 90 years old. The building is occupied, on varying schedules, by both guests and staff throughout the year, 24 hours a day, seven days a week. The majority of the chiller use is expected to be in the summer months between May and August and during the daytime hours.

According to the application, before the retrofit, there was an 80 ton chiller with a power draw of 106 kW at the facility. After the retrofit, an 80 ton chiller with a power draw of 85 kW was installed at the facility. The project saves energy through the installation of a chiller that delivers the same cooling capacity as the original one, but accomplishes it through lower energy consumption.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful life of the measure.

Formulae and Approach

A modified version of IPMVP Option A should be considered. The energy savings will consist of the baseline energy usage minus post-installation energy use.

The actual cooling load for the building will be determined using chilled water supply and return temperatures and the water flow through the main cooling loop as possible. The actual kW demand of the two compressors of the chiller will be measured and tracked through the use of loggers or site instrumentation.

The operating hours, size, and sequencing of the chiller compressors will be confirmed from facility personnel. Proposed data collection will include, as possible, the chilled water supply and return temperatures, outside air temperature, chiller amps or kW, and chilled water flow rate. It will be determined if there are economizer cycles in place that operate the fans to allow "free cooling". The use of economizer or other cycling to save energy was indicated in the output of the SPC Calculator.

Hotel logs and vacancy rates will also be tracked and collected for up to 36 months if possible.

Operators will be queried to ascertain the control strategies, if any, affected at the hotel. It will also be determined if the chiller is deactivated for any part of the year. Other changes that would have affected use, such as increased ballroom use, conventions, equipment, or room thermostats / maintenance / housekeeping functions will be determined.

Operating logs will be obtained for the parameters to be collected, if available. There is reportedly no EMS on site to collect these values.

The performance curve for the installed chiller will be established by plotting the kW vs. the percent of full load for all data points collected for the chiller's operation. The percent load will be determined by calculating the tonnage based on the temperature difference between chilled water supply and return (ΔT) and the chilled water flow (either a constant value or a measured varying value) and comparing it to the rated full load tonnage of the chiller. The tonnage will be calculated by the formula:

Tons = CHW gpm x 500 lb/hr/gpm x CHW ΔT x 1 Btu/lb °F / 12,000 Btu/ton

The measured kW will be plotted and / or regressed against measured cooling load to determine the performance curve. This formula will be used with climate zone temperature data to establish an annual demand profile.

If this cannot be done, the manufacturers' performance data for the pre and post retrofit chillers will be used.

With the chiller performance established, the new system can be modeled and the annual electrical usage determined. From the performance curve or manufacturers' data, an average efficiency for the chiller can be determined. The post-retrofit energy usage will be compared to the baseline energy usage to determine the ex post savings using the following formula, and separated into bins and summed:

kWh pre = operating hours x average tons x $(\text{kW/ton})_{ave}$

kWh post = operating hours x average tons x $(\text{kW/ton})_{ave}$

kWh savings = kWh pre - kWh post

Coincident peak demand period savings = kW_{pre} - kW_{post}

Summer peak period savings = kW_{pre} - kW_{post} during the hottest periods between 2 PM to 5 PM, Monday through Friday, in June, July, August, and September.

Dent TOU power loggers or kW data logging devices should be placed on each of the two chiller compressors, if possible, to obtain the loading profile. The system condenser fans or a total condenser system power draw may also be measured. Ideally, the system would be monitored for a period of 2-3 weeks. However, due to the size of this chiller, and depending on the reported variability of usage, a shorter period may be suitable for this application. The power and operating hours would be recorded to reflect fluctuations in power consumption. The information obtained will allow more accurate pre-retrofit and post retrofit calculations.

HOBO 12 Temperature loggers' meters with surface temperature probes should be used to calculate the supply and return temperatures. The readings will be verified by use of spot readings taken with a Raytek infrared thermometer. Two Hobo temperature loggers will also be placed in a shielded exterior location to determine ambient air temperature.

Uncertainty for the savings estimate for the post-retrofit can be more fully understood by setting ranges on the primary variables that are being verified.

The greatest uncertainties in the measurements are the hourly chilled water loads and how the chillers' efficiencies (kW/ton) vary at different cooling loads. The uncertainty for the savings can be more fully understood by setting projected ranges on the primary variables.

Uncertainty for the savings estimates can be more fully understood by setting projected ranges on the primary variables.

<u>Uncertainty associated with chiller savings / chiller load profile and operation</u>

- Pre retrofit chiller kW: 106 kW (+0%, - 80%)
- Post retrofit chiller kW: 85 kW (+0%, - 80%)
- Hours: 3,504 hrs/yr (+10%, - 30%)

Accuracy and Equipment

Water temperatures will be measured with HOBO temperature loggers and site instrumentation. These devices are generally accurate to within +/- 2 degrees.

Power and other measurements will be obtained either with the customer's installed monitoring equipment or with portable equipment. In the case of portable equipment, spot measurements will be taken with a hand held Fluke amp meter. For trending, current dataloggers and / or true RMS kW meters manufactured by Dent Instruments or Amprobe (with current transformers – CTs - manufactured and calibrated by Dent

Instruments) would be used. The hand held meters are generally accurate to within 1% and the Dent loggers (with CTs) are generally accurate to within 2 %.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 21, 2007. Information provided regarding the pre-retrofit chiller was verified by interviewing the facility personnel. The information provided with the paperwork about the post retrofit chiller was verified physically checking ratings of the chiller and measurements were performed to obtain information to calculate the energy savings.

Installation Verification

The facility representative confirmed that there was an 80 ton chiller before the retrofit and that it was operating continuously. The new chiller was verified physically to be an 80 ton chiller by reading the data on the nameplate and by also from the control panel of the chiller. The new 80 ton chiller alternated the load between the two compressors when both compressors were not needed. Temperature sensors were used to measure the supply and return temperatures. Dent loggers were installed to obtain the loading profile for the chiller over a short period. The measurements obtained were in coherence with expected ranges and showed that the chiller was very lightly loaded. The chiller operating hours (since installation) were obtained from the control panel of the chiller.

This was the only measure in this application. The verification realization rate for this project is 1.00. A verification summary is shown in Table Table 9 below.

Scope of the Impact Assessment

The impact assessment scope is for the AC&R end use measure in the SPC application covering the chiller retrofit. This is the only measure in this application

Summary of Results

Models were calibrated with actual average weather data taken from the DOE2 energy modeling software for the location, the number of compressor hours since installation, and observed operating points at a percentage of cooling load with a concurrent outside air temperature (OAT). Information on the retrofit equipment and operating conditions were collected through an inspection of the chiller and through an interview with the building engineer.

From the available data, a relationship between chiller loading and outdoor dry bulb temperatures was established. Chiller use generally is minimal at 60 degrees outside air temperature and reaches 100% loading at 95 degrees F. To compute the impacts, the following assumptions were used:

- A linear loading strategy was used from 60 F to 80 F, for the analysis of both the original, baseline and rebated chillers, which assumed 5% loading at 60 degrees and 25% loading at 80 degrees F, to account for actual operating points observed.

- For the baseline chiller case, a Title 24 baseline efficiency of 1.222 kW/ton was used, based on a chiller of 80 tons. Pre-retrofit chillers modeled with efficiency of 1.325 kW/ton. Post-retrofit chiller was modeled with efficiency of 1.176 kW/ton. These ratings apply to full load efficiencies; part load efficiencies are higher, as shown in the following tables.

- Chiller efficiencies at various temperatures were obtained from values provided at 25%, 50%, 75%, and 100% loading from the manufacturer. These calculated efficiencies were used to develop a chiller efficiency curve for the post-retrofit case. The baseline chiller efficiency curve and the pre-retrofit chiller efficiency curve were interpolated matched to a typical chiller performance curve.

- The performance of the chillers based on the above analysis is shown in the following tables.

Table 1: Pre Retrofit Chiller Energy Use

Pre-retrofit chiller						
Outside Air (F)	Chiller Load (%)	Chiller Output (Ton)	Chiller Eff. (kW/Ton)	Chiller Input (kW)	Annual Operation (Hrs/Yr)	Total (kWh/Yr)
60	5.00%	5	1.275	12.8	1567	19,979
65	10.00%	10	1.250	15.6	837	13,078
70	15.00%	12.5	1.175	14.7	457	6,712
75	20.00%	15.0	1.100	16.5	177	2,921
80	25.00%	20.0	1.000	20.0	76	1,520
85	50.00%	40.0	1.150	46.0	29	1,334
90	75.00%	60.0	1.250	75.0	1	75
95	100.00%	80.0	1.325	106.0	0	-
Total					**3,144**	**45,619**

Table 2: Title 24 Baseline Chiller Energy Use

Baseline (Title-24) chiller						
Outside Air (F)	Chiller Load (%)	Chiller Output (Ton)	Chiller Eff. (kW/Ton)	Chiller Input (kW)	Annual Operation (Hrs/Yr)	Total (kWh/Yr)
60	5.00%	5	1.200	6.0	1567	9,402
65	10.00%	10	1.200	12.0	837	10,044
70	15.00%	12.5	1.150	14.4	457	6,569
75	20.00%	15.0	1.100	16.5	177	2,921
80	25.00%	20.0	1.000	20.0	76	1,520
85	50.00%	40.0	1.100	44.0	29	1,276
90	75.00%	60.0	1.150	80.0	1	80
95	100.00%	80.0	1.222	97.8	0	-
Total					**3,144**	**31,812**

Table 3: Post Retrofit Chiller Energy Use

Post-retrofit chiller						
Outside Air (F)	Chiller Load (%)	Chiller Output (Ton)	Chiller Eff. (kW/Ton)	Chiller Input (kW)	Annual Operation (Hrs/Yr)	Total (kWh/Yr)
60	5.00%	5	0.950	4.8	1567	7,443
65	10.00%	10	0.950	9.5	837	7,952
70	15.00%	12.5	0.925	11.6	457	5,284
75	20.00%	15.0	0.900	13.5	177	2,390
80	25.00%	20.0	0.875	17.5	76	1,330
85	50.00%	39.9	0.805	32.1	29	931
90	75.00%	59.8	1.026	61.4	1	61
95	100.00%	79.8	1.176	93.8	0	-
Total					**3,144**	**25,391**

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit peak load.

Peak demand reduction is calculated as follows:

- Reduction in kW peak load (50% load @ 85F): (46.0 kW – 32.1 kW) = 13.9 kW.

The energy savings that can be realized from replacing the pre-retrofit chiller with a post-retrofit chiller is given by the following formulae:

$$kWh\ \ savings = (kWh/yr_{pre} - kWh/yr_{post})$$

Therefore, the calculated energy savings are:

$$kWh\ savings = (45{,}619\ kWh/yr_{pre} - 25{,}391\ kWh/yr_{post}) = 20{,}228\ kWh/yr$$

The energy savings that can be realized from replacing the Title 24 standard efficient chiller with post-retrofit chiller is given by the following formulae:

$$kWh\ \ savings = (kW_{Title24} - kW_{post})$$

Therefore, the calculated energy savings are:

$$kWh\ savings = (31{,}812\ kWh/yr_{Title24} - 25{,}391\ kWh/yr_{post}) = 6{,}421\ kWh/yr$$

The typical useful life for a rotary screw chiller is 20 years. The original chiller had been in operation since 1993, which indicates a remaining useful life of 11 years at the time of the application (2004). The replacement chiller then has a useful life that is 11 years longer than when the original chiller would have had to have been replaced. Therefore, in order to calculate the average annual energy usage saved by replacing the original chiller with the proposed chiller is given by the following formulae:

(9 years x 20,228 kWh/year) + (11 years x 6,421 kWh/year)/ 20 years = 12,634 kWh/year

Table 4: Ex Post Savings Summary

	kW	kWh
Pre Retrofit Chiller	46	325,897
Title 24 Baseline Chiller	44	246,804
Post Retrofit Chiller	32.1	105,282
First Year Annual Savings	13.9	20,228

Utility billing data for the site was reviewed. In the 12 month period before, the facility consumed 4,327,766 kWh/yr. Peak demand was 822 kW. Table 1 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results. Table 5 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 1.7% decrease in total meter kW, a 12.9% decrease in AC/R end use kW, a 9.7% decrease in total meter kWh, and a 128.8% decrease in AC/R end use kWh. The ex post results showed a 1.7% decrease in total meter kW, a 13.1% decrease in AC/R end use kW, a 0.5% decrease in total meter kWh, and a 6.2% decrease in AC/R end use kWh.

Table 5: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	822.0	4,327,766
Baseline End Use	106.0	325,897
Ex ante Savings	13.7	34,986
Ex Post Savings	13.9	20,228

Table 6: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	1.7%	0.8%	1.7%	0.5%
Baseline End Use %	12.9%	10.7%	13.1%	6.2%

6. Additional Evaluation Findings

The ex post energy savings are considerably less than the ex ante energy savings because the ex ante savings overestimated the usage and load profile of the chiller. The applicant did not adequately support the savings calculations in any of the paperwork submitted.

The ex-post calculations were more accurate as loading used was measured and load profiles based on the manufacturer specifications.

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. One drawback stated was that chiller made considerable more noise during operation and a sound enclosure needed to be built. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future.

We were unable to verify hours of operation, loading profile and efficiency of the pre retrofit chiller. However, these parameters have been accurately assessed and quantified based on manufacturer data. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures, but could be improved with longer monitoring periods.

With a cost of $60,695 and a $30,417 incentive, the project had a 6.6 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 11.5 years. A summary of the economic parameters for the project is shown in Table 7. The Installation Verification

Summary is shown in Table 5 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 6.

7. Impact Results

The engineering realization rate is 1.01 for demand kW reduction and 0.58 for the first year energy savings kWh. The values shown in the updated tracking system/EEGA agree with those shown as handwritten figures in the installation report for this application. The engineering realization rate for average energy savings (for 20 yrs) is 0.93 for demand kW reduction and 0.36 for the energy savings kWh. A summary of the realization rate is shown in Table 8.

Table 7: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	12/7/2004	$60,695	13.7	34,986	0	$4,548	$30,417	6.66	13.34
SPC Program Review (Ex Post)	4/20/2007	$60,695	13.9	20,228	0	$2,630	$30,417	11.51	23.08

Table 8: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	13.7	34,986	-
SPC Installation Report (ex ante)	13.7	34,986	-
Impact Evaluation (ex post First Year)	13.9	20,228	-
Impact Evaluation (ex post Average)	12.8	12,634	
Engineering Realization Rate (first year)	1.01	0.58	NA
Engineering Realization Rate (average for 20 yrs)	0.93	0.36	NA

Table 9: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Replace 80 ton chiller-	AC/R	Replace 80 ton chiller				80 ton chiller	Physically verified chillere and verified chiller specifications and documentation of previous inspectors.	1.00

Table 10: Multi Year Reporting Table

Program Name:		SPC 04-05 Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	2,916	1,686	-	-	0	0
2	2005	34,986	20,228	13.7	13.9	0	0
3	2006	34,986	20,228	13.7	13.9	0	0
4	2007	34,986	20,228	13.7	13.9	0	0
5	2008	34,986	20,228	13.7	13.9	0	0
6	2009	34,986	20,228	13.7	13.9	0	0
7	2010	34,986	20,228	13.7	13.9	0	0
8	2011	34,986	20,228	13.7	13.9	0	0
9	2012	34,986	20,228	13.7	13.9	0	0
10	2013	34,986	20,228	13.7	13.9	0	0
11	2014	34,986	6,421	13.7	11.9	0	0
12	2015	34,986	6,421	13.7	11.9	0	0
13	2016	34,986	6,421	13.7	11.9	0	0
14	2017	34,986	6,421	13.7	11.9	0	0
15	2018	34,986	6,421	13.7	11.9	0	0
16	2019	34,986	6,421	13.7	11.9	0	0
17	2020	34,986	6,421	13.7	11.9	0	0
18	2021	34,986	6,421	13.7	11.9	0	0
19	2022	34,986	6,421	13.7	11.9	0	0
20	2023	34,986	6,421	13.7	11.9	0	0
TOTAL	**2004-2023**	667,650	247,948	-	-		

Final Report

SITE A028 Vis (2004-xxx) IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 5 END USE: Lighting

Measure	Lighting Retrofit involving delamping and conversion of first generation T8 to third generation T8 lamps and ballasts
Site Description	Large Office

1. Measure Description

Replace 2,283 two and three lamp first generation T8 fixtures with a like number of two lamp third generation fluorescent lamp fixtures.

2. Summary of the Ex Ante Calculations

The Installation Report Review indicates that the only measure in this application – the first generation T8 to third-generation T8 conversion and delamping in the open areas - resulted in savings of 193,581 kWh and 42.0 kW. These were calculated using custom spreadsheets and assumed wattages / hours of operation. It was noted that EMS schedules were used to compute the savings. These figures agree with the utility tracking system.

3. Comments on the Ex Ante Calculations

The ex ante calculated savings measures were calculated using a lighting efficiency table, with operating hour estimates and fixture descriptions. The lighting table included 79 line items, each with 2 to 137 fixtures, on the fifth through twelfth floors of a large office building. Each of the line items is assigned to one of four usage groups. Although the usage groups are not named, they appear to represent the following usage types:

Usage Group	Estimate Operating Hours	Line Items	Fixtures
Perimeter Offices	2,607	8	991
Interior & Open Offices (excl. 6th Fl.)	3,911	35	852
6th Floor Interior & Open Offices	4,605	6	182
Emergency Egress Fixtures	8,760	30	258

The lighting table lists both the total efficiency energy savings and the connected load. The reported demand savings on the application is the same as the connected load. No attempt was made to estimate the coincident or peak demand reduction.

4. Measurement & Verification Plan

The structure is a 12 story office building with 595,428 sf. It was reportedly 9 years old in 2005.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture quantities and hours of operation. The pre-retrofit and post-retrofit connected loads associated with various fixture types are adequately quantified in the SPC lighting wattage tables. The goal of the M&V plan is to verify the fixture quantities and, pre-retrofit and post-retrofit hours of operation, in order to determine savings over the useful life of the measures.

For this application, the pre-retrofit fixture types, quantities and hours of operation will be verified with the facility representative. The post-retrofit fixture quantities and fixture types will also be verified during the site visit. Dent or Hobo light loggers will be installed throughout the retrofit portions of the facility in representative areas for a minimum of 7 days. This monitoring data will be used to estimate the post retrofit hours of operation. These optically triggered loggers record lighting status (on or off). The exact number of loggers to be installed depends on the layout of the facility and the expected variability in fixture operation.

The facility is a large office building. The typical usage and occupancy of an office facility tends to be fairly consistent over the course of a year. The site personnel will be interviewed to verify occupancy consistency. No trouble is expected in extrapolating the monitored hours over the typical year.

The number of loggers to be used to monitor hours at the facility will depend on the expected variability of the operating hours within the facility. In order to best estimate the operating hours of the facility, and thus the energy savings, the retrofit fixtures will be classified by similar usage patterns into usage groups. These usage group divisions will correspond with the different operating hour estimates in the lighting table.

To estimate peak demand kW reduction, we will account for the reduction in connected kW due to the increased lighting efficiency and calculate the average percent of lights on from 2 pm to 5 pm Monday-Friday, during the hottest expected periods in June, July, August and September. The M&V plan is a modified version of IPMVP Option A.

Formulae

Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kW = Fixture watts / 1,000 watts /kW x fixture quantity x percent energized during peak demand period

kWh = kW x operating hours x percent energized

Accuracy

The loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable. The SPC lighting wattage tables and field verified fixture counts are considered to be 100% accurate.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

Uncertainty ranges are described as follows.
Fixtures: 2,283 (+/- 10%)
Wattages per fixture: 88, 60, 54 watts (+/- 10%)
Hours per year: 2,607; 3,911; 4,605 (+/- 20%)

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on April 5, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. The application indicated the savings were from the replacement of 2,283 two- and three-lamp first generation T-8 fixtures with a like number of two-lamp third generation T-8s. These fixtures were the focus of the M&V evaluation.

Installation Verification

The facility representative indicated that 2,283 T-8 fixtures were replaced with third generation 2-lamp T-8 fixtures. Physical verification of all lighting retrofits was attempted but it was only possible to sample selected areas. This inspection, the post installation inspection and the itemized lighting table served to verify the installation. The fixture counts in the sampled areas appeared to be representative of the total fixture count. All fixtures were operational at the time of the site visit. The paper work also indicated that the number of fixtures has been reviewed or verified prior to retrofit.

The verification realization rate for this project is 1.0. A verification summary is shown in Table 5 below.

The paperwork suggests the installation was completed by the end of January 2005.

Scope of the Impact Assessment

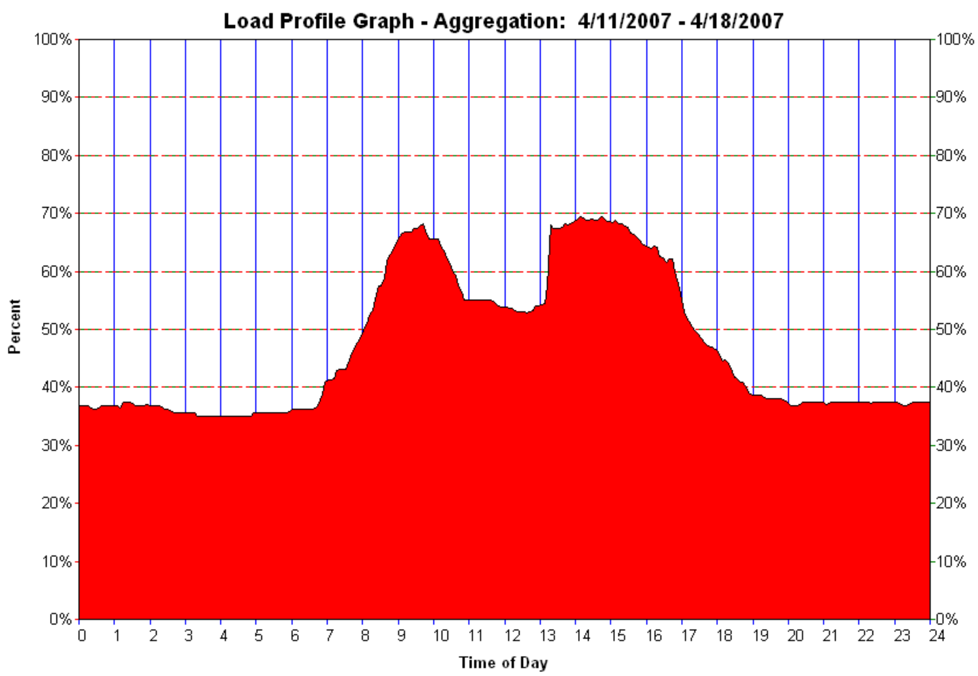
The impact assessment scope is for the lighting end use measure in the SPC application covering more efficient lighting fixtures. This is the only measure in the application.

Summary of Results

Thirty-two Dent lighting loggers were installed in the fifth through twelfth floor. The facility representative indicated that the present level of activity was representative of normal facility operation. The lighting loggers indicated that all lamps burned less than 53% of the time and a few were off the entire 7 day period. The average on-time of all loggers was 44.2%.

During the expected coincident peak demand periods of 2 pm to 5 pm weekdays for the 7 days monitored (April 11th to April 18th 2007), the fixtures were measured to be on an average of 65.9% of the time. Motion sensors were installed on some of the fixtures. Thus, during a normal weekday, 100% of the fixtures would not be energized. No weekdays and no special holidays or off days were included in this period. Figure 1 below shows a typical load profile.

Figure 1: Typical Load Profile



The ex post impacts for the main measure is calculated as follows where kW per fixture is assumed to be the same as the ex ante calculations. Note that the two and three lamp fixtures were equally divided between the three lamp fixtures drawing 88 watts and the two lamp fixtures drawing 60 watts. Thus, 74 watts (or 0.074 kW) is used. The actual average pre retrofit wattage was 72.3 watts. The use of this figure would decrease ex post savings by 3% from the calculated value. The average hours were used, as there wee a large number of lighting loggers used, which served to allow averaging across usage groups.

a.) Actual monitored average pre-retrofit hours of operation for all 1st generation T-8 fixtures was 3,868 hrs/year.
b.) Pre-retrofit wattage was 0.074 kW per fixture x 2,283 fixtures = 168.9kW
c.) Annual kWh usage was 168.9 kW x 3,868 hrs/yr = 653,305 kWh/yr

Based on lighting logger data, post-retrofit hours of operation are 3,868 hrs/year and post-retrofit wattage is 0.054 for all fixtures
a.) Post-retrofit wattage is 0.054 kW per fixture x 2,283 fixtures = 123.3 kW
b.) Annual kWh usage is 123.3 kW x 3,868 hrs/yr = 476,924 kWh/yr

The resulting annual kWh savings is 653,305 kWh/yr – 476,924 kWh/yr = 176,381 kWh/yr.

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load, with an adjustment for the weekday average 2 pm to 5 pm measured usage factor of 65.9%.

Peak kW savings is (168.9 kW –123.3 kW) x 65.9%= 30.1 kW.

The engineering realization rate for this application is 0.72 for demand kW reduction and 0.91 for energy savings kWh. The values shown in the tracking system substantially agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 4.

Utility billing data for the site was reviewed. In the 12 month period from February 2003 – January 2004 (pre-retrofit), the facility consumed 6,134,536 kWh. Peak demand was 1,045 kW in this period. Lighting use was estimated at 30% of total use for this facility. Table 2 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 4.0% decrease in total meter kW, a 13.3% decrease in lighting end use kW, a 3.2% decrease in total meter kWh, and a 10.5% decrease in lighting end use kWh. The ex post results showed a 2.9% decrease in total meter kW, a 9.6% decrease in lighting end use kW, a 2.9% decrease in total meter kWh, and a 9.6% decrease in lighting end use kWh.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1,044.9	6,134,536
Baseline End Use	313.5	1,840,361
Ex Ante Savings	42.0	193,581
Ex Post Savings	30.1	176,381

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	4.0%	3.2%	2.9%	2.9%
Baseline End Use %	13.3%	10.5%	9.6%	9.6%

6. Additional Evaluation Findings

The ex post kWh demand reduction varied from the ex ante estimate because the ex ante calculations for the T-8 retrofit were calculated using estimated hours of use per year that were greater than for the ex post verified hours of use. The estimates of ex post kW savings are less because the expected percentage of fixtures energized during the coincident peak demand periods were measured by the loggers. (instead of assuming all fixtures were energized)

In addition to saving energy, the benefits of the project are better quality of lighting and increased light levels in some areas. One drawback of the project has been an increase in maintenance associated with the need to replace fluorescent lamps. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future.

The customer’s participation in the 2004/2005 SPC Program is not known to have encouraged them to perform other energy efficiency projects.

The cost of $136,500 for the retrofit of 2,283 fixtures is reasonable.

It was impossible to physically verify the pre-retrofit lighting fixture type, quantities and hours of operation. However, these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V

employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $136,500 and a $9,679 incentive, the project had a 5.04 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 5.52 years. A summary of the economic parameters for the project is shown in Table 3.

A summary of the multi-year reporting requirements is given in Table 6. Because this measure was installed approximately February of 2005, the energy savings in year #1 (2005) are assumed to be (83%) of the expected annual savings for this measure.

7. Impact Results

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	4/21/2005	$136,500	42.0	193,581	-	25,166	$9,679	5.04	5.42
SPC Program Review (Ex Post)	11/27/2007	$136,500	30.1	176,381	-	22,959	$9,679	5.52	5.95

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	42.0	193,581	-
SPC Installation Report (ex ante)	42.0	193,581	-
Impact Evaluation (ex post)	30.1	176,381	-
Engineering Realization Rate	0.72	0.91	NA

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		–First Generation two and three lamp T8 lamps/ballasts to Third Generation two lamp T8 lamps/ballasts		2,283		Physically verified lamp type and verified quantity from lighting table.	1.00

Table 6: Multi Year Reporting Table

Program Name:		**Site A028 SPC 04-05 Evaluation**					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004						
2	2005	160,672	146,396	42.0	30.1	0	0
3	2006	193,581	176,381	42.0	30.1	0	0
4	2007	193,581	176,381	42.0	30.1	0	0
5	2008	193,581	176,381	42.0	30.1	0	0
6	2009	193,581	176,381	42.0	30.1	0	0
7	2010	193,581	176,381	42.0	30.1	0	0
8	2011	193,581	176,381	42.0	30.1	0	0
9	2012	193,581	176,381	42.0	30.1	0	0
10	2013	193,581	176,381	42.0	30.1	0	0
11	2014	193,581	176,381	42.0	30.1	0	0
12	2015	193,581	176,381	42.0	30.1	0	0
13	2016	193,581	176,381	42.0	30.1	0	0
14	2017	193,581	176,381	42.0	30.1	0	0
15	2018	193,581	176,381	42.0	30.1	0	0
16	2019	193,581	176,381	42.0	30.1	0	0
17	2020	193,581	176,381	42.0	30.1	0	0
18	2021	32,264	29,397			0	0
19	2022	-	-	-	-		
20	2023	-	-	-	-		
TOTAL	**2004-2023**	3,096,651	2,821,508				

Final Site Report

SITE A029 (2004-xxx) IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 3 END USE: Lighting

Measure	High Bay T5 Lighting Retrofit / Occupancy Sensors
Site Description	Warehouse / Offices

1. Measure Description

Replace 664 high intensity discharge (HID) fixtures utilizing 400 watt lamps with 664 fluorescent fixtures utilizing T5 lamps. Install 664 ceiling/fixture mounted occupancy sensors to reduce lighting hours of operation. Replace five (5) two-lamp, 150 three-lamp, and 42 four-lamp T12 ballasts, controlling a total of 628 lamps, with T8 ballasts. Install 25 wallbox lighting sensors.

2. Summary of the Ex Ante Calculations

The customer used the Itemized Measure Application Form; no kW or kWh savings were submitted. The basis of the incentive payment was the itemized incentive list.

The primary components of energy saving are the HID fixture replacements and the occupancy sensor installation.

The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. These workpapers note that a conversion from metal halide fixtures to high output (HO) T5 fixtures results in wattage reductions from 0.458 kW to 0.234 kW, for a non-coincident peak reduction of 0.224 kW. Coincident peak reduction is noted as 0.205 kW and kwh savings is noted as 843 kwh. The hours of operation for a warehouse are fixed in the workpapers at 3,550 hours/year. The workpapers note a diversity factor of 84% for a warehouse.

For ceiling mounted occupancy sensors, the savings are based on the control of eight (8) fluorescent T12 fixtures consuming 72 watts each in an office conference room. Savings are based on a reduction from 2,210 hours/year to 1,040 hours/year (1,170 hours/year reduction). The workpaper reports 789 kWh savings (674 kWh/year plus a 17% office sector demand interactive effects factor). The non-coincident peak reduction of 0.305 kW was derived from the 0.576 kW controlled wattage and a 53% reduction in hours. Coincident peak reduction in the workpaper was noted to be 0.381, which included a 1.25 demand sector interactive effects factor.

In the project application review, back-calculation was requested by the program manager. This was performed based on figures from a table included in the application paperwork entitled “2004 SPC Prescrip Summary Average Measure Savings”. These calculations are as follows:

For lower wattage fixtures (T5 vs. MH)
664 fixtures x 1,116.24 kwh/unit = 741,183.4 kWh/yr
(reported as 741,182.47 in the Installation Report Review)
664 fixtures x 0.2007 kw/unit = 133.26 kW

For motion sensors controlling the above fixtures
664 fixtures x 788.64 kwh/unit = 523,657.0 kWh/yr
(reported as 523,655.96 in the Installation Report Review)
664 fixtures x 0.3813 kw/unit = 253.18 kW

For the conversion of 628 T12 fluorescent lamps to 628 T8 lamps
628 fixtures x 59.8 kwh/unit = 37,553.46 kWh/yr
628 fixtures: 6.8 kW

For the installation of 25 wall mounted occupancy sensors
25 fixtures: 6,638.29 kWh/yr
25 fixtures: 2.8 kW

Total savings in the calculations
1,309,033 kWh/yr; 395.9 kW

3. Comments on the Ex Ante Calculations

The back calculations yield the savings reported in the Installation Report Review (IRR) and are the ex ante calculations. These were formulated using the “2004 SPC Prescriptive Summary Average Measure Savings” table. For the lighting conversion from high intensity discharge fixtures to T5 fluorescent fixtures and for the ceiling occupancy sensors, these values generally conform to the lighting workpapers. The largest exception is the kwh savings for the T5 conversion from the metal halide fixtures (1,116 kWh was used in the back calculations, as opposed to 843 kWh in the workpaper).

The following paragraphs highlight discrepancies regarding the ex ante calculations.

Using the 84% diversity factor for warehouses from the workpapers and the baseline kw of the assumed controlled fixtures, the coincident peak demand (kW) savings associated with motion sensors on the new fixtures appears to be overstated. The wattage controlled by each motion sensor and the diversity factor in the workpapers do not accurately describe this installation.

In general, the savings figures in the final Implementation Report (IR) would be expected to be identical to the utility tracking system savings figures. The total savings in the final Implementation Report were given as 1,309,030 kWh/yr and 395.9 kW. The utility tracking system notes a total savings of 1,118,347 kWh/yr and 399.01 kW.

The utility tracking system figures will be used to calculate the realization rate.

The lighting survey table lists 6,000 hours per year as the operating hours, verses the 3,550 hours per year in the workpapers.

The actual fixtures replaced were noted to have been 400 watt high pressure sodium, consuming 0.465 kW. There was no workpaper available for high pressure sodium replacements. The customer has indicated that these may have been dual lighting level high pressure sodium fixtures, presumably controlled by motion sensors. In this case, the workpapers would not apply directly to this installation.

The calculations can be checked for reasonableness using a simple pre-retrofit and post-retrofit algorithm with fixture connected loads and energized hours of operation. Corresponding to data in the application, 6,000 annual hours of operation and a 45% reduction in operating hours associated with the installation of occupancy sensors were used in these check calculations.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x (1 – diversity factor)

The check calculations for the main measures (involving conversion from HID fixtures and installation of motion sensors on these fixtures) were performed as follows:

- Pre-retrofit hours of operation were 6,000 hrs/year.
  Pre-retrofit wattage was 0.465 kW per fixture x 664 lamps = 308.76 kW.
  Annual kWh usage was 308.76 kW x 6,000 hrs/yr = 1,852,560 kWh/yr.
- Based on a 45% reduction in operating hours, post-retrofit hours of operation are 6,000 hours x (100% - 45%) = 3,300 hrs/year.
  Post-retrofit wattage is 0.351 kW per six-lamp fixture x 200 fixtures
  + 0.234 kW per four-lamp fixture x 464 fixtures
  = 178.78 kW.
  Annual kWh usage is 178.78 kW x 3,300 hrs/yr = 589,960 kWh/yr.
- The resulting annual kWh savings is 1,852,560 kWh/yr – 589,960 kWh/yr = 1,262,599 kWh/yr.

The kWh savings are similar to those reported in the IRR.

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load and adding the diversity factor adjusted savings for occupancy sensor use.

Coincident peak demand reduction is calculated as follows:

- Reduction in connected kW load plus reduction in load due to motion sensor use is (308.76 kW – 178.78 kW) + (178.78 kW x (100% - 84%)) = 129.98 kW + 28.60 kW = 158.58 kW.

The kW savings are approximately 30% of the value given in the IRR.

4. Measurement & Verification Plan

The building is a single level 625,000 sf unconditioned warehouse that supplies grocery stores with dry goods. It is reported to be approximately 25 years old. The building has minimal windows and skylights. The building is occupied from 4 am to 1 am Monday through Thursday; Friday hours are from 4 am to 1 pm and Sunday hours are from 1 pm to 1 am. The majority of activity occurs between 7 am and 10 pm. Maximum occupancy is approximately 20 employees at any given time. According to the application, before the retrofit there were 664 high pressure sodium fixtures using 400-watt lamps. After the retrofit there are 200 six-lamp T-5 fluorescent fixtures and 464 four-lamp T-5 fluorescent fixtures. All post-retrofit fixtures were equipped with individual occupancy sensors. The project saves energy through the installation of lighting fixtures with a lower connected wattage and by controlling the lighting fixtures with occupancy sensors to reduce the hours of operation.

The documentation in the application indicates that there are three main warehouses (A, B, and C) which have 328 four-lamp T5 fixtures and 231 six-lamp T5 fixtures. The majority of fixtures are located above the aisles.

The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

An IMPVP Option C approach should be considered. The savings reported in the utility tracking system is approximately 20% – 30% of the kW and kWh consumed based upon the pre-retrofit building use (peak demand is approximately 1,200 kW and annual energy use approximates 3,000,000 kWh per year according to the utility billing summary in the application). Utility billing and interval data should support this approach if there are no other significant loads or other significant energy conservation activities which occurred in the months immediately following the retrofit. There is not expected to be significant seasonal variation and several months should be sufficient for comparison; however, a one to two year period would more fully capture actual variations and the persistence of savings. Interval data on a 15 minute basis during the summer months of June to September would be needed to accurately determine coincident peak period demand savings.

If Option C cannot be used due to changes in the facility or its operation in the time periods immediately before or after the retrofit, then a modified version of IPMVP Option A can be utilized. Lighting loggers would be used to quantify hours of operation. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x ((energized $hours_{pre}$ - energized $hours_{post}$)) / energized $hours_{pre}$) during the hottest periods between 2 pm to 5 pm, Monday to Friday, in June, July, August, September

Thus, to estimate peak demand kW reduction, the reduction in connected kW due to the increased lighting efficiency will be added to the post-retrofit connected load multiplied by the percent of energized time according to the above formulae. It will be described how the average percent of time energized used in the above formulae, for both the average peak demand period and the coincident peak demand periods, will be derived or extrapolated from the measured period.

Documentation provided indicates that there are 664 fixtures with individual motion sensors which compromise over 90% of the projected savings. These fixtures would be the primary target for evaluation efforts. The majority of the fixtures are located in the aisles of three warehouses. The savings from other lighting measures not related to the warehouse lighting are less than 10% according to application data. Evaluation efforts will, for this reason, focus on the warehouse lighting.

The most significant variable to be quantified is the fixture hours of operation, both pre-retrofit and post-retrofit. Pre-retrofit hours can be confirmed with site personnel and interviews. The focus would be on verifying that, prior to the retrofit, the entire complement of fixtures was completely energized during the hours listed (6,000 hours/year) and that the listed hours/year were valid (for example, building or staff schedule logs for the pre-retrofit period could be examined if available). If dual level lighting high pressure sodium fixtures were in use, the operating schedules for each lighting level should be confirmed as accurately as possible. Appropriate modifications for the savings calculations would be made to the pre-retrofit usage figures if required, in order to establish a realistic baseline for energy use.

Monitoring with light loggers would be conducted on approximately 5% of the aisles and a center aisle where feasible. A minimum of two sensors for two aisles and one sensor per central aisle would be used in each of the three warehouses. Thus, a minimum of fifteen (15) sensors would be used; however, there could be significantly more sensors required, based on usage and traffic patterns. The customer confirmed that the three warehouses have similar usage patterns. The use of fifteen sampling points is generally consistent with SPC program documentation from March 2001 (Appendix E, Sampling), which suggests guidelines for determining sampling point requirements necessary to achieve an 80% confidence interval with 20% precision (using a coefficient of variation of 0.5).

A more random sampling approach involves setting up a grid for the warehouse, labeling fixtures sequentially according to their location, and randomly selecting from the total number of fixtures using random number generators. This will avoid overweighting or assigning a relatively arbitrary weighting factor for the central aisles. The majority of the lighting is over aisles with racked storage, with a small percent of floor area being used for central aisles, floor storage (un-racked), and a battery charging area. We will consider the warehouse as one usage group for the purposed of assigning fixtures to be sampled. Assignment would be from one corner of the buildings to the adjacent corners. The fifteen fixtures to be sampled using this technique would be as follows:

4, 37, 68, 184, 185, 190, 197, 290, 309, 314, 320, 337, 344, 345, and 387.

A backup sample of ten fixtures would be as follows:

400, 456, 485, 490, 520, 527, 575, 578, 608, and 64.

The light loggers would be placed so as to be unaffected by fixtures not on motion sensors or by ambient outside light.

If the light loggers cannot be placed in proper locations, it was considered that, where the lighting circuits can be isolated and it can be determined that only lighting loads for the warehouse fixtures are controlled by that lighting circuit, a current or power meter could be used to track multiple fixtures. The total current / power would be determined by activating all fixtures and by confirming loads using the electrical drawings. Between three and six current/power meters are expected to be needed, to capture a representative sample of the lighting fixtures.

The lighting loggers or current sensors would be left in place for a period of 7 to 14 days. Attention will be given to the time period for monitoring, in order to avoid periods of irregular usage patterns (such as holidays or breaks). While longer periods might be preferable, these periods are appropriate given the scope of the evaluation and reported usage characteristics.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture hours of operation. The lighting fixture quantities seem to be well established and were counted to within 5% to 10% in utility post-installation inspection visits. The pre-retrofit and post-retrofit connected loads associated with various fixture types are also adequately quantified in the SPC lighting wattage tables.

Uncertainty for the savings estimate for the warehouse fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables:

For lower wattage fixtures (T5 conversion from HID fixtures)

- 664 fixtures expected, minimum 631, maximum 695 (+/- 5 %)
- 6,000 hours pre retrofit expected/reported, minimum 3000 hours, maximum 7000 hours (based on pre retrofit utility bill analysis from application)
- 133.26 kW expected, minimum 120 kW, maximum 146 kW (includes +/- 5 % for number of fixtures and +/- 5 % for fixture wattage difference)

For motion sensors controlling the above fixtures

- 664 fixtures expected, minimum 631, maximum 695 (+/- 5 %)
- 3,300 hours post retrofit expected/reported, minimum 1,650 hours, maximum 6,600 hours (- 50 % , +100 % based on judgment of use for site type; includes + / - 5% from annualizing estimates from short monitoring period)
- 253.18 kW reported savings includes number of fixtures, post-retrofit fixture wattage and diversity factor; 28.6 kW expected, minimum 14.3 kW, maximum 42.9 kW (reflects + / - 50% expected range)

There will be a small potential error estimated at +/- 1% to 2%, since M&V will not be performed on the smallest measures which contribute a small amount of savings. This is not included in the analysis of uncertainty due to its size.

Accuracy and Equipment

The light loggers to be used are Dent TOU-L Lighting Smart*logger* dataloggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Annualizing that data from a 7 to 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

Current or power meters may also be used. The current loggers to be used, if this M&V technique is selected, would be HOBO U-12 loggers, with matched current transformers. The accuracy range is 3.5 %. The sensor would be calibrated to an Amprobe ACD-41PQ, with an accuracy of +/- 2%. An advantage of using current or power meters to monitor load is that the percent of time energized for an increased number of fixtures may be able to be captured.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on April 30, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Lighting fixture quantities and hours of operation were verified.

The building is occupied continuously, starting 6 a.m. Sunday until 5 p.m. Friday (according to operations personnel). The facility has 125 employees. The facility is closed 4 holidays annually (Labor Day, Thanksgiving, Christmas and New Year's Day).

Installation Verification

The facility representative verified that the high pressure sodium fixtures were replaced on a one for one basis. It was physically verified that there were 200 six-lamp T-5 fluorescent fixtures and 464 four-lamp T-5 fixtures installed in the facility with occupancy sensors. The building representative stated that the high pressure sodium fixtures that were existing pre-retrofit were on occupancy sensors that dimmed them to low power when the space was unoccupied. It was also physically verified that there were 197 T8 fixtures installed without occupancy sensors. The retrofit was completed in April 2005.

It was not possible to verify the 25 wall switch motion sensors in offices and bathrooms; it is believed that these sensors were installed as indicated.

The installation of T5 fixtures with motion sensors, T8 fixtures, and switch mounted motion sensors are the only measures in this application. The verification realization rate for this project is 1.00 (861/861 total quantity for all measures). A verification summary is shown in Table 5 below.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measures in the SPC application covering the lighting efficiency retrofit. These are the only measures in this application.

Summary of Results

The facility representative stated that the building is occupied continuously on Sundays and weekdays. The building is closed from 5 p.m. Friday to 6 a.m. Sunday. All lights are on when the building is occupied. It is assumed the lights are off during the unoccupied periods.

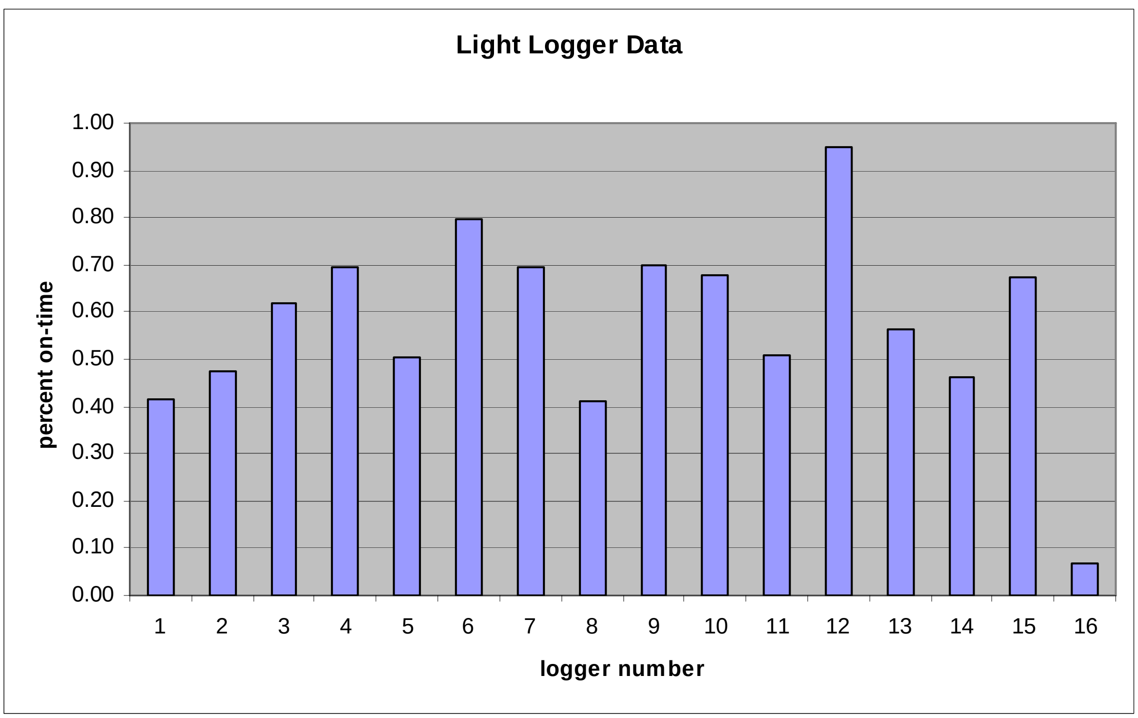
Very few burned out lights were observed during the site visit. Burned out lights are regularly replaced. Therefore, there was no adjustment to the lighting energy consumption due to burned out lamps.

All lights are expected to be operating during the peak demand period defined as the hottest periods between 2 pm to 5 pm, Monday to Friday, in the week with the hottest weekday in June, July, August or September.

The electricity end-uses at this facility are lighting, forklift charging and HVAC for the refrigerated facility. The facility representative confirmed that there was no change in the electricity use patterns before and after the retrofit other than the change to the light fixtures themselves.

The light loggers were installed as planned in the following fixtures: 4, 37, 68, 184, 185, 190, 197, 290, 309, 314, 320, 337, 344, 345, and 387. There was one additional light logger installed in fixture 474. The on-time of the fixtures was recorded between 12:00 AM on 3/31/07 and 11:59 PM on 4/12/07. The percent on-time during this time period is shown for each of the fixtures in Figure 1 below. The average percent on-time was 0.58 for all of the light loggers in this 13 day period.

Figure 1: Light Logger Data at Site A029



The ex ante calculations were revised after the evaluation site visit to reflect actual hours of operation, actual number of fixtures installed, and the motion sensors that were installed on the high pressure sodium fixtures prior to the retrofit.

The savings from wall mounted sensors in offices and bathrooms and for the T12 to T8 conversions were excluded from this analysis because the savings are very small relative to the other measures, and these savings are accepted as accurate for the ex ante and the ex post savings.

- Pre-retrofit hours of operation were 6,734 hrs/year, (3,906 hours for HPS on high power and 2,828 hours on low power, distributed according to post-retrofit lighting logger data, which recorded a usage on time factor of 0.58).

- Pre-retrofit wattage for HPS fixtures was 0.465 kW per fixture x 664 lamps = 308.76 kW. (assumed 185.3 kW or 60% of full power in "low power" state)

- Annual kWh usage was 308.76 kW x 3,906 hrs/yr + 185.3 kW x 2,828 hrs/yr = 1,729,973 kWh/yr.
- Post-retrofit hours of operation are 6,734 hours x (58%) = 3,906 hrs/year for the T5 fixtures.
- Post-retrofit wattage is 0.351 kW per six-lamp fixture x 200 fixtures + 0.234 kW per four-lamp fixture x 464 fixtures = 178.78 kW.
- Annual kWh usage is 178.78 kW x 3,906 hrs/yr = 698,284 kWh/yr.
- The resulting annual kWh savings is 1,729,973 kWh/yr – 698,284 kWh/yr = 1,031,689 kWh/yr.

The total ex post kWh savings is 1,031,689 kWh/yr + 37,553 kWh/yr (T12 conversion) + 6,638 kWh/yr (wallbox motion sensors) = 1,069,542 kWh/yr.

Summer peak impacts were estimated by subtracting post-retrofit load from pre-retrofit load. The load includes connected load and the diversity factor adjusted savings for occupancy sensor use.

Summer peak demand reduction is calculated as follows:

- Pre-retrofit kW load (HPS connected – HPS diversity) minus post-retrofit kW load (T5 connected – T5 diversity) is: (308.8 kW – 19.8 kW) – (178.8 kW – 28.6 kW) = 289.0 kW – 150.2 kW = 138.8 kW.

The total ex post kW savings is 138.8 kW + 6.8 kW (T12 conversion) + 2.8 kW (wallbox motion sensors) = 148.4 kW.

Billing data was analyzed for this site to see if it confirms the savings found in the engineering calculations, and it was found to be too inconclusive to give an indication of energy reduction due to the lighting retrofit. The noise in the data may be due to the large refrigeration load that is weather dependent.

Utility billing data for the site was obtained. Pre-retrofit annual consumption (for one year prior to retrofit) was 6,931,275 kWh. Peak demand was 1161.2 kW. No pre-retrofit baseline usage was listed in the application. Table 1 summarizes the total metered use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The revised ex ante results showed a 34.1% decrease in total meter kW, a 42.6% decrease in lighting end use kW, a 22.8% decrease in total meter kWh, and a 140.4% decrease in lighting end use kWh. These very high savings are due to an over-estimate of the baseline energy use and hence an over estimate in savings because the occupancy sensor dimmers on the high pressure sodium fixtures were overlooked. The ex post results showed a 13.6% decrease in total meter kW, a 56.1% decrease in lighting end use kW, a 15.4% decrease in total meter kWh, and a 56.1% decrease in lighting end use kWh.

The engineering realization rate for this application is 0.40 for demand kW reduction and 0.95 for energy savings kWh. According to the installation report, the ex ante savings are 1,309,030 kWh annually and demand reduction is 399.0 kW. However, tracking system figures revise savings to 1,118347 kWh and 242 kW, and these will be used as the ex ante impacts. A summary of the realization rate is shown in Table 4.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1161.2	6,931,275
Baseline End Use	282.0	1,899,140
Ex Ante Savings	395.9	1,309,030
Ex Post Savings	148.4	1,069,242

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	34.1%	18.9%	12.8%	15.4%
Baseline End Use %	140.4%	68.9%	52.6%	56.3%

6. Additional Evaluation Findings

The ex post kwh and kW demand reduction is lower than the ex ante estimate because the ex ante calculations did not take into account the fact that the high pressure sodium fixtures were equipped with occupancy sensor dimmers which lowered the savings from the fixture replacement and because the motion sensor demand reduction was based on the workpapers which assume a (per unit) controlled wattage of 0.576, much higher than the wattage actually controlled (an average of 0.269 kW). Further, the workpapers assume a use (on time) factor of 47%, lower than the measured use factor of 58%.

In addition to saving energy, the benefits of the project are that the employees find the white light color and the improved lighting levels more agreeable. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. Participation in the 2004/2005 SPC Program has not encouraged them to perform other energy efficiency projects.

The installation costs appear to be reasonable.

7. Impact Results

The pre-retrofit lighting fixture type, quantities and hours of operation were unable to physically verified. However, these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $292,750 and a $76,332 incentive, the project had a 1.27 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 1.56 years. A summary of the economic parameters for the project is shown in Table 3.

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	5/10/2005	$292,750	395.9	1,309,030	0	$170,174	$76,332	1.27	1.72
SPC Program Review (Ex Post)	4/30/2007	$292,750	158.2	1,069,242	0	$139,001	$76,332	1.56	2.11

The realization rate of the peak kW demand is 0.37 and the realization rate of the energy savings is 0.96 as summarized in Table 4. The Installation Verification Summary is shown in Table 5 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 6.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	399.0	1,118,347	-
SPC Installation Report (ex ante)	395.9	1,309,030	-
Impact Evaluation (ex post)	148.4	1,069,242	-
Engineering Realization Rate	0.37	0.96	NA

1. Tracking System values used for realization rate calculations.

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Replace 664 high pressures sodium fixtures with 664 HO T5 fluorescent fixtures and install 664 ceiling/fixture mounted occupancy sensors. Replace 197 T12 ballasts with 197 T8 ballasts.		861	T5 HO fixtures and T8 ballasts	Physically verified lamp type and quantity.	1.00

Table 6: Multi Year Reporting Table

Program ID Program Name		SPC 2004 Application # A029 2004 – 2005 SPC Evaluation					
Year	**Calendar Year**	**Ex-ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004						
2	2005	872,687	712,828	395.9	148.4		
3	2006	1,309,030	1,069,242	395.9	148.4		
4	2007	1,309,030	1,069,242	395.9	148.4		
5	2008	1,309,030	1,069,242	395.9	148.4		
6	2009	1,309,030	1,069,242	395.9	148.4		
7	2010	1,309,030	1,069,242	395.9	148.4		
8	2011	1,309,030	1,069,242	395.9	148.4		
9	2012	1,309,030	1,069,242	395.9	148.4		
10	2013	1,309,030	1,069,242	395.9	148.4		
11	2014	1,309,030	1,069,242	395.9	148.4		
12	2015	1,309,030	1,069,242	395.9	148.4		
13	2016	1,309,030	1,069,242	395.9	148.4		
14	2017	1,309,030	1,069,242	395.9	148.4		
15	2018	1,309,030	1,069,242	395.9	148.4		
16	2019	1,309,030	1,069,242	395.9	148.4		
17	2020	1,309,030	1,069,242	395.9	148.4		
18	2021	436,343	356,414				
19	2022						
20	2023						
TOTA	**2004-2023**	20,944,480	17,107,873				

Final Report

SITE A030 (2004-xxx) For IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 3 END USE: Lighting

Measure	High Bay T5 Lighting Retrofit
Site Description	Warehouse

1. Measure Description

Replace 1180 high intensity discharge fixtures utilizing 400 watt metal halide lamps with 1090 fluorescent fixtures utilizing six (6) high output (HO) T5 lamps and 90 fluorescent fixtures utilizing four (4) T5 lamps. A total of 760 fixture mounted occupancy sensors to reduce lighting hours of operation were installed at the same time but were not a part of the SPC program.

2. Summary of the Ex Ante Calculations

The criteria for itemized measures was used to calculate kW and kWh savings on a stipulated basis. The basis of the incentive payment was the itemized incentive list.

The ex ante savings in the Installation Report Review are listed as 236.8 kW and 1,317,161.6 kWh.

Notes in the Project Application Review show the Application Approved Amount for the savings estimate as 242 kW and 994,633.8 kWh; handwritten notes indicate that these amounts are based on the amount shown in MDSS (the management decision system software, a utility tracking system). The incentive of $ 88,500.00 was not adjusted.

The utility tracking system lists savings as 994,634 kWh/year and 242.01 kW; these are used to calculate the realization rates for this measure.

Calculations were submitted in the application by the customer. These were not, however, the basis of the ex ante calculations.

The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. These workpapers note that a conversion from metal halide fixtures to four lamp high output (HO) T5 fixtures results in a wattage reduction from 0.458 kW to 0.234 kW, for a non-coincident peak reduction of 0.224 kW. Coincident peak reduction is noted as 0.205 kW and kWh savings is noted as 843 kWh/year. The hours of operation for a warehouse are fixed in the workpapers at 3,550 hours/year. The workpapers note a diversity factor of 84% for a warehouse.

3. Comments on the Ex Ante Calculations

The invoice in the application paperwork indicated that there were 1239 fixtures installed, while the post installation inspection noted there were 1187 fixtures. The installation report review and ex ante calculations were based on 1180 fixtures.

The ex ante calculations appear to be embedded in the Itemized Measure Form. The ex ante savings for the itemized measures are typically based on the Express Efficiency workpapers, and for the warehouse sector can be calculated as 994,740 kWh/year and 241.9 kW. These figures are lower than the ex ante savings. This may be attributed to the use of a sector other than warehouses. These figures are very similar to the figures entered in the utility tracking system.

However, it should be noted that the calculations performed with figures from the Express Efficiency workpapers do not accurately represent the actual situation to be evaluated.

The actual fixtures installed were predominately six lamp fixtures using HO T5 lamps. There was no workpaper available for six lamp T5 retrofits. A wattage of 351 watts was assumed for these new fixtures (verses 234 watts for four lamp fixtures using HO T5 lamps). There are expected to be significantly more annual hours of operation at this site than the annual hours of operation as shown in the workpapers.

Expected actual pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x (1 – diversity factor)

The check calculations for the HID fixture retrofit adjusting for longer hours of operation and for the actual quantity of six lamp fixtures used, were performed as follows:

- Pre-retrofit hours of operation: 5,780 hrs/yr
  Pre-retrofit wattage: 0.458 kW per fixture x 1180 lamps = 540.44 kW
  Annual kWh usage: 540.44 kW x 5,780 hrs/yr = 3,123,743 kWh/yr
- Post-retrofit hours of operation: 5,780 hrs/year
  Post-retrofit wattage: 0.351 kW per six-lamp fixture x 1090 fixtures + 0.234 kW per four-lamp fixture x 90 fixtures = 403.65 kW
  Annual kWh usage: 403.65 kW x 5,780 hrs/yr = 2,333,097 kWh/yr
- The resulting annual kWh savings = 3,123,743 kWh/yr – 2,333,097 kWh/yr = 790,646 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load and adding the diversity factor adjusted savings for occupancy sensor use.

Summer peak demand reduction is calculated as follows:

- Reduction in connected kW load : (540.44 kW – 403.65 kW) = 136.79 kW

The ex ante savings figures were thus determined to be higher than expected for this application using these simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation.

In general, the savings figures in the final Implementation Report Review (IRR) would be expected to be identical to the utility tracking system savings figures. As explained above, the total savings in the Installation Report Review were given as 1,317,162 kWh/yr and 236.8 kW. Notes in the Project Application Review give the savings as adjusted and approved as 994,633.8 kWh and 242 kW, stating that these amounts are based on the amount shown in MDSS. The utility tracking system has 994,634 kWh and 242.01 kW and these are used as the ex ante savings.

4. Measurement & Verification Plan

The building is a single level 608,000 sf warehouse used for parts distribution. It is reported to be approximately 3 years old. The building has minimal windows and skylights. The building is occupied on a varying schedule, from approximately 5 am to 3:30 am Monday through Friday with occasional use on Saturdays. Maximum occupancy is approximately 140 employees at any given time, with an average of 60 employees.

According to the application, before the retrofit there were 1,180 metal halide fixtures using 400-watt lamps. After the retrofit, there are 1090 six-lamp T-5 fluorescent fixtures and 90 four-lamp T-5 fluorescent fixtures. Approximately 760 occupancy sensors were installed at the same time as this retrofit but were not part of the SPC program.

The project saves energy through the installation of lighting fixtures with a lower connected wattage.

The documentation in the application indicates that the majority of fixtures are located above the side aisles.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

An approach consistent with IPMVP Option C was considered. The savings reported in the utility tracking system is approximately 20% – 30% of the kW and kWh consumed based upon the pre-retrofit building use (peak demand is approximately 700 kW and annual energy use approximates 4,200,000 kWh per year according to the utility billing summary in the application). Utility billing and interval data should support this approach without adjustments, if there were no other significant loads or other significant energy conservation activities which occurred at the same time or immediately following the retrofit. There is not expected to be significant seasonal variation and several months should be sufficient for comparison; however, a one to two year period would more fully capture actual variations and the persistence of savings. Interval data on a 15 minute basis during the summer months of June to September might be needed to accurately determine summer peak period demand savings.

However, since motion sensors were installed at he same time, Option C cannot be used without adjustments, due to these changes in the facility operation in the time periods immediately after the HID fixture replacement.

A modified version of IPMVP Option A can be utilized. Lighting loggers, however, could only be used to quantify hours of operation if the motion sensors are overridden.

Billing data will be used as a check on the ex post energy savings, as there were no other known changes in facility operation.

Measurement of the wattage draw of lighting fixtures on lighting only circuits could be used to confirm post retrofit energy consumption. This measurement would include the effect of the motion sensors unless all lights were illuminated during the measurement.

Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = $kWh_{pre} - kWh_{post}$

Summer peak demand period savings = $kW_{pre} - kW_{post}$ during the hottest periods between 2 pm to 5 pm, Monday to Friday, in June, July, August, September

To estimate the average expected peak demand kW reduction, since this measure is not weather dependent, the average of all reductions during those periods as stated above could be used.

Uncertainty for the savings estimate for the warehouse fixture retrofit can be more fully understood by setting projected ranges on the primary variables.

Uncertainty associated with hours of operation

- Hours/year: 5,780 expected, 5,180 minimum , 6,380 maximum (+/- 10%)
- kWh: 790,646 kWh expected , 710,000 minimum , 870,000 maximum

Uncertainty from changes in wattage

- kWh: 790,646 kWh expected, 710,000 minimum , 870,000 maximum (+/- 10%)
- kW: 137 kW expected , 124 kW minimum , 150 kW maximum (+/- 10%)

Uncertainty with utility billings

- kWh: 790,646 kWh expected; 782,000 kWh minimum; 798,000 kWh maximum (+ / - 1% for utility metering)
- kW: 137 kW expected , 130 kW minimum , 144 kW maximum hours (+/- 5%, based on extrapolating to actual hottest day period)

Accuracy and Equipment

The utility meters capture 15 minute interval data and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable. Current or power meters may also be used to determine post retrofit fixture wattage. The power meter to be used would be an Amprobe ACD-41PQ, with an accuracy of +/- 2%.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on April 13, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Lighting fixture quantities and hours of operation were verified.

The building is occupied 22.5 hours Monday-Friday (between 5:00 am and 3:30 a.m.) and occasionally on Saturdays. The facility has 140 employees, of which 20% are office staff and 80% are forklift operators. The occupancy is approximately 60 employees at any given time. The facility is closed 4 holidays annually.

Installation Verification

The facility representative verified that the metal halide fixtures were replaced on a one for one basis. It was physically verified that six-lamp T-5 fluorescent fixtures and four-lamp T-5 fixtures were installed in the facility. The facility representative stated that the lamps had been counted eight times and each time it was a different number. He provided a floor plan with the fixtures marked and a hard copy of e-mail correspondence (dated November 29, 2005) confirming the number of fixtures installed is 1239. The retrofit was completed in October 2005. For purposes of the ex post calculations, it is assumed that there were 1239 400-watt metal halide fixtures prior to the retrofit.

This is the only measure in this application. The verification realization rate for this project is 1.05 (1239/1180). A verification summary is shown in Table 5.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measure in the SPC application covering the lighting efficiency retrofit. This is the only measure in this application.

Summary of Results

The facility representative stated that the building is occupied continuously on weekdays, except for 1.5 hours each weekday between 3:30 am and 5 am. The building is closed on weekends except for the occasional Saturday. These Saturdays were excluded from the calculation. All lights are operational when the building is occupied. The shift supervisor and security personnel are responsible for turning lights off during the unoccupied 49.5 hour period between 3:30 a.m. on Saturday and 5 a.m. Monday. For this evaluation, the lights are assumed to be deenergized during all unoccupied periods.

Very few burned out lights were observed during the site visit. Burned out lights are regularly replaced. Therefore, there was no adjustment to the lighting energy consumption due to burned out lamps.

All lights are expected to be operating during the peak demand period defined as the hottest weekday periods between 2 pm to 5 pm, Monday to Friday, in June, July, August or September.

The electricity end-uses at this facility are lighting, forklift charging and ventilation fans. The facility representative confirmed that there was no change in the electricity use patterns before and after the retrofit other than the change to the light fixtures themselves.

The ex post calculations were developed after the evaluation site visit to reflect actual hours of operation and the actual number/type of fixtures installed.

- Pre-retrofit hours of operation: 5,780 hrs/yr (52.18 weeks x 112.5 hours/week – annual holidays totaling 90 hours = 5,780 hours)
  Pre-retrofit wattage: 0.458 kW per fixture x 1239 lamps = 567.46 kW
  Annual kWh usage: 567.46 kW x 5,780 hrs/yr = 3,279,930 kWh/yr
  Post-retrofit hours of operation: 5,780 hours/year

  Post-retrofit wattage of fixtures: 0.351 kW per six-lamp fixture x 1,149 fixtures + 0.234 kW per four-lamp fixture x 90 fixtures = 424.36 kW

  Annual kWh usage: 424.36 kW x 5,780 hrs/yr = 2,452,795 kWh/yr

- The resulting annual kWh savings = 3,279,930 kWh/yr – 2,452,795 kWh/yr = 827,135 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load and adding the diversity factor adjusted savings for occupancy sensor use.

Summer peak demand reduction is calculated as follows:
Reduction in connected kW load: 567.46 kW – 424.36 kW = 143.10 kW

Ex post savings calculations with motion sensors were calculated to compare to billing data.

- Post-retrofit hours of operation (based on an 47% usage factor supported by the workpapers):
  - Fixtures without motion sensors: 5,870 hours/year
  - Fixtures with motion sensors: 5,870 hours x 47% = 2,716.6 hrs/year
  - Post-Retrofit wattage of fixtures without motion sensors: 0.351 kW per six-lamp fixture x 469 fixtures + 0.234 kW per four-lamp fixture x 10 fixtures = 167.96 kW
  - Post-Retrofit wattage of fixtures with motion sensors: 0.351 kW per six-lamp fixture x 680 fixtures + 0.234 kW per four-lamp fixture x 80 fixtures = 257.40 kW
  - Annual kWh usage: 167.96 kW x 5,870 hrs/yr + 257.40 kW x 2,716.6 hrs/yr = 1,664,276 kWh/yr
- The resulting annual kWh savings = 3,279,930 kWh/yr – 1,664,276

  kWh/yr = 1,615,655 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load and adding the 84% warehouse diversity factor adjusted savings for occupancy sensor use.

Summer peak demand reduction is calculated as follows:

- Reduction in connected kW load plus reduction in load due to motion sensor use: (567.46 kW – 424.36 kW) + (257.40 kW x (100% - 84%)) = 143.10 kW + 41.18 kW = 184.29 kW

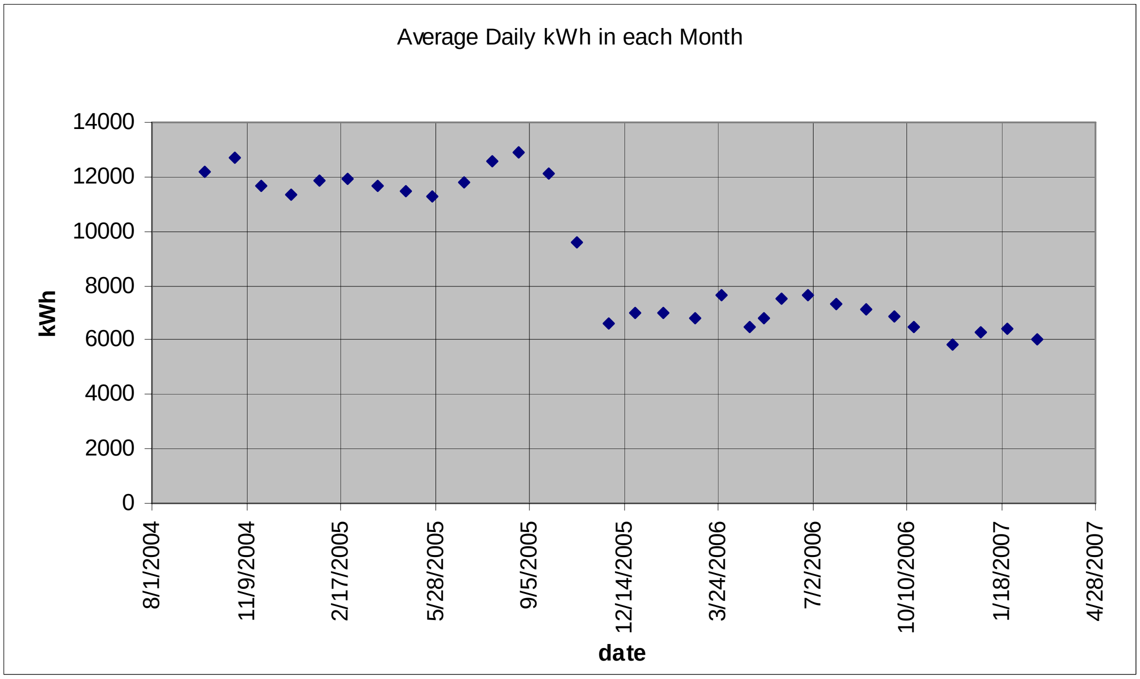
The ex post savings for the HID retrofits with the motion sensor control were compared to actual billing data. Average daily kWh use was plotted from one year prior to the retrofit until one year after the retrofit to confirm that there was no major change in electricity use other than the lighting retrofit in October, 2005. The month of October was removed from the analysis as the retrofit was partially complete during this month.

The ex post impacts were calculated from billing data as follows:

- Pre retrofit kWh use is summed for the 364 day period from 9/28/2004 to 9/26/2005 and adjusted to 365.25 days for annual pre-retrofit kWh of 4,361,025 kWh.
- Post retrofit kWh use is summed for the 354 day period from 10/27/2005 to 10/18/2006 and adjusted to 365.25 days for annual post-retrofit kWh of 2,564,488 kWh.
- Pre-retrofit wattage was averaged over the same period as the pre-retrofit kWh use and found to be 752.5 kW
- Post-retrofit wattage was averaged over the same period as the post-retrofit kWh use and found to be 548.5 kW
- The resulting annual kWh savings is 4,361,025 kWh/yr – 2,564,488 kWh/yr = 1,796,536 kWh/yr
- Summer peak demand reduction impacts were estimated by subtracting average post-retrofit from average pre-retrofit peak load. (Interval data was not used for the 2 pm to 5 pm weekday time periods in the summer months due to the expected maximum kw demand of the facility during this interval.)

  Peak kW savings is 752.5 kW – 548.5 kW = 204.0 kW

Figure 1: Daily kWh Consumption



The combined calculated effects from the HID replacement and the occupancy sensor control are approximately 90% of the kW and kWh savings obtained from the billing analysis.

Thus, the calculated effects of the HID replacements with fluorescent fixtures using T5 lamps are shown to be accurate in aggregate. The values of 827,135 kWh/yr and 143.1 kW are used for ex post savings for the HID replacement measure.

The engineering realization rate for this application is 0.59 for demand kW reduction and 0.83 for energy savings kWh. According to the installation report, the ex ante savings are 1,317,162 kWh annually and demand reduction is 236.8 kW. However, handwritten notes on the Project Application Review by the program administrator revise savings to 994,633.8 kWh and 242 kW. A summary of the realization rate is shown in Table 4.

Utility billing data for the site was obtained from the utility and supplemented with more recent data in hard copy from the customer at the time of the site visit. Pre-retrofit annual consumption (for one year prior to retrofit) was 4,361,025 kWh. Peak demand was 752.5 kW. This coincides with the pre-retrofit usage of 4,181,924 kWh listed in the application. Table 1 summarizes the total metered use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers. The baseline use is estimated, showing that lighting is the expected predominant electricity user.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 31.5% decrease in total meter kW, a 41.7% decrease in lighting end use kW, a 30.2% decrease in total meter kWh, and a 39.5% decrease in lighting end use kWh. The ex post results showed a 19.0 % decrease in total meter kW, a 25.2% decrease in lighting end use kW, a 19.0 % decrease in total meter kWh, and a 24.8% decrease in lighting end use kWh.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	752.5	4,361,025
Baseline End Use	567.5	3,331,002
Ex ante Savings	236.8	1,317,162
Ex Post Savings	143.1	827,135

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	31.5%	30.2%	19.0%	19.0%
Baseline End Use %	41.7%	39.5%	25.2%	24.8%

6. Additional Evaluation Findings

The ex post kW demand reduction is lower than the ex ante estimate because the ex ante savings estimated the four lamp fixture wattage at 0.234 watts per fixture when in actuality most of the six lamp fixtures installed are expected to consume 0.351 watts per fixture. The decrease in the ex post energy savings are offset since the hours of operation were much greater than those assumed in the Express Efficiency work papers and presumably used for the ex ante calculations.

The contribution of occupancy sensors was considered since whole facility energy analysis was useful, although the motion sensors were not part of this SPC application. The diversity factor of 0.84 seems high for this warehouse facility. Additionally, the usage factor is not constant over a 24-hour period for this facility due to reduced warehouse activity at night. The peak kW hours are when the diversity factor is highest. A higher peak diversity factor may more accurately predict peak kW reduction in the billing data, lowering kW savings.

An average usage factor lower than the 47% indicated in the workpapers may also more accurately predict the actual kWh reduction. With an average of 48 workers on the warehouse floor at any given time, and 110 separate rows of storage, the usage factor of less than 47% is reasonable if the lights are illuminated in one row per employee. This would indicate that savings from the occupancy sensors may contribute even more significantly than portrayed above to savings generated by the billing analysis. The energy savings might then be expected to be reduced for the HID fixture replacement measure which received the incentive under the SPC program.

In addition to saving energy, the benefits of the project are increased clarity of light, increased light levels, increased employee comfort and better working conditions. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. Participation in the 2004/2005 SPC Program has encouraged the facility to perform other energy efficiency projects. The customer has: 1) installed motion sensor on office lighting (as part of an incentive program), 2) installed timers for external parking lot lights, and 3) installed new air mixing fans with large blades in the warehouse area (without participating in an incentive program).

The capital costs of $246,720.00 see realistic. Multiple vendors were contacted for quotes.

7. Impact Results

The pre-retrofit lighting fixture type, quantities and hours of operation were unable to physically verified. However, these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $246,720 and a $88,500 incentive, the project had a 1.22 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 1.47 years. A summary of the economic parameters for the project is shown in Table 3.

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	11/30/2005	$246,720	236.8	994,633	0	$129,302	$88,500	1.22	1.91
SPC Program Review (Ex Post)	7/18/2007	$246,720	143.1	827,135	0	$107,528	$88,500	1.47	2.29

The realization rate of the peak kW demand is 0.59 and the realization rate of the energy savings is 0.83 as summarized in Table 4. The Installation Verification Summary is shown in Table 5 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 6.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	242.0	994,633	-
SPC Installation Report (ex ante)	236.8	1,317,162	-
Impact Evaluation (ex post)	143.1	827,135	-
Engineering Realization Rate	0.59	0.83	NA

1. Tracking System values used for realization rate calculations.

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Replace 1149 metal halide fixtures with 1149 6-lamp HO T5 fluorescent fixtures and replace 90 metal halide fixtures with 4-lamp HO T5 fluorescent fixtures		1,239	6 lamp T-5 HO fixtures and 4 lamp T-5 HO fixtures	Physically verified lamp type and verified quantity from floor plan and documentation of previous inspectors.	1.05

Note: Ex ante calculations utilize 1180 fixtures.

Table 6: Multi Year Reporting Table

Program ID Program Name		**SPC 2004 Application # A030 2004 – 2005 SPC Evaluation**					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004					0	0
2	2005	219,527	137,856			0	0
3	2006	1,317,162	827,135	236.8	143.1	0	0
4	2007	1,317,162	827,135	236.8	143.1	0	0
5	2008	1,317,162	827,135	236.8	143.1	0	0
6	2009	1,317,162	827,135	236.8	143.1	0	0
7	2010	1,317,162	827,135	236.8	143.1	0	0
8	2011	1,317,162	827,135	236.8	143.1	0	0
9	2012	1,317,162	827,135	236.8	143.1	0	0
10	2013	1,317,162	827,135	236.8	143.1	0	0
11	2014	1,317,162	827,135	236.8	143.1	0	0
12	2015	1,317,162	827,135	236.8	143.1	0	0
13	2016	1,317,162	827,135	236.8	143.1	0	0
14	2017	1,317,162	827,135	236.8	143.1	0	0
15	2018	1,317,162	827,135	236.8	143.1	0	0
16	2019	1,317,162	827,135	236.8	143.1	0	0
17	2020	1,317,162	827,135	236.8	143.1	0	0
18	2021	1,097,635	689,279	236.8	143.1	0	0
19	2022						
20	2023						
TOTA	**2004-2023**	21,074,592	13,234,160				

Final Site Report

SITE A031 SMCC (2004-xxx) IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 2 END USE: Lighting

Measure	Comprehensive Lighting Retrofit including Delamping, Conversion of T12 to T8 Lamps, and Occupancy Sensors
Site Description	College

1. Measure Description

Lighting is the primary end use measure evaluated. There are seventeen (17) lighting submeasures: install 2081 compact fluorescent lamps / fixtures; install 8,194 new T8 fluorescent lamps in fixtures replacing T12 fluorescent lamps; delamp fixtures (removing 1902 lamps); install 4 high bay T8 fixtures; install 226 wallbox lighting sensors; install16 wall /ceiling mounted lighting sensors, and install 185 LED exit signs.

Two submeasures are in secondary end use measures and are not evaluated. They involve the installation of 10,778 sf of reflective window film and 22 vending machine controllers.

2. Summary of the Ex Ante Calculations

This project consisted exclusively of itemized measures with deemed savings. The total energy savings reported in the Installation Report Review (IRR) for the project are 1,991,913.5 kWh with 363.0 kW in demand savings. The total energy savings in the IRR for the lighting measures are 1,804,812 kWh with 338.7 kW in demand savings and the incentive is $74,454. Measure cost for lighting is $1,155,960.

Incandescent to fluorescent conversions accounted for annual savings of 770,842 kWh. The T12 to T8 conversions and delamping accounted for annual savings of 900,914 kWh. The occupancy sensors accounted for additional savings of 72,628 kWh, while the LED exit signs accounted for savings of 65,002 kWh.

3. Comments on the Ex Ante Calculations

The ex ante calculations were calculated based on deemed savings values for each of the nineteen (19) measures. No lighting tables, operating hour estimates, or fixture descriptions were included in the application.

The utility tracking system savings for the project is 1,857,330 kWh annually and 340.9 kW in demand savings. It is noted that 1,857,426 kWh and 340.9 kW are reported in a sheet identified as “MDSS DPH approved #s” in the application paperwork. Not all of the figures for the submeasures in the utility tracking system agree with corrected numbers in the Project Application Review or original figures in the Installation Report, leading to the discrepancy. The discrepancy is about 6% lower than the total energy savings reported as the Installation Report Approved Amount. The utility tracking system figures will be used to calculate the realization rate: for the lighting measures, the aggregate numbers are 1,638,154 kWh and 316.6 kW. The incentive for lighting measures reported in the tracking system is $74,364.

The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers.

The workpapers discuss conversion from 2 lamp 4 foot T12 fixtures with energy saving magnetic ballasts to 4 foot T8 fixtures with two 32 watt T8 lamps and ballasts. The total installed wattage drops from 0.72 kW to 0.058 kW for a noncoincident demand savings of 0.014 kW per fixture or 0.007 kW per lamp. For a college market sector, coincident demand savings is 0.007 kW and annual kWh savings is 40 kWh per lamp under the assumed operating hours and coincident diversity factor.

The workpapers discuss replacement of a fixture consisting of a 60 watt incandescent lamp fixture with a fixture consisting of 13 watt fluorescent lamp driven by magnetic ballast. The total installed wattage drops from 0.060 kW to 0.015 kW for a non-coincident demand savings of 0.045 kW per fixture. For a college market sector, coincident demand savings is 0.037 kW and annual kWh savings is 202 kWh per fixture under the assumed operating hours and coincident diversity factor.

The workpapers discuss removal of 4 foot lamps. The original fixture wattage is based on T-8, 32-watt lamps with electronic ballast and assumes removal of 1 lamp and its associated ballast. The work paper indicates the total wattage drops from 0.84 kW to 0.058 kW with a non-coincidental demand savings of 0.026 kW per lamp.

The workpapers discuss wall box mounted occupancy sensors, documenting savings based on the control of three (3) 4 foot 2 lamp fluorescent fixtures with 34 watt T-12 lamps, consuming 72 watts each including the ballast, in a private office. Savings are based on a reduction of usage from 2,550 hours/year to 1,500 hours/year (1,050 hours/year reduction). The workpaper reports a total of 266 kWh per fixture savings, which includes a 17% office sector energy interactive effects factor. The non-coincident peak reduction of 0.089 kW was derived from the 0.216 kW controlled wattage and a 41% reduction in hours. Coincident peak reduction was reported at 0.111 kW, which includes a 1.25 average office sector Demand Interactive Effects factor.

The workpapers addressing ceiling or wall mounted occupancy sensors document savings based on the control of eight (8) 4 foot 2 lamp fluorescent fixtures with 34 watt T-12 lamps, consuming 72 watts each including the ballast, in an office conference room. Savings are based on a reduction of usage from 2,210 hours/year to 1,040 hours/year (1,170 hours/year reduction). The workpaper reports a total of 789 kWh savings for all sectors (674 kWh/year plus a 17% office sector energy interactive effects factor). The non-coincident peak reduction of 0.305 kW was derived from the 0.576 kW controlled wattage and a 45% reduction in hours. Coincident peak reduction was reported at 0.381 kW, which includes a 1.25 average office sector Demand Interactive Effects factor.

The workpapers evaluate savings from installation of high efficiency LED exit signs to replace older signs containing two 20-watt incandescent lamps. Total installed wattage drops from 0.040 kW to 0.004 kW. The noncoincident demand savings are 0.036 kW per LED fixture and with 0.18 Demand Interactive Effects. The noncoincident demand savings are 0.042 kW. Fire code requires exit signs to operate all year - 8760 hrs/yr. The savings are 0.036 kW x 8760 x 1.114 = 351 kWh per year. The calculation includes the 11.4% average Energy interactive effects. Coincident demand savings are 0.042 kW x 1.0 = 0.042 kW.

After hours of operation, the greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit quantities. The pre-retrofit and post-retrofit connected loads associated with various fixture types are adequately quantified in the SPC lighting wattage tables.

The lighting project saves energy through the installation of lighting fixtures with a lower connected wattage and through the control of some of the lighting fixtures with occupancy sensors to reduce the hours of operation.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

IPMVP Option A approach should be considered. Lighting loggers would be used if possible to quantify hours of operation. The loggers will be placed in the rooms and hallways to determine the operating hours. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = $kWh_{pre} - kWh_{post}$

Summer peak demand period savings = $kW_{pre} - kW_{post}$ during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, of the week with the hottest day in June, July, August, September
.
Documentation provided indicates that over 90% of the projected savings derive from T8 fluorescent fixture installation, delamping fluorescent fixtures, and incandescent to fluorescent conversions, contributing approximately 30%, 20%, and 40% of the total savings, respectively. These fixtures would be the primary target for evaluation efforts. The focus will be in determining the locations affected and the corresponding hours of operation.

Actual quantities installed will be taken form the original lighting spreadsheets and the ex post savings calculated using measured lighting hours of operation.

The most significant variables to be quantified are the pre-retrofit and post-retrofit fixture hours of operation. Pre-retrofit hours will be confirmed with site personnel and interviews. The focus will be on discovering when, prior to the retrofit, the fixtures were energized. It will be determined whether or not there were changes to usage patterns for areas without motion sensors.

Monitoring with light loggers will be conducted for approximately 20 classrooms total, or five (5) in each building. Selection can be by a random number generator starting from a randomly selected classroom in each building, or by using approximately 20% of the total number of classrooms in each building (100% / 5), selecting randomly a number in that interval, and sequentially placing loggers spaced apart by the number selected.

Monitoring for administrative areas can be conducted with between five and ten loggers. Building personnel can be questioned in order to determine varying occupancy patterns. At a minimum, it will be attempted to place at least one logger in a location with a distinct operating schedule.

The use of between 8 and 13 sampling points per usage group is generally consistent with SPC program documentation from March 2001 (Appendix E, Sampling); this document suggests guidelines for determining sampling point requirements necessary to achieve an 80% confidence interval with 20% precision (using a coefficient of variation of 0.5).

A random sampling approach could involve totalizing the number of classroom and administrative fixtures or rooms, and randomly selecting from the total number of fixtures using a random number generator.

The light loggers would be placed so as to be unaffected by fixtures not on motion sensors or by ambient outside light.

The lighting loggers or current sensors would be left in place for a period of 7 to 14 days. Attention is generally given to the time period for monitoring, in order to avoid periods of irregular usage patterns (e.g., during holidays or breaks). In this case, we will be capturing a break period and two holidays, and savings must be adjusted for this. Savings must also be adjusted for summer usage. While longer periods might be preferable, these periods are appropriate given the scope of the evaluation and reported usage characteristics.

Importantly, the weight given to administrative and to classroom areas must be considered, unless accurate quantities of fixtures can be determined for each area.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture hours of operation. The lighting fixture quantities seem to be well established and were counted to within 5% to 10% in utility post-installation inspection visits. The pre-retrofit and post-retrofit connected loads associated with various fixture types are also adequately quantified in the SPC lighting wattage tables.

However, the previous and new fixture types and wattages will be attempted to be determined at the site.

Verification of all lighting measures, the reflective window film and the vending machine controllers will be attempted.

Uncertainty for the savings estimate for the lighting fixture retrofit (including motion sensors controlling these fixtures) can be more fully understood by setting projected ranges on the primary variables.

<u>For conversion from T12 fixtures to T8 fixtures</u>

- 7,051 lamps expected/reported, lamps minimum 6,700; maximum 7,400 (expected range +/- 5%)
- 2,000 hours pre and post retrofit expected/reported; minimum 1,500 hours; maximum 2,500 hours (expected range +/- 25%))
- 75.8 kW savings expected, 60 kW minimum, 90 kW maximum (+/- 20% expected range).
- kWh savings: 421,691 kWh expected, 380,000 kWh minimum ; 460,000 kWh maximum (+ / - 10% for range of possible savings)

Annualizing that data from a 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

Accuracy and Equipment

The light loggers to be used are Dent TOU-L Lighting Smart*logger* dataloggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format. These optically triggered loggers record lighting status (on or off).

These loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on April 4, 2007. Information on the retrofit and the operating hours were collected by inspection of the lighting fixtures, by installing lighting loggers, and by interviewing the facility representatives.

Installation Verification

It was physically verified on the day of the on-site survey that the fixtures reported were installed at various locations on the building. Since the facility had 25 buildings, random buildings were used as samples to verify the installations. Thirty (30) lighting loggers were installed at various locations to obtain the operating hours of the facility. The facility was at its typical operating schedule. The operating hours for LED exit signs were determined to be 8,760 hours. The facility had installed lighting controls only in a few locations and all the other fixtures were controlled manually.

Samples of the lighting measures submitted in the report were verified in post installation inspections. The verification realization rate for this project is 1.00.

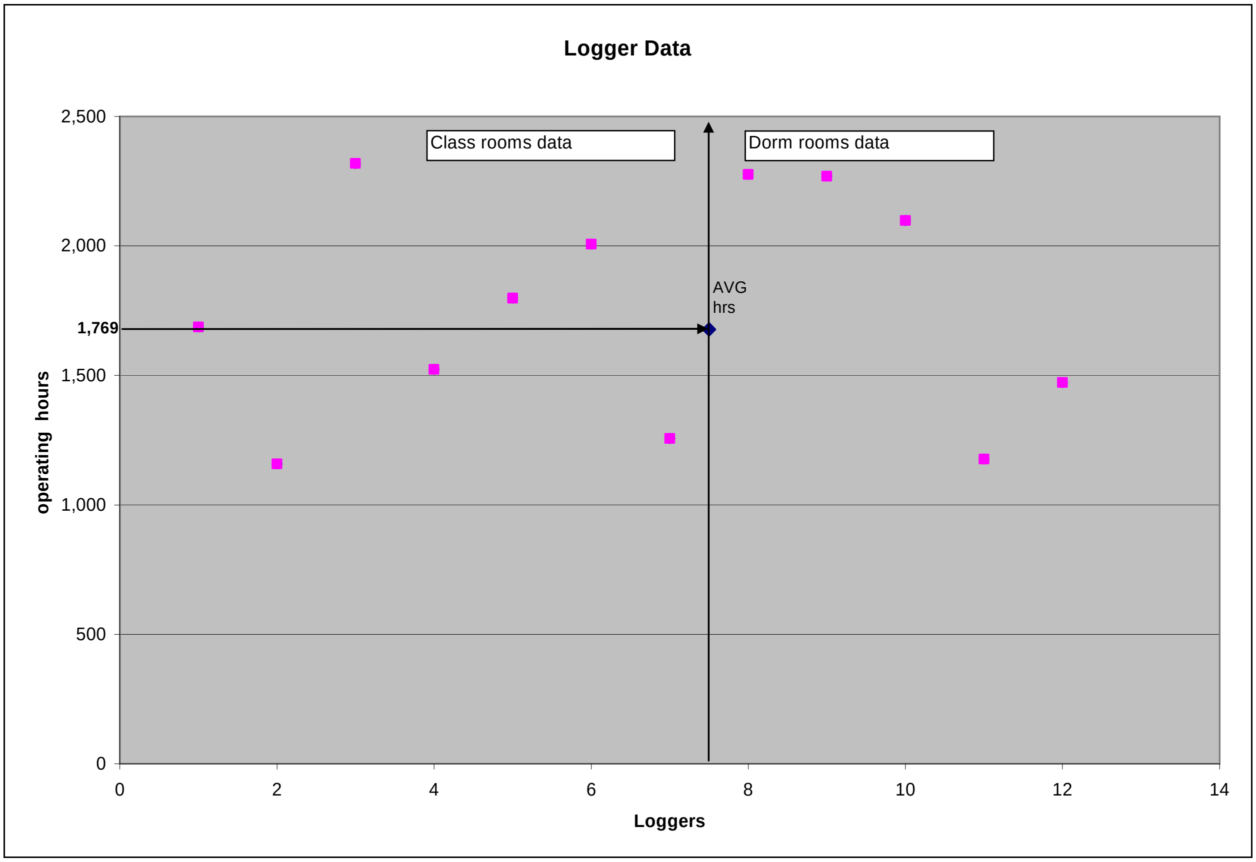
Scope of the Impact Assessments

The impact assessment scope is for the lighting end use measures in the SPC application, covering the CFL lamps, lighting fixture replacements, occupancy sensors and exit signs.

Summary of Results

Lighting loggers were used to measure the operating hours of the lights in the facility. A total of 30 loggers were installed to obtain samples of operating hours in various locations of the facility. From the logger data obtained, it was determined that the average operating hours for T8 fixtures were 1,769 hrs/yr. The data was collected from logging the classrooms and dorm rooms. From the logger data, the operating hours for CFLs were determined to be 1,859 hrs/yr. Since the loggers were installed during typical operating periods, the hours determined are considered to be accurate and are used to calculate the ex-post savings.

Figure 1: Lighting Logger Results



The results of the ex post impacts are shown in the following table:

Table 1: Lighting Recalculations

Measures	Qty	#Op hrs	pre kW/ lamp	post kW/ lamp	pre kW	pre kWh	post kW	post kWh	kW savings	kWh savings
Screw in CFL's 14-26 watts	398	1,859	0.075	0.018	29.9	55,491	7.2	13,318	22.686	42,173
Screw in CFL's >= 27 watts	12	1,859	0.1	0.031	1.2	2,231	0.4	692	0.828	1,539
Fluorescent Fixtures 5-13 watts	1032	1,859	0.06	0.015	61.9	115,109	15.5	28,777	46.44	86,332
Fluorescent Fixtures 14-26 watts	217	1,859	0.1	0.026	21.7	40,340	5.6	10,488	16.058	29,852
Fluorescent Fixtures conversion from incandescent 27-65 watts	306	1,859	0.2	0.058	61.2	113,771	17.7	32,994	43.452	80,777
Fluorescent Fixtures conversion from incandescent 66-90 watts	115	1,859	0.3	0.084	34.5	64,136	9.7	17,958	24.84	46,178
Fluorescent Fixtures conversion from incandescent > 90 watts	1	1,859	0.5	0.116	0.5	930	0.1	216	0.384	714
Replacement of 2 ft T12 with T8 lamps	521	1,769	0.025	0.0145	13.0	23,041	7.6	13,364	5.47	9,677
Replacement of 3 ft T12 with T8 lamps	620	1,769	0.034	0.021	21.1	37,291	13.0	23,032	8.06	14,258
Replacement of 4 ft T12 with T8 lamps	7051	1,769	0.036	0.029	253.8	449,036	204.5	361,723	49.36	87,313
Delamping of 2 ft lamps	111	1,769	0.082	0.05	9.1	16,101	5.6	9,818	3.55	6,283
Delamping of 3 ft lamps	8	1,769	0.112	0.068	0.9	1,585	0.5	962	0.35	623
Delamping of 4 ft lamps	1783	1,769	0.115	0.072	205.0	362,725	128.4	227,097	76.67	135,627
High bay T12 to T8	4	1,769	0.216	0.174	0.9	1,528	0.7	1,231	0.17	297
Wall box occupancy sensors	226	1,769	0.216	0.216	48.8	86,356	48.8	50,950	15.62	35,406
Wall mounted occupancy sensors	16	1,769	0.576	0.576	9.2	16,303	9.2	8,967	2.95	7,336
LED exit signs	185	8,760	0.04	0.004	7.4	64,824	0.7	6,482	6.66	64,993
Totals					780.2	1450797	475.2	808069	**323.55**	**649,379**

Table 2 summarizes the total metered energy use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and the additional data obtained from the customer. The baseline end use energy is the calculated energy use for the pre and post implementation evaluations for the specific quantities of the equipment listed in the specific measures Baseline end use was estimated at 30% of total kWh use and kW demand at this facility.

Table 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	2,194.0	9,938,332
Baseline End Use	658.2	2,981,500
Ex Ante Savings	338.7	1,804,812
Ex Post Savings	323.5	649,379

Lighting baseline use is 30% of total metered use.

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 15.4% decrease in total meter kW, a 51.5% decrease in lighting end use kW, a 18.2% decrease in total meter kWh, and a 60.5% decrease in lighting end use kWh. The ex post results showed a 14.7% decrease in total meter kW, a 49.2% decrease in lighting end use kW, a 6.5% decrease in total meter kWh, and a 21.8% decrease in lighting end use kWh.

Table 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	15.4%	18.2%	14.7%	6.5%
Baseline End Use %	51.5%	60.5%	49.2%	21.8%

6. Additional Evaluation Findings

The ex post energy savings are considerably less than the ex-ante energy savings. The ex ante savings were submitted as itemized measures and no additional documentation was provided to support their calculations. The operating hours considered for the itemized measures are typically 3,900 hours per year. The variation in savings could be because the operating hours considered in the ex-ante savings were higher; in some cases nearly 8,760 hours were used. The ex-post calculations were more accurate as all the parameters used were taken from the lighting loggers, the data collected during the site visit and from information provided by the facility personnel.

The sponsor was a well known ESCO, and the cost estimate provided in the application is presumable based on an invoice or documentation for the work performed for the project, and therefore should be an accurate reflection of the project cost. In addition to saving energy, the benefits of the project are better quality of lighting and longer lasting lighting. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program has increased the energy awareness of the facility.

We were unable to physically verify the pre-retrofit lighting fixture type, quantities and hours of operation for the facility. However, we are satisfied that these parameters have been accurately assessed and quantified based on our verification of accessible fixtures as a sample and discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures. However, a more thorough assessment of pre retrofit conditions would yield a more reliable assessment of energy savings.

With a cost of $1,155,960 and $74,454 incentive, the project had a 4.61 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is substantially less than the ex ante, and the estimated simple payback is 12.81years. A summary of the economic parameters for the project is shown in Table 4.

7. Impact Results

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Annual Cost Savings ($0.13/kWh) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	1/25/2005	$1,155,960	338.7	1,804,812	$234,640	$74,454	4.61	4.93
SPC Program Review (Ex Post)	4/4/2007	$1,155,960	323.5	649,379	$84,419	$74,454	12.81	13.69

The utility tracking data are the approved estimates of ex ante savings. The utility tracking savings were 316.6 kW and 1,638,154 kWh. The ex post savings are 323.5 kW and 649,379 kWh. The engineering realization rate is the ratio of the ex post results to the utility tracking data. The engineering realization rate for this application is 1.02 for demand kW reduction and 0.40 for energy savings kWh. A summary of the realization rate is shown in Table 5. The Installation Verification Summary for major measures is shown in Table 6 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 7.

Table 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	316.6	1,638,154	-
SPC Installation Report (ex ante)	338.7	1,804,812	-
Impact Evaluation (ex post)	323.5	649,379	-
Engineering Realization Rate	1.02	0.40	NA

Table 6: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING	L		Replace 4 foot T12 fixtures with T8 fixtures		7,051	2 lamp T8 fixtures with electronic ballasts	Physically verified lamp type and verified quantity from floor plan and documentation of previous inspectors.	1.00
LIGHTING	L		Replace 3 foot T12 fixtures with T8 fixtures		620	27 watts CFL lamp	Physically verified lamp type and verified quantity from floor plan and documentation of previous inspectors.	1.00
LIGHTING	L		Replace incandescent lamps with 5-13 watts lamps		1,032	LED exit sign	Physically verified the fixtures and the quantity	1.00

Table 7: Multi Year Reporting Table

Program Name:		SPC 04-05 Evaluation A031					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	-	-			0	0
2	2005	1,804,812	649,379	338.7	323.5	0	0
3	2006	1,804,812	649,379	338.7	323.5	0	0
4	2007	1,804,812	649,379	338.7	323.5	0	0
5	2008	1,804,812	649,379	338.7	323.5	0	0
6	2009	1,804,812	649,379	338.7	323.5	0	0
7	2010	1,804,812	649,379	338.7	323.5	0	0
8	2011	1,804,812	649,379	338.7	323.5	0	0
9	2012	1,804,812	649,379	338.7	323.5	0	0
10	2013	1,804,812	649,379	338.7	323.5	0	0
11	2014	1,804,812	649,379	338.7	323.5	0	0
12	2015	1,804,812	649,379	338.7	323.5	0	0
13	2016	1,804,812	649,379	338.7	323.5	0	0
14	2017	1,804,812	649,379	338.7	323.5	0	0
15	2018	1,804,812	649,379	338.7	323.5	0	0
16	2019	1,804,812	649,379	338.7	323.5	0	0
17	2020	1,804,812	649,379	338.7	323.5	0	0
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	28,876,992	10,390,064				

Final Site Report

SITE A032 (2004-xxx) Cis IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 2 END USE: AC&R

Measure	Replacement of six cascade chillers with liquid nitrogen system
Site Description	Semiconductor Manufacturing

1. Measure Description

Replace six electric cascade chillers with a total cooling capacity of 290 tons serving six testing chambers with a liquid nitrogen cooling system.

2. Summary of the Ex Ante Calculations

The ex ante savings for the measure in the primary end use category (AC&R)are 2,082,330 kWh and 408.3 kW as identified in the Installation Report Review and in the utility tracking system. The SPC incentive of $231,000 is based on these savings with a site cap adjustment applied. The ex ante savings appear to have been calculated and submitted by the project reviewer.

3. Comments on the Ex Ante Calculations

According to the reviewer, the energy savings were based on information provided by the system vendor and the customer. The approved energy savings include savings from the replacement of the electric air conditioning compressors in the cooling cycle at full load and in the heating cycle at 20% load.

The savings estimates for replacement of six chillers in the testing lab were calculated by the project reviewer during the application review. The baseline cooling load is calculated using the product of the individual size, efficiency (1.41 kW/ton), chiller load (100% for cooling/20% for heating cycles - chillers in standby mode), and the chamber cooling duty cycle for each of the six chambers. The energy savings calculations are calculated by multiplying this load and the estimated operating hours (4,250 hours for heating and 4,250 hours for cooling). The heating energy savings for each unit are calculated using a similar method, using the 20% duty cycle. The baseline energy usage is the sum of the cooling and heating energy use. There is no post-installation energy usage used in the savings calculations. The check calculations for heating and cooling load savings were calculated using the formulae given below:

Load (kW) savings = Size (tons) x efficiency (kW/ton) x load factor during heating/cooling

kWh savings = Load (kW) savings x operating hours for heating/cooling

One important parameter to check is if the compressors operate at 1.41 kW/ton. This is inefficient performance, particularly for units with a common cooling tower.

The energy use at 20% in the standby mode may also not be accurate and must be checked with the manufacturer if possible, as the removed equipment is no longer in place.

It was assumed that the units ran at 100% load during the cooling cycles; and this may not be an accurate assumption.

The savings can vary considerably if there are variations in the reported loading and operational hours of the cooling and heating stages.

4. Measurement & Verification Plan

The ex ante savings estimates used simplified engineering calculations. No data on the post retrofit system was collected during the installation inspection; the inspection report does not include any description of the post-installation operation. Therefore, the verification of the baseline energy savings will consist of verification of the operational characteristics used to develop the savings calculations. This will be done through an interview with the customer and collection of equipment characteristics to the extent possible for the pre existing equipment.

The savings calculations for the replacement of chillers in the testing lab do not include post-installation energy usage. Therefore we will attempt to estimate the energy usage for the liquid nitrogen system if there is any energy use for the system.

Attempts will be made to measure, or estimate based production data or use, the amount of liquid nitrogen used in the post-installation process. If the liquid nitrogen is produced onsite, the energy used to produce the liquid nitrogen will be calculated. If the liquid nitrogen is obtained from off-site, the energy used to produce the liquid nitrogen will be estimated if possible. Note that if the liquid nitrogen is produced off-site, this project may only transfer energy use, with no qualifying energy or demand savings.

Attempts will also be made to monitor all electric use for the heating elements in order to calculate the cooling required per cycle.

To the extent possible, the improvements made to the environmental chambers will be verified. The size of the original equipment shall be determined by plans and as built drawings including sequencing of the chillers.

The improvements made to the existing nitrogen system in the other testing lab which resulted in energy savings will also be verified. These savings are in another end use category and will not be evaluated in detail.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

A modified version of IPMVP Option A can be utilized. The energy savings will consist of the baseline energy usage minus any post-installation energy use calculated as part of this evaluation.

The variables used in the calculations which are important to verify :

Operating hours per year: 8,500 hours per year
Heating duty cycle: 50%
Cooling duty cycle: 50%
Heating load factor: 20%
Cooling load factor: 100%
Efficiency of the chiller units: 1.41kW/ton for five chillers and 1.35kW/ton for one chiller

The operations hours for cooling and heating cycles will be verified.

Temperature logs of the chambers should be obtained from the facility.

Temperatures for the chambers will not be recorded using the temperature sensors but cycle lengths will be observed.

The data on chillers and loads when the chillers are in standby mode will be determined.

Records of production will be obtained if available.

Amperage of the heating elements will be obtained to determine the cooling to be generated.

Heating elements will be monitored to the extent possible.

Nitrogen flows and use will be confirmed if possible.

The previous operating hours should be verified with the site personnel. The new hours / sequence of operation may be confirmed. The tonnage of the chillers should be obtained from the facility. There are three 60 ton chillers, two 50 ton chillers and one 10 ton chiller. The total tonnage of the chillers is 290 tons.

The rating for the new nitrogen system should be obtained.

Dent TOU power loggers or other power measuring devices could also be placed on the nitrogen system. The system would be monitored for a period of 2-3 days or 1-2 weeks if there is a significant variation in production.

Pre-retrofit and post-retrofit calculations of motor loads and energy use will be calculated using the following formulae:

kWh savings = $kWh_{pre} - kWh_{post}$

kWh savings = kW_{pre} x energized $hours_{pre} - kW_{post}$ x energized $hours_{post}$

Coincident peak demand period savings = $kW_{pre} - kW_{post}$

Summer peak demand period savings = $kW_{pre} - kW_{post}$ during the hottest periods between 2 pm to 5 pm, Monday to Friday, in June, July, August, and September

Uncertainty for the savings estimate for the retrofit can be more fully understood by setting projected ranges on the primary variables.

Size (tons): expected 290 tons, maximum 380 tons; minimum 200 tons (+/- 30%)

Efficiency (kW/ton): expected 1.41 kW/ton, maximum 1.41 kw/ton, minimum 0.8 kW/ton (+0%, - 40%)

Load factor during cooling: expected 100%, maximum 100%, minimum 50 % (- 50%),

Operating hours for heating/cooling: expected 4,250 hrs/yr; maximum 3,200 hrs/yr; minimum 5,300 hrs/yr (+/- 25%),

Accuracy

Dent TOU loggers will be used on nitrogen equipment. The Dent loggers are accurate to within 1% for power. If the energy management system or the Dent loggers are used to monitor hours of operation, these values will be deemed to be 100% accurate.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

The accuracy of the analysis is heavily depended on the assumptions and estimated energy use in the approved savings calculations. We will attempt to estimate the accuracy of these calculations with a customer interview.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on October 22, 2007. Information provided regarding the pre-retrofit air cooling units was not able to be provided by the customer and is to be obtained from the installation contractor. The presence of the six retrofit nitrogen cooling units was verified. The customer did not allow measurements of electric heating elements to confirm some cycle times and power draw to be taken. Some information was collected to refine operating hours.

Installation Verification

The facility representative confirmed that there were six (6) rooftop AC units before the retrofit and that the reported total of 290 tons of cooling capacity was reasonable. The pre retrofit operating hours of 8,500 hours per year were not deemed unreasonable. Six (6) nitrogen cooling units were installed. It was confirmed that these units are in place and they are operational. There was one unit that was being serviced and the other units were not energized at the time of the site visit. The customer did not provide documentation regarding existing operating hours or estimates. A possible existing use factor of 70% was suggested. The customer noted that some product changes may entail the units being operated continuously in the future.

This is the only measure in the AC&R end use in this application. The verification realization rate for this project is 1.00. A verification summary is shown in Table 6 below.

Scope of the Impact Assessment

The impact assessment scope is for the AC/R end use measure in the SPC application covering the chiller retrofit. This is the only measures in this end use in this application

Summary of Results

The ex ante calculations were revised to reflect actual projected operation of 85% (7,446 hours /per year) verses 97% (8500 hours /per year). The ratio of cooling hours was increased per the comments on transition times (dwell time) for 70F to -20 F. The calculations are included in a table at the end of this report.

The kW savings was reduced to account for the operation of chambers in the cooling mode verses heating mode (heating will drive high kW demand and will not always be reduced – the transition from heating to cooling occurs approximately once per hour).

Table 1: Calculation Tables for Hours of Operation

EX POST SAVINGS

	hrs	tons	kW/ton	kW	# units	load	kW	kWh
Pre	4137	280	1.41	394.8	6	100%	394.8	1,633,156
	3309	280	1.41	394.8	6	20%	78.96	261,305
	4137	10	1.35	13.5	6	100%	13.5	55,845
	3309	10	1.35	13.5	6	20%	2.7	8,935
	hrs	**average hp**	**kw/hp**	**kW**	**# compressors**	**load**	**kW**	**kWh**
Post	4137	10	0.746	7.46	6	80%	35.8	148,126
saved							372.5	1,811,115
saved with cooling diversity factor			56%				206.9	
Totals							206.9	1,811,115

	Hrs	% on time	Htg	Clg	Minutes	Hours	Percent
Total	8760	100%	30		30	0.50	42%
Pre	8500	97%		10	10	0.17	14%
Post 1	6132	70%		30	30	0.50	42%
Post 2	7446	85%	2		2	0.03	3%
					72	1.2	100%
Post hours	7446	85%	3309	4137			
Percent			44%	56%			

The engineering realization rate for this application is 0.51 for demand kW reduction and 0.87 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 5.

Utility billing data for the site was reviewed. In the 12 month period from February 2004 to January 2004, the building in the complex consumed 9,027,064 kWh. Peak demand was 1,674 kW in September 2004.

Table 2 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 24.4% decrease in total meter kW, a 48.8% decrease in AC/R end use kW, a 23.1 % decrease in total meter kWh, and a 46.1% decrease in AC/R end use kWh. The ex post results showed a 12.4% decrease in total meter kW, a 24.7% decrease in AC/R end use kW, a 20.1% decrease in total meter kWh, and a 40.1% decrease in AC/R end use kWh.

Table 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1674.0	9,027,064
Baseline End Use	837.0	4,513,532
Ex ante Savings	408.3	2,082,330
Ex Post Savings	206.9	1,811,115

Baseline use is total AC&R use for building, estimated at 50%.

Table 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	24.4%	23.1%	12.4%	20.1%
Baseline End Use %	48.8%	46.1%	24.7%	40.1%

6. Additional Evaluation Findings

The ex post energy (kWh) savings are slightly less than the ex ante energy savings because the hours of use were adjusted due to the fewer operating hours of the equipment. The ex ante savings also did not account for some electric usage of the new nitrogen cooling equipment. The nitrogen is produced in a location nearby and has some energy inputs. This was considered previously to be negligible. However, this input would lower the ex post savings if manufacturing and transport were accounted for as post retrofit energy costs. Likewise, nitrogen costs would decrease monetary savings and extend the simple payback period as well.

Ex post demand savings are considerable less, due to the fact that the test chambers have an aggregate energy demand which is driven by heating loads as well as cooling loads. These loads vary hourly. Removing cooling demand does not remove the demand of this equipment. However, not all the equipment will be in heating mode at the same time; in cooling mode, those units will generate demand savings. The original ex ante load projected operation at 50%; however, based on field surveys, a longer dwell time in the transition to full cooling indicates a higher ratio of on time in the cooling mode (56%).

This factor is applied to the calculated total kW demand load reduction due to the cooling system changeout (including kW demand of compressors on the new equipment).

The facility representative stated that the cost estimate provided in the application is based on a single source quote, as this is a specific application. The costs do not appear to be excessive for the work performed.

The customer does anticipate that the units may be operated for longer periods or continuously in the future. Ex ante savings assumed 97% operation.

It was not possible to verify hours of operation, loading profile and efficiency of the pre retrofit AC units. However, the estimates used in the ex ante and ex post calculations are realistic. Operating hours may have a significant effect on the actual savings.

The level of M&V employed at this site and the customer's provision of supporting documentation could be improved in order to accurately determine the impacts of the installed measures. The periods of time and changeover of personnel since the retrofit complicated analysis at this site.

A very real benefit is the ability of the nitrogen cooling equipment to better meet the intermittent and severe cooling needs of the tests chambers. The AC units were in need of considerable maintenance and often needed repair.

With a cost of $721,000 and a $231,000 incentive, the project had a 0.55 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 1.31years. A summary of the economic parameters for the project is shown in Table 4. The Installation Verification Summary is shown in Table 6 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 7.

7. Impact Results

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	2/24/2004	$721,000	408.3	2,082,330	0	$270,703	$231,000	1.81	2.66
SPC Program Review (Ex Post)	10/23/2007	$721,000	206.9	1,811,115	0	$235,445	$231,000	2.08	3.06

Savings not realized until 2005.

Table 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	408.3	2,082,330	-
SPC Installation Report (ex ante)	408.3	2,082,330	-
Impact Evaluation (ex post)	206.9	1,811,115	-
Engineering Realization Rate	0.51	0.87	NA

Table 6: Installation Verification Summary

Measure Description	End-Use Category	AC&R Measure Description	Lighting Measure Description	Other Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Replace 6 AC units for stress test chanbers	AC/R	Replace six (6) electric AC units totalling 290 tons with six (6) nitrogen cooling units		Reconfigure nitrogen delivery in 4 other chambers		Six nitrogen units	Physically verified six nitrogen units for six test chanbers in primary end use (AC&R).	1.00

Table 7: Multi Year Reporting Table

Program Name:		SPC 04-05 Evaluation A032					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	1,908,803	1,660,189	408.3	206.9		
3	2006	2,082,330	1,811,115	408.3	206.9		
4	2007	2,082,330	1,811,115	408.3	206.9		
5	2008	2,082,330	1,811,115	408.3	206.9		
6	2009	2,082,330	1,811,115	408.3	206.9		
7	2010	2,082,330	1,811,115	408.3	206.9		
8	2011	2,082,330	1,811,115	408.3	206.9		
9	2012	2,082,330	1,811,115	408.3	206.9		
10	2013	2,082,330	1,811,115	408.3	206.9		
11	2014	2,082,330	1,811,115	408.3	206.9		
12	2015	2,082,330	1,811,115	408.3	206.9		
13	2016	2,082,330	1,811,115	408.3	206.9		
14	2017	2,082,330	1,811,115	408.3	206.9		
15	2018	2,082,330	1,811,115	408.3	206.9		
16	2019	2,082,330	1,811,115	408.3	206.9		
17	2020	173,528	150,926				
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	**31,234,950**	**27,166,731**				

Custom measure with 15 year life.

Final Report

SITE A033 Pajo (2004-xxx) IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 5 END USE: Gas

Measure	Installation of double skin acrylic roof on greenhouse
Site Description	Agricultural Greenhouse

1. Measure Description

This project involved replacing a single layer fiberglass curved roof that was past its effective useful life on eight houses of the greenhouse (identified onsite as section one) with a double skin acrylic roof, in order to improve flower yield and reduce gas consumption.

2. Summary of the Ex Ante Calculations

This project consisted of a single calculated measure with savings based on an engineering heat transfer analysis of the pre- and post-installation greenhouse. The calculations used a bin analysis based on the temperature difference between the interior of the greenhouse and the ambient outside temperature, incorporating three heat transfer components: roof heat loss, wall heat loss and infiltration. The calculations assume the heat transfer coefficient for the roof and walls, and a pre / post installation infiltration rates in air changes per hour. The baseline system was estimated to consume 44,852 therms/yr while the installed system was estimated to consume 30,988 therms/yr yielding a total heat savings of 13,864 therms/year. The energy savings estimate included an estimated boiler efficiency of 80%. As a result, the total approved energy savings for the project is 16,637 therms.

3. Comments on the Ex Ante Calculations

The calculations appear to yield reasonable energy savings by calculating a reduction in heat loss through conduction and infiltration. The majority of savings is from conduction, which is consistent with the heat loss percentages provided in publications on California greenhouse energy use (Bond, 1985).[1]

The weather data source is not known and may need to be refined, along with the infiltration and conduction values associated with the material specifications. The efficiency value of the boilers was given as 80%, which may be somewhat high given distribution losses.

The calculations assume a ventilation/infiltration rate of 1.5 and 0.80 air changes per hour in the pre- and post-installation cases, respectively. These values appear to be inline with the values given in Bond, 1985 for glass and double-wall panels. These also fall within the range given in ASHRAE of 0.2 to 2.0 for residential building air changes per hour. When accounting for degradation of the old fiberglass material, the 1.5 air changes per hour may be more accurate than the new fiberglass value given as 1.0 in Bond 1985.

The calculations assume a uniform temperature of 65°F inside the greenhouse. There are no bin hours for the temperature range of 60°F to 64°F degrees, possibly indicating that 60 degrees is the temperature where the boiler heat is utilized.

The time of operation is listed as 96%, but the total hours do not add to 96% of 8,760 hours (1 year). This may be an indication of taking the boiler offline for annual maintenance.

4. Measurement & Verification Plan

The scope of the project covers eight houses making up greenhouse section one served by a steam boiler. IPMVP Option A will be used due to the custom nature of the project. The energy impacts will be estimated by verifying the savings calculation methodology. In addition to analyzing the savings calculations, we will attempt to verify the appropriateness of the assumptions on which the calculations are based and the assumed values for variables in the equations. The following four parameters are the most significant variables to be quantified:

1. Pre and post installation materials verification with the site representative.
2. Greenhouse hours of operation per year and hours of boiler operation verification by site representative in addition to the EMS data comparison of inside and outside temperatures for one day per season.
3. Temperature data gathering, using Hobo data loggers on the inside and outside of the greenhouse, and spot temperature measurements taken with a Raytek IR thermometer in order to verify the Energy Management System(EMS) data.
4. Efficiency of boiler verified from efficiency test results if available or from the serial number and manufacturer information.
5. Dimensions of the greenhouse sections affected.

Formulae

The formula used to estimate energy consumption are standard heat transfer formulas for conductive and infiltration heat loss:

$$Q_{TOTAL} = Q_C + Q_I$$

Conduction:

$$Q_C = \sum_{i=1}^{x} AU\Delta T_i H$$

where,
A = Area of the transfer surface (wall or roof)

U = Heat transfer coefficient for transfer material
ΔT_i = Temperature difference between outside for bin i and inside air
H = Operating hours at specified temperature bin
x = Total number of temperature bins

Infiltration:

$$Q_I = \sum_{i=1}^{x} C_p \rho V N \Delta T_i H$$

where,
C_p = Air heat capacity at constant pressure = 1.0
ρ = Density of air at atmospheric pressure
V = Volume of greenhouse
N = Air changes per hour
ΔT_i = Temperature difference between outside for bin i and inside air
H = Operating hours at specified temperature bin
x = Total number of temperature bins

The greatest uncertainty in the ex ante savings estimate is associated with the hours of operation. The application source of hours per temperature bin is not given. Therefore, the temperature bins will be modified if needed through data available with the EMS or onsite through data collection. The second largest uncertainty is associated with the U value of materials and the change in infiltration (air changes per hour). Areas and volumes may be adequately quantified and will be verified through a site visit and data collection. The remaining large contributor to uncertainty in the ex ante savings estimate is associated with the overall distribution system efficiency of the heating system.

Uncertainty for the savings estimate for this retrofit can be more fully understood by setting projected ranges on the primary variables.

For hours of boiler operation

- 5,475 expected (12 hours half the year & 18 hours half the year), maximum of 5,652 (given in application), minimum of 2,920 (8 hours all year) (+4%, -47%)

For hours at each temperature bin

- Actual percentage and number of hours within each bin varies form the data reported from the weather station used, due to location (expected +/- 20%)

<u>For the U value proposed</u>

- 0.8 expected, maximum of 1.0, minimum 0.5 (+25%, -37%)

<u>For the U value pre retrofit</u>

- 1.21 expected, maximum of 2, minimum 1.0 (+70%, -18%)

For the interior temperature

- 62 F expected, maximum of 70, minimum of 58 (+ 15%, -8%, based on judgment of deviation)

For the air changes per hour proposed

- 0.8 ACH expected, maximum of 1.5 ACH, minimum of 0.5 ACH (+ 100%, -33%,)

For the air changes per hour pre retrofit

- 1.5 ACH expected, maximum of 2.0 ACH, minimum of 1.0 ACH (+/ -33%,)

For the Heating System Efficiency

- 75% expected, maximum of 90% if condensing boiler, minimum of 60% if inefficient steam boiler /system (+/- 20%)

Accuracy

The accuracy of the savings calculation will be dependent upon the accuracy of the assumptions used in the calculations. We will attempt to estimate the error in the calculations through interviews with the customer and temperature data gathered.

The Raytech MiniTemp model MT2 Infrared (IR) thermometer has an accuracy of ±2% of reading or ±3.5F, whichever is greater, for temperatures less than 500F.

Hobo U12 data logger has an accuracy of ±0.63 at 77F.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate. The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on October 2, 2007. Information on the new and old roof, temperature maintained within the greenhouse, and boiler information were collected by inspection of materials and equipment, short term temperature data collection, review of EMS data, and interviewing the facility representative. The EMS temperature data was compared with temperature data collected for a one hour period with the Hobo data loggers and instantaneous measurements using the Raytech Infrared thermometer.

Installation Verification

It was observed that the material of the roof installed was a double skin acrylic. There was 65,139 sf of roof installed. The IRR reported 32,570 sf of roof replaced. The verification rate is 2.0 and the verification results are shown in Table 1. The roof, although slightly curved, was assumed to be a gable roof for purposes of area and volume calculation. The sf of the roof was calculated using the following formula from **Bond 1985**.

$$\text{Gable Roof Area} = ND(4B^2+C^2)^{0.5}$$

Where: N=number of houses (8)
D=Length of one house (180 ft)
B=Gutter to ridge distance (9 ft)
C=Width of one house (41.5 ft)

The facility representative verified that the prior roof material was approximately 21 year old corrugated single fiberglass, which is the same material as three of the four walls of the greenhouse and the gabled faces of each of the eight houses above the rectangular section of double skin acrylic wall. On the inside of the single fiberglass walls, connected to a wooden frame, a sheet of plastic was in place to reduce infiltration and conduction heat losses.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Double Acrylic Roof on 4 houses (total of 32,570 sf)	Gas			8 (total of 65,139 sf)	Dbl Acrylic Roof	Due to an increase in house number from the IRR	2.0

Scope of the Impact Assessment

The acrylic double skin roof is the only measure in the application.

Summary of Results

During the onsite visit temperature readings were taken for approximately one (1) hour using two Hobo data loggers. One data logger was located in the same spot as the inside temperature EMS sensor to check for calibration and the other logger one was placed in a shaded exterior location at a nearby greenhouse. In addition, the representative was able to provide temperature data from the EMS for interior locations and from a company owned outside weather station data for one day of each season, which the representative verified as representing a typical day in that season. The days for which data were collected were from the months of January, March, June, and October (all in 2007). The EMS day chosen for the fall season was October 2^{nd}, which allowed for comparison with the data logger results for verification or adjustments as necessary to increase accuracy of the EMS data.

Temperature Change

In reviewing the logged temperatures, the Hobo datalogger logged values between that of the EMS and the IR values. The EMS sensor is believed to be out of calibration. The temperatures inside the greenhouse were thus adjusted by the average percent variation over the time period where data was gathered for both the EMS and the Hobo data logger, which is approximately 3.4%. The average of the adjusted EMS inside temperatures during the night for each month was 60 degrees which is also inline with the temperature setting for section one provided by the facility representative. This value was used as the inside temperature for temperature differential calculation.

The typical nighttime average temperature per month determined from the applicable forecasting weather station was used to represent the outside temperature over a 12 hour period (nighttime hours). Twelve hours multiplied by the number of days in each month gave the hours/year at each temperature difference. The nighttime hours are assumed to represent the total time the boiler is in operation. The temperature differential bins and hours at each are given in Table 2, below. These temperature bins and hours are used to represent both the pre and post retrofit situations.

Table 2: Hours of Boiler Use per Temperature Differential

Represented Month(s)	Hours	Temp Diff.
9	360	0.8
8	372	2.2
7,10	744	2.9
6	360	4
5	372	7.1
3	372	7.8
11	360	8.4
4	360	8.6
2	336	9.5
1	372	11.9
12	372	12.6

Material Assumptions

The U value of the replacement double acrylic roof was obtained from the manufacturer's technical specifications and was found to be 0.49 Btu/hr*ft^2*F.

The walls of the greenhouse were found to be made of a combination of single layer corrugated fiberglass panels with plastic sheeting attached to the inside of the frame, to provide a dead air space thus reducing heat loss, and double acrylic panels that were not a part of the SPC project. Because there is no energy savings in terms of conduction, it was determined that a U value of 1.21 was sufficient to represent the overall wall U value.

The roof contains one section of glass that was also unaffected by the SPC project, thus this area was also not included.

The air changes per hour values provided in the application were deemed acceptable due to the low percentage (approximately 21% in CA) of heat loss typically associated with infiltration (Bond, 1985) and the variety of materials found in the structure. A total of 1.5 air changes/hr pre installation and 0.8 air changes per hour post installation were supported (Bonds 1985), which provides estimates of 1.00 for fiberglass (without dead air space & before end of effective useful life) and 0.8 for double wall acrylic. Also supporting these values, 82% of the pre-installation materials were fiberglass and 82% of the post installation materials were double acrylic.

Boiler Efficiency

The efficiency of the steam boiler was determined to be 79.7% through recorded boiler efficiency tests during the high firing rate. It should also be noted that this value was obtained through boiler efficiency tests completed after the burner was upgraded and represents present conditions. The value for system efficiency is lower, due to distribution losses; however, these losses are difficult to quantify and the higher efficiency value is used. A lower efficiency value would increase overall savings.

Using the formulas given in section 4 above, and correcting for yearly operation/maintenance down time of 4% (as provided by facility personnel), the following is the resulting energy consumption and savings. Iterations for energy use associated with the roof, and infiltration for the new and old roof can be found at the end of this report in table format.

Table 3: Therms Used

Energy Used	Old Roof	New Roof
Roof	21,695	8,786
Walls	4,065	4,065
Infiltration	5,996	3,198
Total	31,756	16,048

Energy Savings= (Energy Consumption with Old Roof-Energy Consumption with New Roof) / Boiler Efficiency

Energy Savings = (31,756-16,048) / 79.7% = 19,709 Therms

The ex post therm reduction is greater than the ex ante therm reduction primarily due to the building containing eight greenhouses not four as listed in the ex ante calculations, and use of the actual roof material U value of 0.49 as opposed to 0.8 used in the ex ante calculations.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application was from the vendor, who specializes in greenhouses; therefore, no other quotes were considered. The representative did say that the new roof provides more light, thus increasing production, and will last longer than the old roof. He did not give any drawbacks associated with the project and indicated that if roofs on other sections were at the end of the useful life then they would replace them with the double acrylic roof rather than install heat curtains or other mechanical devices that have more potential for operational and maintenance problems. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future.

The representative indicated that there have been no operational changes to section one since the roof retrofit. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures. However, more effort would yield better energy saving estimates, including comparison of data from the facility's weather station with the typical weather data used for that climate zone.

The costs for this measure appear to be realistic.

7. Impact Results

Based on the ex ante savings of 18,014 therms, the engineering realization rate for this application is 1.09.

Utility billing data for the site was reviewed. In the 12 month period from January 2003 to December 2003, the facility consumed 721,538 therms. Table 4 summarized the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 4: Annual Results

	Annual Therms
Total Meter	721,538
Baseline End Use	72,154
Ex ante Savings	18,014
Ex post Savings	19,709

Baseline end use is assumed to be 10% for heating this section of greenhouses.

Table 4a: Realization Rate Table

	kW	kWh	Therm
SPC Tracking System			18,014
SPC Installation Report (ex ante)			18,014
Impact Evaluation (ex post)			19,709
Engineering Realization Rate			1.09

Table 5 is a summary of the percent of therm savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations.

Table 5: Percent Savings: Ex Ante & Ex Post

	Ex Ante	Ex Post
Therm reduction	Therms	Therms
Total Meter	2.5%	2.7%
Baseline End Use	25.0%	27.3%

With a cost of $61,886 and an incentive of $18,014, the project had a 3.0 year simple payback based on ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 2.8 years. A summary of the economic parameters for the project is shown in Table 6.

Table 6: Economic Information

Description	Date	Project Cost	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.80/therm)	SPC Incentive, $	Simple Payback w/incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	6/11/04	$61,886	18,014	$14,411	$18,014	3.04	4.29
SPC Program Review (Ex Post)	10/2/2007	$61,886	19,709	$15,767	$18,014	2.78	3.93

It was determined that the greenhouse roof replacement project was defined as a custom project-SPC in the California Public Utilities Commission *Energy Efficiency Policy Manual*. Therefore, the greenhouse roof is assumed to have a useful life of 15 years.

A summary of the multi-year reporting requirements is given in Table 7. Because this measure was installed approximately June of 2004 the energy savings in year #1 (2004) are assumed to be 1/2 of the expected annual savings for this measure.

Table 7: Multi Year Reporting Table

Program ID:	Application #A033						
Program Name:	SPC 04-05 Evaluation						
Year	Calendar Year	Ex Ante Gross Program Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Program-Projected Program Therm Savings
1	2004	-	-	-	-	9,007	9,854
2	2005	-	-	-	-	18,014	19,709
3	2006	-	-	-	-	18,014	19,709
4	2007	-	-	-	-	18,014	19,709
5	2008	-	-	-	-	18,014	19,709
6	2009	-	-	-	-	18,014	19,709
7	2010	-	-	-	-	18,014	19,709
8	2011	-	-	-	-	18,014	19,709
9	2012	-	-	-	-	18,014	19,709
10	2013	-	-	-	-	18,014	19,709
11	2014	-	-	-	-	18,014	19,709
12	2015	-	-	-	-	18,014	19,709
13	2016	-	-	-	-	18,014	19,709
14	2017	-	-	-	-	18,014	19,709
15	2018	-	-	-	-	18,014	19,709
16	2019	-	-	-	-	18,014	19,709
17	2020	-	-	-	-	9,007	9,854
18	2021	-	-	-	-		
19	2022	-	-	-	-		
20	2023	-	-	-	-		
Total	**2004-2023**					288,224	315,344

Table 1: Old Roof
Conduction Roof Heat Lost

A	U value	Temp Diff	hours/ year	Oper Hrs %	Total Therm
65,139	1.21	0.8	360	0.96	218
65,139	1.21	2.2	372	0.96	619
65,139	1.21	2.9	744	0.96	1,633
65,139	1.21	4	360	0.96	1,090
65,139	1.21	7.1	372	0.96	1,998
65,139	1.21	7.8	372	0.96	2,196
65,139	1.21	8.4	360	0.96	2,288
65,139	1.21	8.6	360	0.96	2,343
65,139	1.21	9.5	336	0.96	2,415
65,139	1.21	11.9	372	0.96	3,350
65,139	1.21	12.6	372	0.96	3,547
				Total Therms	**21,695**

Table 2: New Roof
Conduction Roof Heat Lost

A	U value	Temp Difference	Hrs /yr	Oper Hrs %	Total Therms
65,139	0.49	0.8	360	0.96	88
65,139	0.49	2.2	372	0.96	251
65,139	0.49	2.9	744	0.96	661
65,139	0.49	4	360	0.96	441
65,139	0.49	7.1	372	0.96	809
65,139	0.49	7.8	372	0.96	889
65,139	0.49	8.4	360	0.96	927
65,139	0.49	8.6	360	0.96	949
65,139	0.49	9.5	336	0.96	978
65,139	0.49	11.9	372	0.96	1,356
65,139	0.49	12.6	372	0.96	1,436
				Total Therms	**8,786**

Table 3: Old Roof Infiltration Heat Lost

Cp* air density	Volume	Temp Difference	hours/year	N	Operation Hours %	Total Therms
0.018	806,760	0.8	360	1.5	0.96	60
0.018	806,760	2.2	372	1.5	0.96	171
0.018	806,760	2.9	744	1.5	0.96	451
0.018	806,760	4	360	1.5	0.96	301
0.018	806,760	7.1	372	1.5	0.96	552
0.018	806,760	7.8	372	1.5	0.96	607
0.018	806,760	8.4	360	1.5	0.96	632
0.018	806,760	8.6	360	1.5	0.96	647
0.018	806,760	9.5	336	1.5	0.96	667
0.018	806,760	11.9	372	1.5	0.96	926
0.018	806,760	12.6	372	1.5	0.96	980
					Total Therms	**5,996**

Table 4: New Roof
Infiltration Heat Lost

Cp* air density	Volume	Temp Diff	hours/ year	N	Oper Hrs %	Total Therms
0.018	806,760	0.8	360	0.8	0.96	32
0.018	806,760	2.2	372	0.8	0.96	91
0.018	806,760	2.9	744	0.8	0.96	241
0.018	806,760	4	360	0.8	0.96	161
0.018	806,760	7.1	372	0.8	0.96	295
0.018	806,760	7.8	372	0.8	0.96	324
0.018	806,760	8.4	360	0.8	0.96	337
0.018	806,760	8.6	360	0.8	0.96	345
0.018	806,760	9.5	336	0.8	0.96	356
0.018	806,760	11.9	372	0.8	0.96	494
0.018	806,760	12.6	372	0.8	0.96	523
					Total Therms	**3,198**

References

Bond, T.E., J.F. Thompson, and Ray F Hasek. 1985. Reducing Energy Costs in California Greenhouses. Leaflet 21411. Cooperative Extension University of California. 24p.

Final Site Report

SITE A034 Fost (2005 - xxxx) IMPACT EVALUATION
SAMPLE CELL: ORIGINAL   TIER: 4   END USE: Gas

Measure	Blowdown Heat Exchangers for Five (5) Boilers
Site Description	Poultry Processing facility

1. Measure Description

The project involves installing heat exchangers to recover heat from boiler blowdown streams for use to preheat boiler makeup water. Energy savings will be realized as a result of reduced natural gas use due to the preheating of makeup water. This facility has five (5) fire-tube boilers, with a total normal steaming output of 85,000 lbs/hr at 100 psig. According to the application documentation, 75% of this output is returned to the system as condensate, while 25% of the output must be replenished by the makeup water. The makeup water has a high total dissolved solids (TDS) concentration of 500 ppm. Therefore, there is a need to continuously blowdown the boilers to maintain a 3,000 ppm solids concentration in the boiler.

2. Summary of the Ex Ante Calculations

The ex ante savings were listed in the Installation Report Review and in the utility tracking system as 60, 300 therms. The incentive of $30,000 was capped at 50% of the total measure cost.

Steady-state heat and mass flow equations were applied to the heat exchanger's hot and cold streams to determine blowdown rate and gas savings. Data used for the calculations are taken from both the boiler specifications and the vendor's heat exchanger specifications. Other data including blowdown temperatures and TDS values, as well as assumptions made by PG&E and the vendor heat exchanger in their estimation of savings, were also used in the ex ante calculations.

The SPC evaluation reviewer's calculations are based on the following:

<u>TDS Mass Balance :</u>

Since the TDS levels in the boiler are to be maintained at 3000 ppm, and the makeup water stream brings in 500 ppm of TDS, a mass balance can be performed, as shown below, to determine the blowdown rate (BD_R) needed to maintain the desired TDS concentration.

The makeup water flow rate, MW_R, is estimated as follows:

$$MW_R = SL + BD_R$$

Where

SL = Steam loss mass flow rate, 21,250 lb/hr (25% of steaming rate)

The amount of solvents gained through the makeup water in the boiler needs to be removed by blowdown to maintain the desired TDS.

Thus

BD_R x 3,000 ppm = [SL x 500 ppm] + [BD_R x 500 ppm]

Solving for the above equation, BD_R is 4,250 lbs/hr.

Then, MW_R is calculated as 25,500 lbs/hr.

Energy Balance :

$HR = BD_R \times (BD_{TI} - BD_{TE})$

Where

HR =	Heat recovered from blowdown stream per hour
BD_{TI} =	Blowdown inlet temperature to the heat exchanger, 330°F
BD_{TE} =	Blowdown exit temperature from the heat exchanger, 111°F

Thus, HR is calculated as 9.3 therms/hour (4,250 lbs/hr x (330 F – 111 F) / 100,000 Btu/therm)

According to the facility personnel, the boilers operate 24 hrs/day, 280 days/yr, for a total of 6,720 hours/yr.

The annual gas savings available from installation of heat exchangers, assuming a boiler efficiency of 80%, are estimated to be 78,100 therms/yr.

The utility reviewer's calculations are based on the following:

TDS Mass Balance:

Since the TDS levels in the boiler are to be maintained at 3000 ppm, and the makeup water stream brings in 500 ppm of TDS, a mass balance can be performed, as shown below, to determine the blowdown rate (BD_R) needed to maintain the desired TDS concentration.

BD_R x 3,000 ppm + 85,000 X 0 = [25,500 + 0.3 x BD_R] x 500 ppm + [59,500 + 0.7 x BD_R] x 500 ppm

Where:
25,500 lbs/hr is 30% of 85,000 lbs/hr assumed to be lost in the process
59,500 lbs/hr is 70% of 85,000 lbs/hr condensate return rate

Solving for the above equation, BD_R is estimated to be 4,474 lbs/hr.

Energy Balance :

$HR = BD_R \times (BD_{TI} - BD_{TE})$

Where:

HR =	Heat recovered from blowdown stream per hour
BD_{TI} =	Blowdown inlet temperature to the heat exchanger, 301°F
BD_{TE} =	Blowdown exit temperature from the heat exchanger, 79°F

Thus, HR is calculated as 9.93 therms/ hour (4,474 lbs/hr x (301 F – 79 F) / 100,000 Btu/therm).

According to the facility personnel, the boilers operate 24 hrs/day, 280 days/yr, for a total of 6,720 hours/yr.

The annual gas savings available from installation of heat exchangers, assuming a boiler efficiency of 83%, are estimated to be 80,400 therms/yr. A factor of 75% was applied to this figure to yield savings of 62,500 therm/yr.

3. Comments on the Ex Ante Calculations

After reviewing the documentation, and based on the data available during the pre-retrofit period, the assumptions and estimation in the application are reasonable.

Comments on assumptions in the calculations and points that need clarification are as follows:

- The vendor estimates of energy savings assume four boilers rated at 20,700 lbs/hr, and one boiler rated at 3,450 lbs/hr, with a total normal steaming rate of 85,000 lbs/hr. According to PG&E's pre-installation inspection report, three boilers are rated at 20,700 lbs/hr, one boiler is rated at 20,085 lbs/hr and the fifth boiler is rated at 2,898 lbs/hr. However, the estimation of savings in Section 2 assumes a total steaming rate of 85,000 lbs/hr.
- The savings estimation from SPC evaluation reviewer assumes blowdown temperatures of 330°F and 111°F respectively, according to vendor specifications for the heat exchanger. The savings estimation from the utility reviewer assumes blowdown temperatures before and after the heat exchanger to be 301°F and 79°F, respectively.
- The boiler efficiency according to SPC evaluation reviewer is 80%, while according to utility reviewer is 83%.

4. Measurement & Verification Plan

The facility is a large single story chicken processing plant. There is approximately 820,000 sf of floor area; the facility is approximately 40 years old. The facility installed a heat exchanger to recover heat from the blowdown stream, in order to preheat boiler makeup water. The heat exchanger recovers heat from 330°F to approximately 111°F at the approximate rate of 8 gpm of water. According to the facility personnel, the boilers run fully loaded for 6,720 hrs/yr (continuously for 280 days per year).

According to vendor estimation, a maximum of about 83,400 therms/yr of gas savings are possible. PG&E approved the application for 75% of the vendor's estimated savings, for a total of 62,500 therms/yr. However, the utility tracking system and Installation Report Review show savings of 60,300 therms/yr.

According to the customer, the estimated capital cost for the retrofit was $60,000. There was no invoice provided in the application paperwork. Since the incentive cap is 50% of the total capital cost, the 75% factor on the savings estimates has no impact on the incentive amount.

The goal of the M&V plan is to estimate the actual annual gas savings by this measure over the expected useful life of the measure.

Formulae and Approach

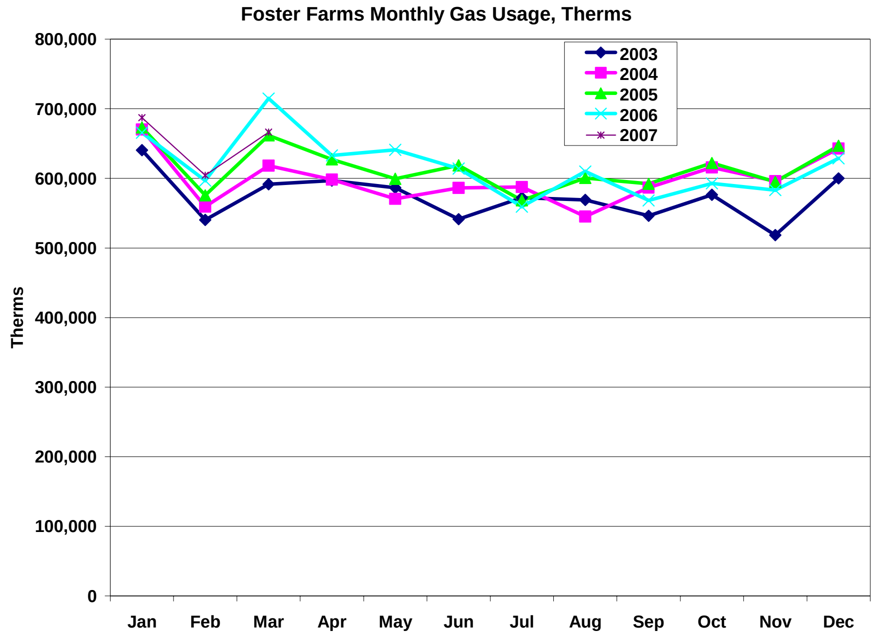
IPMVP Option A approach will be used. Definite conclusions cannot be drawn from IPMVP Option C, since the retrofit saves only about 1% of the gas usage in the boilers, and there are varying factors such as production. The monthly gas usage for the pre-retrofit and post-retrofit period is shown in Figure 1.

Temperature measurements of the blow down and make up streams should be taken before and after the heat exchangers during the site visit. Collection of flow data is also recommended, but not likely to be feasible unless the heat exchangers are equipped with flow meters and read-outs are possible from the panel. The assumption of 6,720 operation hrs/yr will be used in the ex post savings estimation, unless other information is available. The savings estimation will be performed according to the formula in Section 2.

The following data will be gathered during the site visit:

- Steaming capacity for all boilers will be confirmed.
- Temperature measurements of streams before and after the heat exchangers will be collected.
- Collection of flow data will be attempted, but not likely feasible unless the heat exchangers are equipped with flow meters.
- Boiler efficiency will be confirmed from the nameplate data.

Figure 1: Monthly Gas Usage



Uncertainty for the savings estimate can be more fully understood by setting projected ranges on the primary variables.

<u>Flow</u>

- Pre and post-retrofit expected 4,250 lbs/hr, + 0% / - 20%
  Ranges are based on maximum blowdown but could be 20% less.

<u>Temperature</u>

- Post-retrofit blowdown heat exchanger exit temperature, 111 ºF expected, +10% / - 0%. Ranges are based on maximum blowdown but could be 10% more
- Post-retrofit blowdown heat exchanger inlet temperature, 330 ºF, +0% / -10%
  Ranges are based on maximum blowdown but could be 10% less

Accuracy and Equipment

For the purposes of the evaluation, the data collected on site is considered to be 99% - 100% accurate where reviewed data are deemed reasonable.

Customer data and data from temperature gauges will be regarded to have an accuracy of +/- 5%.

All data collected will be reviewed to ensure it conforms to realistic values, and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site visit was conducted on October 3, 2007. Information on boilers and pump motors was gathered from the equipment nameplates. Information on boiler operating characteristics (such as steam pressure, gas usage, etc.) was gathered from facility personnel.

Installation Verification

During the on-site visit, the installation of the blowdown heat exchanger was confirmed. According to the facility personnel, the heat exchanger was installed during October 2005. Since installation, the heat exchanger has been in continuous operation. Maintenance includes a weekly flushing of the heat exchanger. Minimal downtime is assumed for this operation, and operating hours are not adjusted for these operations.

This is the only measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End Use Category	HVAC Measure Description	Lighting Measure Description	Gas Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Blowdown heat exchanger for five boilers	Natural Gas			Installation of heat exchanger for blowdown heat recovery	1	Shell and Tube heat exchanger	Physically verified installation of the new system	1.0

Scope of the Impact Assessment

The impact assessment scope is for the natural gas measure in the SPC application. This is the only measure in the application.

Summary of Results

Estimation of ex post savings was performed using IPMVP Option A. The ex post gas savings are lower than the ex ante savings based upon maximum firing rates and lower boiler system efficiency.

Analysis

The facility has four natural gas-fired boilers:

- Boiler#1- Johnston, Serial number S-4226, build 6/16/77, rated at 20,700 lbs/hr
- Boiler#2- Johnston, Serial number S-4225, build 6/16/77, rated at 20,700 lbs/hr

- Boiler#3- Iron Fireman, Serial number 7192, Model number 302A-H-600, rated at 20,700 lbs/hr, 20,085 MBtu/hr Output, 25,200 MBtu/hr Input, 600 Boiler HP
- Boiler#4- Hurst Boiler and Welding Co, Serial# S3000-150-7, build 1997, rated at 20,700 lbs/hr

Each boiler has its own meter and is logged daily by the facility personnel. Daily operating characteristics such as steam pressure, gas pressure and makeup water flow are also logged as spot measurements.

A fifth boiler (Boiler#5) runs from flue gases of an incinerator and is rated at 2,898 lbs/hr. This boiler does not use natural gas and therefore is not included in this analysis.

According to the facility personnel, makeup water flow logs indicate an average flow rate of 75,000 gallons/day. For the two months from August 1, 2007 thru October 1, 2007, data from the makeup water flow meter indicated an average flow rate of 71,593 gallons/day, which is used in the ex post savings estimations. In Section 2, the total makeup water flow rate is given as 25,500 lbs/hr (73,360 gals/day), which is a 2.5% increase over the metered average. Thus, the ex ante estimation of makeup water flow is confirmed as realistic. However, for savings estimation purposes, only the makeup water that is heated by natural gas is used (neglecting makeup water to Boiler #5), along with the metered data for daily average flow rates.

During the site visit, none of the boilers were on blowdown mode and there was no makeup water flow through the heat exchanger. However, the inlet makeup water temperature can be assumed to be 70°F, as the temperature gauge indicated 70°F, close to ambient air temperature. The makeup water outlet is piped to a holding tank with a temperature gauge that indicated a water temperature of 80°F. According to facility personnel, the temperature differential could range from 10°F to 45°F depending up on the flow in the blowdown and makeup water streams. Facility personnel also indicated that the average temperature differential could be assumed to be about 25°F.

The makeup water flow to the gas-fired boilers, MW_G, is estimated as a percentage of the total flow to all the boilers as shown below.

$$MW_G = (MW_R) \times C_{MN} / C_{MT}$$

where

C_{MN} = Maximum steaming capacity of the four gas-fired boilers, 82,800 lbs/hr
C_{MT} = Maximum steaming capacity of all boilers, 85,698 lbs/hr

Thus

$$MW_G = (71{,}593 \text{ gals/day}) \times 82{,}800 / 85{,}698$$
$$= 69{,}172 \text{ gals/day or } 24{,}044 \text{ lbs/hr}$$

The ex post impacts are calculated as follows:

Boiler hours of operation are 6,720 hrs/yr
Makeup water flow to gas-fired boilers, MW_G = 24,044 lbs/hr

Annual gas savings are 24,044 lbs/hr x 25°F x 6,720 hrs/yr / 80% = 40,394 therms/yr

The boilers are equipped with economizers that recover waste heat from flue gases to preheat combustion air. Therefore the boiler efficiency of 80% assumed in the vendor's estimation is low. However, there are system losses as well. Thus for our estimation purposes, efficiency is assumed to be 80%. Thus the net annual gas savings are estimated to be 50,492 therms/yr .

Annual gas savings are 40,394 therms/yr / 80% = 50,492 therms/yr

The uncertainty is +-25%, as determined from the standard deviation of the savings with a temperature differential min/max set to 10°F and 45°F.

The uncertainty for this application is detailed in the Uncertainty Summary (Table 2)

Table 2: Uncertainty Summary

Input/Output Variable	Expected Value	Low Value	High Value	Type of Distribution
Flow Rate (lbs/hr)	24,044	22,842	25,246	Normal
Hours	6,720	6,384	7,056	Normal
therms saved	50,492	45,570	55,667	Normal

6. Additional Evaluation Findings

The ex post gas savings are lower than the ex ante savings. This is due to the following:

- The ex ante savings appear to have been estimated with a total normal steaming capacity of 85,000 lbs/hr, which includes 2,898 lbs/hr (3,450 lbs/hr according to vendor estimation) steam that is generated by Boiler#5 that does not use natural gas.
- The ex ante savings assume a constant flow through the heat exchanger. In reality, the flow rate of makeup water and blowdown stream varies depending on the need for makeup water and whether the boilers are in blowdown mode. The flow of the blowdown stream also varies depending on the number of boilers that are in the blowdown mode during a given period. Multiple boilers are not necessarily in blowdown mode at the same times. Also, the blowdown could take place when there is no makeup water flowing through the heat exchanger, in which case there is no heat recovery.
- The ex ante and ex post savings assume a boiler efficiency of 80%.
- The ex ante savings from Vendor assume a blowdown heat exchanger exit temperature of 60 °F, while the heat exchanger is designed for a blowdown exit temperature of 111°F.
- The largest difference in the savings estimates derive from the change in the temperature differential for the make up water. The makeup water temperatures used in the ex ante calculations support a temperature differential of 33 F to 37 F

at all times; facility personnel indicated a temperature differential range of 10F to 45 F with an average of approximately 25 F.

The ex post results could be improved though a longer period of time available for monitoring the temperatures and efficiency measurements on the boiler. The customer was, however, difficult to reach and trending of temperatures was not possible.

The cost seems reasonable for this type of application. There does not appear to be any other efficiency programs that were stimulated directly by this measure.

7. Impact Results

The engineering realization rate for this application is 0.84 and savings are 0.8% of baseline end use for gas savings. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 3 and a summary of the percent savings (ex ante and ex post) is shown in Table 4.

Table 3: Realization Rate Summary

	Gas (Therms/yr)
SPC Tracking System	60,300
SPC Installation Report (ex ante)	60,300
Impact Evaluation (ex post)	50,492
Engineering Realization Rate	0.84

Table 4: Ex Ante / Ex Post Savings as Percent of Use

	Gas Usage	Ex Ante Savings	Ex Post Savings	Ex Ante Savings	Ex Post Savings
	Therms	Therms	Therms	%	%
Total Meter	7,176,539	60,300	50,492	0.8%	0.7%
Baseline End Use	5,998,720			1.0%	0.8%

With a cost of $60,000 and a $30,000 incentive, the project had a 1.2 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 1.5 years. A summary of the economic parameters for the project is shown in Table 5.

Table 5: Economic Information

Description	Date	Project Cost	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.8/therm), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	12/19/2005	$60,000	60,300	$48,240	$30,000	0.6	1.2
SPC Program Review (Ex Post)	10/3/2007	$60,000	50,492	$40,394	$30,000	0.7	1.5

It was determined that the heat recovery projects were defined as a Custom Project under the SPC program according to the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the heat exchanger is assumed to have a useful life of fifteen (15) years.

A summary of the multi-year reporting requirements is given in Table 6. Because this measure was installed approximately during October 2005, the energy savings in year #1 (2005) are assumed to be fraction of the expected annual savings for this measure.

Table 6: Multi-year Reporting Table

Program ID:	001 Application # A034						
Program Name:	SPC 04-05 Evaluation						
Year	Calendar Year	Ex-Ante Gross Program-Projected kWh Savings	Ex-Post Gross Evaluation Confirmed kWh Savings	Ex-Ante Gross Program-Projected Peak kW Savings	Ex-Post Gross Evaluation Confirmed kW Savings	Ex-Ante Gross Program-Projected Therm Savings	Ex-Post Gross Evaluation Confirmed Therm Savings
1	2004						
2	2005					15,075	12,623
3	2006					60,300	50,492
4	2007					60,300	50,492
5	2008					60,300	50,492
6	2009					60,300	50,492
7	2010					60,300	50,492
8	2011					60,300	50,492
9	2012					60,300	50,492
10	2013					60,300	50,492
11	2014					60,300	50,492
12	2015					60,300	50,492
13	2016					60,300	50,492
14	2017					60,300	50,492
15	2018					60,300	50,492
16	2019					60,300	50,492
17	2020					45,225	37,869
18	2021						
19	2022						
20	2023						
TOTAL	2004-2023					904,500	757,380

Final Site Report

SITE A035 Micr (2004-xxx) IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 2 END USE: Gas and Electric

Measure	VOC Abatement Retrofit
Site Description	Semiconductor manufacturing facility

1. Measure Description

Replace an incinerator type thermal oxidizer (without heat recovery) with a hydrophobic zeolite concentrator and recuperative thermal oxidizer.

2. Summary of the Ex Ante Calculations

Energy savings from this replacement will be realized as a result of reduced natural gas usage at the burner. Concentrating volatile organic compounds (VOCs) in the exhaust system will result in lower amounts of VOC-laden air being processed, so that a much smaller burner for the thermal oxidizer is required. Gas savings are also achieved through use of a pair of heat exchangers to pre-heat the VOC-laden air (recuperation).

Steady-state heat and mass flow equations were used to calculate energy (gas and electric) usage of the pre-retrofit unit (the "Demand Unit" which was replaced) and the post-retrofit unit (identified as the "Munters Zeol Rotor Concentrator") and energy savings. The data used for the pre-retrofit calculations were gathered from the pre-installation inspection report as well as reviewer and vendor (Munters) data / assumptions. Data used to conduct post-retrofit calculations are from Munters Thermal Oxidizer flow/ temperature specifications, and data / assumptions in the estimations, which are different from the pre-retrofit calculations.

Pre-retrofit System Gas Usage:

The amount of annual gas used, Q_{Fuel}, is estimated as follows:

$$Q_{FUEL} = [Q_P + Q_R - Q_{VOC}] \times H$$

Where.

Q_P = Heat required to raise 3,200 scfm of process air (VOC-laden air) from 80°F (ambient) to 1,150°F
Q_R = Radiation loss associated with the unit shell, assumed 10% of Q_P per reviewer calculations
Q_{VOC} = Heat contributed from combustion of VOC
H = Annual hours of operations = 8,760 hrs/yr

Q_P = 3,200 scfm x 60 min/hr x 0.075 lb/cf x 0.24[1] Btu/lb°F x (1,150°F - 80°F)
= 37 therms/hr

Q_R = 10% of 37 = 3.7 therms/hr

Q_{VOC} = 12,500 Btu/lb x 6 lbs/hr = 0.75 therms/hr[2]

Thus Q_{FUEL} is estimated to be about 350,000 therms/yr

Pre-retrofit System Electricity Usage:

The amount of annual electricity used in fans (process and combustion), E_{FAN}, is estimated as below. According to the pre-installation inspection report, the process fan is rated at 5 HP, and combustion fan is rated at 3 HP with an assumed motor efficiency of 0.78 and load factor of 0.8.

$$E_{FAN} = (8 \text{ HP} \times 0.8 \times 0.746 \text{ kW/hp} \times 8{,}760 \text{ hrs/yr}) / 0.78 = 53{,}600 \text{ kWh/yr}$$

Post-retrofit System Gas Usage:

The amount of annual gas used, Q_{Fuel}, is estimated as follows:

$$Q_{FUEL} = [Q_P + Q_C + Q_R - Q_{VOC}] \times H$$

Where:

Q_P = Heat required to raise 500 scfm of process air (VOC-laden air) from 900°F (from primary HX) to 1,375°F[3]
Q_C = Heat required to raise 210 scfm[4] of combustion air from 80°F to 1,375°F
Q_R = Radiation loss associated with the unit shell, assumed 10% of (Q_P + Q_C) per reviewer calculations
Q_{VOC} = Heat contributed from combustion of VOC
H = Annual hours of operations = 8,760 hrs/yr

Q_P = 500 scfm x 60 min/hr x 0.075 lb/scf x 0.28 Btu/lb°F x (1,375°F - 900°F)
= 3 therms/hr
Q_C = 210 scfm x 60 min/hr x 0.075 lb/scf x 0.24 Btu/lb°F x (1,375°F - 80°F)
= 3 therms/hr

---

[1] Specific heat of air at constant pressure is 0.24 Btu/lb °F. Specific heat of VOC-laden air assumed is 0.28 Btu/lb °F according to the utility reviewer's comments.

[2] Heat content and emission rates of VOC are from notes in application documentation and appear to be reasonable assumption for the process.

[3] Gathered from Minters Zeol Model IZS-2190 specifications.

[4] Gathered from Minters Zeol Model IZS-2190 specifications.

Q_R = 10% of 5 = 0.6 therms/hr
Q_{VOC} = 12,500 Btu/lb x 6 lbs/hr = 0.75 therms/hr

Thus Q_{FUEL} is estimated at about 51,200 therms/yr

Post-retrofit System Electricity Usage:

Fans under consideration are process fans, cooling fans, oxidation fans and combustion fans. According to calculations from Munters, fan ratings are estimated using the formula below. A standard efficiency of 0.78 is assumed for all fans.

kW = acfm x dp (in. wc) x 0.746 kW/hp / (6356 x eff)

- Two process fans are rated for 3,750 scfm for a total of 7,700 acfm at 8" water column (w.c.) = 9.3 kW
- Cooling fan at 612 acfm and 4" w.c. = 0.4 kW
- Oxidation fan at 583 acfm and 16" w.c. = 1.4 kW
- Combustion fan at 220 acfm (per 210 scfm from drawing) at 10" w.c. = 0.3

E_{FAN} = 11.4 kW x 8,760 hrs/yr = 100,000 kWh/yr

Energy Savings Estimations:

Gas Savings = 350,000 – 51,200 =298,800 therms/yr
Electricity Savings = 53,600 – 100,000 = - 46,400 kWh/yr (-1,600 therms/yr)
Demand Reduction = - 5.3 kW/month

Net Energy Savings = 297,200 therms/yr (after adjustment for increased electric usage)

The ex ante savings were reported as 315,093 therms in the Installation Report Review (IRR). This number agrees with the utility tracking system. However, they do not agree with the ex ante savings calculations as provided in the application paperwork.

3. Comments on the Ex Ante Calculations

The ex ante calculations appear to be from vendor supplied calculations. The utility reviewer modified some of the calculations and arrived at slightly lower savings figures. The ex ante savings from the vendor appear to be accepted in the IRR. However, the application paperwork does not clearly show the final ex ante savings figure. The vendor estimations of baseline energy usage for the "On-Demand" unit, project energy usage of the "Munters" units, and the ex-ante energy savings are not clearly described.

Following are comments regarding assumptions in the calculations, and points that need clarification.

- The pre-retrofit calculations assume energy usage in only the "Demand Unit" (rated at 3,200 scfm). The savings estimation (according to Munters) assumes energy usage both in the "Demand Unit" and the "Catalytic Oxidizer" (rated at

4,800 scfm). However estimations from the reviewer assume energy usage only for the "Demand Unit". It is unclear if the catalytic oxidizer should be accounted for in the savings estimations. The new unit is rated for 8,000 scfm. If operating in conjunction with the catalytic oxidizer (Demand Unit), the savings should be adjusted for the actual flow offset from each pre retrofit piece of equipment.

- Production figures and operation (hrs/yr) of all units should be obtained for twelve months prior to the retrofit and subsequent periods. The exact retrofit date should be obtained.
- Energy usage estimations for all the fans assume a motor efficiency of 0.78.
- The Pre-Installation Inspection sheet noted that the pre retrofit heat exchanger leaving temperature was 1,020°F to 1,050°F at the time of inspection. This may not be consistent with 1,150°F identified as the pre-retrofit conditions.
- This sheet also notes a 3 hp combustion fan in the pre retrofit case, which does not appear to be accounted in the pre retrofit energy usage.
- The SPC Post-Installation Inspection Sheet notes an oxidizer temperature of 1,381°F and a primary heat exchanger outlet temps of 923°F. These should be verified with logs (if possible) and may be a basis for modified post retrofit energy use.
- The combustion temperature for pre-retrofit equipment and oxidizer temperature for post retrofit equipment are different (1,150°F and 1,375°F, respectively).

The ex ante calculations appear to be overstated due to overestimation of baseline energy usage.

4. Measurement & Verification Plan

This site application involves a 55,000 sf industrial facility that manufactures semiconductors. The facility replaced its old incinerator type thermal oxidizer (without heat recovery) VOC abatement system with a hydrophobic zeolite concentrator and recuperative thermal oxidizer. Energy savings from this measure will be realized as a result of reduced natural gas usage at the burner.

According to the facility personnel, the VOC abatement system runs for 8,760 hours per year.

The documentation in the application indicates that, according to the reviewer, the net energy savings (accounting for increased fan usage) is 315,093 therms/yr. Gas usage reduction was 321,418 therms/year and electric increase was 63,250 kWh/year.

Note that, as per vendor estimations, the net energy savings (also accounting for decreased fan usage) is estimated at 342,272 therms/yr.

The goal of the M&V plan is to estimate the actual annual gas and electricity savings realized with the measure over the useful life of the equipment, in order to compare these values with the initial estimations.

Based on the data available during the pre-retrofit period, the assumptions and estimations in the application are reasonable.

Formulae and Approach

IPMVP Option C approach should be considered. As per vendor estimations, the gas savings is about 75% of the facility usage. According to facility personnel, the facility's other gas using equipment includes two boilers for space heating, and three abatement burn boxes. By segregating the gas usage for space heating and gathering data (such as nameplate readings and run hours) for the abatement burn boxes, reasonable estimations on gas savings from the retrofit can be performed. Since the VOC abatement system is the major gas user in the facility, utility billing should support this approach if there are no other significant changes in loads (due to significant production variation, or due to other significant energy conservation activities or changes in abatement burn box run hours which occurred in the months immediately following the retrofit). No significant seasonal variations are expected, and several months of data collection should be sufficient for comparison. However, a one to two year period would more fully capture actual variations and the persistence of savings.

Thus, if facility personnel report no significant changes in abatement burn boxes' gas consumption, gas usage (excluding usage of space heating) will be normalized with respect to production, depending on the availability of production data. Reasonable conclusions could be made if the normalized gas consumption is relatively constant before and after the retrofit. According to the facility personnel, the pre-retrofit equipment ran for five days in 2006 and two days in 2007 as an emergency backup. The energy use by this equipment will be accounted for while normalizing the energy usage with production.

Preliminary indications show that billing analysis may yield 55% of the ex ante savings. The reasons for this discrepancy will be discovered if billing analysis is used.

Increased electrical consumption will be calculated in the same manner as the ex ante calculations and applied as an offset to the decreased gas usage.

If definite conclusions can not be made through the above methodology, pre-retrofit and post-retrofit calculations of energy use will be calculated using the following formulae:

Gas savings = $(\text{BurnerRatings}_{pre} \times \text{percent of full load}_{pre} - \text{BurnerRatings}_{post} \times \text{percent of full load}_{post}) \times 8{,}760$ hours / year

Fan kWh savings = $(kW_{pre} - kW_{post}) \times 8{,}760$

In this case, the formulae used in developing the ex ante calculations will be used.

The following data must be gathered or made available during the site visit.

- Burner ratings and fan ratings on pre-retrofit equipment
- Burner ratings and run hours for the two boilers and three abatement burn boxes
- Any significant changes in the abatement burn boxes' energy consumption (due to changes in efficiency or run hours, for several months before and after the retrofit)
- Production data for several months before and after the retrofit (minimum of the quarter before, during, and after the retrofit)
- Burner ratings and fan ratings of the post-retrofit equipment

- One-time power measurement of fan motors for post-retrofit equipment
- Temperature data need to be measured at various points (if and where possible) to check if the equipment is operating to design intent
- Flow data are also preferred but not likely to be a feasible measurement and will be determined by equipment instrumentation
- Historical temperature and flow rate profiles (if monitored and recorded)
- Specifications for pre-retrofit and post-retrofit equipment
- Dates when the pre-retrofit equipment was used as a backup system and determine if it was used as a backup or in addition to the Munters system
- Exact date retrofit

There may be a potential source of error from estimating energy usages based on the nameplate ratings. However, these estimations will be verified with the actual utility bills for major deviations or anomalies. All data collected will be reviewed to ensure that they conform to realistic values, and will be cross-verified with other collected data to identify any anomalies.

Uncertainty for the savings estimate can be more fully understood by setting projected ranges on the primary variables.

Flow

- pre-retrofit expected 3,200 scfm, + 20% / - 20%
- post-retrofit expected 500 scfm, + 20% / - 20%

Energy use by Process

- pre and post retrofit losses 10%, +30% / - 30%

Temperature

- pre-retrofit expected temperatures 1,150 °F, + 10 F or 2% / - 2%
- post-retrofit expected temperatures 1,375 °F, + 10 F or 2% / - 2%

Accuracy and Equipment

Uncertainty with utility billings

- therms: 315,093 expected; 312,000 therms minimum; 318,000 therms maximum (+ / - 1% for utility metering)

The utility meters capture monthly data. For the purposes of the evaluation, the meters are considered to be 99% - 100% accurate where reviewed data are deemed reasonable. Customer data will be regarded to have an accuracy of +/- 5%.

All data collected will be reviewed to ensure they conform to realistic values, and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 26, 2007. Information on pre-retrofit equipment was gathered from the equipment nameplates. Information on post-retrofit equipment and operating conditions was collected from the equipment panel.

Installation Verification

During the on-site visit, the installation and operation of the Munters Thermal Oxidizer was confirmed. The unit as shown in Exhibit 1 is operational for 8,760 hours throughout the year. The pre-retrofit equipment remains in place but is redundant, and used only as an emergency backup. According to the facility personnel, the Munters Thermal Oxidizer was installed on May 9, 2005. Since then, the pre-retrofit equipment was turned on as an emergency backup for five days during 2006 and two days during 2007. The exact dates during which the pre-retrofit equipment was on were not determined; however facility personnel mentioned that the unit did not run the entire day.

This is the only measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
VOC Abatement Retrofit	Natural Gas			Replace VOC Abatement Equipment	1	Hydrophobic zeolite concentrator and recuperative thermal oxidizer	Physically verified operation of the new system	1.0

Scope of the Impact Assessment

The impact assessment scope is for the natural gas and electric measures in the SPC application.

Summary of Results

The ex post savings estimations were performed using two approaches: Utility Bill Analysis and Burner/ Fan Rating Analysis. Neither of the approaches confirmed the ex ante savings in the application document.

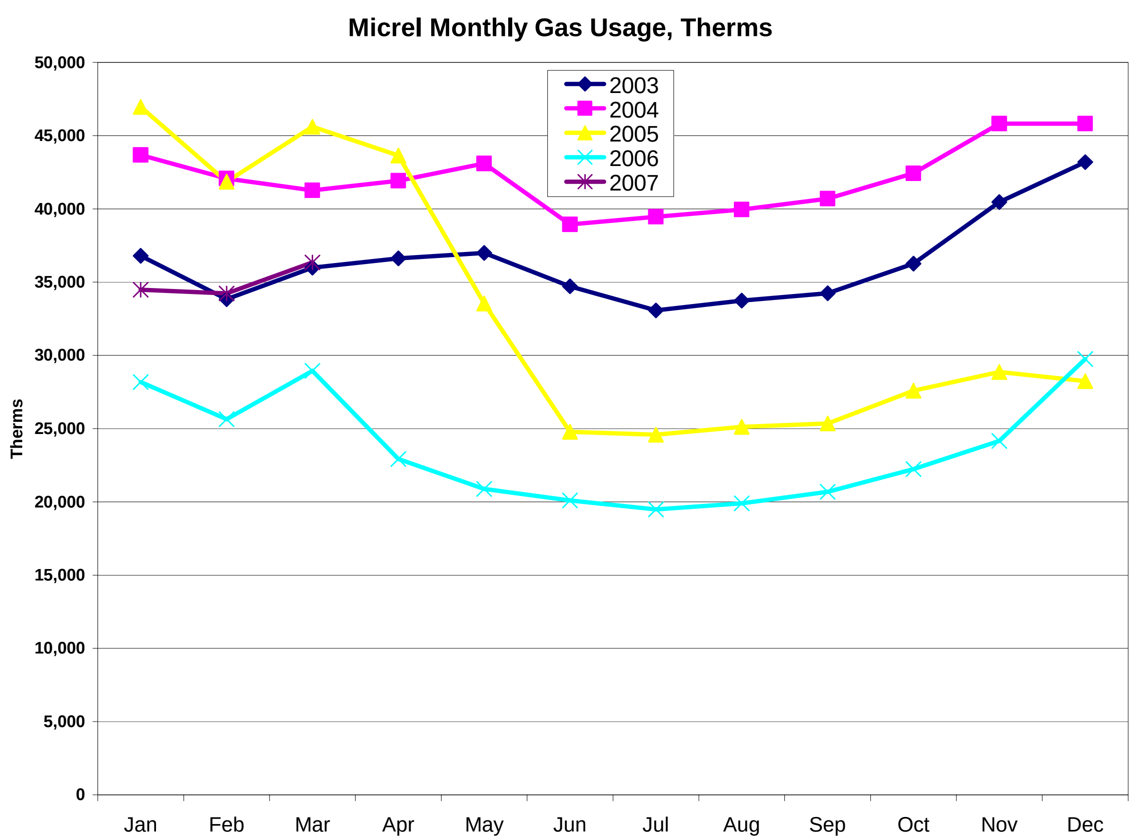
Utility Bill Analysis

The facility has three types of natural gas consuming equipment: a Thermal Oxidizer (1.155 MMBtu/hr), two boilers rated at 5 MMBtu/hr (Input) and 4 MMBtu/hr (Output), and three abatement burn boxes (total rating of 0.1 MMBtu/hr). The equipment is not sub-metered and thus the utility billing data represent energy consumption in all the above equipment.

The boilers produce hot water to maintain set point space temperatures in the fabrication area. The boilers may primarily be considered as space heating boilers; their energy usage is also a function of outside air temperature (heating degree days).

Thus the overall gas usage in the pre-retrofit and post-retrofit equipment is a function of production (number of masks) and the weather (heating degree days). The monthly gas usage for the pre-retrofit and post-retrofit period (Jan 2003 thru April 2005 and June 2005 thru March 2007) is shown in Figure 1.

Figure 1: Monthly gas Usage



Neglecting the changes in gas usage due to weather, as seen in Figure 2 and 3, the gas energy consumed per unit mask is inversely proportional to the number of masks produced.

Figure 2: Monthly Normalized Gas Usage and Production

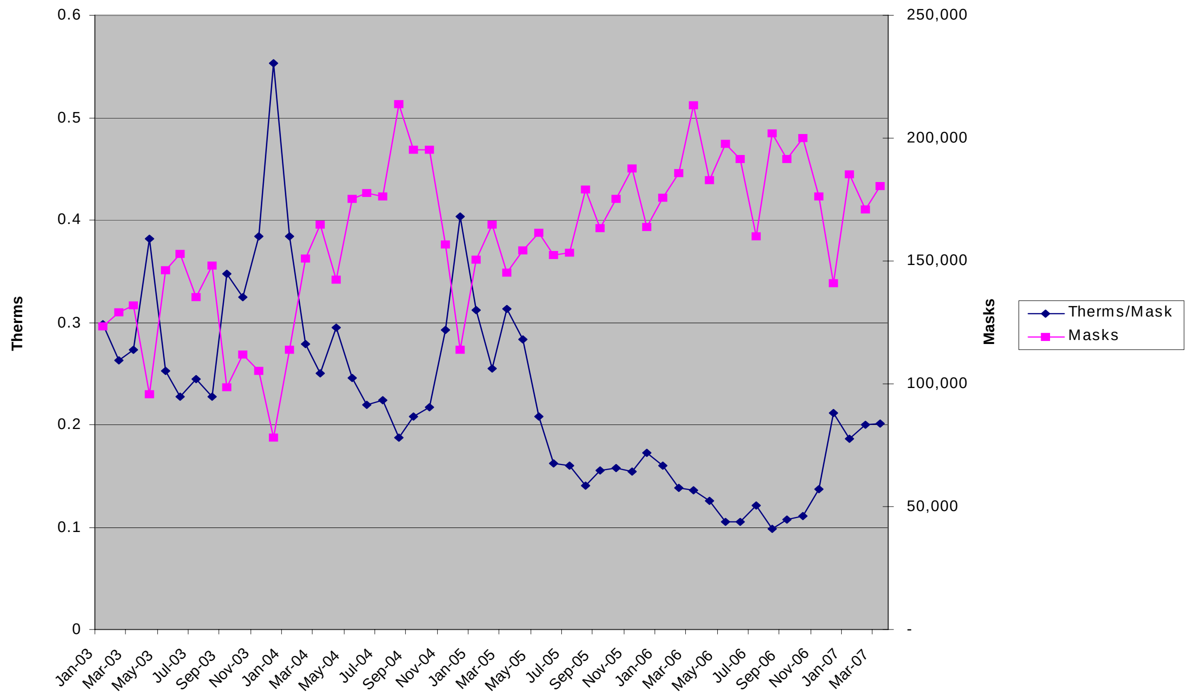
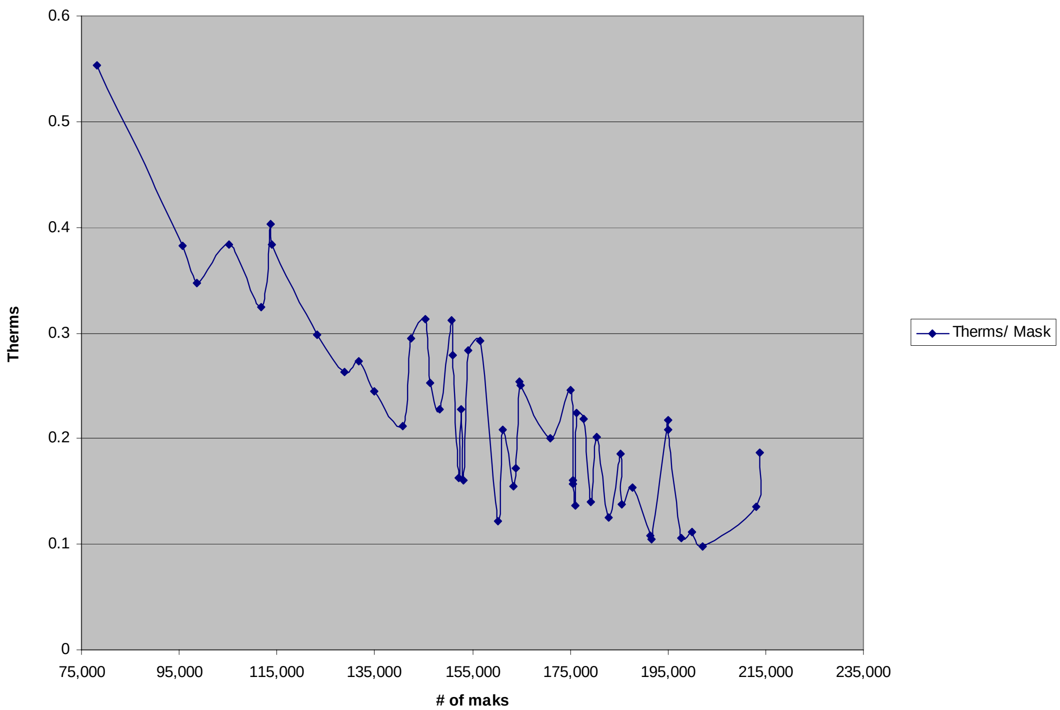


Figure 3: Monthly Normalized Gas Usage and Production



A regression equation is set up as shown below to account for the production and weather effects on monthly gas usage.

$G_t = \alpha_0 + \beta_1 PD_t + \beta_2 HDD_t$

$\beta_1 = \beta_{10} - \beta_{11} POST$

Thus,
$G_t = \alpha_0 + \beta_{10} PD_t - \beta_{11} POST\ PD_t + \beta_2 HDD_t$

Where,
G_t = monthly Gas used in therms from month t
α_0 = regression intercept
β_{10} = regression coefficient for PD_t
PD_t = monthly production data (masks) for month t
β_{11} = regression coefficient for POST PD_t
POST = 0 for pre-retrofit data
POST = 1 for post-retrofit data
β_2 = regression coefficient for HDD
HDD_t = monthly heating degree days base 65 F for the pre-retrofit and post-retrofit period, for month t. Actual weather data was obtained from weatherunderground.com for the period from January 2003 thru March 2007 based on average daily temperatures.

The results of the regression analysis are shown in Table 2.

Table 2: Regression Results

Regression Statistics	
Multiple R	0.9270113
R Square	0.85934994
Adjusted R Square	0.85017711
Standard Error	3200.20633
Observations	50

	Coefficients
α_0	26857.8527
β_{10}	0.06425101
β_{11}	0.0893273
β_2	19.0057604

For the post-retrofit period, $\beta_{11}*PD_t$ is the monthly gas savings due to the measure as shown in Exhibit 6.

Table 3: Monthly Gas Savings

Month	β_{11}	PD_t	Gas Savings
6/1/2005	0.089327308	152,306	13,605.09
7/1/2005	0.089327308	153,169	13,682.17
8/1/2005	0.089327308	179,238	16,010.85
9/1/2005	0.089327308	163,466	14,601.98
10/1/2005	0.089327308	175,470	15,674.26
11/1/2005	0.089327308	187,645	16,761.82
12/1/2005	0.089327308	163,816	14,633.24
1/1/2006	0.089327308	175,690	15,693.91
2/1/2006	0.089327308	185,638	16,582.54
3/1/2006	0.089327308	213,099	19,035.56
4/1/2006	0.089327308	183,006	16,347.43
5/1/2006	0.089327308	197,723	17,662.06
6/1/2006	0.089327308	191,579	17,113.24
7/1/2006	0.089327308	160,156	14,306.30
8/1/2006	0.089327308	202,069	18,050.28
9/1/2006	0.089327308	191,477	17,104.13
10/1/2006	0.089327308	200,046	17,869.57
11/1/2006	0.089327308	176,176	15,737.33
12/1/2006	0.089327308	140,761	12,573.80
1/1/2007	0.089327308	185,308	16,553.06
2/1/2007	0.089327308	171,073	15,281.49
3/1/2007	0.089327308	180,456	16,119.65

From Table 3, the average monthly savings is 15,955 therms/month. Thus the yearly natural gas savings is estimated at 191,500 therms. The uncertainty is +-10%, as determined from the standard deviation of the monthly savings. For the period from June

2005 thru May 2006 (annual period immediately after the retrofit), the savings was 190,300 therms.

Burner/ Fan Rating Analysis

Burner Rating Analysis

During the site visit, the serial number of the Eclipse Winnox burner was gathered. Using this information, it was determined that the burner is rated at 1.155 MMBtu/hr for a chamber pressure of 2" w.c. However, Munters technical support personnel confirmed that the burners are oversized to bring the oxidation temperature to 1,375 F quickly; in steady state conditions, the burner would use gas at a rate of 0.51 MMBtu/hr as estimated in the application documentation. The burner rating for the pre-retrofit equipment is 2.7 MMBtu/hr (confirmed during site visit).

The ex post impacts are calculated as follows:

a) Pre-retrofit hours of operation were 8,760 hrs/yr
Pre-retrofit burner rating = 2.7 MMBtu/hr
Annual gas usage was 2.7 MMBtu/hr x 8,760 hrs/yr = 23,650 MMBtu/yr (236,500 therms/yr)

b) Post-retrofit hours of operation are 8,760 hrs/year.
Steady-state post-retrofit burner rating = 0.51 MMBtu/hr
Annual gas usage is 0.51 MMBtu/hr x 8,760 hrs/yr = 4,468 MMBtu/yr (44,680 therms/yr)

c) The resulting annual gas savings is 236,500 therms/yr – 44,680 therms/yr = 191,820 therms/yr.

Fan Rating Analysis

The ex ante savings were estimated with a total fan rating (process, oxidation, cooling and combustion) of 12.6 kW for the post retrofit equipment. During the site visit, only the nameplate data of the combustion fan (which is rated at 3.06 hp) could be gathered. Also, during the site visit, the combustion and oxidation fans were found to be operating at 25" w.c., rather than 10" w.c. and 16" w.c. respectively, according to the ex ante estimations. Assuming steady state operating conditions, a total rating of 14 kW (based on individual fan ratings totaling to 19 BHP) according to vendor estimations was used for ex post savings estimation. The total fan rating (process and combustion) for the pre-retrofit equipment is 7 hp (as confirmed during site visit). A load factor of 0.8 and motor efficiency of 0.78 is assumed for estimation purposes.

The ex post impacts are calculated as follows:

a) Pre-retrofit hours of operation were 8,760 hrs/yr
Pre-retrofit total fan rating = 7 hp
Annual electric usage was (7 hp x 0.8 x 0.746 kW/hp x 8,760 hrs/yr)/ 0.78 = 46,900 kWh/yr

10 kWh = 1 therm equivalent

Thus 46,900 kWh/yr = 4,690 therms/yr

b) Post-retrofit hours of operation are 8,760 hrs/yr.
Steady-state post-retrofit total fan rating = 14 kW
Annual electric usage is 14 kW x 8,760 hrs/yr = 122,640 kWh/yr (12,264 therms/yr)

c) The resulting annual electric savings is 46,900 kWh/yr – 122,640 kWh/yr = -75,740 kWh/yr.

10 kWh = 1 therm equivalent

Thus -75,740 kWh/yr = -7,574 therms/yr

6. Additional Evaluation Findings

The ex post gas savings do not confirm the ex ante savings with either of the approaches discussed in Section 5. This is because the ex ante savings seem to have been estimated with a burner rating of 4.2 MMBtu/hr for the pre-retrofit equipment. During the site visit, it was confirmed that the equipment was rated only at 2.7 MMBtu/hr.

Facility personnel also mentioned that an additional abatement burn box was installed during April 2005. The burn boxes consume 16.5 lpm of gas each, equivalent to a total burner rating of 0.1 MMBtu/hr for all the three boxes.

The normalized gas usage (therms/mask) is a function of production (masks) and the weather (heating degree days). The normalized gas usage is inversely proportional to production due to the following:

- Higher production results in higher VOC emissions that contribute to heat and lower gas consumption
- Economy of scale

With a cost of $821,804 and a $300,000 incentive, the project had a 3.3 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 5.7 years. A summary of the economic parameters for the project is shown in Exhibit 8.

However, facility personnel mentioned that the facility's operation is expanding, and they were planning for the upgrade of the VOC abatement system to meet increased production requirements. This was the reason for purchasing new 8,000 scfm equipment to replace the old 3,200 scfm equipment. Facility personnel also mentioned that the old unit was over 15 years old, and has been rebuilt several times. The cost of the measure seems to be reasonable and other energy efficiency measures have been implemented after this measure, particularly an air handling unit replacement with utility involvement. It was noted the company always buys energy efficient products and has a high environmental awareness.

7. Impact Results

The engineering realization rate for this application is 0.61 for gas savings and cannot be computed for electric savings (since tracking system savings are zero). The overall realization rate is 0.61. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 4.

Table 4: Realization Rate Summary

	Gas (Therms/yr)	Electric (kWh/yr)
SPC Tracking System	315,093	0
SPC Installation Report (ex ante)	315,093	0
Impact Evaluation (ex post)	191,820	-75,740
Engineering Realization Rate	0.61	NA

With a cost of $821,804 and a $300,000 incentive the project had a 2.1 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 3.6 years. A summary of the economic parameters for the project is shown in Table 5 and the savings over the life of the equipment is shown in Table 6.

Table 5: Economic Information

Description	Date	Project Cost	Estimated Gas Savings, Therms	Estimated Electric Savings, kWh	Estimated Net Savings ($0.8/Therm) Gas, ($0.13/kWh) Elec	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	11/10/2004	$821,804	315,093	0	$252,074	$300,000	2.07	3.26
SPC Program Review (Ex Post)	9/26/2007	$821,804	191,820	-75,740	$143,610	$300,000	3.63	5.72

Table 6: Multi-Year Reporting Table

Program ID:		001 Application # A035					
Program Name:		**SPC 04-05 Evaluation**					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected kWh Savings**	**Ex-Post Gross Evaluation Confirmed kWh Savings**	**Ex-Ante Gross Program-Projected Peak kW Savings**	**Ex-Post Gross Evaluation Confirmed kW Savings**	**Ex-Ante Gross Program-Projected Therm Savings**	**Ex-Post Gross Evaluation Confirmed Therm Savings**
1	2004						
2	2005	-	(47,338)			196,933	119,888
3	2006	-	(75,740)			315,093	191,820
4	2007	-	(75,740)			315,093	191,820
5	2008	-	(75,740)			315,093	191,820
6	2009	-	(75,740)			315,093	191,820
7	2010	-	(75,740)			315,093	191,820
8	2011	-	(75,740)			315,093	191,820
9	2012	-	(75,740)			315,093	191,820
10	2013	-	(75,740)			315,093	191,820
11	2014	-	(75,740)			315,093	191,820
12	2015	-	(75,740)			315,093	191,820
13	2016	-	(75,740)			315,093	191,820
14	2017	-	(75,740)			315,093	191,820
15	2018	-	(75,740)			315,093	191,820
16	2019	-	(75,740)			315,093	191,820
17	2020	-	(28,403)			118,160	71,933
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	**-**	**(1,136,100)**			**4,726,395**	**2,877,300**

Since the pre-retrofit equipment is more than 15 years old and has been rebuilt several times, an analysis was performed assuming that the pre-retrofit equipment was replaced with an equipment of current energy efficiency standards. Such VOC abatement equipment is a catalytic oxidizer that works on a different principle than the Munters unit. While procuring the Munters system, the customer has also looked into the option of installing catalytic oxidizers. It is estimated that catalytic oxidizers would consume about 2.5 MMBtu/hr of gas to process 8,000 cfm of VOC-laden air and require process and combustion fans of a rating of 16 kW. Using this data, the savings achieved by Munters system over the catalytic oxidizers is summarized in Table 7 below.

Note that if this equipment is accepted as baseline, the savings would be substantially less than forecast. Actual savings would be on the order of 10% of ex ante savings. However, the unit was not in need of being replaced and may have lasted considerable longer.

Table 7: Multi-Year Standard Practice Reporting Table

Program ID:		001 Application # A035					
Program Name:		**SPC 04-05 Evaluation**					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected kWh Savings**	**Ex-Post Gross Evaluation Confirmed kWh Savings**	**Ex-Ante Gross Program-Projected Peak kW Savings**	**Ex-Post Gross Evaluation Confirmed kW Savings**	**Ex-Ante Gross Program-Projected Therm Savings**	**Ex-Post Gross Evaluation Confirmed Therm Savings**
1							
2	2005	-	10,950			196,933	108,953
3	2006	-	17,520			315,093	174,324
4	2007	-	17,520			315,093	174,324
5	2008	-	17,520			315,093	174,324
6	2009	-	17,520			315,093	174,324
7	2010	-	17,520			315,093	174,324
8	2011	-	17,520			315,093	174,324
9	2012	-	17,520			315,093	174,324
10	2013	-	17,520			315,093	174,324
11	2014	-	17,520			315,093	174,324
12	2015	-	17,520			315,093	174,324
13	2016	-	17,520			315,093	174,324
14	2017	-	17,520			315,093	174,324
15	2018	-	17,520			315,093	174,324
16	2019	-	17,520			315,093	174,324
17	2020	-	6,570			118,160	65,372
18	2021						
19	2022						
20	2023						
TOTAL	**2003-2024**	**-**	**262,800**			**4,726,395**	**2,614,860**

Final Site Report

SITE A036 (2K5-L-457) Darl IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 3 END USE: Gas

Measure	Thermal Oxidizer Replacement
Site Description	Food Processing Byproduct Recycler

1. Measure Description

This project involves the replacement of a 16.2 MMBtu/hr thermal oxidizer with a 3 MMBtu/hr regenerative thermal oxidizer (RTO). Thermal oxidizers are used for VOC abatement of process released exhaust gases.

2. Summary of Calculations

The customer submitted calculations based upon equipment operation as described in this section. There were a number of variables that entered into these calculations.

However, ex ante savings approved by the utility were limited to 125,247 therms, determined through billing analysis adjusted for production.

As described above, the facility replaced a 16.2 MCF/hr thermal oxidizer with a 3.0 MCF/hr regenerative thermal oxidizer. Hot exhaust gases from the boiler were captured by the original thermal oxidizer and used to generate steam. However, the new RTO has internal regeneration capability and releases approximately 200^o F gas, which is insufficient for generating steam. The customer estimated that the waste heat boiler has 9,461 lbs/hr of steam generation capability, and that 1.2 cubic feet of natural gas is required to produce 1 pound of steam (80% boiler efficiency). Operational hours are estimated to be 7,488 hrs. The calculation results are presented in Table 1.

Table 1: Measure Savings Calculations

Unit	Unit Rating	Estimated Use (MCF/hr)	Hours/yr	Energy (Therms)
Thermal Oxidizer (TO)	16.2 MCF/hr	15.5 MCF/hr	7,488	1,160,640
Regenerative Thermal Oxidizer (RTO)	3.0 MCF/hr	1.27 MCF/hr	7,488	-95,098
Waste Heat Boiler	9,461 lbs/hr	11.3532 MCF/hr	7,488	-850,128
Savings				215,414

The customer determined the waste heat boiler capacity based on calculations from the system manufacturer. The details are as follows:

Heat available to boiler (Q) = $m_w \times C_p \times \Delta T$ / Heat Available
where m_w = mass flow rate of the waste steam, 40,712 lbs/hr (~ 10,000 scfm at 125 ^{o}F‡)
C_p = Constant pressure specific heat of waste steam, 0.26 Btu/lb- ^{o}F

‡ m_w = (10,000 scfm) * (0.06785 lb/cu ft)*(60 min/hr) ~ 40,712
Density of air at 125 F ~ 0.06785 lb/cu ft

$\Delta T = (1400\ ^oF - 125\ ^oF) = 1275\ ^oF$
Heat available = Heat Available to heat the mass in thermal oxidizer, assumed 95 percent with a given range of 90% to 95%
$Q = (40{,}712\ lbs/hr) \times (0.26\ Btu/lb\text{-}^oF) \times (1{,}275\ ^oF) / (0.95)$
$= 14{,}206{,}345\ Btu/hr$

Assuming that the boiler is 65% efficient[§], and that boiler heat recovery (Q_b) is calculated as:

$Q_b = Q \times 0.65 = 9{,}234{,}124\ Btu/hr$ (saturated steam, 140 psig and 250 ^oF[**])

The boiler steam capacity, m_s, in lbs/hr, is estimated as:

$$m_s = Q_b / (h_g - h_f)$$

where h_g = Latent heat at 140 psi operating pressure, 1,194.6 Btu/lb
h_f = Feed water enthalpy at 250 ^oF, 218.59 Btu/lb

$m_s = (9{,}234{,}124\ Btu/hr) / (1{,}194.6\ Btu/lb - 218.59\ Btu/lb)$
$= 9{,}461\ lbs/hr$ (saturated steam at 140 psig)

Boiler Energy = 9,461 lbs/hr × 1.20 CF nat. gas/lb steam × 7,488 hrs/yr × 0.01 Therms/CF
= 850,128 Therms

The customer calculated the net savings as:

Savings = 1,160,640 Therms/yr – 95,098 Therms/yr - 850,128 Therms/yr
= 215, 414 Therms/yr

The savings calculated originally by this method were 215,420 Therms/yr. It is noted that the utility requested correction of the first submittal from the customer. The annual savings were first submitted as 1,246,548 therms, which did not take into account the value of the steam generated through the waste heat recovery boiler.

The ex ante savings were reduced by the utility to 125,247 therms, through billing analysis adjusted for production. This is listed in the utility tracking system and in the Installation Report Review (IRR).

3. Comments on the Ex Ante Calculations

The estimated use values of pre and post equipment used in customer's calculations. Table 1 could not be verified from the site visit. Based on the discussions with the customer, it is inferred that these values seem to be reasonable. Operational hours and

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[§] Estimated value based on boiler vendor information
[**] Estimated values based on boiler vendor information

load ratings of oxidizers used in the calculations for pre and post installations need to be verified.

However, if 90% verses 95% was used as the heat available, the savings would decrease by 47,229 therms per year. Additionally, the efficiency of the waste heat recovery boiler could be approximated at 70%, and this would decrease savings by an additional 69,027 therms per year. These changes would cause the customers submitted calculated savings to decrease to 99, 157 therms per year.

PG&E calculated the post installation savings using the production normalized billing data for three months; May to July, during 2005. The savings are 125,247 therms/yr. This could be expanded if billing analysis is utilized for ex post savings. Production quantities need to be obtained and compared to update this estimate.

After reviewing the documentation, based on data available during the pre-installation period, both the customer and the utility assumptions and estimations in the application are reasonable. However, billing analysis may produce a better estimation based on the inability to accurately ascertain the pre retrofit variables for the waste heat recovery boiler.

4. Measurement & Verification Plan

The participant operates a plant that recycles food byproducts. The operation is on an 80 acre site and the main operation buildings are reported to be 60 years old.

According to the application documents, the thermal oxidizer in a VOC abatement process was replaced with an energy efficient regenerative thermal oxidizer. The new unit recovers the heat from the oxidation process more efficiently through an internal regeneration process, and thus saves energy at the facility. According to the facility representative, the new thermal oxidizer runs the same amount of time annually as the pre retrofit thermal oxidizer (7,488 hours a year).

The goal of the M&V plan is to estimate the actual annual gas savings realized with the measure, in order to compare this savings with the initial estimations.

Formulae and Approach

There are two potential approaches to calculate this measure's energy savings. The first approach, a modified version of IPMVP option A (partially measured retrofit isolation), determines the true savings by determining the difference in temperature between the heat going up the old oxidizer's stack to that of the new unit. The second approach, IPMVP option C, determines the savings by analyzing production normalized billed data.

For the first approach, heat savings (Q) are calculated using the following formulae:

$$Q = M1 \times C_p \times T1 - M2 \times C_p \times T2$$

Where:

M1 = Pre retrofit thermal oxidizer flue gas flow rate, lbs/hr
C_p = Specific heat of flue gas
T1 = Pre retrofit thermal oxidizer's exhaust temperature, ^oF
M2 = Post retrofit regenerative thermal oxidizer flue gas flow rate, lbs/hr
T2 = Post retrofit regenerative thermal oxidizer's exhaust temperature, ^oF

This plan requires that the facility has the old and new thermal oxidizer stack flue gases composition and exhaust temperature data available, and also has data on the natural gas flow rate through the burners.

The following data needs to be gathered or made available during the site visit:

- Burner ratings for the old and new oxidizers
- Production data for several months before and after equipment retrofit (minimum 3 months of the year during pre and post installations.
- Stack flue gas composition and exhaust temperature data, for both the old and new equipment
- Thermal oxidizer operational hours
- Historical flow rate, and flue gas and stack exhaust temperature profiles (if monitored and recorded)
- Specifications of the old oxidizer, the old waste heat boiler, and the new regenerative thermal oxidizer equipment

The second approach will be used if the flue gas composition details for the old and new oxidizers are not available. This method incorporates the pre and post installation production hours based on information from the facility and normalizes the utility natural gas billing data according to this production data.

Uncertainty is estimated as follows:

Average annual value of flue gas flow rate, lbs/hr: 10,000 scfm expected, +/- 20%
Average T1 = Pre retrofit thermal oxidizer's exhaust temperature: 400 ^oF expected, +/- 40 ^oF
Average T2 = Post retrofit thermal oxidizer's exhaust temperature: 100 ^oF expected, +/- 10 ^oF

Accuracy and Equipment

Uncertainty with utility billings

- therms: 125,247 expected; 123,000 therms minimum; 128,000 therms maximum (+ / - 1% for utility metering)

The utility meters capture monthly data. For the purposes of the evaluation, these meters are considered to be between 99% and 100% accurate, where reviewed data are deemed reasonable.

Customer data and data from instrumentation provided will be regarded to have an accuracy of +/- 5%.

All data collected will be reviewed to ensure it conforms to realistic values, and will be cross-verified with other data collected to identify any anomalies. Outliers and other suspicious elements within the data set will be scrutinized and removed from the analysis where appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 26, 2007. Information on the retrofit equipment and its operating conditions was collected by inspection of the equipment and by interviewing the facility representative.

Installation Verification

The use of the old and new thermal oxidizers at the site was physically verified; their ratings were observed to be 16.2 MCF/hr and 3.0 MCF/hr, respectively. The old oxidizer unit was not in use, and had been disconnected. The facility representative stated that the new oxidizer was in operation the entire month of June 2005. At that time, the old oxidizer was removed from service.

These are the only measures in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 2.

Table 2: Installation Verification Summary

Measure Description	End Use Category	Equipment Description	Quantity	Installation Verified	Verification Realization Rate
Thermal Oxidizer Replacement	Natural Gas	Replace 16.2 MCF/hr Thermal Oxidizer with 3.0 MCF/hr Regenerative Thermal Oxidizer	1.0	Physically verified the equipment installation	1.0

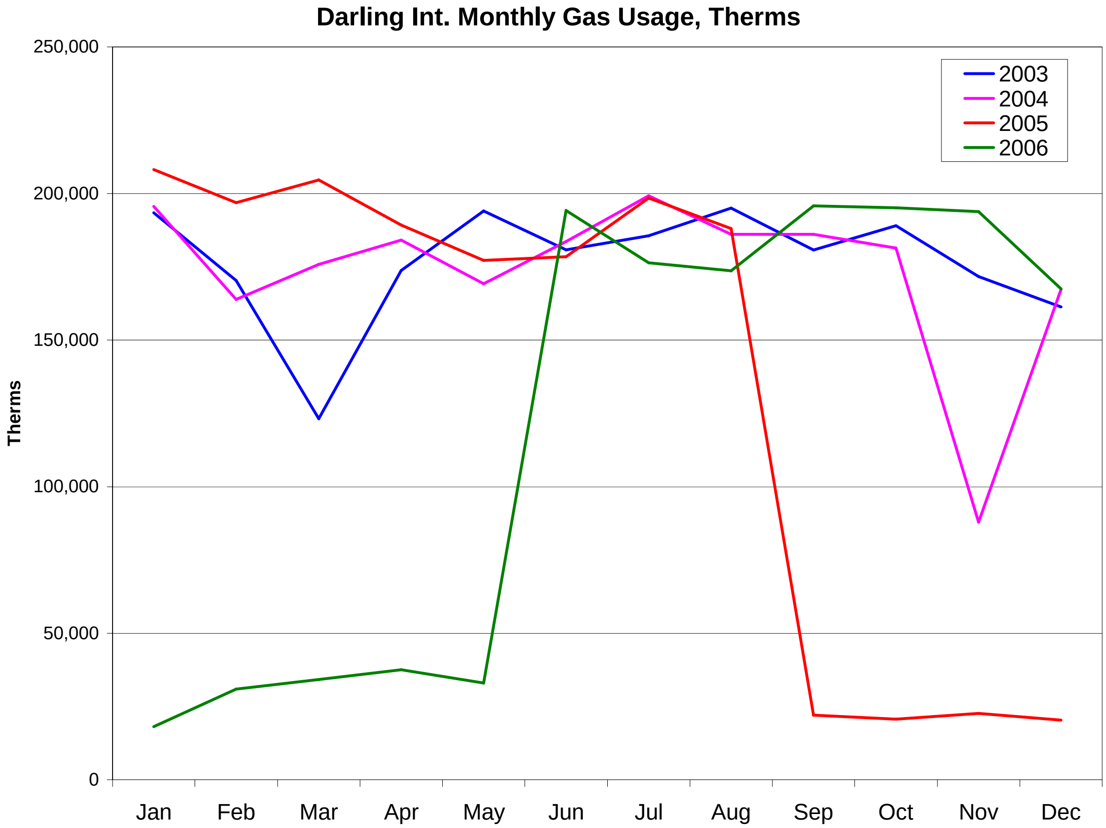
Scope of the Impact Assessment

The impact assessment scope is for the natural gas end use measure in the SPC application. This a the only measure in this application.

Summary of Results

Since there was no in situ equipment to measure the flue gases of the new oxidizer, and the facility does not have any records of flue gas composition, production based normalized billed data will be used for measure savings verification. Figure 1 presents four years of natural gas metered billing data. The meter is read on the last day of each month.

Figure 1: Monthly Gas Usage



The facility representative stated that the new oxidizer, boiler and feather drier use natural gas fuel. He also said that the boiler has the option of burning yellow grease fuel, and that the facility will use yellow grease as fuel whenever the natural gas selling price exceeds the yellow grease price. However, thus far, the old and new oxidizers and feather dryers used natural gas fuel.

It is not possible to measure the gas consumption of individual equipment, since the units do not have separate metering devices. Since there are no changes in the operation schedules of the boiler, new oxidizer, and feather dryer throughout the year, it is estimated that changes in the production-based normalized billed data will reflect the new oxidizer unit's energy efficiency savings. The facility does not have any information about the heating value of yellow grease. Hence, operational hour data for the new oxidizer unit was collected from the customer logs during the period when the entire system (boiler, thermal oxidizer, and feather dryer) was fueled by natural gas (June '06, July '06, and August '06). Access to 2004 logs, for comparison of pre retrofit energy usage was not available. Therefore, August data could not be used in the calculations. Previous utility calculations provided the production hour data for May, June and July of 2004 and 2005. The production hours data are presented in Table 3. The new oxidizer has operated since May 11, 2005 and operated 21 days in May 2005.

Table 3: Production Hours and Gas Consumption Data

Month	Production Hours			Natural Gas Usage (Therms)		
	2004	2005	2006	2004	2005	2006
May	501*	541.5*		169,238*	177,194*	
June	646	688.5	720	183,653	178,441	194,217
July	551	574	545	199,207	198,492	176,438

* New oxidizer unit started operation on May 11, 2005

Table 4: Natural Gas Reduction with Energy Efficient Oxidizer

Month	Gas Usage in 2004 (Therms)	Gas Usage in 2005/2006 (Therms)	Normalized Gas Baseline Usage (Therms)	Monthly Gas Reduction (Therms)	% Gas Reduction	Projected Annual Gas Reduction (Therms)
May (04 vs 05)	169,238*	177,194*	182,919*	5,725*	3.13%*	99,504
June (04 vs 05)	183,563	178,441	195,640	17,199	8.79%	209,249
July (04 vs 05)	199,207	198,492	207,522	9,030	4.35%	106,325
June (04 vs 06)	183,563	194,217	204,590	10,373	5.07%	126,209
July (04 vs 06)	199,207	176,438	197,038	20,600	10.46%	242,546
Average Savings						**156,767**

* New oxidizer unit started operation on May 11, 2005

The ex post impacts are calculated as follows:

As per the customer logs, the old oxidizer operated for 646 hours in June 2004, and the new oxidizer unit operated for 688.5 hours in June 2005. The oxidizer unit operational hours presented in Table 4 are full calendar days for applicable months except May 2005. May 2005 records show 21 days of operation for the new oxidizer. The natural gas usage in 2005 is normalized with the increased production in 2005 compared to 2004. June data is used as an example below to show Table 4 calculations.

Normalized Gas Usage in June 2005 = Production Hrs in June 2005 / Production Hrs in June 2004 × Gas Usage (GU) in June 2004
= 688.5/646 × 183,563 Therms
= 195,640 Therms

Gas Reduction in June 2005 = Normalized Baseline Gas Usage (NGU) in June 2005 – GU in June 2005
= 195,640 Therms – 178,441Therms
= 17,199 Therms

% of Gas Reduction = (NGU-GU)/NGU
= (195,640 Therms -178,441Therms)/ (195,640 Therms)
= 8.79 %

Projected Annual Gas Reduction = Gas Reduction in June 2005 × 365 / Number of Days in June 2005
= 17,198.51 Therms × 365days / 30 days
= 209,249 Therms/yr

A similar procedure was used to calculate the gas reduction for other months mentioned in Table 5, and also to estimate gas reduction for a full year. The average annual gas reduction value is determined to be 156,767 Therms, according to the above calculations. The uncertainty is estimated at +/- 10% based on the standard deviation of the monthly savings values.

Ex Ante Savings = 125,247 therms

Ex Post Savings = 156,767 therms (from Table 4)

The uncertainty for this application is detailed in the uncertainty summary below (Table 5).

Table 5: Uncertainty Summary

Input/Output Variable	Expected Value	Low Value	High Value	Type of Distribution
Hours	7,800	7,410	8,190	Normal Distribution
Therms saved	156,767	148,929	164,605	Normal Distribution

6. Additional Evaluation Findings

The previous thermal oxidizer unit has a 75 HP fan, whereas new unit has a 60 HP fan. The facility only has a gas account and electricity is provided by the municipal utility districts. Since the municipal utility electricity does not come under SPC evaluation, the electrical savings are not quantified here. However, at a heat rate of 10,000 Btu/kWh, annual gas usage to generate this increased amount of electricity is approximately 8,500 therms per year.

Additional months of production data during and periods when yellow tallow was not used as fuel would improve the level of this analysis.

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project, and is an accurate reflection of the project cost. In addition to saving energy, the benefits of the project are reduced odor levels and reduced emissions. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program has not encouraged them to perform any other energy efficiency projects for which they did not participate in an incentive program.

It was not possible to physically verify the pre retrofit oxidizer and waste heat recovery boiler, including obtaining actual gas flow ratings and hours of operation. However, the oxidizers operating hours were obtained from customer logs. These parameters have been accurately assessed. Equipment is uniformly operated for the pre and post periods, and this was quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measure.

7. Impact Results

The engineering realization rate for this application is 1.25 for natural gas reduction. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 6.

Table 6: Realization Rate Summary

	Therms
SPC Tracking System	125,247
SPC Installation Report (Ex Ante)	125,247
Impact Evaluation (Ex Post)	156,767
Engineering Realization Rate	1.25

Utility billing data for the site was reviewed. The facility consumed 2,080,899 therms in 2004. The facility fueled the boiler with yellow grease for a few months, September 2005 to May 2006. The yellow grease usage data and its heating value is not available from the site. Hence, the annual natural gas usage for 2005 and 2006 has been estimated, based on the monthly production hours and natural gas usage data from May through July of each year. The projected average annual gas consumption, normalized with respect to production in 2005 and 2006, is estimated to be 2,405,661 therms. A breakdown of these estimates is provided in Table 7 followed by a sample calculation for June 2005.

Table 7: Estimation of 2005/2006 Natural Gas Usage Based on Production

Month	Gas Usage (Therms)	Projected Annual Gas Usage (Therms)
May 05	177,194	3,079,800
June 05	178,441	2,171,032
July 05	198,492	2,337,083
June 06	194,217	2,362,974
July 06	176,438	2,077,415
Average Projected Natural Gas Usage for 2005 & 2006*		**2,405,661**

* If only natural gas used

Data from June 2005 are used as an example below to show Table 7 calculations.

Annual Projected Gas Usage based on June 2005 = Gas Usage in June 05 × 365/ Number of days in June 05
= 178,441 Therms × 365 / 30
= 2,171,032 Therms

Similarly, natural gas usage data from the other months are projected to estimate annual gas usage, as shown in Table 7, above. The average annual gas usage presented in Table 8 is assumed as the ex post projected annual natural gas usage.

The total meter usage of the facility in 2004 = 2,080,299 therms (PG&E meter)

The projected average annual total meter usage of 2005 and 2006 would equal 2,405,661 therms if yellow grease was not used as a fuel.

Table 8 summarizes the total metered use, the baseline end use energy, the ex ante savings, and the ex post calculation results.

Table 8: Total Meter, Ex Ante, and Ex Post Results

	Therms
Meter Use	2,080,299
Base Line End Use	1,377,800
Ex Ante Savings	125,247
Ex Post Savings	156,767

Table 9 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 6.0% decrease in total meter therms, and a 9.1% decrease in baseline end use therms. The ex post results showed a 7.5% decrease in total meter therms, and an 11.4% decrease in baseline end use therms.

Table 9: Percentage Natural Gas Reduction, Ex Ante and Ex Post

Natural Gas Reduction	Ex Ante Therms	Ex Post Therms
Total Meter	6.0%	7.5%
Base Line End Use	9.1%	11.4%

Baseline is the gas use of the pre retrofit unit.

With a cost of $475,000 and a $125,247 incentive, the project had a 3.5 year simple payback period, based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 2.8 years. A summary of the economic parameters for the project is shown in Table 10 and the savings over 15 year useful life of the equipment is shown in Table 11.

Table 10: Economic Information

Description	Date	Project Cost,$	Estimated Gas Savings, Therms	Gas Cost Savings ($0.8/Therm), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	02/21/06	475,000	125,247	100,198	125,247	3.49	4.74
SPC Program Review (Ex Post)	09/07/07	475,000	156,767	125,414	125,247	2.79	3.79

Table 11: Multi Year Reporting Table

Program Name:		Site A036 - SPC 0405 Evaluation					
Year	**Calendar Year**	**Ex-ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2005	0	0	0	0	44,609	55,835
2	2006	0	0	0	0	125,247	156,767
3	2007	0	0	0	0	125,247	156,767
4	2008	0	0	0	0	125,247	156,767
5	2009	0	0	0	0	125,247	156,767
6	2010	0	0	0	0	125,247	156,767
7	2011	0	0	0	0	125,247	156,767
8	2012	0	0	0	0	125,247	156,767
9	2013	0	0	0	0	125,247	156,767
10	2014	0	0	0	0	125,247	156,767
11	2015	0	0	0	0	125,247	156,767
12	2016	0	0	0	0	125,247	156,767
13	2017	0	0	0	0	125,247	156,767
14	2018	0	0	0	0	125,247	156,767
15	2019	0	0	0	0	125,247	156,767
16	2020	0	0	0	0	78,923	98,785
TOTAL	**2004-2023**	-	-			**1,876,989**	**2,349,358**

Note that the existing thermal oxidizer still has 5 years useful life and assumed that it would have served the facility for the rest of its useful life. The existing oxidizer would most likely need to be replaced after its useful life expired in 2010. It is estimated that the standard thermal oxidizer available in 2010 will have 10 percent higher thermal efficiency than the existing oxidizer with the improved technologies obtainable at that time.

Under an alternate baseline, it would be possible to calculate the full impact for the first five years and then adjust the baseline to the available equipment and industry practice in 2010 for the remaining ten years of the useful life of the new equipment. However, this baseline would need to be investigated further and is beyond the scope of this report.

FINAL SITE REPORT

SITE A037 Holl (2005-xxx) IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 2 END USE: Gas

Measure	Replace / Retrofit Eight Existing Heat Exchangers and Install a Contact Heater for Condensate Heat Recovery
Site Description	Manufacturing (Food Products)

1. Measure Description

Replace five existing heat exchangers, install new plates for three exchangers, and install a contact heater for condensate heat recovery in the sugar juice concentration process.

2. Summary of the Ex Ante Calculations

The ex ante savings were derived using customized calculations. The spreadsheet was provided in hard copy in the application paperwork. An electronic format was provided by the customer, who originally submitted the calculations. According to the customer, the spreadsheet is a distilled form derived from a comprehensive process management system in place, created for the purposes of showing energy savings. The calculated savings are 388,797 therms.

Juice flow rates and temperatures given at various stages of the process and estimated annual operating hours provided in the calculations.

The Installation Report states that the ex ante savings are 388,797 therms. This concurs with the utility tracking system.

3. Comments on the Ex Ante Calculations

The ex ante savings were calculated using a customized spreadsheet. There is not enough information to determine the validity of all inputs. However, the savings was calculated as 32.1% of the existing usage due to new higher efficiency equipment. This level of savings appears reasonable.

A customer summary of the project is as follows:

Replace 5 tubular heat exchangers with plate heat exchangers. New heaters will more efficiently use low temperature vapors. Heaters will be rotated to do all the heating with the lower temperature vapor. Cleaning will be required during the down time to maintain performance. Add plates to 3 existing plate evaporators on extract service. Additional plates will concentrate the juice in the multiple effect evaporators. Less evaporation will be done in the single step vacuum pan. Add a contact heater on the carb gas using waste heat from condensate. Currently all of the heat from condensates is not utilized. By using the heat from condensates, less steam will be required.

The reviewer accepted the calculation provided by the customer as this was a complex industrial process.

The customer noted that flow is measured in various points in the process and that flow is also calculated based on raw product throughput. The application paperwork notes that it requires 1 pound of steam to boil off 4 pounds of water in this process.

The calculations indicate that more heat exchanger surface area and higher heat transfer efficiencies will result in less steam use and lower hours of operation for certain heat exchangers. Energy use is calculated as a percent of energy input (20%, 40%, 80%, or 100%, and in one case 13.3%) relating to the steam usage by that portion of the process. The energy savings of the new contact heater for the second carb heater is accounted for by showing a temperature decrease in the steam temperature input for this process. Energy use for new pumps is not included. The extractors appear to use a heat of vaporization rate of 970 btu/lb for removing water from the juice. This may require modification if the juice temperature needs to be increased to allow vaporization.

The calculations and process components are interdependent and some equipment appears to require more energy input where some equipment requires less energy input. Hours of operation vary from the raw juice heaters and the 2nd carb heaters.

The baseline energy inputs do not seem to account for the efficiency of steam production. Adjustments due to this inefficiency would increase energy savings.

4. Measurement & Verification Plan

The facility is a 150,000 sf, five story manufacturing plant producing sugar products. It is approximately 40 years old. The project to be evaluated entails retrofit and replacement of heat exchangers.

The project saves energy through the replacement of tubular heat exchangers with plate and frame heat exchangers, installation of additional plates for extraction heat exchangers, and installation of a new contact heater for condensate heat recovery. The modified process will use less steam to achieve the same effect.

The greatest uncertainties in the ex ante savings estimate are associated with overall efficiency of the process, and the ratios used in attributing energy input to process energy use.

The goal of the M&V plan is to verify the gas usage reduction, in therms, over the useful life of the equipment.

Formulae and Approach

The M&V plan is a modified version of IPMVP Option A.

Boiler efficiency and steam production efficiencies on an average basis will be determined from the system operator and any process / energy management system in place.

The basis of energy use savings are the temperatures, the hours of operation, and the ratio of energy use to energy input (presumably based on percentage of steam used by that process flow), as well as the flow rates.

These variables will be determined through the process / energy management system and through operator interviews to the extent possible. Changes in production will be noted from the customer records. If steam flow is recorded on a submetered basis for this process, pre retrofit and post retrofit consumption can be used to estimate energy impacts.

Temperature readings will be taken over the course of two hours if fluctuating to determine the values and temperatures profiles. Temperature differences on the input and output of the entire product stream will be attempted. The first raw juice heater and on the first effect extractor will be specifically targeted (as these components show the largest differences in the pre and post conditions).

Heat exchanger efficiencies and energy use prior to the retrofit may also be able to be determined. With new heat exchanger efficiencies, energy saving may be calculated using a different formulae.

Uncertainty for the savings estimate can be more fully understood by setting projected ranges on the primary variables.

<u>Flow</u>

- pre-retrofit expected gpm, + 20% / - 20%

<u>Heat Exchanger efficiency</u>

- pre-retrofit and post retrofit 60% , + 20% / - 20%

<u>Energy use by Process</u>

- ratios expected , + 20% / - 20%

<u>Temperature</u>

- pre-retrofit expected temperatures, + 2 % / - 2%

Accuracy and Equipment

Customer data will be regarded to have an accuracy of +/- 5%. A Raytek infrared thermometer and HOBO U12-012 loggers with temperature bulbs have an expected accuracy of +/- 1F (or 2%, whichever is higher) and a resolution of 0.1 F. Annualizing if temperature measurements are used is estimated to be +/- 10% accurate.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 13, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the heat exchanger and taking temperature measurements on the input and output streams. Production data was also collected.

The raw juice heat exchangers were initially targeted as a major component of energy savings in the M&V plan. However, these were removed due to clogging and replaced with the original equipment.

It was also revealed during the evaluation site visit that production decreased dramatically due to lower input product availability.

The facility is occupied continuously from the start of the crushing season to the end of the season (typically April 1 to November 1. There is variation, however, and the range is from 140 days to 230 days.

Installation Verification

The facility representative verified that there were eight heat exchangers modified and a carb gas heater added. These were inspected during the site visit. Two heat exchangers were removed due to clogging and replaced with original equipment.

This is the only measure in this application. The verification realization rate for this project is 0.78 (7/9). A verification summary is shown in Table 8 below.

Scope of the Impact Assessment

The impact assessment scope is for the gas end use measure in the SPC application covering the heat exchanger retrofit. This is the only measure in this application.

Summary of Results

The customer utilized customized calculations which were a distilled version of the facility wide process management system. Data was collected on site regarding the temperatures used as inputs in these calculations and for production. Production in current years is less than previous years, due to low input product availability. This would change the number of hours of the process. It is uncertain why the process was represented in the format it was presented, particularly why certain hours changed and why percentages of the total process energy were used as line items. However, the savings calculations may be reasonable given the position of this measure in the overall process.

The tables below present the figures used for the ex ante savings. The raw juice (RJ) heaters were replaced with the original heat exchangers due to plugging, and the ex ante savings figures were adjusted for this change.

- The facility representative stated that the period monitored was reflective of average operation and that the operation of the facility had not changed in any significant way since the new equipment was installed. Temperature measurements were not used as the basis for any adjustments to the ex ante savings but were consistent with the inputs used in the calculations.

Table 1: Pre Retrofit U Values and Temperatures

Equip. Name	Juice Flow lb/hr	RDS	U BTU/hrft2F	Steam Temp F	Juice Temp In F	Juice Temp Out F
RJ Htr	475000	13	106	219	140	165
RJ Htr	475000	13	106	225	165	184
2nd Carb Htr	495000	12.5	123	240	165	190
2nd Carb Htr spare	495000	12.5	123	210	190	197
1st Vapor TH Juice Htr	495000	12.5	176	276	249	265
Exhaust TJ Htr	495000	12.5	176	292	265	274

Equip. Name	Juice Flow In lb/hr	RDS In	U BTU/hrft2F	Steam Temp F	Juice Temp	RDS Out	Juice Flow Out lb/hr
1st Eff. Extract Evap	66200	27	300	230	210	35.49	50,362
2nd Eff. Extract Evap	50362	35.49	150	208	186	43.58	41,012
3rd Eff. Extract Evap	41012	43.58	100	184	149	58	30,817
Pan Evap	30817	58	100	219	160	93	19,219
Carb Gas Heater							

Table 2: Pre Retrofit Energy Use

Equip. Name	Operation Description (ie 2nd shift, etc.)	Baseline Input Therms	Annual Op. Hours	Baseline Energy Use
RJ Htr	24 hr/day 200 days/yr	519,224	4800	103,845
RJ Htr	24 hr/day 200 days/yr	394,347	4800	157,739
2nd Carb Htr	24 hr/day 200 days/yr	563,335	4800	225,334
2nd Carb Htr	24 hr/day 200 days/yr	149,623	4800	59,849
1st Vapor TH Juice Htr	24 hr/day 200 days/yr	360,579	4800	288,463
Exhaust TJ Htr	24 hr/day 200 days/yr	189,174	4800	189,174

Equip. Name	Operation Description (ie 2nd shift, etc.)	Baseline Input Therms	Annual Op.	Baseline Energy Use
1st Eff. Extract Evap	24 hr/day 200 days/yr	737,417	4800	-
2nd Eff. Extract Evap	24 hr/day 200 days/yr	435,336	4800	-
3rd Eff. Extract Evap	24 hr/day 200 days/yr	474,679	4800	79,113
Pan Steam	24 hr/day 200 days/yr	539,993	4800	107,999
Carb Gas Heater	24 hr/day 200 days/yr	-		-
		1,837,485		1,211,516

Table 3: Post Retrofit Energy Use

Equip. Name	Operation Description (ie 2nd shift, etc.)	Baseline Input Therms	Annual Op. Hours	Baseline Energy Use
RJ Htr	24 hr/day 100 days/yr	459,332	2400	91,866
RJ Htr	24 hr/day 100 days/yr	459,332	2400	91,866
2nd Carb Htr	24 hr/day 100 days/yr	186,566	2400	37,313
2nd Carb Htr	24 hr/day 100 days/yr	186,566	2400	37,313
1st Vapor TH Juice Htr	24 hr/day 200 days/yr	469,943	4800	375,954
Exhaust TJ Htr	24 hr/day 200 days/yr	44,560	4800	44,560

Equip. Name	Operation Description (ie 2nd shift, etc.)	Baseline Input Therms	Annual Op.	Baseline Energy Use
1st Eff. Extract Evap	24 hr/day 200 days/yr	844,319	4800	-
2nd Eff. Extract Evap	24 hr/day 200 days/yr	532,227	4800	-
3rd Eff. Extract Evap	24 hr/day 200 days/yr	549,874	4800	91,646
Pan Steam	24 hr/day 200 days/yr	260,999	4800	52,200
Carb Gas Heater	24 hr/day 200 days/yr	-	4800	-
		2,187,419	4800	822,719

Table 4: Ex Ante and Ex Post Savings

		Ex Ante		Ex Post	
Annual Totals		1,211,516	Therms/yr	1,211,516	Therms/yr
Annual Totals		822,719	Therms/yr	900,570	Therms/yr
	Savings	388,797	Therms/yr	310,946	Therms/yr

Table 5: Billing Usage Analysis

Year	Dates	Therms	Beets (tons)	Days	Therms/ ton	Therms normalized to 2004	Therms normalized to 2005
2004	Dec 1 - Nov 30	13,422,289	860,023	221	15.61	13,422,289	14,060,642
2005	Dec 1 - Nov 30	13,892,808	900,925	228	15.42	13,262,074	13,892,808
2006			651,795	174			
2007				*140 (estimated)*			
Savings						160,215	167,834

It is more accurate to use calculated savings verses billing savings due to the small amount of energy savings relative to the total bill and other variables in the operation of a large plant. The ex ante savings were adjusted based on the effects of removed equipment. It should be noted that use of the boiler efficiency to produce steam would increase savings. However, the ex ante savings incorporates savings factors that are estimates and it was determined that these are a large source of uncertainty. Given that billing data supports a smaller decrease in energy use, the ex post savings were not adjusted upward for boiler efficiency.

The engineering realization rate for this application is 0.80 for natural gas (therm) savings. A summary of the realization rate is shown in Table 8.

Utility billing data for the site was provided in the application. For the period from December 1, 2003 to November 30, 2004, pre-retrofit annual consumption was 13,442,289 therms. Table 5 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility provided numbers.

Table 6 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 2.8% decrease in total meter kW, a 26.8% decrease in compressor end use kW, a 7.2% decrease in total meter kWh, and a 57.1% decrease in compressor end use kWh. The ex post results showed a 0.9% decrease in total meter kW, a 8.3%

decrease in compressor end use kW, a 2.0% decrease in total meter kWh, and a 15.7% decrease in compressor end use kWh.

Table 5: Total Meter, Ex Ante, Ex Post Results

	Therms
Total Meter	13,422,289
Baseline End Use	10,737,831
Ex Ante Savings	388,797
Ex Post Savings	310,946

Baseline End Use of Gas is 80% of total meter use.

Table 6: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante	Ex Post
Gas Savings	therms	therms
Total Meter %	2.9%	2.3%
Baseline End Use %	3.6%	2.9%

6. Additional Evaluation Findings

The ex post reduction is less than the ex ante estimate because of the removed equipment.

The facility representative stated that the cost estimate provided in the application is from multiple quotes. Analysis included both simple payback and IRR calculations (including depreciation). The measure cost includes full measure costs and internal customer labor costs. There was no breakdown of these costs in the application documentation. However, the costs appear to be a reasonable reflection of the project cost.

In addition to saving energy, there were no other benefits of the project. The customer does not anticipate any changes to operation that will affect energy, besides normal production variations.

However, there are nearby gas wells and the customer may receive gas from these sources, as has been done in the past. Energy savings from the IOU may thus be decreased.

Participation in the 2004/2005 SPC Program has not specifically encouraged the customer to perform any other energy efficiency projects without participating in an incentive program. The customer actively pursues other energy efficiency opportunities and will use incentive programs when available (and has done so in the past). Energy costs are primarily responsible for the emphasis on energy efficiency.

The replaced tube heaters were reported to be original equipment from 1963 and were thus 42 years old at the time of the retrofit. The extractor plate and frame heat exchangers were from 1998. They sometimes had leaks; however, leaks were more prevalent in the new equipment. A total of 40 to 100 hours downtime per season was reported. The equipment can be bypassed when non-functional. Overall, the heat exchangers were performing functionally with minimal maintenance, but were not satisfactory from an energy standpoint.

The level of M&V employed at this site would need to be increased dramatically to accurately determine the impacts of the installed measure.

With a cost of $400,000 and a $200,000 incentive, the project had a 0.64 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 0.8 years. A summary of the economic parameters for the project is shown in Table 7. The customer stated that they have no reason to believe that the operation of the facility will change in the foreseeable future, therefore the multi-year impacts, shown in Table 9 below, are expected to remain constant over the life of the equipment.

7. Impact Results

Table 7: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.80/therm), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	6/29/2005	$400,000	-	-	388,797	311,037	$200,000	0.64	1.29
SPC Program Review (Ex Post)	12/5/2007	$400,000	-	-	310,946	248,757	$200,000	0.80	1.61

Table 8: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System			388,797
SPC Installation Report (ex ante)			388,797
Impact Evaluation (ex post)			310,946
Engineering Realization Rate			0.80

Table 8: Installation Verification Summary

Measure Description	End-Use Category	Gas Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Heat Recovery Equipment Enhancements	G	Replacement of tube heat exchangers, expanded plates on three exchangers	5 of 7 heat exchangers	Seven New Plate and Frame Heat Exchangers, and one Carb Gas Heater	Physically verified equipment installations	0.71

Table 9: Multi Year Reporting Table

Program Name:		A037 SPC 04-05 Evaluation					
		Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005					388,797	310,946
3	2006					388,797	310,946
4	2007					388,797	310,946
5	2008					388,797	310,946
6	2009					388,797	310,946
7	2010					388,797	310,946
8	2011					388,797	310,946
9	2012					388,797	310,946
10	2013					388,797	310,946
11	2014					388,797	310,946
12	2015					388,797	310,946
13	2016					388,797	310,946
14	2017					388,797	310,946
15	2018					388,797	310,946
16	2019					388,797	310,946
17	2020						
18	2021						
19	2022						
20	2023						
21	2024						
TOTAL	2004-2024	-	-			5,831,950	4,664,190

Final Report

SITE A038 Sola1 IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 5 END USE: Gas

Measure	Install Direct Digital Controls and Retrofit Five Air Handlers
Site Description	Health and Social Services Facility

1. Measure Description

Install a direct digital control based energy management system (EMS) and retrofit five (5) rooftop air handling systems from single deck constant speed to dual deck variable speed units.

2. Summary of the Ex Ante Calculations

The ex ante savings for the measures is 20,266 therms as identified in the Implementation Report Review and in the utility tracking system. The SPC incentive of $20,266 is based on these savings. Electric savings result from this measure but only the gas savings are evaluated as the primary end use. The savings were submitted as calculated by the project reviewer and were adjusted upward from 12,730 therms submitted by the project sponsor. The electrical savings were reduced from 236,655 kWh and 0 kW to 160,833 kWh and 33.9 kW by the reviewer.

3. Comments on the Ex Ante Calculations

The customer's sponsor submitted the original SPC application for retrofit of five rooftop air handling units for modification from single deck, constant volume units with functionally disabled time clocks to dual-deck, variable air volume units with outside-air lockout, hot and cold deck reset, digital time clocks and related VFD and air-handling unit controls. The project sponsor performed original ex ante calculations using Trace 600 Analysis software.

The approved project energy savings were re-calculated using proprietary in-house temperature bin simulation modeling software for HVAC retrofits by the installation review firm. A separate bin simulation model was performed for each of the five air-handling units. Energy savings were modeled based on the following data inputs: annual operating hours, climate data, fan hp / kW, supply air flow, minimum outside air percentage, minimum supply air flow percentage, design supply air temperature, average return air temperature, balance temperature, nameplate chiller and boiler efficiency, outside air lockout temperatures, deck temperatures and reset schedules, and heating and cooling design temperatures. Data inputs were verified from the submitted project application, from detailed email communications with the project sponsor, and from ASHRAE references.

After installation of the control measures, the reviewer and project sponsor toured the facility and verified that the measures had been installed and were functional.

The inspection revealed that the proposed direct digital controls were installed, each air handling unit was equipped with VFD and DDC controls (custom programmed), and the dual deck variable air volume conversions replaced original single deck configuration.

The supply and return fan motors on each air handling unit (AHU) were equipped with custom designed VFDs and controls. The VFD-generated savings were not included in the recalculated savings since the VFDs were rebated in another program. Each AHU had a control box with control equipment and sequence listed within each control box. The entire system is controlled by a Johnson Metasys EMS and had been programmed by the project sponsor's representatives. The controls work with AHU fan motors, as well as new heating and cooling equipment, to control and adjust space conditioning depending on load.

Specific changes which reduce energy use are the change to electronic from digital controls, temperature adjustments (setback and setup), hot water / chilled water temperature reset, and boiler / chiller lockout based on outdoor temperatures.

The application and application review calculations for energy use in the building differed based on the inputs and the specific modeling software used in the initial application and in the installation review. In particular, the savings from the recommissioning of nonfunctional existing timeclocks was incorporated in the initial savings estimates, but these timeclocks were assumed to be operating for the baseline condition in the calculation of the ex ante savings (as repair is not eligible for incentives under program guidelines).

The ex ante savings from the Installation Report Review were analyzed. The reported (calculated) natural gas savings from the control measures are 20,266 therms. This is equivalent to 2,026.6 MMBtu. The electrical savings from the control measures is 160,833 kWh, which is equivalent to 1646.8 MMBtu at a source heat rate of 10,239 Btu/kWh. The gas savings, therefore, are the major savings component of the control measures implemented and the primary end use and savings to be evaluated are in this category.

Complete inputs and outputs were not provided for the savings calculations generated from the Trane Tracer program or for the in-house model used by the project reviewer.

4. Measurement & Verification Plan

The building is a single story, 52,116 square foot medical clinic and social services office building. It is reported to be approximately 22 years old. Approximately 20% of the building is occupied on a 24 hour / 7 day a week schedule. The balance of the building is occupied on a varying schedule, from approximately 5 am to 7 pm Monday through Friday with occasional use on evenings and Saturdays. Maximum occupancy is approximately 100 staff members at any given time, with over 100 visitors per day. The inpatient facility houses approximately 12 clients and has 8 staff; this portion operates on a continuous schedule.

According to the application, before the retrofit there were functionally disabled timeclocks on five single zone constant speed air handling systems. After the retrofit, there was a DDC based EMS system for the building, and the five air handling systems were converted to dual deck variable volume air handling systems.

The project saves energy through the installation of more efficient units and better control of building temperatures and unit operation.

The goal of the M&V plan is to verify actual annual gas reduction over the expected useful life of the measure (15 years for the EMS).

Billing analysis would be appropriate for the controls measure; however, the need to account for other changes, such as boiler and domestic hot water replacement, along with the adjustment for the proper operation of the timeclocks, would require these other changes to be backed out, with a possible regression with weather data. Other changes in building use or demand that would have a significant impact on the gas savings may also have occurred and will need to be incorporated.

If this is not possible, a simple building model based on the run time of the heating units at full output will be constructed, distributed throughout the year according to weather data, and compared to billing data. A simple block load and run time data calculation will be constructed for gas use only from the information available on the site.

It is not possible to measure actual inputs directly, since measurements on the many variables for accurate analysis could only be conducted during the heating season. Pre retrofit conditions would also require monitoring.

Attempts to obtain the necessary data, including temperature set points and actual fan / heating unit operation, from the EMS system, will be made. Data to be collected includes: HP of fans and other motors, airflow in CFM (from as built drawings), MBH in boiler heating output, cooling output, time clock hours before and after installation of measures, equipment efficiencies, heating and cooling temperature settings, and set-points before and after the retrofit.

Formulae and Approach

IPMVP Option C approach should be considered. The savings reported in the utility tracking system is approximately 40% of the therms consumed based upon the pre-retrofit building use of 51,586 therms as reported by the sponsor.

A review of the gas billing data for the pre-retrofit and post-retrofit periods indicates that the gas use relative to the same month in the previous year begins to decline in April 2004. The greatest savings appeared between the months of January and December 2005 with highest savings occurring in January 2005 compared to gas use in January 2004. The calculated annual gas savings from implementation of the measures was 20,266 therms compared to actual 12 month billing savings which ranged from a low value of 18,784 therms in May 2006 (spring) to a high value of 30,837 therms in December 2005 (winter). The average of each of the annualized (12 month) savings periods between June 2005 and May 2006 following the controls retrofit was 24,490 therms.

The initial paperwork was submitted in October 2004. The facility representative gave an EMS installation date of January 2005. That month is concurrent with the reduction seen in the gas bills.

Formulae and Approach

The approach preferred is a modified version of IPMVP Option C, with adjustments for weather and changes in operation.

If this is unsuccessful, a modified version of IPMVP Option A could be attempted.

The previous operating hours should be verified with the building operator. The new hours / sequence of operation may be confirmed from the operator and the energy management system. The cfm of the existing equipment kW of the existing motors may be obtained from the energy management system. Hobo temperature dataloggers could be used if analysis is conducted in the heating season. However, they are useful as inputs into building models. The pre retrofit temperatures can be estimated and not confirmed. These measurements, then, have limited value. However, if this is the desired approach, HOBO temperature loggers could capture actual outdoor temperature conditions at the site.

Pre-retrofit and post-retrofit calculations of motor loads and energy use will be calculated using the following formulae:

$$Q = U \times A \times \Delta T \times h$$

$$Q = 1.08\ cfm \times \Delta T \times h$$

Uncertainty for the savings estimate for the retrofit can be more fully understood by setting projected ranges on the primary variables.

<u>Uncertainty associated with billing analysis</u>

- Gas Readings: 25000 ccf expected, +/- 1 %
- Hours for timeclock adjustment: 108 hrs reduced, +/- 10%

- Portion of building controlled, 80% , +/- 15 %
- Efficiency Increase: 10%, +/- 50%

Accuracy and Equipment

Hobo dataloggers for temperature readings would be used if Option A is selected. Accuracy is expected to be +/- 1 %.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on June 25, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the air handling units, the building plans, and the energy management system (EMS).

The building is occupied from 5 am to 7 pm Monday through Friday. A small portion of the facility serves approximately 12 inpatients and 8 staff and is occupied continuously. The chillers and chilled water pumps are operated as needed to serve this area. The facility, in normal weekday operation, is host to 100 staff and over 100 visitors per day. The facility is closed on holidays.

Installation Verification

The air handling units were observed to be in place. The energy management system was inspected and queried for control strategies. This is the only measure in this application. The verification realization rate for this project is 1.00. The verification summary is shown in Table 7.

Scope of the Impact Assessment

The impact assessment scope is for the gas savings associated with the retrofit and EMS control of the five air handling units. This is the only measure in this application. The electric savings are not being evaluated.

Summary of Results

Option C was selected as the gas savings was significant at this facility. Pre retrofit use (in 2004) was 55,371 therms. Gas use in 2005 was 24,534 therms. Unadjusted savings was 30,837 therms. Savings after normalization with heating degree days taken on an hourly basis (HDh/24) with a 60 degree base have a minimal effect and are not shown.

Adjustments were required for increased boiler efficiency for the boiler installed in January 2005 (the savings over 2004 usage was 7,910 therms). This reduced the ex post savings to 22,927 therms. A further reduction is needed for the disallowance of typical timeclock based control, which was functionally disabled according to the application paperwork and pre inspection reports. This reduction of 9,427 therms (accounting for continuous occupancy of 20 percent of the facility with 36% estimate of HVAC system capacity based on hp and cfm collected at the facility and 12 hours per day usage five days per week as reported by the facility) brings the total savings to 13,499 therms.

The tables below show the calculations described.

Table 1: Annual Gas Savings

	Actual Period 2005	Normal Month	Therms	Therms	Savings
Month	HDh/24	HDh/24	Year 2004	Year 2005	Therms
Jan	467.3	464.5	7207	3516	3712
Feb	359.4	284.0	6007	3496	3244
Mar	173.1	237.7	5121	2170	2141
Apr	196.8	174.5	4829	2481	2630
May	70.8	83.9	3753	1735	1698
Jun	34.6	37.6	3885	1388	2497
Jul	6.6	24.1	3352	1377	1975
Aug	7.5	27.2	3899	1296	2603
Sept	40.6	40.9	4047	1292	2746
Oct	61.4	104.1	3678	1170	1695
Nov	179.0	253.1	4569	1722	2135
Dec	371.4	444.3	5024	2891	1566
Totals			55371	24534	30837

Table 2: Adjusted Gas Savings

Boiler savings	Original Efficiency	70%	
	New Efficiency	80%	
	Increase in Efficiency	10%	
	Efficiency Increase as Percentage	14%	
	Decrease in therms from 2004 use		-7910
Total Adjusted Gas Usage After New Boilers			22927
	Original Hours/Week	168	
	New Unoccupied hours per week	108	
	Decrease due to hours adjustment	64%	
	Decrease due to 4 of 5 AHUs affected	41%	
Total Adjusted Gas Usage After New Boilers and Timeclock Disallowance			-9427
EX POST - Total Adjusted Gas Usage After New Boilers and Timeclock Disallowance			13499

The engineering realization rate for this application is 0.67 for gas usage. A summary of the realization rate is shown in Table 6.

Utility billing data for the site was obtained from the utility. Pre-retrofit annual consumption (for calendar year 2004) was 55,371 therms. The pre-retrofit baseline usage for heating was calculated based on 90% of the total meter use for gas. Table 3 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers.

Table 4 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 4.9 % decrease in total meter kW, a 12.3 % decrease in end use kW, a 2.9% decrease in total meter kWh, and a 7.2% decrease in end use kWh. The ex post results showed a 5.1 % decrease in total meter kW, a 12.7% decrease in end use kW, a 3.8% decrease in total meter kWh, and a 9.4 % decrease in end use kWh.

Table 3: Total Meter, Ex Ante, Ex Post Results

	Therms
Total Meter	55,371
Baseline End Use	49,834
Ex ante Savings	20,266
Ex Post Savings	13,499

Baseline use is heating/reheat at 90% of total use / excludes domestic hot water

Table 4: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante	Ex Post
kWh Savings/kW Demand Reduction	therms	therms
Total Meter %	36.6%	24.4%
Baseline End Use %	40.7%	27.1%

6. Additional Evaluation Findings

The ex ante gas savings are higher than the ex post gas savings. This analysis used billing analysis and adjusted savings downward for the high efficiency boilers installed after this project occurred. The savings in the energy models used should have similar differences for this variable, however.

The disallowance for the timeclocks was accounted for in the building models, but not reflected in the pre retrofit energy bills. Thus, this change was also necessary.
The reviewers correctly excluded the new time based control from the original application, as the older timeclocks constituted a maintenance or repair item.

Accuracy may have been improved by having pre retrofit boiler efficiency tests performed. It is uncertain whether more detailed building models would increase accuracy as the number of variables, particularly associated with the pre retrofit conditions, may not be able to be accurately quantified.

The customer does not anticipate any changes to the operation of this measure that will affect energy consumption in the foreseeable future

The measure was performed by an energy service provider and costs were broken out by that entity; based on experience and Means cost data, costs are realistic but may be slightly high.

The equipment was functional but suboptimal. Repairs were needed.

In addition to saving energy, the benefits of the project are reduced maintenance. Regular maintenance was required previously.

All SPC measures at this facility were performed to combat high energy costs. Participation in the 2004/2005 SPC Program for this and other SPC measures has encouraged the customer to perform other energy efficiency projects with energy efficiency programs, primarily lighting measures.

7. Impact Results

The pre retrofit condition was unable to physically verified. However, the facility was inspected prior to the retrofit and so had been accurately assessed and quantified. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $ 97,525 and a $ 20,266 incentive, the project had a 4.8 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is lower than the ex ante, and the estimated simple payback is 7.2 years. A summary of the economic parameters for the project is shown in Table 5.

Table 5: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.8/therm), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	11/17/2005	$97,525	-	0	20,266	$16,213	$20,266	4.8	6.0
SPC Program Review (Ex Post)	10/24/2007	$97,525	-	0	13,499	$10,800	$20,266	7.2	9.0

The realization rate of the gas use is 0.67, as summarized in Table 6. The Installation Verification Summary is shown in Table 7 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 8.

Table 6: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	-	-	20,266
SPC Installation Report (ex ante)	-	-	20,266
Impact Evaluation (ex post)	-	-	13,499
Engineering Realization Rate			0.67

Table 7: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Gas Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
GAS	G				EMS and Air Handling Unit changes	1	EMS and Air Handling Units (5 - 15 hp)	Physically verified EMS operation and the five air handling units	1.00

Table 8: Multi Year Reporting Table

Program Name:		SPC 04-05 Evaluation Site A038					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004					0	0
2	2005					20,266	13,499
3	2006					20,266	13,499
4	2007					20,266	13,499
5	2008					20,266	13,499
6	2009					20,266	13,499
7	2010					20,266	13,499
8	2011					20,266	13,499
9	2012					20,266	13,499
10	2013					20,266	13,499
11	2014					20,266	13,499
12	2015					20,266	13,499
13	2016					20,266	13,499
14	2017					20,266	13,499
15	2018					20,266	13,499
16	2019					20,266	13,499
17	2020						
18	2021						
19	2022						
20	2023						
TOTAL	2004-2023					303,990	202,491

EMS measure life 15 years

Final Report

SITE A039 Sola2 **IMPACT EVALUATION**
SAMPLE CELL: ORIGINAL TIER: 5 END USE: Other

Measure	Pump Motor Replacement
Site Description	Health and social services facility

1. Measure Description

Replace two (2) 15 hp chilled water pump motors with two (2) 5 hp chilled water pump motors.

2. Summary of the Ex Ante Calculations

The ex ante savings for the measures are 26,423 kWh and 13.0 kW as identified in the Implementation Report Review and in the utility tracking system. The SPC incentive of $2113.84 is based on these savings. The savings were submitted as calculated by the project reviewer and were not submitted by the applicant or the project sponsor. Note these figures were not generated by the SPC calculator and were not submitted as itemized measures.

3. Comments on the Ex Ante Calculations

The customer's sponsor submitted the original SPC application for replacement of two 111 ton York air-cooled reciprocating chillers with one 50 ton and one 60 ton Trane air-cooled scroll compressor chillers. The chiller project included replacement of pump motors. The calculations for the pump motors were not broken out separately from the chiller calculations. The new chillers did not qualify for incentives because they did not exceed the minimum performance requirements of California Title 24 guidelines, as indicated for air-cooled water chilling packages under the 2004 SPC Procedures Manual (Appendix C, Table C3). However, the chilled water pump motors were allowed. The incentive was based on the savings calculated due to the replacement of 15 hp motors with 5 hp motors.

The SPC project reviewer calculated the energy use based on assumptions about efficiency and loading of the old and new pump motors. The calculations were as follows:

kW Pre-retrofit = ((15 hp x 0.745 kW/hp) / 91% min. required NEMA efficiency) * 80% assumed loading = 9.8 kW
kW Post-Retrofit = ((5 hp x 0.745 kW/hp) / 89.5% min. required NEMA efficiency) * 80% assumed loading = 3.3 kW

Chiller #1 Post-Retrofit Annual Pumping Hours = 2,421 Hours
Chiller #2 Post-Retrofit Annual Pumping Hours = 1,642 Hours

Chiller #1 Pump Motor Annual kWh savings = (9.8 kW – 3.3 kW) x 2,421 Hours x 1 motor = 15,745 kWh
Chiller #2 Pump Motor Annual kWh savings = (9.8 kW – 3.3 kW) x 1,642 Hours x 1 motor = 10,678 kWh

These figures equate to total savings of 26,423 kWh (15,745 kWh + 10,678 kWh) and 13.0 kW (2 motors x (9.8 kW-3.3 kW)).

The ex ante savings are 26,423 kWh and 13.0 kW and the SPC incentive of $2113.84 was based on these savings.

Energy savings were calculated based on the pump operating hours for the post-retrofit operating schedule. Chiller #1's pump motor was assumed to operate at an outside air temperature of 68°F and higher during the entire year (8760 hours) to maintain cooling to the 24-hour clinic (approximately 20% of the floor space). Chiller #2's pump motor was assumed to operate at an outside air temperature of 68°F and higher for six days per week, twelve hours per day to service all areas. Weather data used is from the applicable climate zone. Pump motor electrical savings resulting from the installation of VFDs were not eligible for SPC incentives because they were rebated under the Express Efficiency Program.

Both the kW and kWh calculation are reasonable. Better estimates of motor loading and operating hours will improve the accuracy of savings estimates.

4. Measurement & Verification Plan

The building is a single story, 52,116 square foot medical clinic and social services office building and hospital. It is reported to be approximately 22 years old. Approximately 20% of the building is occupied on a 24 hour / 7 day a week schedule. The balance of the building is occupied on a varying schedule, from approximately 5 am to 7 pm Monday through Friday with occasional use on evenings and Saturdays. Maximum occupancy is approximately 100 staff members at any given time, with over 100 visitors per day. The inpatient facility houses approximately 12 clients and has 8 staff; this portion operates on a continuous schedule.

According to the application, before the retrofit there were two 15 hp chilled water pump motors. After the retrofit, the motors were replaced with 5 hp motors when the two chillers had been downsized to 50 and 60 tons (from two 111 ton chillers). The project saves energy through the installation of appropriately sized (smaller) and more efficient pump motors for the smaller chillers.

The documentation in the application indicates that the chilled water pump motors operate on different schedules based on demand due to higher outdoor temperatures.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

The previous operating hours should be verified with the building operator. The new hours / sequence of operation may be confirmed from the operator and the energy management system. The kW of the existing motors may be obtained from the energy management system or direct measurement.

Dent TOU power loggers or other power measuring devices could also be placed on each pump motor. The motors would be monitored for a period of one week. The kw and the energization time would be recorded to show power draw (kW) changes due to changes in flow and head requirements associated with chiller valve operation and variable speed drive operation, if present. The periods of energization could also be recorded and tracked to weather data. A HOBO temperature logger could capture actual outdoor temperature conditions at the site. It should be noted that reduced motor loading due to variable speed operation is not being evaluated, so that maximum kW draw should be used for pre retrofit and post retrofit calculations.

The loading on the pre-retrofit motors may be obtained from the as built drawings showing actual motor loads. The pre retrofit motors were identified as 15 hp motors driving B&G Model 1510-3E pumps delivering 267 gpm at 95 feet of head.

This approach is a modified version of IPMVP Option A.

Pre-retrofit and post-retrofit calculations of motor loads and energy use will be calculated using the following formulae:

kWh savings = $kWh_{pre} - kWh_{post}$

kWh savings = kW_{pre} x energized $hours_{pre} - kW_{post}$ x energized $hours_{post}$

Coincident peak demand period savings = $kW_{pre} - kW_{post}$

Summer peak demand period savings = $kW_{pre} - kW_{post}$ during the hottest periods between 2 pm to 5 pm, Monday to Friday, in June, July, August, and September

Uncertainty for the savings estimate of the retrofit can be more fully understood by setting projected ranges on the primary variables.

Uncertainty associated with kW and hours

- Hours 2,000 kWh expected, 1,000 minimum , 6000 maximum (-50% for additional hours, + 200 %)
- kW post retrofit: 3 kW expected , 2 minimum , 3.6 maximum (- 50%, +20% based on experience)
- kW pre retrofit: 9 kW expected , 6 minimum , 11 maximum (- 50%, +20% based on experience)

Accuracy and Equipment

One Dent TOU logger will be used on each pump motor. The Dent loggers are estimated to be accurate to within 3% for power (including CT accuracy). HOBO temperature loggers for temperature recording are accurate to +/- 1 F. If the energy management system or the Dent loggers are used to monitor hours of operation, these values will be deemed to be 100% accurate.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on June 25, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the motors, review of energy management system parameters, measurement of motor kW draws, and by interviewing the facility representative.

The building is occupied from 5 am to 7 pm Monday through Friday. A small portion of the facility serves approximately 12 inpatients and 8 staff and is occupied continuously. The chillers and chilled water pumps are operated as needed to serve this area. The facility, in normal weekday operation, is host to 100 staff and over 100 visitors per day. The facility is closed on holidays.

Installation Verification

The two motors were inspected and it was determined that they were 5 hp motors, in accordance with the submitted application. This is the only measure in this application. The verification realization rate for this project is 1.00. The verification summary is shown in Table 5.

Scope of the Impact Assessment

The impact assessment scope is for the two new chilled water pump motors. This is the only measure in this application.

Summary of Results

The facility representative stated that the chilled water pumps are operated on a lead lag schedule, and enabled all year round. They are only de-energized when the outside air temperature is less than 57 F or when all air handlers are shut down.

It was possible to retrieve accumulated run time hours from the energy management system. This was determined to yield the best estimate of annual operation, as short term monitoring would not yield results that could be annualized with a high degree of certainty.

The building operator was unable to provide any estimates of run time for the pre retrofit chiller pumps or chillers. An adjustment factor derived from the ratio of pre retrofit to post retrofit chiller capacity or from estimates based on assumed control sequences may not accurately represent the pre existing operation. For this reason, the same run time hours will be utilized for the pre and post retrofit scenarios.

The post retrofit kW was measured for each pump motor for a period of approximately 30 minutes. The monitoring was performed with a Dent TOU power meter for one motor and a Powersight meter for the other motor. The highest kW recorded was used as the post retrofit kW for all periods. This was used since the measure covered only motor replacement and savings from variable speed operation were not part of the evaluated measure. Higher kW measurement may have resulted if the measurements were taken with the variable speed drive in bypass mode. For this reason, the kW will be compared to the maximum required by the pump at full speed operation.

For the pre retrofit kW motor draw, the maximum required by the pump at full speed will be used to determine kW draw.

The motor replacement provides kW savings during all periods of operation. One pump is expected to be operating in the pre retrofit and post retrofit scenarios, during the peak demand periods defined as the hottest weekdays between 2 pm to 5 pm, Monday to Friday, in June, July, August or September.

The ex post calculations reflect actual measurements for kW taken for a 50 minute period beginning at approximately 11:20 am. The hours of use in the ex ante calculations were unchanged as the hours obtained from the energy management system at the site appear to be consistent on an annualized basis but overestimated for a 13 week summer period in 2007. There is some uncertainty introduced by annualizing these numbers and measurements taken over the course of a full year would mitigate this uncertainty.

Chilled Water Pump 1: hours from Jan. 1, 2005 (estimated) – June 25, 2007 = 5,578 hours (2,246 hrs/yr, based on 2.5 years)

Chilled Water Pump 1: hours from June 25, 2007 – September 26, 2007 = 7,607 hours - 5,578 hours (2,029 hrs or 156 hours/week)

Chilled Water Pump 2 hours from Jan. 1, 2005 (estimated) – June 25, 2007 = 5,189 hours (2,089 hrs/yr, based on 2.5 years)

Chilled Water Pump 2 hours from June 25, 2007 – September 26, 2007 = 7,545 hours - 5,189 hours (2,356 hrs or 181 hours/week)

The pumps operate on a lead lag schedule when only one pump is needed and hours are similar for pump 1 and pump 2. The hourly information obtained from the EMS is inconclusive but supports operation at over 2,000 hours per year. The higher hours per year operation used in the ex ante savings is utilized in the ex post calculations.

Hours per year for both pumps: 2,421 hours/year

kW Pre-retrofit = ((15 hp x 0.745 kW/hp) / 91% min. required NEMA efficiency) * 80% assumed loading = 9.8 kW
Pumping requirements = 267 gpm x 95 feet head/ 3960 / 60% eff pump = 10.7 hp = 8.0 kW (the pump efficiency is estimated)

kW Post-Retrofit = ((5 hp x 0.745 kW/hp) / 89.5% min. required NEMA efficiency) * 80% assumed loading = 3.3 kW

Pumping requirements = 120 gpm x 75 feet head/ 3960 / 60% eff pump = 3.8 hp = 2.8 kW (the pump efficiency is estimated)

kW post retrofit measured:
Chilled Water Pump 1: 2.6 kW (Powersight) average, 2.9 kW maximum
Chilled Water Pump 2: 2.8 kW (Dent), 3.3 kW maximum

- Pre retrofit hours of operation: 2,421 hrs/yr

  Pre retrofit wattage: 9.8 kW (from ex ante calculations)
  Annual kWh usage: 9.8 kW x 2,421 hrs/yr x 2 pumps = 47,452 kWh/yr

- Post retrofit hours of operation: 2,421 hrs/yr

  Pre retrofit wattage: 2.7 kW (average measurement for two pumps energized on a lead lag schedule with equal proportion of hours)

  Annual kWh usage: 2.7 kW x 2,421 hrs/yr x 2 pumps = 13,074 kWh/yr

- The resulting annual kWh savings = 47,452 kWh/yr – 13,074 kWh/yr = 34,378 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load.

Summer peak demand reduction is calculated as follows:

- Reduction in connected kW load: (9.8 kW – 3.3 kW) + (9.8 kW - 2.9 kW) = 13.4 kW

The engineering realization rate for this application is 1.03 for demand kW reduction and 1.08 for energy savings kWh. According to the installation report, the ex ante savings are 26,423 kWh annually and demand reduction is 13.0 kW. A summary of the realization rate is shown in Table 5.

Utility billing data for the site was obtained from the utility. Pre-retrofit annual consumption (for calendar year 2005) was 915,922 kWh. Peak demand was 264 kW. The pre-retrofit baseline usage for the other end use category was calculated based on 40% of the total meter use for air conditioning. Table 1 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers.

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 4.9 % decrease in total meter kW, a 12.3 % decrease in end use kW, a 2.9% decrease in total meter kWh, and a 7.2% decrease in end use kWh. The ex post results showed a 5.1 % decrease in total meter kW, a 12.7% decrease in end use kW, a 3.8% decrease in total meter kWh, and a 9.4 % decrease in end use kWh.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	264	915,922
Baseline End Use	106	366,369
Ex ante Savings	13	26,423
Ex Post Savings	13.4	34,378

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	4.9%	2.9%	5.1%	3.8%
Baseline End Use %	12.3%	7.2%	12.7%	9.4%

6. Additional Evaluation Findings

The ex ante kW savings are very similar to the ex post kW savings based on measurements taken at the site. At the time of the measurements, the motors were believed to be operating at full speed. The variable speed drives were not part of this program or the evaluation, and so short term measurements of maximum kW taken on summer midday are sufficient. However, EMS data can possibly trend both kW and kWh. Accuracy may be improved by monitoring for longer periods. The EMS was used to quantify hours of run time. Based on these measurements, run times were adjusted upward for one motor to the higher usage factor used for one of the chilled water pumps in the ex ante calculations. Actual EMS data did not cover a full year and was not used due to this factor.

The ex post kWh savings are higher due primarily to the hours of use adjustment, but also due to the slightly lower kW draw when compared to the ex ante engineering calculations.

The reviewers correctly excluded the new chillers from the original application, as they did not meet Title 24 efficiency standards.

Changes in operation of this measure are not anticipated. The customer does not anticipate any changes to the operation of this measure that will affect energy consumption in the foreseeable future

The measure was performed by an energy service provider and costs were broken out by that entity; based on experience and Means cost data, costs are realistic but may be slightly high.

The motors were replaced to support the new chillers which were part of the original application. They were not independently installed to save energy. The existing motors were 23 years old and possibly only had 2 more year of useful life, according to the customer. They were, however, functional at the time of the retrofit. In addition to saving energy, the benefits of the project are increased reliability. Only normal maintenance was conducted previously.

The measure was not identified from another program. All SPC measures at this facility were performed to combat high energy costs. Participation in the 2004/2005 SPC Program for this and other SPC measures has encouraged the customer to perform other energy efficiency projects with energy efficiency programs, primarily lighting measures.

7. Impact Results

The pre retrofit motors and hours of operation were unable to be physically verified. However, the pump and motors were inspected prior to the retrofit and so had been accurately assessed and quantified. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of 6,490 and a $ 2,114 incentive, the project had a 1.27 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 0.98 years. A summary of the economic parameters for the project is shown in Table 3.

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	11/17/2005	$6,490	13.0	26,423	0	$3,435	$2,114	1.27	1.89
SPC Program Review (Ex Post)	10/4/2007	$6,490	13.4	34,378	0	$4,469	$2,114	0.98	1.45

The realization rate of the peak kW demand is 1.03 and the realization rate of the energy savings is 1.30 as summarized in Table 4. The Installation Verification Summary is shown in Table 5 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 6.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	13.0	26,423	-
SPC Installation Report (ex ante)	13.0	26,423	-
Impact Evaluation (ex post)	13.4	34,378	-
Engineering Realization Rate	1.03	1.30	NA

1. Tracking System values used for realization rate calculations.

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Other Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Chilled Water Pump Rreplacement	O			Replace two (2) 15 hp chilled water pumps with two (2) 5 hp pumps	2	Two 5 hp motors	Physically verified quantity installed at site	1.00

Table 6: Multi Year Reporting Table

Program ID:	2005-0xxx Application # A039						
Program Name:	SPC 04-05 Evaluation						
Year	Calendar Year	Ex-ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	2,202	5,730				
3	2006	26,423	34,378	13.0	13.4		
4	2007	26,423	34,378	13.0	13.4		
5	2008	26,423	34,378	13.0	13.4		
6	2009	26,423	34,378	13.0	13.4		
7	2010	26,423	34,378	13.0	13.4		
8	2011	26,423	34,378	13.0	13.4		
9	2012	26,423	34,378	13.0	13.4		
10	2013	26,423	34,378	13.0	13.4		
11	2014	26,423	34,378	13.0	13.4		
12	2015	26,423	34,378	13.0	13.4		
13	2016	26,423	34,378	13.0	13.4		
14	2017	26,423	34,378	13.0	13.4		
15	2018	26,423	34,378	13.0	13.4		
16	2019	26,423	34,378	13.0	13.4		
17	2020	24,221	31,513	13.0	13.4		
18	2021						
19	2022						
20	2023						
TOTAL	2004-2023	396,345	518,538				

Final Report

A040 (SITE 2005-xxx) East IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 5 END USE: Other

Measure	Cool Roof
Site Description	Shopping / Retail Complex

1. Measure Description

Install 14,600 square feet of cool roof reflective white coating.

2. Summary of the Ex Ante Calculations

The kWh savings were determined using the SPC Calculator and algorithms contained in the calculator. The total ex ante savings are recorded as 16,549 kWh/year and 0.0 kW in the Installation Report Review.

The relevant inputs to the SPC calculator are recorded in the application paperwork and include: location (city), roof R-value, solar reflectance, infrared emittance, air conditioner efficiency, and roof area.

3. Comments on the Ex Ante Calculations

The total savings in the Installation Report Review were recorded as 16,549 kWh/year and 0.0 kW; these figures agree with the utility tracking system.

There were changes in relevant inputs into the SPC Calculator at various stages in the application process. During the post inspection review and for the installation report review, the pre retrofit solar reflectance was adjusted from 26% to 12% and the infrared emittance was adjusted from 11% to 90%. This was based on information from the Lawrence Berkeley National Laboratory giving approximations for this type of roofing material and the determination by the roofing contractor that the pre retrofit roof construction is plywood covered with a dark asphalt roll roofing material. The area was changed from 11,500 sf to 14,800 sf, based on the installation reviewer pacing the roof perimeter (in contrast to customer submitted documentation for roof area).

No kW savings were recorded. No summer peak kW impacts are expected, based on the relatively low heat load reductions and the intermittent cycling nature of the air conditioning equipment in place at the facility.

4. Measurement & Verification Plan

The facility has one building. This SPC application only refers to a portion of the building roof (the portion covering “Shops C”). The entire roof covering “Shops C” is coated with the cool roofing material. The portion of the roof covering “Shops A” was not treated with the cool roofing material.

The measure saves energy by increasing roof reflectivity, and limits heat buildup in the roof and heat transmission through the roofing materials to interior spaces.

The measure savings were calculated using the 2005 SPC calculator program.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful life of the measure.

Formulae and Approach

A modified version of IPMVP Option A can be utilized, incorporating the SPC calculator. Some parameters, such as pre-retrofit roof surface characteristics and HVAC equipment efficiency, will be stipulated according to manufacturers’ data.

The condition of the roof will be inspected for wear, as the customer reported peeling in come places. The square footage will be determined accurately from the drawings and rooftop equipment areas/penthouses will be deducted. Any shading from adjacent structures or landscaping will be noted. Additionally, the conditioned area will be determined.

The 2005 SPC calculator will be used to calculate the savings with the measured and stipulated variables. The inputs to the model used in the SPC calculator are the location of the building, solar reflectance (SR), infrared emittance (IE), roof insulation value (R), air conditioner efficiency, and roof area. The solar reflectance of the new roof may be measured with an albedometer. The parameters that have the most effect on the savings are the roof R value, solar reflectance, and roof area. The focus will be on determining these variables accurately for the pre and post retrofit situations.

The SPC calculator cool roof calculation code was examined to ascertain the approach used. The calculations all involve polynomial equations of the second or third order which appear to be fitted to empirical data. There are no notes as to the source of the empirical data; a possible source is the Demonstration of Energy Savings of Cool Roofs project by the Heat Islands Group at Lawrence Berkeley National Lab. (http://eetd.lbl.gov/HeatIsland/PROJECTS/DEMO/)

Thickness of building components for the insulation R value calculation will be measured to the extent possible, and the type of insulation material determined. Building plans will be consulted for roof construction and slope.

The complexity of the building systems and heat transfer variables, along with the magnitude of the savings for this measure, preclude the use of a calibrated building model. A calibrated building model constructed for this purpose should take into account many variables, such as reflectivity, emissivity, interior building configuration, insulation value, and actual cooling equipment efficiencies. The development of a model based on the size and type of this particular project is generally very complicated. A building model *may* also be largely inaccurate for this type of evaluation because the magnitude of change between the pre and post conditions is small compared to the total building energy use. Furthermore, many models rely on empirical data for cool roof savings estimations, further calling into question validity of an entirely calculated approach.

If a large uncoated area is not available for measurement, the uncertainty associated with the older roof reflectivity introduces a large source of error, also limiting the building model approach. Direct measurements using a albedometer and other tools to measure the post retrofit reflectivity are possible. However, reflectivity values specified by the manufacturer of the cool roof can also be used. It should be noted that these are typically values for the reflectivity of a new cool roof; weathered values have a lower reflectivity and should be used if available.

Uncertainty for the savings estimate for the retrofit can be more fully understood by setting projected ranges on the primary variables.

<u>For the SPC calculator inputs</u>

- U = 1/R; R = 19 for standard insulated roof assembly (+/- 5%)
- Solar Reflectance: pre 0.16, post 0.85 (+/- 40% pre, +/- 10% post due to degradation)
- Infrared Emittance: pre 0.91, post 0.90 (+/-15% pre, and +/- 5% post due to degradation)
- Area = 10,586 sf; + 5%, -30% (based on application paperwork)
- SEER = 10; +/- 20%

Accuracy and Equipment

If necessary, measuring wheels will be used to record roof area.

Standard measurement devices for area and insulation thickness calculation will be made to the nearest 0.5 inch and converted to two decimal places for area calculations. Error is expected to be less than 2%.

Roof Surface Albedometer if used: spectral range: 305 - 2800 nm, resolution: 1 W/m2, accuracy +/- 5% estimated.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The entire roof surface of this production/warehouse facility was coated with Heat Shield Roof Coating, classified as a cool roof product because of its high reflectivity (90%, Cool Roof Rating Council, CRRC) and high emissivity (0.85, CRRC). This product will decrease the heat gain to the area under the roof. The on-site survey was conducted on April 13, 2007. Information on the retrofit materials and building operating conditions was collected by inspection of the roof. The facility representative was uncooperative so it was not possible to perform the on-site interview.

The pre-retrofit roof was grey rolled asphalt. This roof was buckling in places and had been patched in places with tar, and with a silver reflective patching material. The white roof coating did not stick to the roof in the places where the existing roof surface had been patched and was peeling up in those places. The roof area designated 3D was not accessible, but from roof area 3B it was ascertained that half of the roof was white and half was grey. It appeared that standing water on the roof that had either degraded the white roof coating, or had deposited a layer of dirt on the surface. In either case, the white coating was no longer fully functional for that portion of the roof. The roof was in reasonable condition with just a few areas that were peeling up in the area over the area covered in this application. Fiberglass batt insulation was in place on the under side of the roof decking, between the metal roof joists, 24 inches on center. This insulation was not noted in the initial calculations, and will reduce the effect of the cool roof coating.

Installation Verification

It was physically verified that 10,586 square feet of roof coating was applied at the facility. The area was verified by direct measurement using a wheel and the roof coating was verified by inspection. The exterior roof is plywood with asphalt roll roofing material that has been covered with the cool roof coating. The retrofit was completed in August 2005.

The cool roof retrofit is the only measure in this application. The verification realization rate for this project is 0.73 (10,586 / 16,400). A verification summary is shown in Table 7.

Scope of the Impact Assessment

The impact assessment scope is for the cool roof end use measures in the SPC application covering the application of the acrylic cool roof coating. This is the only measure in this application.

Summary of Results

In 2004, all cool roof measures were itemized, and savings were calculated based on the workpapers. In 2005, when this application was submitted to SPC, a cool roof measure was included in the SPC calculator. The 2005 SPC calculator is the modeling tool that is used to calculate the ex ante and ex post savings for this site. As a check on the SPC calculator tool, savings for a different site (A075) in the SPC evaluation effort were also calculated using e-Quest/DOE 2.2, and the result is compared to the result from the SPC Calculator. The e-Quest/DOE 2.2 program has the limitation, however, that it does not model changes in infrared emittance. For many applications, this is acceptable because a black asphalt roof and cool roof products have high infrared emittance, usually about 90%, as is the case at this site. The savings calculated with e-Quest/DOE 2.2 agreed very well with the SPC calculator at other sites, so it was not deemed necessary to use the e-Quest model at subsequent sites.

The radiative properties of the cool roof were determined by values listed in the Cool Roof Rating Council (CRRC) products directory. The CRRC administers a Rating Program under which companies can label roof surface products with radiative property values rated under a strict program administered by the CRRC. All radiative property testing is conducted by accredited testing laboratories. Solar reflectance can be measured in accordance with ASTM test methods C1549, E1918, E903 and CRRC-1 Method #1: Test Method for Certain Variegated Products. Thermal emittance is measured in accordance with ASTM C1371. For aged ratings, product samples are exposed for three years at the CRRC Approved Test Farm. Product ratings are verified periodically through the CRRC's Random Testing Program. The product used in this application, “Heat Shield” manufactured by L&L Suppliers, Inc., is listed with a solar reflectance of 0.85 and an infrared emittance of 0.90 in the CRRC directory.

The radiative properties of the pre retrofit roof surface were determined by values listed in the Cool Roofing Materials Database prepared by the Heat Island Project at Lawrence Berkeley National Laboratory. The properties of asphalt shingle roofs are determined by measurements taken at the Florida Solar Energy Center and at Lawrence Berkeley National Laboratory. The solar reflectance of 0.16 is an average of five measured values for varying colors of grey asphalt shingle. The infrared emittance was equal to 0.91 for all five roofs.

Table 1: Physical Characteristics of Roofing Materials

	Grey Asphalt Shingle	Cool Roof
Solar Reflectivity	0.16	0.85
Infrared Emittance	0.91	0.91

The roof area was determined from roof dimensions measured with a measurement wheel to calculate gross floor area, and then subtracting the area for the HVAC equipment observed on the roof. The calculated roof area, 10,586 square feet, is somewhat smaller than the original ex ante roof area of 11,500 square feet given by the roofing contractor. It is significantly smaller than the 14,600 square feet used in the ex ante calculation. (determined by the SPC installation reviewer by pacing the roof).

The model numbers of the HVAC equipment were recorded at the site visit, and were queried in the ARI Unitary Directory but were not available in that directory. The manufacture date for all the air conditioners on the roof was listed as 1991. A SEER value of 10 is used in the calculation because this is the most commonly used default value. This will yield higher savings than if newer equipment with higher SEER is assumed.

The roof was observed to have R-19 fiberglass batt insulation installed under the roof decking between the metal joists. The existence of the insulation decreases the savings from the cool roof significantly.

The input and output values used in and generated by the SPC Calculator for this cool roof are shown in Table 2.

Table 2: Ex Ante and Ex Post Results of SPC Calculator

SPC Calculator - Ex Ante		
	Baseline	Cool Roof
Solar Reflectance	0.12	0.85
Infrared Emmittance	0.9	0.9
SEER	10	10
R-value	5	5
Floor Area	14,600	10,586
CA Climate Zone	12	12
Roof Component Space	20,999	4,450
Savings (kWh)	16,549	

SPC Calculator - Ex Post		
	Baseline	Cool Roof
Solar Reflectance	0.16	0.85
Infrared Emmittance	0.91	0.9
SEER	10	10
R-value	19	19
Net Roof Area	10,586	10,586
CA Climate Zone	12	12
Space Cooling (kWh)	4,240	899
Savings (kWh)	3,341	

The ex post savings calculated with the 2005 SPC Calculator (3,341 kWh/year) are 80% lower than the ex ante calculations with the same 2005 SPC Calculator (16,549 kWh/year). The difference is primarily due to the insulation added for the ex post calculations. These may still be overstated because the solar reflectance and infrared emittance values used in the calculation refer to a newly installed cool roof, whereas the roof at this location showed some degradation.

Table 3 summarizes the total metered use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers. The baseline use is calculated as 30% of the total electricity use for the facility; the percent dedicated to other uses assumes 40% for lighting and 30% for air conditioning equipment. Interval data was not available for this site so the total meter peak demand is undetermined. There are no results for peak period kW demand savings because the SPC calculator does not calculate these savings due to the cycling nature of the AC equipment.

Table 4 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results show energy savings ranging from 72.1 % to 240.4%. If this is the correct account, it is obvious that the ex ante savings are overstated since they are more than double the baseline end use. The ex post results for the cool roof show smaller savings ranging from 14.6% to 48.5%.

Table 3: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	-	22,942
Baseline End Use	-	6,883
Ex Ante Savings	0	16,549
Ex Post Savings	0.0	3,341

Note: Meter use was low for a facility this size. Other meter information was not found in information supplied.

Table 4: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	N/A	72.1%	N/A	14.6%
Baseline End Use %	N/A	240.4%	N/A	48.5%

6. Additional Evaluation Findings

The building manager noted that the cool roof was implemented due to concerns regarding water-tightness and for enhanced extended roof life more than for energy savings. The occupants find that the building is perhaps somewhat cooler after the installation of the cool roof.

Installation costs appear to be realistic.

It does not appear that participation in the SPC program stimulated involvement in other energy efficiency efforts or programs.

7. Impact Results

The pre-retrofit roof type was able to physically verified by evaluating the untreated section of the roof. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $6,720 and a $1,042 incentive, the project had a 2.51 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is smaller than the ex ante, and the estimated simple payback is 12.42 years. A summary of the economic parameters for the project is shown in Table 5.

Table 5: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	9/13/2005	$6,720	-	16,549	0	$2,151	$1,324	2.51	3.12
SPC Program Review (Ex Post)	4/13/2007	$6,720	-	3,341	0	$434	$1,324	12.42	15.47

The engineering realization rate for this application is 0.20 for energy savings. According to the installation report, the ex ante savings are 16,549 kWh annually and demand reduction is not calculated because of the cycling nature of air conditioning equipment. A summary of the realization rate is shown in Table 6.

Table 6: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	-	16,549	-
SPC Installation Report (ex ante)	-	16,549	-
Impact Evaluation (ex post)	-	3,341	-
Engineering Realization Rate	-	0.20	NA

1. Tracking System values used for realization rate calculations.

The Installation Verification Summary is shown in Table 7.

The savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 8.

Table 7: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Installation of a Cool Roof	O- Other			Installation of a Cool Roof using SPC calculator	10,586 ft^2	Cool Roof	Physically verified cool roof type and area.	0.73

Table 8: Multi Year Reporting Table

Program ID Program Name		**SPC 2004 Application # A040 2004 – 2005 SPC Evaluation**					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004						
2	2005	5,516	1,114	0.0	0.0		
3	2006	16,549	3,341	0.00	0.00	0	0
4	2007	16,549	3,341	0.00	0.00	0	0
5	2008	16,549	3,341	0.00	0.00	0	0
6	2009	16,549	3,341	0.00	0.00	0	0
7	2010	16,549	3,341	0.00	0.00	0	0
8	2011	16,549	3,341	0.00	0.00	0	0
9	2012	16,549	3,341	0.00	0.00	0	0
10	2013	16,549	3,341	0.00	0.00	0	0
11	2014	16,549	3,341	0.00	0.00	0	0
12	2015	16,549	3,341	0.00	0.00	0	0
13	2016	16,549	3,341	0.00	0.00	0	0
14	2017	16,549	3,341	0.00	0.00	0	0
15	2018	16,549	3,341	0.00	0.00	0	0
16	2019	16,549	3,341	0.00	0.00	0	0
17	2020	11,033	2,227	0.00	0.00	0	0
18	2021					0	0
19	2022						
20	2023						
TOTA	**2004-2023**	248,235	50,115				

Final Site Report

SITE A041 Sysc (2005-xxx) IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 3 END USE: Lighting

Measure	Metal Halide to Fluorescent T8 Lighting Retrofit
Site Description	Warehouse / Offices

1. Measure Description

Replace 785 metal halide fixtures utilizing 400 watt lamps with 785 fluorescent fixtures utilizing eight (8) 32 watt T8 lamps.

2. Summary of the Ex Ante Calculations

The customer used custom calculations

The kWh and kW savings submitted were 1,427,209 kWh/yr and 164.1 kW.

The ex ante savings are reported in the Installation Report Review and are identical to the savings in the utility tracking system, allowing for rounding functions.

3. Comments on the Ex Ante Calculations

The ex ante calculations are customized calculations calculated as follows:

Fixture savings: 465 watts – 256 watts = 209 watts
kW savings: 785 fixtures x 209 watts = 164.07 kW

The customer indicated the lamps operated continuously (i.e.: 8,760 hrs/year)

kWh savings are given as 1,437,209 kWh/yr.

The kWh and kW savings calculations appear to be valid with minor exceptions. The fixture wattages were given as 256 watts for the new 8 lamp T8 fixtures; this is not supported by the application paperwork, that includes a specification cutsheet for the fixture which shows 294 input watts. The standard wattage given in the workpapers for a 400 watt metal halide fixture is 458 watts. These values will result in lower actual energy savings as compared to the ex ante savings.

4. Measurement & Verification Plan

The building is a 366,800 sf single story warehouse that houses dry goods. It is reported to be approximately 16 years old. The building has minimal windows and skylights. The building is occupied continuously.

According to the application, before the retrofit there were 785 metal halide fixtures using 400-watt lamps. After the retrofit, there are 785 eight-lamp T8 fluorescent fixtures. The project saves energy through the installation of lighting fixtures with a lower connected wattage.

Documentation provided indicates that there are 785 fixtures as follows:

Dry Warehouse: 403
Cooler: 142
Freezer: 240

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

IPMVP Option C approach should be considered. The savings reported in the utility tracking system is approximately 25% of the kW and 35% of the kWh consumed based upon the pre-retrofit building use (peak demand is approximately 624 kW and annual energy use approximates 3,912,888 kWh per year according to the utility billing summary in the application). Utility billing and interval data should support this approach if there are no other significant loads or energy conservation activities which occurred in the months immediately following the retrofit. There is not expected to be significant seasonal variation and several months should be sufficient for comparison; however, a one to two year period would more fully capture actual variations and the persistence of savings. Interval data on a 15 minute basis during the summer months of June to September would be needed to accurately determine coincident peak period demand savings.

If Option C cannot be used due to changes in the facility or its operation in the time periods immediately before or after the retrofit, then a modified version of IPMVP Option A can be utilized. Lighting loggers may be used to quantify hours of operation; if continuous operation cannot be confirmed.

Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} expected during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in June, July, August, September.

The most significant variables to be quantified are the pre-retrofit and post-retrofit fixture hours of operation and wattages. Pre-retrofit hours will be confirmed with site personnel and interviews. The focus will be on verifying that, prior to the retrofit, the entire complement of fixtures was completely energized during the hours listed (8,760 hours/year) and that the listed hours/year were valid (for example, building or staff schedule logs for the pre-retrofit period could be examined if available).

Monitoring with light loggers would be conducted, utilizing two to three sensors in each of the three main areas. This would be performed to confirm the continuous or regular weekly schedules, if necessary.

The light loggers would be placed so as to be unaffected by ambient outside light.

Where lighting circuits can be isolated and it can be determined that only lighting loads for the retrofit fixtures are controlled by that lighting circuit, a current or power meter could be used to track multiple fixtures. The total current / power would be determined by activating all fixtures and by confirming loads using the electrical drawings. Spot measurements would be needed on several circuits to verify post-retrofit wattages. Between three and six measurements are expected to be needed, to capture a representative sample of the lighting fixtures.

The lighting loggers or current sensors would be left in place for a minimum period of 14 days. Attention will be given to the time period for monitoring, in order to avoid periods of irregular usage patterns (e.g., during holidays or breaks). While longer periods might be preferable, these periods are appropriate given the scope of the evaluation and reported usage characteristics.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture hours of operation. The lighting fixture quantities seem to be well established and were counted to within 5% to 10% in utility post-installation inspection visits. The pre-retrofit and post-retrofit connected loads associated with various fixture types are also adequately quantified in the SPC lighting wattage tables. However, the post-retrofit lighting fixture wattages should be confirmed.

Uncertainty for the savings estimate for the warehouse fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables.

- 785 fixtures expected, minimum 735, maximum 825 (+/- 5%)
- 8,760 hours pre retrofit expected/reported, minimum 6000 hours, maximum 8760 hours (based on building manager comments)
- 294 watts per fixture post retrofit expected, minimum 228 watts, maximum 302 watts (+3% / - 25% based upon lowest standard wattages and documentation in the application paperwork)

Accuracy and Equipment

The light loggers to be used are Dent TOU-L Lighting *Smartlogger* dataloggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Annualizing that data from a 7 to 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

Current or power meters may also be used. The power meter used will be an Amprobe ACD-41PQ, with an accuracy of +/- 3.5%. An advantage of using current or power meters to monitor load is that the percent of time energized for an increased number of fixtures may be able to be captured.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on April 5, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Lighting fixture quantities and hours of operation were verified.

Installation Verification

The facility representative verified that the metal halide fixtures were replaced on a one for one basis. It was physically verified that 8-lamp T8 fluorescent fixtures were installed in the facility. This is the only measure in this application. The verification realization rate for this project is 1.0 (785/785). A verification summary is shown in Table 5 below.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measure in the SPC application covering the lighting efficiency retrofit. This is the only measure in this application.

Summary of Results

The facility representative stated that the building is occupied continuously.

Very few burned out lights were observed during the site visit. Burned out lights are regularly replaced. Therefore, there was no adjustment to the lighting energy consumption due to burned out lamps.

All lights are expected to be operating during the peak demand period defined as the three contiguous hottest weekdays between 2 pm to 5 pm, Monday to Friday, in the week with the hottest weekday in June, July, August or September.

The ex ante calculations were revised after the evaluation site visit to reflect actual wattages expected for the fixtures.

- Pre-retrofit hours of operation: 8,760 hrs/yr
- Pre-retrofit wattage: 0.458 kW per fixture x 785 lamps = 359.53kW
- Annual kWh usage: 359.53 kW x 8,760 hrs/yr = 3,149,483 kWh/yr
- Post-retrofit hours of operation: 8.760 hrs/yr
- Post-retrofit wattage: 0.294 kW per fixture x 785 lamps = 230.79 kW
- Annual kWh usage: 230.8 kW x 8,760 hrs/yr =2,021,720 kWh/yr
- The resulting annual kWh savings = 3,149,483 kWh/yr –2,021,720 kWh/yr= 1,127,763 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load and adding the diversity factor adjusted savings for occupancy sensor use.

Summer peak demand reduction is calculated as the entire reduction in connected kW load:

359.53 kW – 230.79 kW =128.74 kW

The engineering realization rate for this application is 0.78 for both demand kW reduction and energy savings kWh. A summary of the realization rate is shown in Table 4.

Utility billing data for the site was obtained from the utility and supplemented with more recent data from the customer at the time of the site visit. Pre-retrofit annual consumption (for one year prior to retrofit) was 3,912,888 Wh. Peak demand was 624.6 kW. and the ex post calculation results based on the utility billing data and the evaluation site visit.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The revised ex ante results showed a 26.3% decrease in total meter kW, a 65.6% decrease in lighting end use kW, a 36.7% decrease in total meter kWh, and a 70.0% decrease in lighting end use kWh. The ex post results showed a 20.6% decrease in total meter kW, a 51.4% decrease in lighting end use kW, a 28.8% decrease in total meter kWh, and a 54.9% decrease in lighting end use kWh.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak	Annual
	Demand kW	kWh
Total Meter	624.6	3,912,888
Baseline End Use	250.3	2,054,511
Ex ante Savings	164.1	1,437,209
Ex Post Savings	128.7	1,127,763

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	26.3%	36.7%	20.6%	28.8%
Baseline End Use %	65.6%	70.0%	51.4%	54.9%

6. Additional Evaluation Findings

The ex post kW demand and kWh reduction is lower than the ex ante estimate because the ex ante savings estimated each post retrofit fixture at 0.256 kW when in actuality the fixtures installed used 0.294 kW. The ex post energy savings also used a slightly lower pre retrofit fixture wattage for the metal halide fixtures, conforming with values used in the Express Efficiency work papers.

The lighting baseline use was estimated in Table 1. However, the pre retrofit lighting use is a large portion of the total meter use. It is possible that there is another meter serving the site or that the lights are not fully energized.

In addition to saving energy, the benefits of the project are increased clarity of light, increased light levels, increased employee comfort and better working conditions. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future.

Participation in the 2004/2005 SPC Program has not been known to encourage the customer to perform other energy efficiency projects.

With a cost of $217,951 and a $71,860 incentive, the project had a 0.78 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 1.00 years. A summary of the economic parameters for the project is shown in Table 3.

7. Impact Results

The pre-retrofit lighting fixture type, quantities and hours of operation were unable to be physically verified. However, these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	2/7/2006	$217,951	164.1	1,437,209	0	$186,837	$71,860	0.78	1.17
SPC Program Review (Ex Post)	4/5/2007	$217,951	128.7	1,127,763	0	$146,609	$71,860	1.00	1.49

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	134.6	1,175,899	-
SPC Installation Report (ex ante)	164.1	1,437,209	-
Impact Evaluation (ex post)	128.7	1,127,763	-
Engineering Realization Rate	0.96	0.96	NA

Note: tracking system values updated by IOU in January 2008 are included above.

The Installation Verification Summary is shown in Table 5 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 6.

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING – OTHER	L		Replace 785 metal halide fixtures with 785 8-lamp T8 fluorescent fixtures		785	8 lamp T-8 fixtures	Physically verified lamp type and verified quantity from floor plan and documentation of previous inspectors.	1.00

Table 6: Multi Year Reporting Table

Program ID:	Application # A041						
Program Name:	SPC 04-05 Evaluation						
Year	Calendar Year	Ex-ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005						
3	2006	1,437,209	1,127,763	164	128.7	0	0
4	2007	1,437,209	1,127,763	164	128.7	0	0
5	2008	1,437,209	1,127,763	164	128.7	0	0
6	2009	1,437,209	1,127,763	164	128.7	0	0
7	2010	1,437,209	1,127,763	164	128.7	0	0
8	2011	1,437,209	1,127,763	164	128.7	0	0
9	2012	1,437,209	1,127,763	164	128.7	0	0
10	2013	1,437,209	1,127,763	164	128.7	0	0
11	2014	1,437,209	1,127,763	164	128.7	0	0
12	2015	1,437,209	1,127,763	164	128.7	0	0
13	2016	1,437,209	1,127,763	164	128.7	0	0
14	2017	1,437,209	1,127,763	164	128.7	0	0
15	2018	1,437,209	1,127,763	164	128.7	0	0
16	2019	1,437,209	1,127,763	164	128.7	0	0
17	2020	1,437,209	1,127,763	164	128.7	0	0
18	2021	1,437,209	1,127,763	164	128.7	0	0
19	2022					0	0
20	2023					0	0
TOTAL	2004-2023	22,995,350	18,044,208				

Final Report

SITE A042 COCO **IMPACT EVALUATION**
SAMPLE CELL: ORIGINAL **TIER: 4** **END USE: Lighting**

Measures	Lighting Retrofit (including Occupancy Sensors and Photocells)
Site Description	Food / Beverage Processing

1. Measure Description

Replace 508 T12 fixtures with fixtures using T8 lamps and electronic ballasts. Replace 338 HID fixtures with high output (HO) T5 fixtures and T8 fixtures. Install 80 high bay lighting sensors and 12 photocells. De-lamp 26 eight foot T12 lamps.

2. Summary of the Ex Ante Calculations

The total ex ante kW demand and kWh savings approved in the Installation Report Review were 102.3 kW and 529,258.5 kWh. This agrees with the utility tracking system figures (allowing for rounding functions). The majority of savings (85%) are obtained from two of the five itemized measures involving the replacement of 338 high intensity discharge (HID) fixtures with HO T5 fixtures or T8 fixtures and installation of high bay lighting sensors to control 80 of these fixtures. The other itemized measures involved replacement of T12 fixtures with T8 fixtures/electronic ballast, de-lamping of T8 lamps, and installation of photocells.

The ex ante calculations for the itemized measures are typically based on the 2004-2005 Express Efficiency workpapers. The workpapers discuss general descriptions of measures that are the basis for evaluation. The process industrial market sector is used for this application. The workpaper assumptions for the lighting measures implemented at this site prescribe 6,650 annual operating hours and a coincident diversity factor of 0.99 where applicable.

The workpapers cover replacement of standard 400 watt metal halide (MH) fixtures with high output four lamp T5 fixtures. The work paper indicates the total wattage drops from 0.458 kW to 0.234 kW with a non-coincidental demand savings of 0.224 kW per lamp. The coincident kW and kWh savings are listed as 0.210 kW and 1,504 kWh/year for a process industrial application.

The workpapers also detail conversion from 4 foot fixtures (using T12 lamps and energy saving ballasts) to 4 foot fixtures (using T8 lamps and electronic ballasts). The average of the two lamp fixture and three lamp fixture savings is used as the basis of the per fixture savings of 0.024 kW. Coincident demand savings for the process industrial market sector is 0.012 kW and annual kWh savings of 81 kWh per lamp.

For removal of eight foot lamps, the original fixture wattage is based on T-12, 60-watt lamps in fixtures employing energy savings ballasts and assumes removal of one lamp and its associated ballast. The work paper indicates the total wattage drops from 0.205 kW to 0.126 kW with a non-coincidental demand savings of 0.079 kW per removed lamp. The coincident kW and kWh savings are listed as 0.080 kW and 531 kWh for a process industrial application.

For occupancy sensors, the workpaper savings are based on the control of eight (8) 4 foot 2 lamp fluorescent fixtures with 34 watt T-12 lamps, consuming 72 watts each including the ballast. Savings are based on a reduction of use hours from 2,210 hours/year to 1,040 hours/year (1,170 hours/year reduction). The workpaper reports a total 789 kWh savings (674 kWh/year plus a 17% office sector demand interactive effects factor). The non-coincident peak reduction of 0.305 kW was derived from the 0.576 kW controlled wattage and a 45% reduction in hours. Coincident peak reduction was reported at 0.381 kW, which included a 1.25 demand sector interactive effects factor

For photocells, the workpaper savings are based on the control of outside lamps in conjunction with time clocks. Savings are based on a reduction of 280 hours per year due to the use of photocells. The photocell is assumed to control four 70-watt high pressure sodium lamps that provide exterior lighting. The workpaper reports a total 106 kWh per year savings for all market sectors. The non-coincident peak is reduced by 0.3805 kW. There is no reduction in coincident peak demand.

3. Comments on the Ex Ante Calculations

All measures were itemized; the ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. The calculations performed with figures from those workpapers did not result in the exact kW and kWh savings listed for the sub-measures.

In addition, the workpapers prescribe savings based on certain conditions, which do not always apply to the installed conditions, and so do not accurately represent the actual situation evaluated.

Based upon the wattage reduction resulting from the pre and post retrofit of the HID fixtures, as dictated by the fixture wattages in the post installation lighting tables contained in the application paperwork; the savings of 59.9 kW for the 338 fixtures may be reasonable; they may however, be overstated by up to 10%. The kWh savings are based upon operating hours of the facility. No information has been provided regarding the operating hours for the plant. However, these may be reasonable estimates.

All the sensors have been installed in the warehouse type facility. Therefore, ex-ante savings calculations for sensors may be better characterized by using the typical diversity factor of a warehouse instead of a process industry. According to the workpapers, the diversity factor to calculate the peak demand savings for a typical warehouse is 0.84 and the demand for the process industrial sector is 0.99.

The greatest discrepancy between the workpapers and the actual operating conditions at this facility appear to be related to the use of the occupancy sensors. In this facility, the motion sensors control one new fluorescent fixture verses the eight fixtures as forecast in the workpapers, reducing the controlled wattage. The motion sensors are claimed to be responsible for about 25% of the total savings.

The ex ante savings figures can be checked for accuracy using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation. The workpapers assume typical operating hours for such a facility to be 6,650 hours per year. There was no better estimate at this point of actual hours of operation. Therefore, these operating hours were used for check calculations. However, there can be a variation of + / - 10 % or more from the actual operating hours.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x (1 – diversity factor)

The check calculations for the main measures (involving conversion from fluorescent, installation of motion sensors, time clocks and LED exit signs) were performed as follows:

Retrofit from HID to HO T5 or T8 fixtures

- Pre-installation hours of operation: 6,650 hrs/yr

  0.458 kW per fixture x 338 fixture = 154.8 kW

  Annual pre measure kWh use: 154.8 kW x 6,650 hrs/yr = 1,013,940 kWh/yr
- Post -installation hours of operation: 6,650 hrs/yr

  0.224 kW per (T8) fixture x 59 fixtures = 13.2 kW

  0.234 kW per (T5) fixture x 279 fixtures = 65.3 kW

  Annual post measure kWh use: 78.5 kW x 6,650 hrs/yr = 514,175 kWh/yr

- kWh savings = 1,013,940 kWh/yr – 514,175 kWh/yr = 499,765 kWh/yr (verses 334,214 kWh/yr identified as the ex ante savings for this sub-measure)
- kW savings = 154.8 kW – 78.5 kW = 76.3 kW(versus 59.9 kW identified as the ex ante savings for this sub-measure)

High bay lighting sensors

- Pre-installation hours of operation: 6,650 hrs/yr

  0.234 kW per fixture x 80 fixtures = 18.72 kW

  Annual pre measure kWh use: 18.72 kW x 6,650 hrs/yr = 122,616 kWh/yr
- Based on 45% reduction due to sensors post -installation hours

operation: 3,658 hrs/yr

0.234 kW per fixture x 80 fixtures = 18.72 kW
Annual post measure kWh use: 18.72 kW x 3,658 hrs/yr = 68,478 kWh/yr

- kWh savings = 122,626 kWh/yr – 68,478 kWh/yr = 54,138 kWh/yr (verses 132,912 kWh/yr identified as the ex ante savings for this sub-measure)
- kW savings = 18.72 x (1 – 0.84) = 3.0 kW (versus 30 kW identified as the ex ante savings for this sub-measure)

Other measures also show savings that appear realistic in this application.

4. Measurement & Verification Plan

The facility encompasses a building with 200,000 square feet. The building is reported to be approximately 25 years old.

The most important information to obtain will be an accurate determination of the operating hours for various areas of the facility. No information has been provided about the operating hours of the facility.

The exact count of fixtures and wattages will be verified using the post installation lighting table provided by the facility. Spot checks will be performed for verifying lighting counts in non warehouse areas and in a minimum 10% of the other areas in the facility. According to the installation review report (IRR), 508 T12 lamps were replaced with T8 lamps with electronic ballast but the post installation lighting table has only 496 T12 lamps replaced with T8 lamps.

There are two main measures that will be evaluated, the HID fixture retrofit (338), and the installation of lighting sensors (80 sensors) in the main east and west warehouses to control these fixtures. The retrofit of 338 HID (400 watt metal halide) fixtures involved 279 HO four lamp T5 fixtures and 59 six lamp T8 fixtures.

The following activities should be performed for this evaluation:

- The complete number of retrofitted fixtures should be verified.
- Verify operating hours before and after the installation of these fixtures through logs and questioning operation personnel (including energization at nights, weekends holidays).
- Place lighting loggers to determine the operating hours if required (four loggers place in areas where fixtures are not controlled by motion sensors in the east and west warehouse, and four loggers in the filling room, production rooms, and other areas).
- Check wattages of the pre and post lamps or fixtures through check with lighting drawings, old ballasts and lamps in stock, and new ballasts/lamps.
- Verify presence of motion sensors and photocells

- Estimate hours of use and pre retrofit control of fixtures controlled by photocell (timer, etc.)
- Where lighting circuits can be isolated, spot measurements will be performed to verify post installation wattages.

These lighting sensors were installed in the east warehouse and west warehouse of the facility. A total of 25 sensors were installed in the east warehouse and 55 sensors were installed in the west warehouse.

Formulae and Approach

A modified version of IPMVP Option A can be utilized. There will be an estimated 12 lighting loggers installed for about 7 -14 days in the facility to quantify hours of operation. The lighting loggers will be installed in production area, warehouses and other places strategically. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = $kWh_{pre} - kWh_{post}$

Summer peak demand period savings = average $kW_{pre} - kW_{post}$ during the hottest periods between 2 pm to 5 pm, Monday to Friday, in June, July, August, September

Uncertainty for the savings estimate for the warehouse fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables.

<u>Uncertainty with HID retrofit</u>

- 6,650 expected operation hours, minimum 5,500, maximum 7,500(+ /- 15% expected range)
- 76.3 kW savings expected, 90 kW minimum, 60 kW maximum (+/- 20% expected range).
- kWh savings: 499,765 kWh expected, 400,000 kWh minimum ; 600,000 kWh maximum (+ / - 20% expected range)

Uncertainty with installation of lighting sensors

- 6,650 pre-installation expected operation hours, minimum 5,500, maximum 7,500 (+ /- 15% expected range)
- 3,658 post-installation expected operation hours, minimum 3,000, maximum 4,000(+ /- 15% expected range)
- kWh savings: 54,138 kWh expected (+ / - 20% for range of possible savings)

Accuracy and Equipment

The lighting loggers capture on/off cycles of the lighting equipment 15 minute interval data and for the purposes of the evaluation are considered to be 100% accurate where reviewed data are deemed reasonable.

Annualizing the kW data to the hottest summer period is projected to result in a possible error in the final results of +/- 5 %.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 28, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Eight lighting loggers were installed in four main areas of the facility – the production, packaging, warehouse, and interior loading dock areas of the plant.

Installation Verification

The facility representative verified that there were 303 high pressure sodium or metal halide fixtures with 400-watt lamps and approximately 500 one lamp, two lamp, or four lamp fixtures using T12 lamps before the retrofit and that generally they were operating continuously with the exception of seven holidays when the plant was shut down. The retrofit was completed in October 2005. There are 45 six-lamp T8 recessed fixtures with fluorescent lamps, 276 four-lamp fixtures with T-5 HO fluorescent lamps, and additional two-lamp and four-lamp 8 foot fixtures. There are four-lamp T8 fixtures with 508 lamps. All lamps are high output (HO) or high efficiency lamps. Seventy-seven occupancy sensors of 80 were counted on the post-retrofit fixtures in the warehouse areas. Additional eight-foot T12 fixtures were removed and photocells were installed to control new exterior fluorescent fixtures. The approved total of sensors and lamps appears reasonable. The verification rate is recorded, based on the sample of fixtures inspected, as 1.00. A verification summary is shown in Table 5.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measures in the SPC application covering both lighting efficiency and lighting control retrofits. These are the only measures in this application.

Summary of Results

Eight (8) Dent TOU-L lighting Smart Loggers were installed in the warehouse for 46 days (from September 28, 2007-November 13, 2007) to measure the operating hours of a representative sample of the retrofit lighting fixtures. The facility representative stated that the monitoring period had been representative of normal facility operation. It was found that on average, the lights without occupancy sensors were on !00% of the time (all lights at the facility were off briefly during a power failure or plant shutdown). Fixtures with occupancy sensors were energized 75% of the entire time, in comparison to 55% assumed in the ex ante calculations. On weekends, the hours of operation and the staffing is one third that of weekdays. The energy use for controlled fixtures on weekdays appears to be 89% on average, and on weekends, 59%.

Other than lighting, the significant electrical loads in the unconditioned warehouse are conveyor motors, product container fabrication, packaging machines, and battery chargers for the forklifts. The customer also occupies a 2-story air conditioned office space at this site.

Figure 1: Measured Hourly Lighting Intensity Profiles

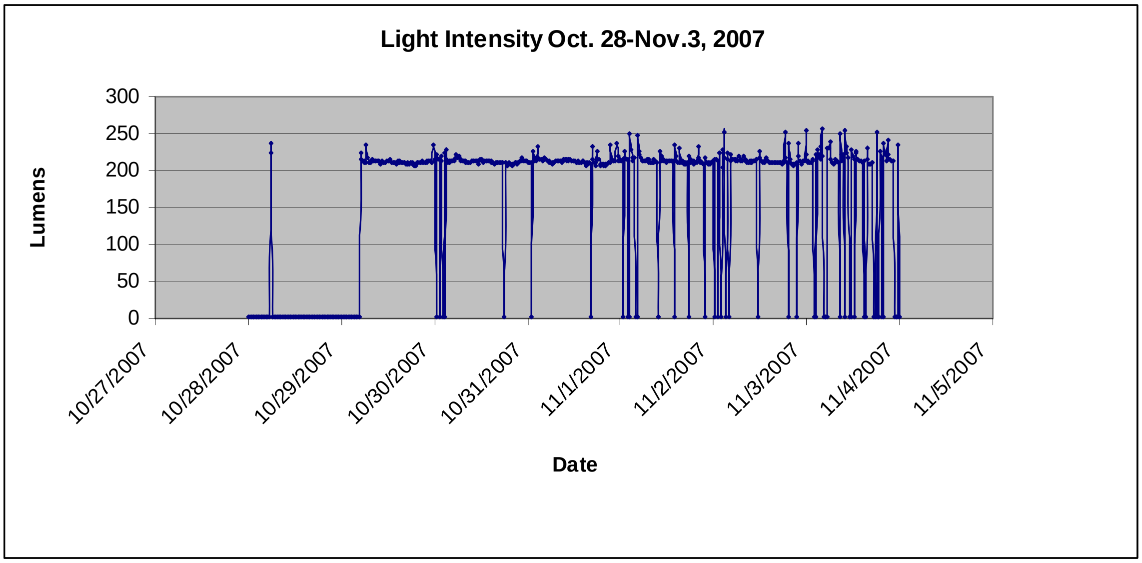


Figure 1 displays light intensity measured for one occupancy controlled fixture over a period of one week. The view is typical of the lighting control for the warehouse portion of this facility. The top of the graph line indicates periods when the light was energized and when the intensity drops to the zero baseline, the fixture was de-energized. For example, the first day on the graph, October 27, 2007 was Sunday. The logged data indicate the fixture was not energized most of the day.

Ex ante calculations were performed on the measures producing the greatest savings using the verified operating schedule and the lighting fixture wattage provided in tables included with the SPC application paperwork.

The ex post impacts are calculated as follows:

Pre-retrofit hours of operation was 100% less seven holidays or (8,760 - 168 hours) for 8,592 hrs/year.

Pre-retrofit wattage for HID lamps was:

0.455 watts per lamp x 338lamps = 153.8 kW

Annual kWh usage was 153.8 kW x 8,592 hrs/yr = 1,321,450 kWh/yr

Post-retrofit hours of operation are 8,592 hrs/yr for 258 four-lamp fixtures without occupancy sensors.

Post-retrofit hours of operation for controlled fixtures based on lighting logger use data are 6,132 hrs/yr (75% x 8,760 hrs/yr) for 80 four-lamp fixtures with occupancy sensors.

For fixtures without occupancy sensors post-retrofit wattage is 78 watts for each of 14 fixtures, 156 watts for 3 fixtures, 224 watts for 45 fixtures, 234 watts for 196 fixtures = 1.09 kW + 0.468 kW + 10.08 kW + 45.86 kW = 57.5 kW

For fixtures with occupancy sensors post-retrofit wattage is 234 watts for 80 fixtures = 18.72 kW

- Annual kWh usage is 57.5 kW x 8,592 hrs/yr + 18.72 kW x 6,132 hrs/yr = 494,040 kWh/yr + 114,791 kWh/yr = 608,831 kWh/yr

- The resulting annual kWh savings for these fixtures is 1,321,450 kWh/yr – 608,831 kWh/yr = 712,619 kWh/yr.

- The annual kW savings for these fixtures is 153.8 kW – 57.5 kW = 96.3 kW.

There are no kW savings attributed for the occupancy sensors.

Including the smaller savings the total kWh and kW savings for the five measures are: 712,619 kWh/yr + 62,131 kWh/yr = 774,750 kWh/yr and 96.3 kW + 10.9 kW =107.2 kW.

Utility billing data was reviewed for 2 meters r at the site for which data were provided during the retrofit period. In the 12 month period for 2003 (pre-retrofit), the facility consumed 769,760 kWh. The highest demand was 266.4 kW. Table 1 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 38.4 % decrease in total meter kW, a 48% decrease in lighting end use kW, a 68.8% decrease in total meter kWh, and a 86% decrease in lighting end use kWh. The ex post results showed a 40.2% decrease in total meter kW, a 50.3% decrease in lighting end use kW, a 100.6 % decrease in total meter kWh, and a 125.8% decrease in lighting end use kWh. As these results indicate, all meters from the site may not be included in the facility totals.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	266.4	769,760
Baseline End Use	213.1	615,808
Ex Ante Savings	102.3	529,257
Ex Post Savings	107.2	774,750

Lighting was estimated at 80% of the total use.

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	38.4%	68.8%	40.2%	100.6%
Baseline End Use %	48.0%	85.9%	50.3%	125.8%

6. Additional Evaluation Findings

The ex post kW demand reduction is greater than the ex ante estimate because the ex ante estimated demand savings associated with the HID changeouts less than determined by the ex post calculations. The ex post energy savings are greater than the ex ante energy savings because the ex ante savings underestimated the amount of time the lights would be turned off by the occupancy sensors. The installation of occupancy sensors was an itemized measure. The itemized measures are based on the workpaper scenarios which predict approximately 1,000 hours/year reduction in lighting use over manual switching. The actual reduction determined from the lighting loggers is 25%, or closer to 2,000 hours per year.

The facility representative stated that cost estimates were provided by three vendors. The representative evaluated the estimates for return on investment and made a recommendation to the corporate entity for implementation. In addition to saving energy, the benefits of the project are better quality of lighting and better illumination, particularly for housekeeping and safety. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program was near the tail end of several energy saving retrofits. This measure has not encouraged them to perform any other energy efficiency projects for which they did not participate in an incentive program. However, management always looks for ways to save money and energy savings was reported to be a big contributor.

We were unable to physically verify the pre-retrofit lighting fixture type, quantities and hours of operation. However, these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The fixtures indicated in the application were installed and verified. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $201,807 and a $31,389 incentive, the project had a 2.48 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 1.69 years. A summary of the economic parameters for the project is shown in Table 3.

7. Impact Results

The engineering realization rate for this application is 1.05 for demand kW reduction and 1.47 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 4.

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	11/21/2005	$201,807	102.26	529,259	0	$68,804	$31,389	2.48	2.93
SPC Program Review (Ex Post)	11/26/2007	$201,807	107.2	774,750	0	$100,718	$31,389	1.69	2.00

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	102.3	529,258	-
SPC Installation Report (ex ante)	102.3	529,258	-
Impact Evaluation (ex post)	107.2	774,750	-
Engineering Realization Rate	1.05	1.46	NA

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Installation of 338 T5 fixtures, installation of 80 motion sensors, installation of 508 T8 lamps with ballasts, 26 T12 lamps removed, installation of 18 photocells		944	T5 fixtures, T8 fixtures, occupancy sensors, photocells	Physically verified lamp type and spot checked quantity	1.00

Table 6: Multi Year Reporting

Program ID:	001 Application # A042						
Program Name:	SPC 04-05 Evaluation						
Year	**Calendar Year**	**Ex-ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004						
2	2005	88,210	129,125				
3	2006	529,259	774750	102.25	107.18		
4	2007	529,259	774,750	102.25	107.18		
5	2008	529,259	774,750	102.25	107.18		
6	2009	529,259	774,750	102.25	107.18		
7	2010	529,259	774,750	102.25	107.18		
8	2011	529,259	774,750	102.25	107.18		
9	2012	529,259	774,750	102.25	107.18		
10	2013	529,259	774,750	102.25	107.18		
11	2014	529,259	774,750	102.25	107.18		
12	2015	529,259	774,750	102.25	107.18		
13	2016	529,259	774,750	102.25	107.18		
14	2017	529,259	774,750	102.25	107.18		
15	2018	529,259	774,750	102.25	107.18		
16	2019	529,259	774,750	102.25	107.18		
17	2020	529,259	774,750	102.25	107.18		
18	2021	441,049	645,625	102.25	107.18		
19	2022						
20	2023						
TOTAL	**2004-2023**	8,468,136	12,396,000				

Final Site Report

SITE A043 PLNU IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: AC&R

Measure	Installation of two new computer room air conditioning units and economizers on air handling units
Site Description	College / Educational Campus

1. Measure Description

Install two (2) new 10 ton computer room air conditioning (CRAC) units for nighttime computer room cooling and install seven (7) new economizers on existing air handling units.

2. Summary of the Ex Ante Calculations

The ex ante savings for the measures is 364,968 kWh and 0 kW as defined in the Operating Report for the computer room AC units. The Operating Report gives the final ex ante savings, as M&V was required on this project under the SPC program. Savings of 239,058 kWh were as identified in the Implementation Report Review. The utility tracking system reported savings as 484,200 kWh (which includes 364,968 kWh for the new AC units and 119,232 kWh for the economizers. It appears the AC unit savings used customized calculations and the economizer savings were calculated using the SPC Calculator (both measures were submitted as calculated measures).

3. Comments on the Ex Ante Calculations

According to the application paperwork, the AC unit energy savings were calculated based on the measurements taken on the central plant (not operated for 6 hours at night) and estimates of the new computer room cooling units. The central chiller system is estimated to be shut off for a total of 2,104 hours for the year. This results in a demand reduction of 181 kW for the central chiller system. The newly installed two 10 ton A/C units consume 7 kW, which results in an overall demand savings of 173 kw. The energy usage savings are calculated to be 364,968 kWh (kW usage and savings are rounded in the application paperwork).

The savings calculations for the AC units were performed from the information provided by the reviewer and the facility. The calculated savings are equal to the savings reported in the operating report review. However, there could be significant variation in the savings due to the actual system loading of the chillers, HVAC auxiliaries, and the new CRAC units. Based on the application paperwork, a period in June 2004 was monitored and the chiller was found to go off for 15 minutes in a 24 hour period. The average is approximately 87 kWh for the larger chiller (verses 96.8 kW in the calculations). Chiller 1 and chiller pump 1 were off during this entire period. Pump 10 and 11 (PHW - primary hot water) and pump 13 (SHW – secondary hot water) and the cooling tower fans should be confirmed to be operating if included in the pre retrofit energy use.

Hours of chiller plant reduction should also be confirmed but appear to be realistic. The paperwork indicates that the chiller plant is not operated from 11 pm to 5 am each night. If the chiller plant is operated 365 days per year, this equates to 2190 hrs per year (not 2104).

The average CRAC unit consumption of 7 kW, based on the size of the units and nighttime operation, appear reasonable.

Based on these considerations, pre retrofit energy use and savings appear to be realistic.

The 2004 SPC Calculator was used to calculate the savings for the economizers. The savings obtained according to the SPC Calculator output sheets contained in the application paperwork are not equal to the savings reported in the utility tracking system.

Inputs for the A/C Economizers:

Equipment specification

- Cooling system type: Chillers, Water Cooled >150 tons <300 tons - Centrifugal
- Efficiency: 0.85 kW/ton
- No: of AH Units: 7
- Total tons: 136 tons
- Control method: Modulating

Building description

- Building type: College
- Conditioned area: 152,274 sq ft
- System operating hours: 6 am – 8 pm Mon. – Fri.; 6 am to 5 am Saturday (note error in end time)

2004 SPC Energy Savings Calculator output:

- Baseline usage: 189,441 kWh
- Proposed usage: 87,315 kWh
- Savings of: 102,125 kWh (verses 119,232 kWh reported in the utility tracking system)
- Runtime hours: 1,019

There is no peak demand saving for this measure as the savings realized are due to turning off the central chiller system and using newly installed CRAC units for the computer room during the night time, and in using economizers when outdoor air is sufficient for building cooling (also occurring predominantly during the early morning/evening and outside peak demand periods).

The Post-Installation Inspection Report identified the new units as 12.5 ton and the total number of economizers as nine (9) units. These discrepancies could affect the overall energy savings, particularly for the economizers.

4. Measurement & Verification Plan

The facility encompasses several buildings of which four buildings are connected to the central plant cooling and hot water systems. These buildings comprise an area of 152,274 square feet. The economizers are on air handling units at these four buildings. The computer room with the new air cooled direct expansion (DX) CRAC units is in one of these buildings.

The existing computer room cooling system consists of one 10 ton DX air cooled unit and one 12.5 ton air handling system using chiller water form the central plant. The 12.5 ton chilled water system operates continuously while the 10 ton chiller system acts as a stand by and comes on during high load periods. It is not sufficient to handle the nighttime computer room load. As a result, the central chiller operates continuously to provide cooling to the facility during the night time. During night time cooling is required only for the computer rooms. Two new 10 ton A/C units were installed to provide cooling for the computer rooms. This allowed the facility to reduce the operating hours of the central chiller system, shutting the plant down during the night. This measure resulted in significant energy savings for the facility from the chillers and chilled water auxiliaries.

As part of the M&V activities, the following factors will be verified, to the extent possible:

1. The central chiller system is shut down for 6 hours per night.

2. The chiller was energized 365 days per year prior to the retrofit.

3. The chiller is energized 365 days per year after the retrofit.

4. No significant changes were made to the building since the installation that would affect the cooling load profiles.

The energy management system will be used as possible to obtain hours of chiller operation, kW of new AC units over year, the kW of HVAC auxiliaries (pumps, fans, etc.), the nighttime cooling fan operation and PHW/SHW pump operation, confirming data for kW draws on chillers in morning after warm up or evening before shutdown to verify minimum kW draw.

Spot readings for kW will be taken as possible on pumps 2, 4, 6, 7, and 8.

KW or current monitoring could be conducting on the two new CRAC units (otherwise 7 kW will be accepted as this is the average measured data over 12 months and not the biggest source of uncertainty.)

The facility installed 7 economizers cycles for the air handlers serving four buildings conditioning an area of 152,274 sf. The installation of economizers allows ambient air to be used for cooling the building for a calculated total of 1,019 hours per year.

The reported operating hours and cooling capacity of the air handlers' hours will be verified. Additionally the air flow (cfm) - both total and minimum outside air, will be obtained. Setpoints for supply air will be obtained. It will be determined if they are on variable speed drives (VSDs) to slow fan operation.

The goal of the measurement and verification (M&V) plan is to estimate the actual annual kWh and peak kW savings over the useful life of the measure. This will be done by establishing the load and operational time of the new AC units, the existing chiller plant, and the air handling unit's auxiliary mechanical chillers, pumps and fans.

Formulae and Approach

A modified version of IPMVP Option A can be used. The energy savings will consist of the baseline energy usage minus any post-installation energy use calculated as part of this evaluation.

The operating hours / sequence of operation of the central chiller system, the auxiliaries and the two new A/C units will be ascertained from the facility operators and the energy management system.

Hours and kW readings will be obtained.

Spot kW readings on major pumps and cooling tower fans will be performed, as possible

KW readings may be obtained on each of the chillers over a nighttime period from the EMS.

Ratings and models of the chillers will help determine minimum loadings.

Size of the fan / pump motors will determine maximum expected kW draw.

KW or current on the new AC units should be monitored over the nighttime period to determine loading and compare to the ex post calculations. The results will be averaged.

Operators will be queried to ascertain the control strategies, if any, used at the facility – particularly periods of deenergization of chillers and air handlers during the holidays and supply air temperature setpoints at the air handlers. It also will be determined if the chiller is deactivated for any part of the year.

Dent TOU power loggers or kW data loggers measuring devices will be used to the monitor the new A/C units to obtain the load profiles of the systems. The loading data obtained will determine the average kW demand during the night time. The systems would be monitored for a period of 1 nighttime period to 3-7 days.

For the evaluation of the economizer measures, air flow may be obtained from the drawings.

A vane anemometer may be used if outside air intakes are accessible, using a traverse method on several air handlers, taking a minimum of 12 readings, to determine outside air.

Airflow, CFM and outside air (OA) percentages will be determined by the EMS and T&B reports, as well as from as built drawings if available. Use of VFDs and lower CFMs will be determined from the EMS. The tonnage of units will be assessed from drawings.

The EMS control strategy for the economizers will be determined. The use of economizers on all air handlers will be confirmed.

Temperature sensors will be placed in the air streams of a larger and a mid size units. Placement in the outside and mixed air stream will be needed to determine full economizer operation. Placement of a sensor in the return air stream will allow measurement of the outside air percentages, as well, and will be attempted. Outside air will be monitored to determine the potential operating hours of the systems.

The information obtained will give sufficient data for accurate pre retrofit and post retrofit calculations. The following formulae will be used to calculate the energy usage savings:

(kW pre – kW post) x hrs = kWh saved

Q (btuh) = OA CFM x delta T x hrs x 1.08

kWh saved = btuh / 12000 Btu / ton hr x 0.85 kW/ton

Hours will be derived from 8760 hour climate zone data adjusted for affected hours

Two economizers will be monitored and used as the sample to estimate the savings for all seven economizers.

Uncertainty for the savings estimate for the retrofit can be more fully understood by setting projected ranges on the primary variables.

Uncertainties in installation of A/C units:

- 2,104 central chiller system off hours expected, minimum 1,700, maximum 2,500(+ /- 20% expected range)
- Chiller plant kW: 180 kW expected, minimum 140 kW, maximum 200 kW (+10%, -20%)
- New A/C units demand 7 kW expected, minimum 4 kW, maximum 15 kW (+ 120% /- 40% expected range)
- kWh savings: 364,568 kWh expected, 300,000 kWh minimum ; 430,000 kWh maximum (+ / - 20% expected range)

Uncertainties in economizer calculations

- 1000 hours possible, minimum 600, maximum 1,400 (+ /- 40% expected range)
- Chiller plant kW/ton: 0.85 kW/ton expected, minimum 0.8 kW/ton, maximum 1.0 kW /ton (+20%, -6%)
- Delta T : 20 F expected, 15 minimum , 25 maximum (+ 25% /- 25% expected range)
- 7000 average CFM expected; 3,500 CFM minimum ; 10,500 CFM maximum (+ / - 50% expected range)

Accuracy

Two Dent TOU loggers will be used on each system. The Dent loggers are accurate to within 1% for power. If the energy management system or the Dent loggers are used to monitor hours of operation, these values will be deemed to be 99% accurate.

The vane anemometer is expected to be 10% accurate (instrument plus reading error).

HOBO dataloggers, if used, are expected to be 2% accurate.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on October 11, 2007. Information on the retrofit equipment and operating conditions was collected by inspecting the new cooling units and the air handlers, utilizing the energy management system, and by interviewing the facility representative. It was also possible to interview the energy service company personnel responsible for the retrofit.

The customer was able to provide electronic data from the EMS and as built drawings to assist this evaluation.

Installation Verification

The installation of the two computer room air conditioning (CRAC) units was confirmed. The application paperwork, particularly the SPC calculator, stated that there were seven economizers on air handling units installed. The electronic version of the Installation Report Review and Post installation Report noted nine units were retrofit with economizer cycles. The operated provided printouts for nine units; however, one of these units was a 100% outside air unit for which economizers do not apply. The economizer function and outside air dampers for one unit were deactivated due to humidity problems associated with the location of the outdoor air intake. Further, the economizer cycles on the other units were reverted to operate at pre retrofit conditions (20% minimum outside air at any time. The verification rate is 1.0 (2/2) for the air handlers. The verification rate for the economizers is 0 (0/8) for the economizer installations. The overall verification rate is 0.20 for equipment. The rate is approximately 75% on estimated energy savings in the utility tracking system.

Scope of the Impact Assessment

The impact assessment scope is for the AC cooling units and the economizer installations in the AC&R end use category in this SPC application. These are the only measures in the application.

Summary of Results

Measurements were taken from the facility's energy management system (EMS) for the new CRAC units. The amperages were taken with spot measurements and confirmed to be in the range of the EMS data. Hobo current loggers were placed on one leg of the input power to the CRAC unit compressors. Supply fan operation was estimated to be identical before and after the retrofit. The measure involved the compressor use for cooling only.

Custom calculations were used for the ex ante calculations. These calculations were based on the energy use of the entire chiller plant at night offset by the energy use of the new units. The use of the chilled water plant is the greatest component to the energy savings. The same methodology was used for the ex post analysis.

Information on nightly chiller plant use was obtained from the EMS. It was shown that the chiller consumes an average of 96.3 kW at night prior to the retrofit. This was adjusted from 96.8 kW, as the last period in the analysis including a portion of the nightly shutdown period (skewing the results from the true average).

The chilled water auxiliaries also are able to be shut down, including chilled water pumps and cooling tower fans. All three cooling tower fans were included in the savings. While this may occur to take advantage of night temperatures, the operator indicated that the fans cycle according to demand. Thus, the two smaller cooling tower fans may be able to be excluded from the savings. However, without other supporting information, these fans were remained as savings in the ex post analysis.

Likewise, hot water pumps, specifically pump 10 and pump 13 (SHW – secondary hot water) were also included in the ex ante savings. These were deleted form the ex post savings calculations.

The use of the pre retrofit CRAC units was added to the pre retrofit usage. The use of the new CRAC units was added to the post retrofit usage. The increase in usage averages 2.99 kW over 8760 hours (verses 7.09 kW over 2104 hours as reported in the ex ante savings.

The ex post use of this measure was determined as follows:

(96.3 kW chiller average at night + 76.8 kW chiller auxiliaries) x 2104 hrs /year (about 6 hrs per night) – 2.99 kW x 8,760 hours / year = 338,010 kWh / year

Note that the CRAC units are expected to operate on chilled water during the day. The energy demand would thus be expected to decrease during the day periods. However, the average demand during a typical weekday period between 2 pm and 5 pm, over the course of three days, was found to increase by 4.9 kW. This is likely because on improper setting of controls or high demand on the CRAC units.

The second measure involves the economizers. The ex ante savings for this measure were calculated using the SPC calculator for seven units with a cooling capacity of 136 tons, operation from 6 am to 10 pm Monday through Friday, and a chiller efficiency of 0.85 kW/ton.

However, it was found in the field that, according to the building operators, on one unit the outside air dampers were disabled and on the other units the economizer cycles were deactivated due to humidity concerns. The amount of outside air was constrained to the normal 20% minimum outside air on these units at all times, instead of 100% outside air. The savings from this sub-measure are thus 0 kWh/year and 0 kW.

Table 1: Chiller Auxiliaries

ID	Service	kW
Pump 1	PCHW	2.06
Pump 2	PCHW	7.75
Pump 4	SCHW	21.65
Pump 6	CDW	9.78
Pump 7	CDW	11.9
Pump 8	CDW	10.46
Pump 10	PHW	1.63
Pump 11	PHW	1.67
Pump 13	SHW	5.3
CTF1	CT	5.1
CTF2	CT	4.9
CTF3	CT	5.3

Table 2: Ex Ante Chiller Plant Usage

Total Pump & Fan kW		83.77
Chiller kW		96.80
Total Plant kW		180.57

Table 3: Ex Ante Chiller Plant Usage

Total Pump & Fan kW		76.8
Chiller kW		96.3
Total Plant kW		173.10

Table 4: Ex Post Savings Calculations

	hrs		**kW**		**#**		**kW**		**kWh**
Pre	2104		173.1		1		173.1		364,202
	8760		9.96		1		9.96		87,250
									451,452
Post	2104		0.0		1		0		-
	8760		12.95		1		12.95		113,442
									113,442
Saved							4.95		338,010
Totals							4.95		338,010

Early retirement considerations do not apply, as the measure was not submitted as an early retirement measure and the equipment was not required to be replaced. However, only the DX unit would be expected to be more efficient by a small amount. The main drivers for energy savings are not, as explained previously, the efficiency of the new equipment, but rather, the energy savings by deactivating the chiller plant.

Utility billing data for the site was reviewed. In a 12 month period, the buildings in the complex consume an estimated 2,000,000 kWh. Peak demand is estimated at 750 kW. Table 5 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 5: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Peak Demand kW	Annual kWh
Total Meter	750.0	2,000,000
Baseline End Use	375.0	1,000,000
Ex ante Savings	0.0	364,968
Ex Post Savings	-4.9	338,010

Baseline use is total AC&R use for building, estimated at 50%. Total meter use is estimated based on square footage.

Table 6 is a summary of the percent of energy savings for the total metered use and for the baseline end use. Energy changes show an 18.2 % decrease in total meter kWh, and a 36.5 % decrease in AC/R end use kWh. The ex post results showed a 0.7 % increase in total meter kW, a 1.3 % increase in AC/R end use kW, a 16.9 % decrease in total meter kWh, and a 33.8 % decrease in AC/R end use kWh.

Table 6: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	750.0	2,000,000
Baseline End Use	375.0	1,000,000
Ex ante Savings	0.0	364,968
Ex Post Savings	-4.9	338,010

Baseline use is total AC&R use for building, estimated at 50%. Total meter use is estimated based on square footage.

Table 7: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	0.0%	18.2%	-0.7%	16.9%
Baseline End Use %	0.0%	36.5%	-1.3%	33.8%

6. Additional Evaluation Findings

The ex post energy (kWh) savings are different than the ex ante energy savings because the chiller and CRAC unit use changed slightly. The economizer measure failed to perform as intended and was deactivated. These savings were in the utility tracking system but did not appear to be included in the ex ante savings.

The facility representative stated that the cost estimate provided in the application is based on the facility's energy service company. One ESCO was selected to implement several projects at the facility. The costs do not appear to be excessive for the work performed.

It was not possible to verify hours of operation, loading profile and efficiency of the pre retrofit AC units. However, the estimates used in the ex ante and ex post calculations are realistic.

The level of M&V employed at this site and the customer's and sponsor's provision of allowed accurate determination the impacts of the installed measures.

The installation did promote energy awareness at the college, especially among upper management. There were follow on projects implemented because of this measure; it was unknown if these projects were implemented through SPC and other incentive programs.

The pre retrofit equipment was over 15 years old and was undersized. However, the driver for the project was shutting down the utility plant and baseline considerations are not paramount. The main source of savings is from the shutdown of the power plant.

With a cost of $ 168,388 and a $ 33,468 incentive, the project had a 2.84 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 3.07 years. A summary of the economic parameters for the project is shown in Table 8. The Installation Verification Summary is shown in Table 10 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 11.

7. Impact Results

The engineering realization rate for this application is negative for demand kW reduction and 0.70 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 9.

Table 8: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	1/11/2005	$168,388	-	364,968	0	$47,446	$33,468	2.84	3.55
SPC Program Review (Ex Post)	12/4/2007	$168,388	(4.9)	338,010	0	$43,941	$33,468	3.07	3.83

Estimated energy savings are based on ex ante savings in the Operating Report and not savings in the utility tracking system.

Table 9: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	-	484,200	-
SPC Installation Report (ex ante)	-	364,968	-
Impact Evaluation (ex post)	(4.9)	338,010	-
Engineering Realization Rate	NA	0.70	NA

Table 10: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
AC Unit Replacement	AC&R	Replace two CRAC units with two new CRAC units to enable night central plant shutdown			2	Two ten ton Compuaire CRAC units	Physically verified quantity and operation - monitored amps	1.00
Economizers	AC&R	Install economizer ability for eight air handlers			0	Economizer (outside air damper) control disabled	Verified with building operator that OA damper econmoizer control was disabled.	0

Table 11: Multi Year Reporting Table

Program Name:		SPC 04-05 Evaluation A043					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	121,656	112,670				
2	2005	364,968	338,010	0	-4.9		
3	2006	364,968	338,010	0	-4.9		
4	2007	364,968	338,010	0	-4.9		
5	2008	364,968	338,010	0	-4.9		
6	2009	364,968	338,010	0	-4.9		
7	2010	364,968	338,010	0	-4.9		
8	2011	364,968	338,010	0	-4.9		
9	2012	364,968	338,010	0	-4.9		
10	2013	364,968	338,010	0	-4.9		
11	2014	364,968	338,010	0	-4.9		
12	2015	364,968	338,010	0	-4.9		
13	2016	364,968	338,010	0	-4.9		
14	2017	364,968	338,010	0	-4.9		
15	2018	364,968	338,010	0	-4.9		
16	2019	243,312	225,340	0	-4.9		
17	2020						
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	5,474,520	5,070,150				

Final Report

SITE A044 LOE IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 3 END USE: AC&R

Measure	Replace Chiller
Site Description	Hotel

1. Measure Description

Replace existing chiller with new more efficient 500 ton chiller.

2. Summary of the Ex Ante Calculations

The ex ante savings for the measure are 946,841 kWh and 164.0 kW as identified in the Installation Report Review. The SPC incentive of $132,557.74 was based on these calculated savings. The measure was submitted as a calculated measure with savings generated by the SPC Calculator.

3. Comments on the Ex Ante Calculations

The ex ante calculations were performed using the SPC 2005 calculator.

The savings calculations were verified using the 2005 SPC Calculator for chillers. The inputs for the calculator include efficiency, chiller model, serial number, and operating hours. The calculated savings were equal to savings reported in the Implementation Report Review. It is not apparent that the calculations performed accounted for the loading profile of the chillers. There was no documentation provided to determine the loading profile of the chillers. This may be performed internally in the SPC Calculator.

Project Application Inputs:

Equipment Specification

- Equipment: Trane
- Cooling system type: Chillers, water cooled >300 tons – centrifugal
- Efficiency: 0.51 kW/ton
- Total tons: 500 tons
- Control method: Modulating
- Lifetime: 23 years
- VSD on Chiller
- No economizer cycle

Building Description

- Building type: Hotel
- Conditioned area: 450,000 sq ft
- System operating hours: 24 hours, 7 days a week

2004 SPC Energy Savings Calculator Output:

- Baseline usage: 430.1 kW; 1,673,051 kWh
- Title 24 usage: 284.8 kW; 1,108,053 kWh
- Proposed usage: 266.1 kW; 726,210 kWh
- Savings: 164.0 kW; 946,841 kWh

Incentive: $0.14/kWh; $132,558 for measure
Runtime Hours: 7,336

Although the measure was submitted as an early retirement measure, there was no adjustment of savings for the number of years of remaining useful life. The original equipment was 14 years old at the time of the retrofit with 9 years of remaining useful life (23 years total useful life); however the motor was deficient and needed to be replaced. Motor replacement is a small cost compared to chiller replacement, and, for the purposes of this evaluation, does not affect the remaining useful life of nine years. Thus, the average annual savings are the sum of the savings due to the installation of the new chiller compared to the existing chiller (the baseline) for nine years, and the savings compared to the minimum standard efficiency chiller dictated by Title 24 for the remaining 14 years of the new chiller's useful life.

The paperwork indicates that a 500 ton centrifugal chiller without a VFD was replaced.

The SPC Calculator output sheet did indicate a baseline use of 430.1 kw and 1,673,051 kWh/yr – equating to a 500 ton chiller at 0.86 kw/ton and full load operation at 3,890 hrs/yr (44% of the yearly total of 8,760 hours/year).

Proposed usage was 266.1 kW and 726,210 kWh/yr – equating to a 500 ton chiller at 0.53 kw/ton and 2,729 full load hrs/yr (70% of the previous total of 3,890 hours/year, presumably due to the use of the modulating controls and chiller VSD). No economy cycle was indicated.

The run time hours of 7,336 hours/year indicated by the SPC calculator do not appear to be full load hours.

The SPC Calculator was the basis of the kW and annual kWh savings listed as the ex ante savings in the Installation Report Review and in the utility tracking system.

Current minimum standard (Title 24) usage was listed 284.8 kW and 1,108,053 kWh/yr – equating to a 500 ton chiller at 0.57 kW/ton and 3,891 hours/year (100 % of the previous total of 3,890 hours/year). The savings for the new chiller over the minimum standard (Title 24) equates to 381,843 kWh/yr.

Check calculations were performed using information from the proposed equipment specifications and the assumed replaced equipment's specification. This calculation was based on operating hours of 8,760 hours per year and an assumed load factor of 45% over the entire year (note that this factor equates to about 50% more run time than used in the

SPC calculator). Pre- retrofit and post-retrofit energy use were calculated using the following formulae:

$kWh_{pre=}$ 500 tons x 0.86 kw/ton x 45% x 8,760 hours/years = 1,695,060 kWh/year

$kWh_{post=}$ 500 kw x 0.53 kW/ton x 45% x 8,760 hours/years x 70% for VSD use = 731,241 kWh/year

kWh savings =($kWh_{pre} - kWh_{post}$) = 1,695,060 kWh/year – 731,241 kWh/year = 963,819 kWh/year

The energy savings that is realized when the new chiller is compared to the Title 24 standard efficient chiller is given by the following formulae:

$kW_{Title24\,=}$ 500 kw x 0.57 kW/ton x 45% x 8,760 hours/years = 1,123,470 kWh/year

($kW_{Title24} - kW_{post}$) = kWh = 1,123,470 kWh/year – 731,241 kWh/year = 392,229 kWh

The typical useful life for a centrifugal chiller is 23 years. The original chiller had been in operation since 1991, which indicates a remaining useful life of 9 years at the time of the application. In order to calculate the annual energy savings the old chiller is used as the baseline for the first 9 years of the new chiller's life, and a Title 24 compliant chiller is used for the remaining 14 years of the new chiller's life. The following formulae describe the calculation:

(9 years x 963,819 kWh/year) + (14 years x 392,229 kWh/year)/ 23 years = 615,895 kWh/year

These savings are lower than the ex ante savings figures submitted due to the effect of early retirement. The actual savings may be lower due to the actual kW performance rating and the effect of the VFD on chiller performance. It should be confirmed that there was no VFD on the pre-retrofit chiller.

4. Measurement & Verification Plan

The building is a 450,000 square foot hotel. The building is occupied on varying schedules by both guests and staff throughout the year, 24 hours a day, seven days a week. The majority of the chiller use will be in the summer time between May and August and during the daytime hours.

According to the SPC Calculator, before the retrofit, there was a 500 ton chiller consuming 430.1 kW at the facility. In this retrofit, a 500 ton chiller consuming 266.1 kW was installed at the facility. The project saves energy through the installation of a chiller that delivers the same cooling capacity as the original one, but accomplishes it through lower energy draw and consumption. It also saves energy through the use of a variable speed drive on the chiller and modulation on the chiller, reducing effective full load hours of operation.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful life of the measure.

Formulae and Approach

A modified version of IPMVP Option A approach should be considered. The energy savings will consist of the baseline energy usage minus any post-installation energy use calculated as part of this evaluation.

The actual cooling load for the building will be determined using chilled water supply and return temperatures and the water flow through each cooling loop. The actual kW demand of the chillers will be measured.

The operating hours, size, and sequencing of the chillers will be confirmed from facility personnel. Proposed data collection will include the chilled water supply and return temperatures, chiller amps or kW, and chilled water flow rate.

To the extent possible, this data will be gathered from the EMS and chiller logs for a full 12 month period. Information on the pre retrofit chillers will be collected to the extent possible.

The performance curve for the installed chiller will be established by plotting the kW vs. the percent of full load for all data points collected for the chillers' operation. The percent load will be determined by calculating the tonnage based on the temperature difference between chilled water supply and return (ΔT) and the chilled water flow (either a constant value or a measured varying value) and comparing it to the rated full load tonnage of the chiller. The tonnage will be calculated by the formula:

$$\text{Tons} = \text{CHW gpm} \times 500\ \text{lb/hr/gpm} \times \text{CHW}\ \Delta T \times 1\ \text{Btu/lb}\ ^\circ\text{F} / 12{,}000\ \text{Btu/ton}$$

The measured kW will be regressed against measured cooling load to determine the performance curve. This formula will be used with climate zone temperature data to establish an annual demand profile.

The building cooling load profile will be determined using the same approach with outside temperature. The supplied tonnage will be plotted vs. outside air temperature and a curve will be fit to the plotted data. If the plotted data shows little or no correlation between chiller load and outside air temperature, then other variables affecting the chiller load will be evaluated. This formula will be used with climate zone temperature data to establish an annual cooling load profile.

With the building load and the chiller performance established the new system can be modeled and the annual electrical usage determined. The post-retrofit energy usage using pre-retrofit chiller information will be compared to the baseline energy usage to determine the ex post savings using the following formula:

$$\text{kWh Savings} = \sum_{1}^{8,760} \text{Hours} \times \text{Average Tons} \times \left(\text{kW/ton}_{\text{w/o VSD}} - \text{kW/ton}_{\text{w/VSD}}\right).$$

Ideally, the information in Table 1 would be collected for the pre-existing and post-retrofit chillers.

Table 1: Data needed for chiller energy analysis

Data Element	Proposed Means of Collecting Data
Base case equipment configuration	Confirm via customer interview and review of customer records. Verify use of 2-way control valves.
Post case chiller duty	Obtain one month or longer of hourly customer EMS data of chiller kW, chilled water flow rate, and chilled water return and supply temperatures.
Post case equipment configuration	Confirm via site survey, customer interview, and review of customer records. Obtain manufacturers' data sheets for equipment and equipment nameplate information.
Post case system operating hours	Confirm via customer interview and review of customer records and the planned maintenance schedule for each chiller and pump.

Dent TOU power loggers or kW data logging devices should be placed on the chiller system to obtain the loading profile. The system would be monitored for a minimum period of 2-3 days if occupancy patterns are regular. The power and operating hours would be recorded to reflect fluctuations in power consumption. The information obtained will allow more accurate pre-retrofit and post retrofit calculations.

Pre-retrofit and post-retrofit calculations of energy usage will be calculated using the following formulae:

kWh savings = (kW_{pre} x energized $hours_{pre}$) - (kW_{post} x energized $hours_{post}$)

Coincident peak demand period savings = kW_{pre} - kW_{post}

Summer peak period savings = kW_{pre} - kW_{post} during the hottest periods between 2 PM to 5 PM, Monday through Friday, in June, July, August, and September.

The greatest uncertainties in the measurements are the hourly chilled water loads and how the chillers' efficiencies (kW/ton) vary at different cooling loads. The uncertainty for the savings can be more fully understood by setting projected ranges on the primary variables.

Uncertainty associated with chiller VFD savings / chiller load profile

- Flow: 1250 gpm expected, 1000 minimum , 1500 maximum (+/- 20%)
- Delta T: 10 F expected, 4 F minimum , 12 F maximum (+ 20%, -60%)
- kW measured: 266 kW expected, 226 minimum , 306 maximum (+/- 15%,)

Accuracy and Equipment

One Dent Elite Pro TOU logger will be used the chiller. The Dent logger, with accompanying current transformers (CTs), is accurate to within 2% for power. If the energy management system or the Dent logger is used to monitor hours of operation, these values will be deemed to be 98% accurate.

HOBO temperature loggers will be placed to monitor outdoor temperature and humidity and to monitor chilled water supply and return temperatures, if not available for the EMS.

Flow meters (either portable ultrasonic or permanent meters) have varying accuracies; generally +/- 2 to 10% is an expected range normal for this equipment.

The actual expected temperature measurement accuracy with the dataloggers is expected to be 1°F to 2°F. Greater accuracy is generally available for readings from the sensors for the energy management system. As possible, spot checks will be performed with a Raytek infrared thermometer, with a resolution of 0.1 °F and an accuracy of +/- 1 °F.

All data collected will be reviewed to ensure that it conforms to realistic values and will be cross verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 29, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the new chiller plant equipment and by interviewing the facility representative.

The customer provided hard copy data from the EMS in order to complete this evaluation.

Installation Verification

The installation of equipment was physically verified. The new chiller is a Trane model CVHF 485 with a variable frequency drive. The verification rate is 1.0.

Scope of the Impact Assessment

The impact assessment scope is for the chiller measure in the AC&R end use category in this SPC application. This is the only measure in the application.

Summary of Results

Measurements were taken from the facility's energy management system (EMS) and used to calculate the tonnage of the chillers at several operating points to construct a load profile. The present mode of operation requires the use of only the new 500 ton chiller for most of the year. The smaller 300 ton chiller is brought on line manually only when the load cannot be met by the new chiller alone. This typically occurs when outdoor air temperatures are at their highest levels.

Weather data from the relevant California climate zone were used to determine the bib hours in 2 degree increments. Building load models were constructed which correlated outside air temperature (OAT) to tonnage. The chiller run model was constructed based upon actual operation of the primary chiller. The secondary chiller did not run while our measurements were taken, and the temperature also did not exceed 80 F on that day. The assumption is made that the second chiller is energized to meet the load when outdoor temperatures exceed 86 F. Actual performance data from the EMS during a 24 hour period was used to plot a performance curve for the new chiller. A chiller performance curve for a typical chiller of the type being retrofit was used for the old chiller, and was adjusted based on the 430.1 kW baseline usage given in the SPC calculator summary sheet from the ex ante calculations, which was determined to be realistic (although possibly on the high side, with an efficiency of 0.86 kW/ton).

Table 2 shows the annual energy use for the base case (old 500 ton chiller and old 300 ton chiller for peak days), the new case (new 500 ton chiller with the old 300 ton chiller for peak days). The first year savings are calculated by subtracting the two simulated cases. The baseline savings describes the savings that are in effect after the end of the useful life of the pre-existing chiller. The ratio of the difference in maximum kW/ton output between the new chiller and the baseline Title 24 chiller (0.51-0.53 kW/ton) versus the new chiller over the old chiller (0.51-0.87 kW/ton) is used to adjust the first year savings yielding baseline savings. Baseline savings are calculated as 6.5% of the first year kW and kWh savings.

Table 2: First Year Savings and Savings over Baseline

	Base case	New case	First year Savings	Baseline Savings
kWh	1701173	827060	**874113**	56,972
kW	439.4	228.8	**210.6**	13.7
kW/ton at peak avg (94F)	0.499	0.429		6.5%
tons at peak avg (94F)	533	533		

The chiller replacement savings is calculated as an early retirement measure, with an old chiller being replaced 9 years before the end of its useful life by a new chiller with a useful life of 23 years. For the remaining 14 years of the new chiller's life, the savings are compared to a Title 24 chiller[1]. Therefore, the annual savings is calculated as a weighted average of the chiller savings over its 23 years of useful life. The annual ex post impact savings are:

Average kWh savings = (9 years x 874,113 kWh/year) + (14 years x 56,972 kWh/year)/23 years = 376,723 kWh

Average kW savings = (9 years x 210.6 kW) + (14 years x 13.7 kW)/23 years = 90.8 kW

A year by year look at the savings is shown in the multi year reporting table, Table 8.

Utility billing data for the main meter at the site was reviewed. In the 12 month period from January 2005 to December 2005, the building consumed 8,729,667 kWh. Peak demand was not available since interval data was only provided for one of the two meters onsite. Peak demand was estimated as a function of floor area at 6 watts per square foot, yielding peak demand of 2,600 kW for the facility. The baseline energy use is the total AC&R use for the building, estimated at 30% of the total meter. The average ex post savings are the average yearly savings over the 23 year life of the measure, the first 9 years compared to the old equipment, and the next 14 years compared to new Title 24 compliant equipment. Table 3 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 4 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 6.3% decrease in total meter kW, a 21.0% decrease in AC/R end use kW, a 10.8 % decrease in total meter kWh, and a 36.2% decrease in AC/R end use kWh. The first year ex post results were slightly lower for kWh and slightly higher for kw reduction. The average ex post results showed a 3.5% decrease in total meter kW, a 11.6 % decrease in AC/R end use kW, a 4.3% decrease in total meter kWh, and a 14.4% decrease in AC/R end use kWh.

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[1] California Title 24, 2001 Building Energy Standards, Table 1-C3 Chilling Packages-Minimum Efficiency Requirements, Water Cooled Centrifugal Rotary Screw and Scroll 6.1 COP, 6.4 IPLV

Table 3: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	2600	8,729,667
Baseline End Use	780	2,618,900
Ex Ante Savings	164	946,841
First Year Ex Post Savings	210.6	874,113
Average Ex Post Savings	91	376,723

Table 4: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Average Ex Post		First Year Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh	kW	kWh
Total Meter %	6.3%	10.8%	3.5%	4.3%	8.1%	10.0%
Baseline End Use %	21.0%	36.2%	11.6%	14.4%	27.0%	33.4%

6. Additional Evaluation Findings

The ex post energy (kWh) savings are lower than the ex ante energy savings because the ex ante savings used the SPC calculator. The SPC Calculator does not take into effect the lower use of the post retrofit chiller when used in a plant with multiple chillers or the actual building loads and characteristics. It is likely that full M&V for a period of one year would yield lower savings than forecast in the ex ante calculations.

The source of the capital cost submitted of $303,667 provided in the application is not known. However, these costs do not appear to be excessive for the work performed. The project cost will be reduced in the ex post calculations by the cost of the replacement motor since the motor needed to be replaced for the existing equipment to function. 2007 Means data lists an installed cost of $16,250 for a 200 hp, totally enclosed, premium efficiency motor. No larger size motor was listed in Means, but the 430 kW maximum power of the chiller indicates a motor on the order of 300 hp. The cost of the 200 hp motor is multiplied by a factor of 1.25 to approximate the cost of a larger motor.

The customer does not anticipate changes that would affect energy use from this equipment. Participation in this program increased energy awareness in the company and lead to increased participation in other incentive programs offered through the utility.

The level of M&V employed at this site and the customer's provision of supporting documentation could be improved in order to accurately determine the impacts of the installed measures.

7. Impact Results

With a cost of $303,667 and a $132,557.74 incentive, the project had a 1.39 year simple payback based on the ex ante calculations and a 1.15 year simple payback based on first year savings. The ex post savings estimate for the project uses a total project cost reduced by the replacement cost of the motor, which reduces the total cost by approximately 6%. The average ex post demand and energy savings calculations use the average yearly savings over the life of the new equipment instead of the first year savings. The ex post estimated simple payback on average savings is 3.09 years. A summary of the economic parameters for the project is shown in Table 5.

The average savings taking into account the first year savings for 9 years and the baseline savings for 14 years are 376,723 kWh/year and 90.8 kW. The engineering realization rate for this application based on the average savings is 0.55 for demand reduction (kW) and 0.40 for energy savings (kWh). For the first year savings, the realization rate is 1.28 for kW savings and 0.92 for kWh savings.

The values shown in the tracking system agree with those shown in the installation report for this application. The Realization Rate Summary is shown in Table 6.

The Installation Verification Summary is shown in Table 7 and the savings in each year over the full life of the measure are shown in the Multi Year Reporting Table in Table 8.

Table 5: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	3/10/2006	$303,667	164.0	946,841	0	$123,089	$132,558	1.39	2.47
SPC Program Review (Average Ex Post)	11/29/2007	$283,667	90.8	376,723	0	$48,974	$132,558	3.09	5.79
SPC Program Review (First Year Ex Post)	11/29/2007	$263,667	210.6	874,113	0	$113,635	$132,558	1.15	2.32

Table 6: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	164.0	946,841	-
SPC Installation Report (ex ante)	164.0	946,841	-
Impact Evaluation (average ex post)	90.8	376,723	-
Average Engineering Realization Rate	0.55	0.40	NA
Impact Evaluation (First year ex post)	210.6	874,113	-
First Year Engineering Realization Rate	1.28	0.92	NA

Table 7: Installation Verification Summary

Measure Description	End-Use Category	AC&R - Measure Description	Lighting - Measure Description	Other - Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Chiller Replacement	AC&R	500 ton chiller replaced with 500 ton VSD driven chiller			1	Trane CVHF 485	Physically verified installation.	1.00

Table 8: Multi Year Reporting Table

Program Name:		**SPC 04-05 Evaluation A046**					
Year	**Calendar Year**	**Ex-ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004						
2	2005						
3	2006	789,034	728,428	164	210.6		
4	2007	946,841	874,113	164	210.6		
5	2008	946,841	874,113	164	210.6		
6	2009	946,841	874,113	164	210.6		
7	2010	946,841	874,113	164	210.6		
8	2011	946,841	874,113	164	210.6		
9	2012	946,841	874,113	164	210.6		
10	2013	946,841	874,113	164	210.6		
11	2014	946,841	874,113	164	210.6		
12	2015	946,841	56,972	164	13.7		
13	2016	946,841	56,972	164	13.7		
14	2017	946,841	56,972	164	13.7		
15	2018	946,841	56,972	164	13.7		
16	2019	946,841	56,972	164	13.7		
17	2020	946,841	56,972	164	13.7		
18	2021	946,841	56,972	164	13.7		
19	2022	946,841	56,972	164	13.7		
20	2023	946,841	56,972	164	13.7		
TOTAL	**2004-2025**	16,885,331	8,234,083				

Chiller measure with 20 year life – assume installation / commissioning complete by March 2006; 9 years at first year savings, remaining years with savings over baseline; no partial year savings at transition after remaining useful life due to inexact timing of expiration of useful life.

Final Report

SITE A045 (2004-xxx) Pren IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 2 END USE: AC&R

Measure	Replace Compressors on Two Chillers
Site Description	Large Office Building

1. Measure Description

Replace six 60 ton compressors on two 240 ton chillers.

2. Summary of the Ex Ante Calculations

The ex ante savings for the measure are 3,258,547 kWh and 30.2 kW as identified in the Installation Report Review. The utility tracking system notes the same kWh and kW savings and 30.2 kW. The savings were generated by the 2004 SPC calculator and the retrofits were submitted as a calculated measure.

The total capital cost and the incentive was listed as $300,000.00 in the Installation Report Review. The incentive is listed as $ 140,307.02 in both the Installation Report Review and in the utility tracking system. The incentive was based on the initial Project Application Review which listed annual savings of 1,002,193 kWh.

The kWh savings are grossly overstated as a result of using annual kWh savings summed over the remaining useful life of the chillers as the annual savings. The incentive is based upon the summed annual savings.

3. Comments on the Ex Ante Calculations

The energy savings were calculated using the early retirement feature in two runs for the SPC Calculator. The replacement of six compressors on two (2) 240 ton chillers manufactured in 2000 is the basis of the savings. However, 1998 is used as the year of manufacture when the SPC Calculator is run for the computer room cooling on two floors of the building.

The savings were calculated using the 2004 SPC calculator for chillers. The inputs for the calculator include efficiency, chiller model serial number, and the operating schedule of the chiller. The calculated savings for the entire remaining 17 or 19 year life of the existing equipment were the reported savings in the Implementation Report Review and the utility tracking system. This figure drastically overestimated savings.

The method by which the data centers were accounted for was also questionable. In the first SPC Calculator run, the entire allotment of the two (2) 240 tons were assumed to handle six of eight floors (127,500 sf) from 7 am to 5 pm Monday through Friday. This was not adjusted for the estimated 40 to 60 ton load of the two data center floors with continuous operation.

In the second SPC Calculator run, an allotment of 60 tons was assumed to handle two of the eight floors (42,500 sf) continuously (24 hrs per day).

Inputs for the two 240 ton chillers serving six floors

Equipment specification

- Equipment: McQuay
- Cooling system type: Chillers, Water Cooled >150 tons <300 tons - Centrifugal
- Efficiency: 0.66 kW/ton
- No: of units: 2
- Total tons: 480 tons
- Control method: Modulating
- VSD: Yes
- Year Manufactured: 2000

Building description

- Building type: Large Office
- Conditioned area: 127,500 (conditioning provided for 6 floors)
- System Operating Hours: Mon – Fri, 7:00 am – 5:00 pm

2004 SPC Energy Savings Calculator output

- Baseline usage: 239.0 kW; 405,457 kWh
- Current Minimum Standard (Title 24); 229.4 kW; 389,239 kWh
- Proposed usage: 211.9 kW; 263,964 kWh
- Savings of: 27.1 kW; 141,493 kWh
- Total Savings (19 years useful life remaining): 2,688,367 kWh
- Run Time hours: 2,607 run-time hours.

Inputs for the 60 ton load for the two computer rooms floors

Equipment specification

- Equipment: McQuay
- Cooling system type: Chillers, Water Cooled <150 tons - Centrifugal
- Efficiency: 0.66 kW/ton
- No: of units: 1
- Total tons: 60 tons
- Control method: Modulating
- VSD: Yes
- Year Manufactured: 1998

Building description

- Building type: Large Office
- Conditioned area: 42,500 (two floors - conditioning provided for computer rooms)

- System Operating Hours: 8,760 run-time hours.

2004 SPC Energy Savings Calculator output

- Baseline usage: 43.8 kW; 364,455 kWh
- Current Minimum Standard (Title 24); 41.2 kW; 342,588 kWh
- Proposed usage: 40.8 kW; 330,915 kWh
- Savings of: 3.0 kW; 33,540 kWh
- Total Savings (17 years useful life remaining): 570,180 kWh
- Run Time hours: 8,602 run-time hours.

Although the measure was submitted as an early retirement measure, there was no adjustment of savings for the number of years of remaining useful life. The original equipment was manufactured in 2000, according to the application paperwork. In 2004, the equipment would have nineteen (19) years of remaining life (of 23 years total). Thus, the average annual savings are derived from savings due to the installation of the new compressors on the chillers compared to the existing chiller (the baseline) for nineteen years, and the savings compared to the minimum standard efficiency chiller dictated by Title 24 for the remaining 4 years of the new chiller's useful life.

The SPC Calculator output sheet for the main floors with non continuous occupancy did indicate a baseline use of 239.0 kW and 405,407 kWh/yr – equating to 480 tons of cooling at 0.5 kW/ton and full load operation at 1,708 hrs/yr (19.5% of the yearly total of 8,760 hours/year).

Proposed usage was 211.9 kW and 263,964 kWh/yr – equating to 480 tons of cooling at 0.44 kW/ton and 1,226 hrs/yr (14 % of the yearly total of 8,760 hours/year, presumably due to the use of the modulating controls and chiller VSD). No economy cycle was indicated.

Current minimum standard (Title 24) usage was listed 229.4 kW and 389,239 kWh/yr – equating to 480 tons of cooling at 0.46 kW/ton and 1,664 hours/year (19 % of the yearly total of 8,760 hours/year).

Ex ante savings are expected to be impacted by the size, efficiency, and usage of the equipment.

The greatest change will come about from using the actual annual verses lifetime kWh savings.

4. Measurement & Verification Plan

This site is an eight-story office building. The building contains 170,000 square feet of office space. The third and fourth floors of the facility have data centers and operate for 24 hours/day, seven days/week. The load for these two floors is estimated to be 40-60 tons. The remaining six floors operate from 7 am to 5 pm for 5 days a week. Six compressors were retrofit on the two chillers, each of which has a size of 240 tons. The chillers condition the six office floors spread over 127,500 square feet and the two data center floors spread over 42,500 square feet. The compressors on the chillers are equipped with VSDs and are reported to be modulating.

The goal of the measurement and verification (M&V) plan is to estimate the actual annual kWh and peak kW savings over the useful life of the measure.

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Formulae and Approach

A modified version of IPMVP Option A can be utilized. The energy savings will consist of the baseline energy usage minus any post-installation energy use calculated as part of this evaluation.

Given the large error existing through misapplication of the lifetime savings results, corrections will be made for the expected annual kWh savings.

Early retirement will not be considered for this measure, and no adjustment for baseline will be made, as the chillers reportedly had 19 years of remaining life, and this evaluation projects savings for twenty years.

The operating hours / sequence of operation may be confirmed from the operator.

The ratings (specifications and efficiencies) of the pre retrofit and post retrofit chillers will be obtained from the facility.

The actual cooling load for the building may be determined using chilled water supply and return temperatures and the water flow through the main cooling loop. The actual kW demand of the two compressors of the chiller will be obtained.

Proposed data collection will include the chilled water supply and return temperatures, outside air temperature, chiller amps or kW, and chilled water flow rate. Condenser system run time control strategies will be analyzed.

Operators will be queried to ascertain the control strategies, if any, affected at the facility. It will also be determined if the chiller is deactivated for any part of the year. Operating logs will be obtained for the parameters to be collected from the energy management control system (EMS) if available. The building operator has indicated that spot readings of temperatures and flow are available form the EMS.

Electrical and temperature measurements may be taken to verify the accuracy of the readings from the EMS. Flowmeter readings will not be taken but the EMS data will be used as available.

A minimum of one 24 hour weekday period and one 24 hour weekend period showing kW consumption of the chillers may be used in conjunction with ambient temperatures and weather data to estimate building load profiles and use.

Tonnage can be calculated by the formula:

Tons = CHW gpm x 500 lb/hr/gpm x CHW ΔT x 1 Btu/lb °F / 12,000 Btu/ton

The measured kW can be plotted and / or regressed against measured cooling load to determine the performance curve. This formula will be used with climate zone temperature data to establish an annual demand profile.

With the building load and the chiller performance established the new system can be modeled and the annual electrical usage determined. The post-retrofit energy usage using pre-retrofit chiller information will be compared to the baseline energy usage to determine the ex post savings using the following formula:

$$\text{kWh Savings} = \sum_{1}^{8,760} \text{Hours} \times \text{Average Tons} \times \left(\text{kW/ton}_{\text{w/o VSD}} - \text{kW/ton}_{\text{w/VSD}}\right).$$

Dent TOU power loggers or kW data loggers measuring devices should be placed on the chiller compressors to obtain the loading profile, or the EMS data will be used. The system would be monitored for a period of 1 week if possible. The kW and the operating time would be recorded to show power draw (kW) due to changes in flow.

If EMS data is available, a confirming spot measurement should be taken for power demand in kW.

Coincident peak demand period savings = $kW_{pre} - kW_{post}$

Summer peak demand period savings = $kW_{pre} - kW_{post}$ during the hottest periods between 2 pm to 5 pm, Monday to Friday, in June, July, August, and September.

Uncertainty for the savings estimate for the retrofit can be more fully understood by setting projected ranges on the primary variables.

The greatest uncertainties in the ex ante savings estimate are the hourly chilled water loads, the pre retrofit chiller performance, and to what extent the cooling loads and to a lesser extent, how the chillers' efficiencies (kW/ton) vary at different cooling loads.

Table 1: Data Collection Elements

Data Element	Proposed Means of Collecting Data
Base case equipment configuration	Confirm via customer interview and review of customer records. Verify use of 2-way control valves.
Post case chiller duty	Obtain one month or longer of hourly customer EMS data of chiller kW, chilled water flow rate, and chilled water return and supply temperatures.
Post case equipment configuration	Confirm via site survey, customer interview, and review of customer records. Obtain manufacturers' data sheets for equipment and equipment nameplate information.
Pre and Post case system operating hours	Confirm via customer interview and review of customer records and the planned maintenance schedule for each chiller and pump.

Uncertainty for the savings estimates can be more fully understood by setting projected ranges on the primary variables.

Uncertainty associated with chiller VFD savings / chiller load profile

- Flow 500 gpm expected, 400 minimum, 1200 maximum (+140% for two chillers /- 20%)
- Delta T 10 F expected, 6 F minimum, 14 F maximum (+/- 40%)
- kW measured 250 expected, 100 minimum (one chiller), 300 maximum (+ 20%, / - 60%)

Accuracy and Equipment

One Dent Elite Pro TOU logger will be used for the chiller if EMS data is insufficient. The Dent loggers are accurate to within 1% for power. If the energy management system or the Dent loggers are used to monitor hours of operation, these values will be deemed to be 100% accurate.

Amprobe kW meters may be used for spot measurements (+/- 2%).

HOBO temperature loggers will be placed to monitor outdoor temperature and humidity and to monitor chilled water supply and return temperatures if not available from the EMS.

Flowmeters (either portable ultrasonic or permanent meters) have varying accuracies; generally +/- 2 to 10% is an expected range normal for this equipment.

The actual expected temperature measurement errors associated with the dataloggers is expected to be 1F to 2F. Greater accuracy is generally available for readings from the sensors for the energy management system. As possible, spot checks will be performed with a Raytek infrared thermometer, with a resolution of 0.1 F and an accuracy of +/- 1 F.

All data collected will be reviewed to ensure that it conforms to realistic values and will be cross verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 28, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the new chiller plant equipment and by interviewing the facility representative.

The intent was that the customer would provide electronic data from the EMS in order to complete this evaluation. The data provided was sufficient to gain considerable knowledge on actual chiller operation.

Installation Verification

The installation of the chiller compressors was physically verified. The verification rate is 1.0 (6/6)

Scope of the Impact Assessment

The impact assessment scope is for the chiller measure in the AC&R end use category in this SPC application. This is the only measure in the application.

Summary of Results

Measurements were taken from the facility's energy management system EMS and an average of 0.47 kW / ton was calculated.

Ex ante savings were based upon pre retrofit consumption generated by the SPC Calculator. These outputs were reasonable and used as the pre retrofit consumption for the ex post calculations. The consumption was 769,912 kWh/yr (equating to approximately 26.8% hours of use at this loading) and the demand was 239.0 kW.

480 tons x 0.47 kW/ton = 225.6 kW.

kW Savings are calculated at 13.4 kW.

The building usage factor was 29.7% based on the reduction in usage from the SPC Calculator (corrected to accurately reflect the use of the five verses six compressors for the main floors).

225.6 kW x 29.7% x 8,760 hours / year = 585,991 kWh/yr

Usage (kWh) savings from this measure are:

769,912 kWh/yr - 585,991 kWh /yr = 183,921 kWh/yr.

Note that this is slightly higher than the first year savings as calculated by the SPC Calculator and used as the basis for the IRR and the utility tracking system.

Baseline adjustments are not made, as the AC compressors had 19 years left in their operating life and these changes do not impact the figures in the 20 year reporting timeframe.

Utility billing data for the site was reviewed. In the 12 month period from February 2004 to January 2005, the building consumed 3,412,610 kWh. Peak demand was 828 kW in June 2004. Table 2 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Usage savings are as expected. However, kW savings might be expected to be higher. Utility billing data shows significantly higher kW demand in August (894 kw) and higher kW demand in September. The demand savings are less certain than the usage savings.

The utility billing data confirms the kWh usage reduction as defined for the ex post calculations.

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 3.6 % decrease in total meter kW, a 12.2% decrease in AC/R end use kW, a 95.5 % decrease in total meter kWh, and a 318.3% decrease in AC/R end use kWh. The ex post results showed a 1.6% decrease in total meter kW, a 5.4% decrease in AC/R end use kW, a 5.4% decrease in total meter kWh, and a 18 % decrease in AC/R end use kWh.

Table 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	828.0	3,412,610
Baseline End Use	248.4	1,023,783
Ex ante Savings	30.2	3,258,547
Ex Post Savings	13.4	183,921

Baseline use is total AC&R use for building, estimated at 30%.

Table 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	3.6%	95.5%	1.6%	5.4%
Baseline End Use %	12.2%	318.3%	5.4%	18.0%

6. Additional Evaluation Findings

The ex post energy (kWh) savings are significantly less than the ex ante energy savings because of the reporting error listing multi year savings. Without this error, the savings for kW would be slightly higher than the ex ante savings. The SPC Calculator appeared to produce realistic results for savings. In this case, both the application of the Calculator and the transfer of data were sources of error.

The kW savings estimated were lowered due to lower actual kW/ton values obtained through the EMS System, as compared to the values used in the SPC Calculator.

The facility representative stated that the cost estimate provided in the application is based on a single source quote, as this is a specific application with only one vendor providing this compressor retrofit. There were no invoices provided. The costs appear to be excessive (nearly double) for the work performed, based upon a compressor installed cost of $300/ton. The project was financed by the vendor.

The customer does not anticipate that the units may be operated for longer periods in the future.

It was not possible to verify hours of operation, loading profile and efficiency of the pre retrofit AC units. However, the estimates used in the ex ante and ex post calculations are realistic. Operating hours may have a significant effect on the actual savings.

The level of M&V employed at this site and the customer's provision of supporting documentation was adequate to accurately determine the impacts of the installed measures. The kW values could have been more accurately estimated if pre retrofit information was available.

The customer participated in a window tinting rebate program. However, this project was not known to spur participation in other programs or lead to implementation of other measures.

With a cost of $300,000 and a $140,307 incentive, the project had a 0.25 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 4.45 years. A summary of the economic parameters for the project is shown in Table 4. The Installation Verification Summary is shown in Table 6 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 7.

7. Impact Results

The engineering realization rate for this application is 0.44 for demand kW reduction and 0.06 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 5.

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	4/6/2005	$246,720	30.2	3,258,547	0	$423,611	$140,307	0.25	0.58
SPC Program Review (Ex Post)	12/6/2007	$246,720	13.4	183,921	0	$23,910	$140,307	4.45	10.32

Table 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	30.2	3,258,547	-
SPC Installation Report (ex ante)	30.2	3,258,547	-
Impact Evaluation (ex post)	13.4	183,921	-
Engineering Realization Rate	0.44	0.06	NA

Table 6: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Replace Chiller Compressors	AC/R	Replace Chiller Compressors			6	Six (60) ton Danfoss Compressors with variable speed capability on two existing McQuay chillers	Physically verified compressors.	1.00

Table 7: Multi Year Reporting Table

Program Name:		**SPC 04-05 Evaluation Site A045**					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program MWh Savings**	**Ex-Post Gross Evaluation Confirmed Program MWh Savings**	**Ex-Ante Gross Program-Projected Peak Program MW Savings**	**Ex-Post Gross Evaluation Projected Peak MW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004					0	0
2	2005	814,637	45,980	30.2	13.4	0	0
3	2006	3,258,547	183,921	30.2	13.4	0	0
4	2007	3,258,547	183,921	30.2	13.4	0	0
5	2008	3,258,547	183,921	30.2	13.4	0	0
6	2009	3,258,547	183,921	30.2	13.4	0	0
7	2010	3,258,547	183,921	30.2	13.4	0	0
8	2011	3,258,547	183,921	30.2	13.4	0	0
9	2012	3,258,547	183,921	30.2	13.4	0	0
10	2013	3,258,547	183,921	30.2	13.4	0	0
11	2014	3,258,547	183,921	30.2	13.4	0	0
12	2015	3,258,547	183,921	30.2	13.4	0	0
13	2016	3,258,547	183,921	30.2	13.4	0	0
14	2017	3,258,547	183,921	30.2	13.4	0	0
15	2018	3,258,547	183,921	30.2	13.4	0	0
16	2019	3,258,547	183,921	30.2	13.4	0	0
17	2020	3,258,547	183,921	30.2	13.4	0	0
18	2021	3,258,547	183,921	30.2	13.4	0	0
19	2022	3,258,547	183,921	30.2	13.4		
20	2023	3,258,547	183,921	30.2	13.4		
TOTAL	**2004-2023**	59,468,483	3,356,559				

Note: If the multi year ex ante savings of 3,258,547 kWh are replaced with first year savings of 175,033 kWh in the realization rate calculations, the kWh realization rate is increased from 0.06 to 1.05 (6% to 105%). The kW realization rate is not affected.

Final Report

SITE A046 EMDF (2004-xxxx) IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 3 END USE: AC&R

Measure	Replace 450 ton Chiller with more efficient 700 ton VSD Chiller
Site Description	Detention Facility

1. Measure Description

Replace existing 450 ton chiller with more efficient 700 ton variable speed drive chiller.

2. Summary of the Ex Ante Calculations

The ex ante savings for the measure are 991,647 kWh and 215.8 kW as identified in the Installation Report Review. The SPC incentive of $138,805.38 was based on these calculated savings. The measure was submitted as a calculated measure with savings generated by the SPC Calculator.

The ex ante savings in the Installation Report Review agree with the utility tracking system figures, except for a numerical transposition error, which listed 991,467 kWh for the annual savings.

3. Comments on the Ex Ante Calculations

The ex ante savings were calculated using the SPC 2005 calculator.

The savings calculations were verified using the 2005 SPC Calculator for water cooled chillers greater than 300tons. The inputs for the calculator include efficiency, chiller model number, and operating hours. The calculated savings were equal to the first year savings reported in the Installation Report Review.

It is not apparent that the calculations performed accounted for an accurate loading profile of the chiller in use when combined with the other two chillers at the facility. The SPC Procedures Manual indicates that weather variations are accounted for using the ASHRAE modified bin simulation method as part of the Calculator program. There was no documentation provided to determine the loading profile of the chillers.

Project Application Inputs:

Equipment Specification

- Equipment: Trane CVHF770
- Cooling system type: Chillers, water cooled >300 tons – centrifugal
- Efficiency: 0.51 kW/ton
- Total tons: 700 tons
- Control method: Modulating

- VSD on Chiller
- No economizer cycle

Building Description
- Building type: Hotel (as proxy for detention facility)
- Proportioned Conditioned area: 264,856 sq ft (total facility is 700,00 sq. ft.)
- System operating hours: 24 hours, 7 days a week

2004 SPC Energy Savings Calculator Output:
- Baseline usage: 421.3 kW; 1,407,639 kWh
- Proposed usage: 205.6 kW; 415,992 kWh
- Savings: 215.8 kW; 991,647 kWh
- Run time hours: 7,338

Incentive: $0.14/kWh; $138,830.58 for measure

The SPC Calculator indicated an early retirement evaluation; however, there was no adjustment of savings for the number of years of remaining useful life. The original equipment was manufactured in 1991, according to the application paperwork. In 2005, the equipment would have nine (9) years of remaining life (of 23 years total). Thus, the average annual savings are derived from savings due to the installation of the new chiller compared to the existing chiller (the baseline) for nine years, and the savings compared to the minimum standard efficiency chiller dictated by Title 24 for the remaining 14 years of the new chiller's useful life.

The paperwork indicates that a 450 ton chiller was replaced with a 700 ton chiller with variable frequency drive (VFD). The other two chillers at the facility are a 450 ton and a 700 ton chiller. Both of these other chillers have VFDs.

The SPC Calculator output sheet did indicate a baseline use of 421.3 kW and 1,407,639 kWh/yr. Proposed usage was 205.6 kW and 415,992 kWh/yr – equating to a 700 ton chiller at 0.51 kW/ton and 7,338 hours/year (the run time hours of 7,338 hours/year are not full load hours).

Check calculations were performed using information from the proposed equipment specifications and the assumed replaced equipment's specification. This calculation was based on operating hours of 8,760 hours per year and an assumed load factor of 40% over the entire year.

Expected first year pre- retrofit and post-retrofit energy use were calculated using the following formulae:

$kWh_{pre=}$ 700 tons x 0.8 kW/ton x 40% load factor x 8,760 hours/years = 1,962,240 kWh/year
(700 tons verses 450 tons was used as the load of other chillers of similar characteristics are offset).

$kWh_{post=}$ 700 kw x 0.51 kW/ton x 40% load factor x 8,760 hours/years = 1,250,928 kWh/year

kWh savings =($kWh_{pre} - kWh_{post}$) = 1,962,240 kWh/year - 1,250,928 kWh/year = 711,312 kWh/year

The energy savings that can be realized from replacing the original chiller with a chiller that exceeds the Title 24 standard efficient chiller at 0.58 kw/ton were calculated and are given by the following formulae:

($kW_{Title24} - kW_{post}$) = 1,422,624 kWh - 1,250,928 kWh/year = 171,696 kWh

The typical useful life for a centrifugal chiller is 23 years. The original chiller had been in operation since 1991, which indicates a remaining useful life of 9 years at the time of the application. The replacement chiller then has a useful life that is 14 years longer than when the original chiller would have had to have been replaced. Therefore, to the calculation of the annual energy usage saved by replacing the original chiller (using the SPC Calculator results) with the proposed chiller is given by the following formulae:

(9 years x 711,312 kWh/year) + (14 years x 171,696 kWh/year)/ 23 years = 383,850 kWh/year

This amount is lower than the ex ante savings figures submitted due to the effect of early retirement. The actual savings may be lower on the actual kW performance rating and the effect of the VFD on chiller performance. It should also be confirmed that there was no VFD on the pre-retrofit chiller.

4. Measurement & Verification Plan

The building is a 700,000 square foot single story detention facility. The building is occupied at varying levels continuously throughout the year, 24 hours a day, seven days a week. The majority of the chiller use will be in the summer time between May and September during the daytime hours.

According to the application paperwork, before the retrofit there was a 450 ton chiller. After the retrofit, a 700 ton chiller was installed at the facility. The project saves energy through the installation of a chiller that has variable speed and modulating capability, reducing effective full load hours of operation.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful life of the measure.

Formulae and Approach

A modified version of IPMVP Option A approach should be considered. The energy savings will consist of the baseline energy usage minus any post-installation energy use calculated as part of this evaluation.

The actual cooling load for the building will be determined using chilled water supply and return temperatures and the water flow through the cooling loop. The actual kW demand of the chillers will be measured.

The operating hours, size, and sequencing of the chillers will be confirmed from facility personnel. Proposed data collection will include the chilled water supply and return temperatures, chiller amps or kW, and chilled water flow rate.

To the extent possible, these data will be gathered from the EMS and chiller logs for a full 12 month period. Information on the pre retrofit chillers will be collected to the extent possible.

If enough data can be collected, the performance curve for the installed chiller will be established by plotting (in MS Excel) the kW vs. the percent of full load for all data points collected for the chillers' operation. The percent load will be determined by calculating the tonnage based on the temperature difference between chilled water supply and return (ΔT) and the chilled water flow (either a constant value or a measured varying value) and comparing it to the rated full load tonnage of the chiller. The tonnage will be calculated by the formula:

Tons = CHW gpm x 500 lb/hr/gpm x CHW ΔT x 1 Btu/lb °F / 12,000 Btu/ton

The measured kW will be regressed against measured cooling load to determine the performance curve. This formula will be used with climate zone temperature data to establish an annual demand profile.

The building cooling load profile will be determined using outside temperature. The supplied tonnage will be plotted vs. outside air temperature and a curve will be fit to the plotted data. If the plotted data shows little or no correlation between chiller load and outside air temperature, then other variables affecting the chiller load will be evaluated. This formula will be used with climate zone temperature data to establish an annual cooling load profile.

With the building load and the chiller performance established the new system can be modeled and the annual electrical usage determined. The post-retrofit energy usage using pre-retrofit chiller information will be compared to the baseline energy usage to determine the ex post savings using the following formula:

$$\text{kWh Savings} = \sum_{1}^{8,760} \text{Hours} \times \text{Average Tons} \times \left(\text{kW/ton}_{\text{w/o VSD}} - \text{kW/ton}_{\text{w/VSD}}\right).$$

Dent TOU power loggers or kW data logging devices should be placed on the chiller system to obtain the loading profile. The system would be monitored for a period of two weeks if possible. The power and operating hours would be recorded to reflect fluctuations in power consumption. The information obtained will allow more accurate pre-retrofit and post retrofit calculations.

Pre-retrofit and post-retrofit calculations of energy usage will be calculated using the following formulae:

kWh savings = $\text{kWh}_{\text{pre}} - \text{kWh}_{\text{post}}$

Coincident peak demand period savings = $\text{kW}_{\text{pre}} - \text{kW}_{\text{post}}$

Summer peak period savings = $\text{kW}_{\text{pre}} - \text{kW}_{\text{post}}$ during the hottest periods between 2 PM to 5 PM, Monday through Friday, in June, July, August, and September.

The greatest uncertainties in the measurements are the hourly chilled water loads and the chiller efficiencies (kW/ton) at different cooling loads. The uncertainty for the savings can be more fully understood by setting projected ranges on the primary variables.

Data Element	Proposed Means of Collecting Data
Base case equipment configuration	Confirm via customer interview and review of customer records. Verify use of 2-way control valves.
Post case chiller duty	Obtain one month or longer of hourly customer EMS data of chiller kW, chilled water flow rate, and chilled water return and supply temperatures.
Post case equipment configuration	Confirm via site survey, customer interview, and review of customer records. Obtain manufacturers' data sheets for equipment and equipment nameplate information.
Post case system operating hours	Confirm via customer interview and review of customer records and the planned maintenance schedule for each chiller and pump.

<u>Uncertainty associated with chiller savings / chiller load profile</u>

- Flow 1,000 gpm expected; 500 minimum; 1,500 maximum (+/- 50%)
- Delta T 10 °F expected, 4 °F minimum , 14°F maximum (+/- 20%)

Accuracy and Equipment

One Dent Elite Pro TOU logger will be used on the chiller energy demand. The Dent loggers are accurate to within 1% for power. If the energy management system is used to monitor hours of operation, these values will be deemed to be 100% accurate.

HOBO temperature loggers will be placed to monitor outdoor temperature and humidity and to monitor chilled water supply and return temperatures if not available for the EMS.

Flowmeters (either portable ultrasonic or permanent meters) have varying accuracies; generally +/- 2 to 10% is an expected range normal for this equipment.

The actual expected temperature measurement accuracy with dataloggers is expected to be 1°F to 2°F. Greater accuracy is generally available for readings from the sensors for the energy management system. As possible, spot checks will be performed with a Raytek infrared thermometer, with a resolution of 0.1 °F and an accuracy of +/- 1 °F.

All data collected will be reviewed to ensure that it conforms to realistic values and will be cross verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 27, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the new chiller plant equipment and by interviewing the facility representative.

The intent was that the customer would provide electronic data from the EMS in order to complete this evaluation. However, the data provided was not able to be read and it was also determined that the facility’s relative humidity sensor was faulty.

As a result, it was decided to utilize several readings from the EMS with different outside air conditions to determine new chiller performance.

Installation Verification

The installation of equipment was physically verified. The new chiller is a Trane model CVHF 770 with a variable frequency drive. The verification rate is 1.0.

Scope of the Impact Assessment

The impact assessment scope is for the chiller measure in the AC&R end use category in this SPC application. This is the only measure in the application.

Summary of Results

Measurements were taken from the facility's energy management system EMS and used to calculate the tonnage of the chillers. The present mode of operation allows chillers to ramp down together when more than one of the chillers operates. This typically occurs when outdoor air temperatures are above 87 F.

Weather data from the relevant California climate zone were used to determine the hours in 2 degree increments. Building load models were constructed which correlated outside air temperature (OAT) to tonnage. The chiller run model was constructed based upon actual operation, which dictates that a second chiller be energized at 80% of the capacity of the run chiller and above 88 F OAT. The hours correlated to actual run hours taken from the new chiller. Chiller performance curves for typical chillers of the type being retrofitted and the new chiller were used. An adjustment factor for both chillers was required to match the actual performance as measured on the post retrofit chiller and a similar chiller at the facility which was retrofit with a variable speed drive.

Table 1a: First Year Savings and Savings over Baseline

			First year	Baseline
	Base case	VSD chiller	Savings	Savings
kWh	1373757	609685	764,072	250,929
kWh	435.4	264.1	171.4	56.2
kW/ton at peak avg (100F)	0.494	0.405		
tons at peak avg (100F)	617	617		

The average savings taking into account the first year savings for 9 years and the baseline savings for 14 years are 451,724 kWh/year and 101.3 kW. Baseline savings were calculated as 32.8% of first year kW and kWh savings.

The chiller replacement savings is calculated as an early retirement measure, with an old chiller being replaced 14 years before the end of its useful life by a new chiller with a useful life of 23 years. Therefore, the annual savings is calculated as a weighted average of the savings of the new chiller vs. the old chiller for 9 years and the new chiller vs. a Title 24 compliant chiller[1] for 14 year.

The engineering realization rate for this application is 0.79 for demand kW reduction and 0.77 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 4.

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[1] California Title 24, 2001 Building Energy Standards, Table 1-C3 Chilling Packages-Minimum Efficiency Requirements, Water Cooled Centrifugal Rotary Screw and Scroll 6.1 COP, 6.4 IPLV

Utility billing data for the main meter at the site was reviewed. In the 12 month period from August 2004 to July 2005, the buildings in the complex consumed 16,566,507 kWh. Peak demand was 3,278 kW in August 2004. Table 1b summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 6.6% decrease in total meter kW, a 21.9% decrease in AC/R end use kW, a 6.0 % decrease in total meter kWh, and a 19.9% decrease in AC/R end use kWh. The ex post results showed a 5.2% decrease in total meter kW, a 17.4 % decrease in AC/R end use kW, a 4.6% decrease in total meter kWh, and a 15.4% decrease in AC/R end use kWh.

Table 1b: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	3278.4	16,566,507
Baseline End Use	983.5	4,969,952
Ex ante Savings	215.8	991,467
Ex Post Savings	171.4	764,072

Baseline use is total AC&R use for building, estimated at 30%. Ex post savings is first year savings.

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	6.6%	6.0%	5.2%	4.6%
Baseline End Use %	21.9%	19.9%	17.4%	15.4%

6. Additional Evaluation Findings

The ex post energy (kWh) savings are lower than the ex ante energy savings because the ex ante savings used the SPC calculator. The SPC Calculator does not take into effect the lower usage of the post retrofit chiller due to use in a plant with multiple chillers. It is likely that full M&V for a period of one year would yield lower savings than forecast in the ex ante estimate. Savings were increased due to the use of more accurate weather data at this site (as opposed to that used in the SPC Calculator).

The source of the capital cost submitted of $280,000 provided in the application is not known. However, these costs do not appear to be excessive for the work performed.

The customer does not anticipate changes that would affect energy use from this equipment. It is not known whether this participation increased energy awareness or participation in other incentive programs or implementation outside of incentive programs.

The level of M&V employed at this site and the customer's provision of supporting documentation could be improved in order to accurately determine the impacts of the installed measures.

A very real benefit is the ability of the new chiller to better meet the cooling needs of the facility. The replaced unit was tests chambers. The AC units were in need of considerable maintenance and often needed repair.

With a cost of $280,000 and a $138,805 incentive, the project had a 1.1 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 1.42 years. A summary of the economic parameters for the project is shown in Table 3. The Installation Verification Summary is shown in Table 5 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 6.

7. Impact Results

Impact results are presented in the following tables.

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	8/22/2005	$280,000	215.8	991,647	0	$128,914	$ 138,805	1.10	2.17
SPC Program Review (Ex Post)	11/29/2007	$280,000	171.4	764,072	0	$99,329	$138,805	1.42	2.82

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	215.8	991,467	-
SPC Installation Report (ex ante)	215.8	991,647	-
Impact Evaluation (ex post)	171.4	764,072	-
Engineering Realization Rate	0.79	0.77	NA

Realization rate based on first year savings.

The average savings, taking into account the first year savings for 9 years and the baseline savings for 14 years, are 451,724 kWh/year and 101.3 kW. The realization rates are 0.46 for kW savings and 0.47 for kWh savings based on average savings.

Table 5: Installation Verification Summary

Measure Description	*End-Use Category*	*AC&R - Measure Description*	*Lighting - Measure Description*	*Other - Measure Description*	*Count*	*Equipment Description*	*Installation Verified (Explain)*	*Verification Realization Rate*
Chiller Replacement	AC&R	450 ton chiller replaced with 700 ton VSD driven chiller			1	Trane CVHF 770	Physically verified installation.	1.00

Table 6: Multi Year Reporting Table

Program ID:		**Application # A046**					
Program Name:		**SPC 04-05 Evaluation**					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004					0	0
2	2005	495,734	382,036	215.8	171.4	0	0
3	2006	991,467	764,072	215.8	171.4	0	0
4	2007	991,467	764,072	215.8	171.4	0	0
5	2008	991,467	764,072	215.8	171.4	0	0
6	2009	991,467	764,072	215.8	171.4	0	0
7	2010	991,467	764,072	215.8	171.4	0	0
8	2011	991,467	764,072	215.8	171.4	0	0
9	2012	991,467	764,072	215.8	171.4	0	0
10	2013	991,467	764,072	215.8	171.4	0	0
11	2014	991,467	764,072	215.8	171.4	0	0
12	2015	991,467	250,929	215.8	56.3	0	0
13	2016	991,467	250,929	215.8	56.3	0	0
14	2017	991,467	250,929	215.8	56.3	0	0
15	2018	991,467	250,929	215.8	56.3	0	0
16	2019	991,467	250,929	215.8	56.3	0	0
17	2020	991,467	250,929	215.8	56.3	0	0
18	2021	991,467	250,929	215.8	56.3	0	0
19	2022	991,467	250,929	215.8	56.3		
20	2023	991,467	250,929	215.8	56.3		
21	2024	991,467	250,929	215.8	56.3		
TOTAL	**2004-2023**	19,333,607	9,767,969				

Chiller measure with 20 year life – assume 9.5 years at first year savings, remaining years with savings over baseline.

Final Report

SITE A047(2004-xxx) Home1 IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: Lighting

Measure	High Bay T5 Lighting Retrofit
Site Description	Retail Store

1. Measure Description

Replace 400 high intensity discharge fixtures utilizing 400 watt metal halide lamps with 400 fluorescent fixtures utilizing six (6) high output (HO) T5 lamps.

2. Summary of the Ex Ante Calculations

The Measure Savings Worksheet was used to calculate kW and kWh savings. The basis of the incentive payment was the itemized incentive list.

The ex ante savings in the Installation Report Review are listed as 70.9 kW and 395,520 kWh. A cost of $177,000 and an incentive of $30,000 were noted. These figures agree with the utility tracking system.

The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. These workpapers note that a conversion from metal halide fixtures to four lamp high output (HO) T5 fixtures results in a wattage reduction from 0.458 kW to 0.234 kW, for a non-coincident peak reduction of 0.224 kW. For a retail store with a diversity factor of 0.88, the coincident peak reduction per fixture is noted as 0.235 kW and kWh savings per fixture is noted as 1,106 kWh/year. The hours of operation for a retail application are fixed in the workpapers at 4,450 hours/year. The electronic version of the application paperwork reference 988.8 kWh and 0.1773 kW as the itemized savings.

3. Comments on the Ex Ante Calculations

The ex ante calculations are generally embedded in the Measure Savings Worksheet ,The ex ante savings for the itemized measures are typically based on the Express Efficiency workpapers, and for the retail sector can be calculated as 442,400 kWh/year and 94.0 kW for the 400 fixtures retrofit. These figures are higher than the ex ante savings. This may be attributed to the use of savings figures lower than the figures cited above for the retail sector (864 kWh/yr and 0.22 kW per fixture). These figures are very similar to the figures entered in the utility tracking system. It should be noted that an early version of the Measure Savings worksheet included in the paperwork lists 345,600 kWh/yr and 88.0 kW as the savings.

However, it should be noted that the calculations performed with figures from the Express Efficiency workpapers or the Measure Savings Worksheet do not accurately represent the actual situation to be evaluated.

The actual fixtures installed were predominately six lamp fixtures using HO T5 lamps. There was no workpaper available for six lamp T5 retrofits. A wattage of 351 watts is typical for these new fixtures (verses 234 watts for four lamp fixtures using HO T5 lamps). There were also significantly more hours than shown in the Express Efficiency workpapers.

The ex ante savings figures can be checked for reasonableness using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} (the diversity factor does not apply since motion sensors are not used and all lamps are energized during summer weekdays)

The check calculations for the HID fixture retrofit adjusting for longer hours of operation and for the actual quantity of six lamp fixtures used, were performed as follows:

- Pre-retrofit hours of operation: 6,882 hrs/yr
  Pre-retrofit wattage: 0.458 kW per fixture x 400 lamps = 183.2 kW
  Annual kWh usage: 183.2 kW x 6,682 hrs/yr = 1,260,783 kWh/yr
- Post-retrofit hours of operation: 6,6,82 hrs/year
  Post-retrofit wattage: 0.351 kW per six-lamp fixture x 400 fixtures = 140.4 kW
  Annual kWh usage: 140.4 kW x 6,882 hrs/yr = 966,263 kWh/yr
- The resulting annual kWh savings = 1,260,783 kWh/yr – 966,263 kWh/yr = 294,550 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load.

Summer peak demand reduction is calculated as follows:

- Reduction in connected kW load : (183.2 kW – 140.4 kW) = 42.8 kW

4. Measurement & Verification Plan

The building is a large single level retail store with open floor area. It is reported to be approximately 4 years old. The building has minimal windows and skylights. The building is occupied on a fixed schedule, from 6 am to 10 pm Monday through Saturday and 7 am to 8 pm on Sunday. Every other row is reported on for stocking on Monday through Friday 10 pm to 6 am. Lights are reported to be energized fully only after 8 am. The lighting is controlled on schedules input into the energy management system. Maximum occupancy is approximately 200 employees at any given time, with a normal occupancy of 200 customers during store hours. According to the application, before the retrofit there were 400 metal halide fixtures using 400-watt lamps. After the retrofit, there are 400 six-lamp T-5 fluorescent fixtures.

The project saves energy through the installation of lighting fixtures with a lower connected wattage.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

An approach consistent with IPMVP Option C was considered. The savings reported in the utility tracking system is approximately 20%of the kWh consumed based upon the pre-retrofit building use (annual energy use approximates 1,800,000 kWh per year according to the utility billing summary in the application). Utility billing and interval data should support this approach without adjustments, if there were no other significant loads or other significant energy conservation activities which occurred at the same time or immediately following the retrofit. There is not expected to be significant seasonal variation and several months should be sufficient for comparison; however, a one to two year period would more fully capture actual variations and the persistence of savings. Interval data on a 15 minute basis during the summer months of June to September might be needed to accurately determine summer peak period demand savings.

However, kWh billing data did not support this approach. While the total use after the retrofit did decrease on an annual basis, billing use showed increases in certain months. Weather dependency is not expected to be considerable for this facility, and it is uncertain what had caused these monthly increases. The total use after the retrofit did decrease on an annual basis, however.

A modified version of IPMVP Option A can be utilized. Lighting loggers would be used to quantify hours of operation and verify that lighting circuits are de-energized for stocking. A minimum of four loggers in contiguous rows would be utilized for this application; as many as twelve loggers can be placed throughout the facility, depending on usage areas.

Measurement on a spot or trending of the wattage or current draw of lighting fixtures on lighting only circuits could be used to confirm post retrofit fixture energy consumption and changes if trending is utilized. Attempts shall be made to isolate a minimum of three lighting circuits and monitor those circuits for power or current. If current is used, simultaneous power draw measurements could be taken to determine the current / power relationship.

Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = $kWh_{pre} - kWh_{post}$

Summer peak demand period savings = $kW_{pre} - kW_{post}$ during the hottest periods between 2 pm to 5 pm, Monday to Friday, in June, July, August, September

To estimate the average expected peak demand kW reduction, since this measure is not weather dependent, the typical reduction during those periods as stated above could be used.

Uncertainty for the savings estimate for the warehouse fixture retrofit can be more fully understood by setting projected ranges on the primary variables.

Uncertainty associated with hours of operation

- Hours/year: 6,882 expected, 5,400 minimum, 8,300 maximum (+/- 20%, depending on EMS system operation)

Uncertainty from changes in wattage

- kW: 140.4 kW expected, 110 minimum, 170 kW maximum (+/- 20%, depending on ballast factors)

Accuracy and Equipment

Lighting loggers will be utilized. Dent Smart loggers capture lighting system energization with a resolution of 1 second. For the purposes of the evaluation, these are considered to be 100% accurate where reviewed data is deemed reasonable.

Current or power meters may also be used to determine post retrofit fixture wattage. The power meter to be used would be an Amprobe ACD-41PQ, with an accuracy of +/- 2%. Dent ELITE Pro loggers have an accuracy of +/- 1%.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted August 8, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Lighting fixture quantities and hours of operation were verified.

Installation Verification

The facility representative verified that the metal halide fixtures were replaced on a one for one basis. It was physically verified that six-lamp T-5 fluorescent fixtures were installed in the facility.

This is the only measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Exhibit 5.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measure in the SPC application covering the lighting efficiency retrofit. This is the only measure in this application.

Summary of Results

The building is occupied and all lights are assumed to energized a total of 110 hours which represents Monday-Saturday (between 6 a.m. and 10 p.m.) and Sunday from 7 a.m. to 9 p.m.

Three current loggers were used to determine that lights that were scheduled to turn off did turn off. A total of 113.71 hours/week of lighting on time was recorded.

At night, the lights in every other aisle are turned off, so 50% of the total T-5 fixtures are energized for the remaining periods:

7days * 24 hours/day - 113.71 (logged hours/week = 54.29 hours / week.

The facility is closed 2 holidays annually.

Very few burned out lights were observed during the site visit. Burned out lights are regularly replaced. Therefore, there was no adjustment to the lighting energy consumption due to burned out lamps.

All lights are expected to be operating during the peak demand period defined as the hottest weekday periods between 2 pm to 5 pm, Monday to Friday, in June, July, August or September.

The electricity end-uses at this facility are lighting, forklifts charging and ventilation fans. There was not believed to be any change in the electricity use patterns before and after the retrofit other than the change to the light fixtures themselves.

The ex post calculations were developed after the evaluation site visit to reflect actual hours of operation and the actual number/type of fixtures installed.

- Pre-retrofit fully energized hours of operation: 5,896 hrs/yr (52.14 weeks x 113.71 hours/week – annual holidays of 24 hours x 2 x 67.7% = 5,896 hours)
  Pre-retrofit wattage: 0.458 kW per fixture x 400 fixtures = 183.2 kW
  Annual kWh usage: 183.2 kW x 5,896 hrs/yr = 1,080,210 kWh/yr
- Pre-retrofit period corresponding with the post retrofit period for 50% energized hours of operation: 2,815 hrs/yr (52.14 weeks x 54.29 hours/week – annual holidays of 24 hours x 2 days x 32.3% = 2,815 hours)

  Pre-retrofit wattage: 0.458 kW per fixture x 200 fixtures = 91.6 kW

  Annual kWh usage: 91.6 kW x 2,815 hrs/yr = 257,870 kWh/yr
- Post-retrofit fully energized hours of operation: 5,896 hrs/yr (52.14 weeks x 113.71 hours/week – annual holidays of 24 hours x 2 x 67.7% = 5,896 hours)
  Post-retrofit wattage: 0.351 kW per six lamp fixture x 400 fixtures = 140.4 kW

  Annual kWh usage: 140.4 kW x 5,896 hrs/yr = 827,847 kWh/yr
- Post-retrofit 50% energized hours of operation: 2,815 hrs/yr (52.14 weeks x 54.29 hours/week – annual holidays of 24 hours x 2 days x 32.3% = 2,815 hours)

  Post-retrofit wattage: 0.351 kW per fixture x 200 fixtures = 70.2 kW Annual kWh usage: 70.2 kW x 2,815 hrs/yr = 197,625 kWh/yr
- The resulting annual kWh savings = (1,080,210 kWh/yr + 257,870 kWh/yr)– (827,847 kWh/yr + 197,625 kWh/yr)
  kWh/yr = 312,608 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load and adding the diversity factor adjusted savings for occupancy sensor use.

Summer peak demand reduction is calculated as follows:
Reduction in connected kW load: (183.2 kW – 140.4 kW) = 42.8 kW

The engineering realization rate for this application is 0.6 for demand kW reduction and 0.79 for energy savings kWh. According to the installation report, the ex ante savings are 395,520 kWh annually and demand reduction is 70.9 kW. A summary of the realization rate is shown in Table 4.

Utility billing data for the site was obtained from the utility and supplemented with more recent data in hard copy from the customer at the time of the site visit. Pre-retrofit annual consumption (for 2003 prior to retrofit) was 1,977,583 kWh. Peak demand was 565.71 kW. Assuming 50% of the total meter peak demand and annual electricity usage, the baseline end use is 282.6 kW, 988,792 kWh. Table 1 summarizes the total metered use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers. The baseline use is estimated, showing that lighting is the expected predominant electricity user.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 12.5% decrease in total meter kW, a 25.1% decrease in lighting end use kW, a 20.0% decrease in total meter kWh, and a 40.0% decrease in lighting end use kWh. The ex post results showed a 7.6% decrease in total meter kW, a 15.1% decrease in lighting end use kW, a 15.8% decrease in total meter kWh, and a 31.6% decrease in lighting end use kWh.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	565.1	1,977,583
Baseline End Use	282.6	988,792
Ex Ante Savings	70.9	395,520
Ex Post Savings	42.8	312,608

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	12.5%	20.0%	7.6%	15.8%
Baseline End Use %	25.1%	40.0%	15.1%	31.6%

6. Additional Evaluation Findings

The ex post kW demand reduction is lower than the ex ante estimate because the ex ante savings estimated the four lamp fixture wattage at 0.234 watts per fixture when in actuality the six lamp fixtures installed are expected to consume 0.351 watts per fixture. The decrease in the ex post energy savings are offset since the hours of operation were much greater than those assumed in the Express Efficiency work papers and the hours used for the ex ante calculations.

In addition to saving energy, the benefits of the project are unclear. The store manager noted that the measure “probably” helped in increasing energy awareness in the company. The project was part of a corporate energy program encompassing many stores.

increased clarity of light, increased light levels, increased employee comfort and better working conditions. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. Participation in the 2004/2005 SPC Program was most likely a part of overall corporate energy policy and may encourage other marginal energy efficiency projects.

The costs appear slightly high for this type of retrofit on a per unit basis. No invoices or documentation supporting cost were provided.

7. Impact Results

The pre-retrofit lighting fixture type, quantities and hours of operation were unable to be physically verified. However, these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $177,000 and a $30,000 incentive, the project had a 2.86 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 3.62 years. A summary of the economic parameters for the project is shown in Table 3.

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	4/20/2005	$177,000	70.9	395,520	0	$51,418	$30,000	2.86	3.44
SPC Program Review (Ex Post)	8/8/2007	$177,000	42.8	312,608	0	$40,639	$30,000	3.62	4.36

The realization rate of the peak kW demand is 0.6 and the realization rate of the energy savings is 0.79 as summarized in Table 4. The Installation Verification Summary is shown in Table 5 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 6.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	70.9	395,520	-
SPC Installation Report (ex ante)	70.9	395,520	-
Impact Evaluation (ex post)	42.8	312,608	-
Engineering Realization Rate	0.60	0.79	NA

Table 5: Installation Verification Summary

Measure Description	End-Use Category	AC&R Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Interior High Bay Linear Fluorescent Fixtures		400	6 lamp T-5 HO fixtures and 4 lamp T-5 HO fixtures	Physically verified lamp type and verified quantity from floor plan and documentation of previous inspectors.	1.00

Table 6: Multi Year Reporting Table

	Program Name:	SPC 04-05 Evaluation Site A047					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	65,920	52,101				
3	2006	395,520	312,608	70.90	42.80		
4	2007	395,520	312,608	70.90	42.80		
5	2008	395,520	312,608	70.90	42.80		
6	2009	395,520	312,608	70.90	42.80		
7	2010	395,520	312,608	70.90	42.80		
8	2011	395,520	312,608	70.90	42.80		
9	2012	395,520	312,608	70.90	42.80		
10	2013	395,520	312,608	70.90	42.80		
11	2014	395,520	312,608	70.90	42.80		
12	2015	395,520	312,608	70.90	42.80		
13	2016	395,520	312,608	70.90	42.80		
14	2017	395,520	312,608	70.90	42.80		
15	2018	395,520	312,608	70.90	42.80		
16	2019	395,520	312,608	70.90	42.80		
17	2020	395,520	312,608	70.90	42.80		
18	2021	329,600	260,507	70.90	42.80		
19	2022						
20	2023						
TOTAL	2004-2023	6,328,320	5,001,732				

Note: Lighting measure with 16 year life, fully commissioned in late 2005.

FINAL SITE REPORT

SITE A048 (04-xxxx) Rowl IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: AC&R

Measure	Install multizone units with economizers, early retirement of heat pump units
Site Description	Multiple schools

1. Measure Description

This project involved the replacement of air conditioning units at several schools. Five schools had a total of twenty-one (21) units. Existing multizone units without economizers were replaced with new multizone units with economizers. All units are served by central chilled water plants that were not altered.

According to the documentation, one school had five (5) 20 ton self-contained air source heat pumps replaced. The savings were documented under the early retirement feature of the SPC Program.

An energy management system was also installed. Evaluation of the energy management system impacts is beyond the scope of this report.

2. Summary of the Ex Ante Calculations

The SPC calculator was used for the ex ante savings estimates. The SPC calculator required inputs for the measure involving multi-zone units with economizers include: existing cooling system type and efficiency, number of units and capacity, building type, location, conditioned area, whether or not the compressor runs with the economizer, and annual hours of operation. Calculations for all schools indicate that the cooling system at each school has a screw chiller operating at 0.71 kW/ton. Four of the schools had four (4) units replaced with a total of 115 tons capacity. One of the schools had five (5) units replaced with a total of 126 tons capacity.

The SPC calculator required inputs for the measure involving the early retirement of heat pumps include: existing and proposed cooling system type, number of units and capacity, building type, location, conditioned area, whether or not the compressor runs with the economizer, and annual hours of operation. The proposed system efficiency at full load is input. Also required is the year of manufacture and the year the unit was overhauled. All five units are shown to have 20 tons capacity, to have been manufactured in 1964 and overhauled between 1998 and 2002.

The Installation Review Report (IRR) states that the ex ante savings for the economizer measure are 232,052 kWh annually with no demand reduction. The ex ante savings for the early retirement measure are 220,228 kWh annually with a demand reduction of 22.0

kW. Total ex ante estimates for the AC&R end use are 452,280 kWh annually with a demand reduction of 22 kW. The kW value agrees with the utility tracking system; the kWh figures for these measures and another measure - the energy management control system in another end use category and not included in this evaluation - are aggregated and a total of 878,964 kWh is given. The energy management system installation is correctly listed in the "Other" category (encompassing controls) in the IRR; however, it is listed in the utility tracking system as an AC&R measure (previously denoted by H for HVACR).

3. Comments on the Ex Ante Calculations

The economizer measure involves replacing HVAC units without economizers with new units with economizers. The old and new units are served by chilled water systems that were not modified. Title 24 clearly requires economizers on new units over 6.25 tons (or 2,500 CFM) capacity. All of the replaced units have capacities greater than 2,500 CFM. The SPC program rules state that "State Mandated Energy Efficiency Performance" (Title 24) is the baseline, therefore the savings associated with the economizers should be excluded.

From the SPC Procedures Manual, Section 1:

"2. Must Exceed Government Standards. Incentives are paid only on the energy savings above and beyond minimum federal- and state-mandated energy efficiency performance. If there are no government standards for a particular measure, current industry practices are used to establish baseline performance. The only exception to this policy is with the Early Retirement feature for qualifying equipment, which allows the efficiency standards of the existing equipment being replaced to determine the baseline."

From Section 144 of Title 24 (2001 version in effect at the time of the application):

(e) **Economizers**.
1. Each individual cooling fan system that has a design supply capacity over 2,500 cfm and a total mechanical cooling capacity over 75,000 Btu/hr. shall include either:
A. An air economizer capable of modulating outside-air and return-air dampers to supply 100 percent of the design supply air quantity as outside-air; or
B. A water economizer capable of providing 100 percent of the expected system cooling load as calculated in accordance with a method approved by the commission, at outside air temperatures of 50°F dry-bulb/45°F wet-bulb and below.

The other sub measure evaluated involves the replacement of 20 ton heat pumps. The application states that the heat pumps had been rebuilt prior to their replacement, and this rebuild date is the basis of the early retirement claim.

Review of the SPC calculator results for this measure has revealed a significant discrepancy involving reporting multi year savings. The annual savings result has been multiplied by the remaining years of useful life and the result has been reported as the annual savings. For example, the calculator output sheet indicates an annual savings of 6,322 kWh for HP-1 and an incentive of $885, with 9 years remaining useful life. The reported savings for the measure are 56,901 kWh with an incentive of $7,966. This error has created a gross over-reporting of the ex ante impacts. This error was not found for the demand reduction impacts. Table 1 summarizes the calculated and reported ex ante impacts for the heat pump measure. The reported savings for the early retirement measure are 220,228 kWh annually, a demand reduction of 22 kW and an incentive of $30,832. The recalculated ex ante savings for the measure are 30,869 kWh annually. A demand reduction of 22 kW is unchanged. The recalculated incentive is $4,296.

Table 1: Summary of Calculated and Reported Ex Ante Impacts for the Heat Pumps

Unit	Remaining Useful Life (Years)	Calculated			Reported		
		Annual kWh	Peak Demand kW	Incentive $	Annual kWh	Peak Demand kW	Incentive $
HP-1	9	6,322	4.4	$ 885	56,901	4.4	$ 7,966
HP-2 & 3	8	11,724	8.8	$ 1,641	93,791	8.8	$ 13,131
HP-4	6	6,317	4.4	$ 884	37,904	4.4	$ 5,307
HP-5	5	6,326	4.4	$ 886	31,632	4.4	$ 4,428
Total		30,689	22	$ 4,296	220,228	22	$ 30,832

4. Measurement & Verification Plan

As described above, the ex ante baseline used for economizer measure does not comply with the SPC program rules. Using the correct Title 24 baseline, there are no reportable savings associated with this measure and the ex post savings will be reported as 0 kWh.

However, meteorological data will be used, in conjunction with customer reported operating hours (as verified by energy management system data as available), to determine the reasonableness of reported savings from economizer operation.

For the early retirement measure, the savings are calculated using the pre retrofit equipment as a baseline for the expected remaining useful life of the pre retrofit equipment, then using Title 24 minimum efficiency as the baseline for the remainder of the expected equipment life.

For example, the expected useful life of packaged air conditioning equipment is 15 years. One of the 20 ton heat pumps was rebuilt in 2000 and replaced in 2005. According to the program guidelines, this heat pump would have 10 more years of useful life when it was replaced. The first 10 years of savings are calculated using the pre-retrofit equipment efficiency as a baseline. The remaining five years of savings are calculated using Title 24 minimum equipment efficiency as a baseline. The ex post impact is the average annual kWh savings and average peak demand reduction over the 15 year expected useful life of the new equipment.

The ex post impacts will be calculated using a simplified temperature bin analysis comparing the efficiency of the new units to the pre retrofit equipment efficiency and Title 24 minimum equipment efficiency. Annual hours of operation will be determined from the customer interview (and verified by energy management system data as available). System load will be estimated and energy consumption at various outdoor conditions will be calculated. The baseline equipment performance will be compared to the new equipment performance.

The project saves energy by the installation of more efficient heat pumps serving school buildings.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit hours of operation and the pre-retrofit heat pump energy consumption.

The goal of the M&V plan is to verify the peak demand kW and annual kWh savings over the useful life of the equipment.

Formulae and Approach

The M&V plan is a modified version of IPMVP Option A.

The application contains the post retrofit efficiency of the heat pumps, the heat pump rebuild date and the annual hours of operation for each unit.

The approach will entail the verification of the installed equipment full load efficiency and the annual hours of operation for each unit.

To determine pre and post retrofit heat pump kW and kWh:

For each temperature bin, we will calculate kW and kWh as follows:

kW= tons x kW/ton
kWh= kW x annual hours

The annual kWh and peak demand will be calculated for each scenario - existing pre retrofit equipment, Title 24 pre retrofit equipment, and installed equipment. The average impact will be calculated as described above, with consideration for the expected useful life of the equipment and the rebuild date shown in the application.

To estimate peak demand kW reduction, the expected reduction in connected kW due to the higher efficiency units during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in the week with the hottest weekday in June, July, August, September will be determined by calculating the expected kW reduction during the hottest periods in the hours from 2 pm to 5 pm, Monday to Friday, in June, July, August, September.

The post retrofit kW demand savings as determined above will be subtracted from the pre retrofit kW demand and the peak demand reduction will be calculated.

Peak demand reduction kW= maximum kW_{pre} – maximum kW_{post}

Uncertainty for the savings estimate can be more fully understood by setting projected ranges on the primary variables.

Heat Pump Replacement

- 150 kW pre-retrofit expected maximum demand, +/- 20% (120 -180 kW)
- 2,120 hours/yr pre retrofit expected, +/- 20% (1,696 - 2,544 hrs/yr)

Accuracy and Equipment

Using the manufacturer's nameplate data for equipment efficiency is expected to have a error of 10 - 15%. Utilizing the modified bin analysis is expected to be +/- 15% accurate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 19, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the energy management system and air conditioning units and by interviewing the facility representatives. Air conditioning unit make, model, quantities and hours of operation were verified. We obtained temperature bin weather data from the National Climatic Data Center for an airport located in close proximity to the schools. The data contains 23 year averaged observations. We used this data for the ex post analysis.

The air conditioning units are enabled to operate from 7 a.m. to 5 p.m., Monday-Friday, they are off at other times. In addition to standard State holidays, the schools are closed for 3 weeks during the Christmas Holidays, 1 week for Spring break (usually in March) and July through August.

Installation Verification

The facility representatives verified that five of the schools had a total of twenty-one (21) existing multizone units without economizers that were replaced with new multizone units with economizers. We physically verified the installation at three schools. All units are served by central chilled water plants.

According to the documentation, one school had five (5) 20 ton self-contained air source heat pumps replaced. The facility representatives stated that the units at this school were multizone units, not heat pumps as stated in the application. We physically verified that the new units are also multizone units. Additionally, the documentation states that there are five (5) units at this school. We verified that eight (8) units have been replaced. However, only five (5) units qualified for the program and were included in the ex ante and ex post analysis.

These are the only AC&R end use measures in this application. The verification realization rate for this project is 1.0 (26 units/26 units). A verification summary is shown in Table 7 below.

Scope of the Impact Assessment

The impact assessment scope is for the AC & R end use measures in the SPC application covering the economizer and early retirement measures. These are the only AC & R end use measures in this application.

Summary of Results

As described above, the ex ante baseline used for economizer measure does not comply with the SPC program rules. Using the correct Title 24 baseline, there are no reportable savings associated with this measure and the ex post savings will be reported as 0 kWh for this measure.

To determine the reasonableness of reported savings from economizer operation, meteorological data was used, in conjunction with customer reported operating hours (as verified by energy management system data) to calculate the impacts of the economizers. Air flow data obtained from air balance reports provided by the customer were used to estimate the total air flow of the units. Additionally the air balance reports provided the minimum outside air quantity. Using this data we calculated the impact of the economizers to be an annual savings of 101,648 kWh annually versus the ex ante reported savings of 232,052 kWh.

We were not able to obtain information on the pre retrofit equipment efficiency during the site visit for the early retirement measure. We used the 2005 DEER Non Residential Prototype Characteristics to estimate the pre-retrofit equipment efficiency. According to the DEER study, for rooftop packaged air conditioning equipment installed prior to 1978, the EER is 7.7. The Title 24 Standards in effect at the time of the project installation (2001 version) show a minimum EER of 9.3 for unitary air conditioning units.

For the early retirement measure, the impacts were calculated using the pre retrofit equipment as a baseline for the expected remaining useful life of the pre retrofit equipment, then using Title 24 minimum efficiency for the remainder of the expected equipment life. For example, the expected useful life of packaged air conditioning equipment is 15 years. One of the 20 ton heat pumps was rebuilt in 2000 and replaced in

2005. According to the program guidelines, this heat pump would have 10 more years of useful life when it was replaced. The first 10 years of savings are calculated using the pre-retrofit equipment efficiency as a baseline. The remaining five years of savings are calculated using Title 24 minimum equipment efficiency as a baseline. The ex post impact is the average annual kWh savings and average peak demand reduction over the 15 year expected useful life of the new equipment. Using this methodology, the average impacts of the early retirement measure were calculated to be 26.5 kW demand reduction and 12,667 kWh annual energy savings. Table 2 summarizes the analysis of the early retirement measure.

Table 2: Summary of the Ex Post Analysis for the Early Retirement Measure

	Remaining Useful	Annual Impact over Baselines				Useful Life Weighted	
		Existing Equipment		Title 24 (2001)		Average Annual Impact	
Unit	Life (Years)	kW	kWh	kW	kWh	kW	kWh
HP-1	9	8.1	3,865	2.7	1,304	5.9	2,841
HP-2 & 3	8	16.2	7,731	5.5	2,608	11.2	5,340
HP-4	6	8.1	3,865	2.7	1,304	4.9	2,328
HP-5	5	8.1	3,865	2.7	1,304	4.5	2,158
Total		40.5	19,327	13.6	6,519	26.5	12,667

The engineering realization rate for this application based on the average annual impact over the useful life of the equipment is 1.21 for demand kW reduction and 0.03 for energy savings kWh. The engineering realization rate based on the first year impacts (using the existing equipment efficiency as a baseline) is 1.84 for demand kW reduction and 0.04 for energy savings kWh. A summary of the realization rate is shown in Table 5.

Utility billing data for six of the schools was provided in the application. Pre-retrofit annual consumption was 3,250,122 kWh. Peak demand was 1,613 kW. Table 3 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility provided numbers.

Table 4 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 1.4% decrease in total meter kW, a 4.5% decrease in compressor end use kW, a 13.9% decrease in total meter kWh, and a 115% decrease in compressor end use kWh. The ex post results showed a 1.6 % decrease in total meter kW, an 5.4 % decrease in compressor end use kW, a 0.4 % decrease in total meter kWh, and a 3.2 % decrease in compressor end use kWh.

Table 3: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1,613	3,250,122
Baseline End Use	492	393,200
Ex ante Savings	22	452,280
Ex Post Savings	26.5	12,667

Table 4: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	1.4%	13.9%	1.6%	0.4%
Baseline End Use %	4.5%	115.0%	5.4%	3.2%

6. Additional Evaluation Findings

The ex post energy savings are less than the ex ante energy savings because we determined that the early retirement measure has a calculation discrepancy reporting multi year savings (described above) and that the ex ante baseline used for economizer measure does not comply with the SPC program rules. Using the correct Title 24 baseline, there are no reportable savings associated with the economizer measure and the ex post savings are reported as 0 kWh

The facility representative stated that the cost estimate provided in the application ($164,500) is an approximation of the cost for the work performed for the project and may not be an accurate reflection of the true project cost. In addition to saving energy, the benefits of the project are more reliable equipment operation and improved comfort conditions. Participation in the 2004/2005 SPC Program has not encouraged the customer to perform any other energy efficiency projects without participating in an incentive program.

With a cost of $164,500 and a $63,319 incentive, the project had a 1.7 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 61 years using the average impacts. A summary of the economic parameters for the project is shown in Table 5. The customer stated that they have no reason to believe that the operation of the equipment will change in the future, therefore the multi-year impacts, shown in Table 8 below, are expected to remain constant over the life of the equipment. Table 8 accounts for the different years of remaining useful life for each air conditioning unit according to the program guidelines.

7. Impact Results

Table 5: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	5/16/2005	$164,500	22.0	452,280	0	$58,796	$63,319	1.72	2.80
SPC Program Review (Ex Post)	10/10/2007	$164,500	26.5	12,667	0	$1,647	$63,319	61.44	99.90

Table 6: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	22.0	452,280	-
SPC Installation Report (ex ante)	22.0	452,280	-
Average Impact Evaluation (ex post)	26.5	12,667	-
Average Engineering Realization Rate	1.21	0.03	NA
First Year Impact Evaluation (ex post)	40.5	19,327	-
First Year Engineering Realization Rate	1.84	0.04	NA

Table 7: Installation Verification Summary

Measure Description	End-Use Category	AC&R Measure Description	Lighting Measure Description	Other Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Early Retirement of packaged air conditioning units.	A	Replace self contained multizone units with new self contained multizone units.			5	Seasons 4 Model 6MMF self contained multizone units	Physically verified air handler quantity and installation. Five (50 qualifying units were installed and five (5) were indicated in the documentation.	1.0
Economizer Installation	A	Install New Multizone units with Economizers			21	Seasons 4 Custom built chilled water cooled air handling units (also 21 of 21 economizers).	Physically verified air handler quantity and installation of economizers	1.0

Table 8: Multi Year Reporting Table

Year	Calendar Year	Ex-Ante Gross Program Projected kWh Savings	Ex post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program Projected Peak kW Reduction	Ex-Post Gross Evaluation Projected Peak kW Reduction	Ex-Ante Gross Program Projected Therm Savings	Ex post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	226,140	9,664	22.0	40.5		
3	2006	452,280	19,327	22.0	40.5		
4	2007	452,280	19,327	22.0	40.5		
5	2008	452,280	19,327	22.0	40.5		
6	2009	452,280	19,327	22.0	40.5		
7	2010	452,280	19,327	22.0	40.5		
8	2011	452,280	16,766	22.0	35.1		
9	2012	452,280	14,204	22.0	29.7		
10	2013	452,280	14,204	22.0	29.7		
11	2014	452,280	9,081	22.0	19.0		
12	2015	452,280	6,519	22.0	13.6		
13	2016	452,280	6,519	22.0	13.6		
14	2017	452,280	6,519	22.0	13.6		
15	2018	452,280	6,519	22.0	13.6		
16	2019	452,280	6,519	22.0	13.6		
17	2020	226,140	3,260	22.0	13.6		
18	2021						
19	2022						
20	2023						
Total	**2004 - 2023**	6,784,200	196,409				

Note: If the multi year ex ante savings of 452,280 kWh are replaced with first year savings of 262,741 kWh in the realization rate calculations, the kWh realization rate is increased from 0.04 to 0.07 (4% to 7%). The low rate of change is due to excluding the economizer sub-measure that accounts for 51 of the ex post kWh savings. The kW realization rate is not affected.

FINAL SITE REPORT

SITE A049 APPLICATION #04-xxxx Palm IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 5 END USE: AC&R

Measure	Install economizers on roof top packaged units
Site Description	Community Services Building

1. Measure Description

This project involved the installation of economizers on twenty-five (25) roof top packaged units at a Community Services Building. All units are self contained with DX cooling and natural gas furnaces.

An energy management system was also installed. Evaluation of the energy management system impacts is beyond the scope of this report.

2. Summary of the Ex Ante Calculations

The SPC calculation software was used for the ex ante savings estimates. The SPC calculation software required inputs for the economizer measure include: existing cooling system type and efficiency, number of units and capacity, building type, location, conditioned area, whether or not the compressor runs with the economizer, and annual hours of operation. A single calculation was performed for all units. The calculation indicates that the cooling system has an efficiency of 1.3 kW/ton.

The Installation Review Report (IRR) states that the ex ante savings for the economizer measure are 118,673 kWh annually with no demand reduction. This is the only measure in the AC&R end use.

3. Comments on the Ex Ante Calculations

The ex ante calculations were performed according the SPC Program guidelines using the SPC calculation software. The existing cooling system type and efficiency, number of units and capacity, building type, location, conditioned area, whether or not the compressor runs with the economizer, and annual hours of operation are input into the calculator. The customer used the default “Small Office” Building Type. Analysis of the methodologies utilized by the SPC calculation software for this measure is beyond the scope of this report.

4. Measurement & Verification Plan

Meteorological data for the climate zone in which the project is located will be used, in conjunction with customer reported operating hours (as verified by energy management system data as available), to determine the impacts from economizer operation.

The ex post impacts will be calculated using a simplified temperature bin analysis comparing the operation of the existing air conditioning units with and without an outside air economizer. Annual hours of operation will be determined from the customer interview (and verified by energy management system data as available). Economizer sequences of operation will be verified by reviewing the energy management and control system documentation (if available). If control system documentation is not available, data loggers may be installed to determine the economizer system set points. A visual inspection verifying economizer operation will be performed if ambient conditions are favorable to economizer operation during the site inspection.

System load will be estimated and energy consumption at various outdoor conditions will be calculated. The baseline equipment performance without economizers will be compared to the baseline equipment performance with economizers.

The project saves energy by the installation of air side economizers which utilize outside air for cooling when ambient conditions are favorable.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit hours of operation, the economizer sequences of operation and the existing equipment cooling efficiency.

The goal of the M&V plan is to verify the peak demand kW and annual kWh savings over the useful life of the equipment.

Formulae and Approach

The M&V plan is a modified version of IPMVP Option A.

The application contains the existing equipment cooling capacity and full load efficiency (EER) of the rooftop air conditioning units.

The approach will entail the verification of the installed equipment full load efficiency and the annual hours of operation for each unit. We will also verify the economizer lockout setpoint for the units. There is no demand reduction kW for this measure since economizer operation is typically locked out above 72 ºF and peak demand impacts occur well above this temperature.

To determine pre and post retrofit air conditioning unit kW and kWh

We will verify the operation of the economizers by viewing the sequences of operation for the energy management system and the economizer lockout set points. If we are unable to confirm the economizer operation from the energy management system, we may install data loggers inside randomly selected air conditioning units to verify the operation of the economizer cycle.

We will determine the supply air (SA), return air (RA) and minimum outside air (OA) quantities from design documents if available. If design documents are not available, we will assume the minimum outside air to be 20%, and that the supply air quantity is 400 CFM per ton of nominal cooling capacity.

The outside air and return air enthalpy will be obtained from a psychrometric chart. The economizer cooling load savings will be calculated using the total heat equation as follows:

Cooling tons saved = 4.45 x total CFM x (RA enthalpy-OA enthalpy) x (1-% min OA)/(12,000 btu/ton-hr)

For each temperature bin we will calculate kW and kWh as follows:

kW= tons x kW/ton
kWh= kW x annual hours

As discussed above, there is no demand kW reduction during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in the week with the hottest weekday in June, July, August, September for this measure.

The post retrofit annual cooling kWh as determined above will be subtracted from the pre retrofit annual cooling kWh and the result will be the annual kWh savings.

Annual kWh savings= $kWh_{pre} – kWh_{post}$

Uncertainty for the savings estimate can be more fully understood by setting projected ranges on the primary variables.

Economizer Installation

- Average existing AC unit efficiency 9 EER, +/- 20% (7.2-10.8 EER)
- 2,800 hours/yr pre retrofit expected, +/- 15% (2,380-3,220 hrs/yr)

Accuracy and Equipment

Using the manufacturer’s nameplate data for equipment efficiency is expected to have a error of 10-15%. Utilizing the modified bin analysis is expected to be +/- 15% accurate. Hobo Model HO8-001-02 temperature data loggers may be used to verify economizer operation. These loggers are stand-alone single channel temperature loggers with internal thermistors and non-volatile memory. The logger uses a PC serial interface for data transfer and real time readings. Sensor range- dry bulb temperature: - 4° to 158° F (accuracy ± 1.27° F at 70° F)

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

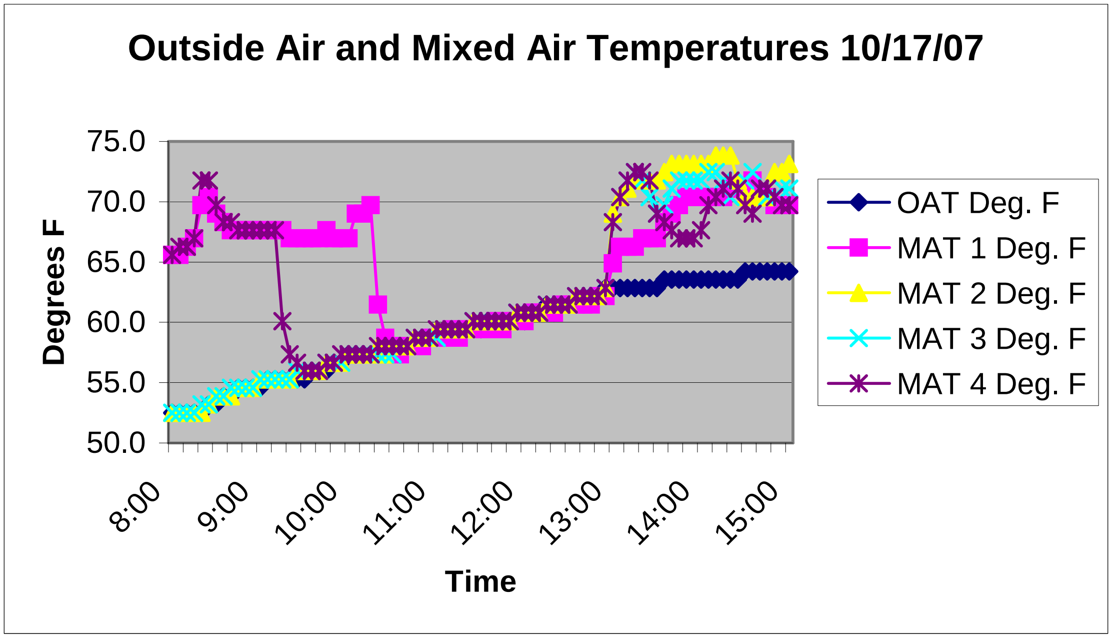
The on-site survey was conducted on October 17, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the energy management system and air conditioning units and by interviewing the facility representatives. Air conditioning unit make, model, quantities and hours of operation were verified. We obtained temperature bin weather data from the National Climatic Data Center for an airport located in close proximity to the facility. The data contains 23 year averaged observations. We used this data for the ex post analysis.

We reviewed the energy management and control system schedules and set points with the facility representative. The air conditioning units are enabled to operate from 7 a.m. to 6 p.m., Monday-Friday, they are scheduled off at other times. Manually operated bypass timers are installed to allow after hours operation. The facility is closed 9 holidays annually. The economizers are locked out when the outside air temperature is above 62 ºF, or when the air conditioning units are in a heating mode. The economizers do not operate when the compressors are running.

We installed Hobo data loggers in the mixed air plenum of four randomly selected units, and one logger for the outside air temperature. Data was collected from 8 a.m. to 3 p.m. on October 17, 2007. Figure 1 shows the results of the data logging. The data analyzed from the Hobo loggers confirmed the control sequence of operation for the economizers. The economizers do not operate when the air conditioning units are in the heating mode or when the outside air temperature is above approximately 62 ºF.

At 8 a.m., the outside air temperature is approximately 52 ºF, sample units 1 and 4 are in the heating mode and the outside air dampers are at a minimum position. Sample units 2 and 3 are in a cooling mode and the mixed air temperature is approximately equal to the outside air temperature indicating the units are operating at 100% outside air. Between 9:30 a.m. and 11 a.m., units 1 and 4, go into the cooling mode and their mixed air temperatures are approximately equal to the outside air temperature indicating the units are operating at 100% outside air. Shortly after 1 p.m. (13:00 hours), the outside air temperature reaches approximately 62 ºF, and the mixed air temperature on all units rises, indicating that the units are operating with the outside air dampers at a minimum position.

FIgure 1: Results of the Data logging on October 17, 2001



Installation Verification

We physically verified the installation of the economizers on the 25 roof top air conditioning units. The economizers were manufactured by York Company, the manufacturer of the roof top air condition equipment installed at the facility. During the site inspection, access panels on several air conditioning units were removed and we viewed the economizer damper sections. All units were operating properly. Two units in the cooling mode had their outside air dampers fully opened. Two units in the heating mode had their outside air dampers at a minimum position.

The economizer installations are the only AC&R end use measures in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 5 below.

Scope of the Impact Assessment

The impact assessment scope is for the AC & R end use measures in the SPC application covering the economizer measures. These are the only AC & R end use measures in this application.

Summary of Results

Meteorological data was used, in conjunction with customer reported operating hours and sequences of operation (as verified by energy management system data) to calculate the impacts of the economizers. Data loggers were installed in the mixed air plenum of four units to verify economizer operation. Total air flow of the units was estimated at 400

CFM per ton based on the verified capacity of the units. The 25 units total 100 nominal tons of capacity. Total airflow is estimated to be 40,000 CFM. Based on the customer's representative statements and confirmed by field observation, the minimum outside air quantity was estimated to be 20% of total flow. Using this data, we calculated the impact of the economizers to be an annual savings of 37,824 kWh annually versus the ex ante reported savings of 118,673 kWh.

The engineering realization rate for this application is 0.32 for energy savings kWh. There is no demand kW reduction for the AC&R end use. A summary of the realization rate is shown in Table 4.

Utility billing data for was provided by the Utility. For the calendar year 2004, annual consumption was 355,200 kWh. Peak demand data was not provided. Table 1 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility 2004 kWh data.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 33.4% decrease in total meter kWh, and a 64.3% decrease in compressor end use kWh. The ex post results showed a 10.6% decrease in total meter kWh, and a 20.5% decrease in compressor end use kWh.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	NA	355,200
Baseline End Use	132	184,615
Ex ante Savings	-	118,673
Ex Post Savings	-	37,824

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	NA	33.4%	NA	10.6%
Baseline End Use %	NA	64.3%	NA	20.5%

6. Additional Evaluation Findings

The ex post energy savings are less than the ex ante energy savings because we determined that the economizers are locked out when the outside air temperature is less than 62 ºF. We do not know what assumption the SPC calculation software uses for the economizer lockout, but it is likely higher than 62 ºF. There is no reportable kW demand reduction associated with the economizer measure and the ex post and ex ante demand reduction are shown as 0 kW.

The facility representative stated that the cost estimate provided in the application ($24,000) is an approximation of the cost for the economizer installation and may not be an accurate reflection of the true project cost. In addition to saving energy, the benefits of the project are more reliable equipment operation, remote access to the operation and control of the HVAC system, and improved comfort conditions. Participation in the 2004/2005 SPC Program has not encouraged the customer to perform any other energy efficiency projects without participating in an incentive program.

With a cost of $24,000 and a $12,000 incentive, the project had a 0.78 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 2.44 years. A summary of the economic parameters for the project is shown in Table 3. The customer stated that they have no reason to believe that the operation of the equipment will change in the future, therefore the multi-year impacts, shown in Table 6 below, are expected to remain constant over the life of the equipment.

7. Impact Results

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	8/16/2005	$24,000	-	118,673	0	$15,427	$12,000	0.78	1.56
SPC Program Review (Ex Post)	10/23/2007	$24,000	-	37,824	0	$4,917	$12,000	2.44	4.88

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	-	118,673	-
SPC Installation Report (ex ante)	-	118,673	-
Impact Evaluation (ex post)	-	37,824	-
Engineering Realization Rate	NA	0.32	NA

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Economizer Installation	AC&R	Install Economizers			25	York roof top packaged units with factory manufactured economizer retrofit kits.	Physically verified packaged unit quantity and installation of economizers	1.0

Table 6: Multi Year Reporting Table

Program ID	**SPC 2005 Application # A049**
Program Name	**2004-2005 SPC Application**

Year	Calendar Year	Ex-Ante Gross Program Projected kWh Savings	Ex post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program Projected Peak kW Reduction	Ex-Post Gross Evalaution Projected Peak kW Reduction	Ex-Ante Gross Program Projected Therm Savings	Ex post Gross Evaluation Confirmed Program Therm Savings
1	2004	0	0	0	0	0	0
2	2005	29,668	9,456	0	0	0	0
3	2006	118,673	37,824	0	0	0	0
4	2007	118,673	37,824	0	0	0	0
5	2008	118,673	37,824	0	0	0	0
6	2009	118,673	37,824	0	0	0	0
7	2010	118,673	37,824	0	0	0	0
8	2011	118,673	37,824	0	0	0	0
9	2012	118,673	37,824	0	0	0	0
10	2013	118,673	37,824	0	0	0	0
11	2014	118,673	37,824	0	0	0	0
12	2015	118,673	37,824	0	0	0	0
13	2016	118,673	37,824	0	0	0	0
14	2017	118,673	37,824	0	0	0	0
15	2018	118,673	37,824	0	0	0	0
16	2019	118,673	37,824	0	0	0	0
17	2020	89,005	28,368	0	0	0	0
18	2021	0	0	0	0	0	0
19	2022	0	0	0	0	0	0
20	2023	0	0	0	0	0	0
Totals	**2004 - 23**	**1,780,095**	**567,353**				

FINAL SITE REPORT

SITE A050 Plai1 (04-xxxx) IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 2 END USE: Other

Measure	Pipeline De-Bottlenecking
Site Description	Petroleum Product Production

1. Measure Description

This project involved the installation of additional parallel piping on a discharge header at an oilfield to decrease system pumping head. Prior to the project, flow requirements had increased and the customer had to utilize four auxiliary 700 HP pumps. Adding the takeoffs to the discharge header lowered the system pressure drop while maintaining the required flow rate and allowed the customer to turn off one of the auxiliary 700 HP pumps.

2. Summary of the Ex Ante Calculations

During the reviewer's pre-installation inspection one 3,000 HP pump, one 950 HP pump, and four auxiliary 700 HP pumps were observed to be operating. The reviewer's baseline energy consumption is based on four auxiliary pumps being turned on. The ex ante calculations are based on measurements of amps and voltage performed by the customer for the 950 HP and 700 HP pumps. The measurements were witnessed by the reviewer. The 3,000 HP pump has power monitoring equipment. The power readings were recorded by the reviewer. The reviewer estimated the power factor to be 0.88 and 0.95 for the 700 HP and 950 HP pumps, respectively, and calculated the pump kW. The savings calculations indicate that the pumps operate 8,736 hours annually.

Originally, the customer expected to be able to turn off two of the 700 HP pumps post-retrofit. However following the completion of the project, the system required three of the 700 HP auxiliary pumps to operate. The reviewer adjusted the savings calculations accordingly.

The following formulas were utilized:
kW= (amps x volts x power factor x sq. root of three)/(1,000 watts/kW)
kWh = kW x annual hours

The Installation Report states that the ex ante savings are 2,406,450 kWh annually and demand reduction is 275 kW. These values agree with the Tracking System data.

3. Comments on the Ex Ante Calculations

The ex ante calculations are based on readings of power monitoring equipment for the 3,000 HP pump and on measurements of amps and voltage performed by the customer and witnessed by the reviewer for the 700 HP and 950 HP pumps. The reviewer estimated power factors appear reasonable.

4. Measurement & Verification Plan

According to the application, prior to the retrofit there was one 3,000 HP pump, one 950 HP pump, and four auxiliary 700 HP pumps operating. Following the completion of the project, the installation report documents state that one 3,000 HP pump, one 950 HP pump, and three auxiliary 700 HP pumps were operating.

The project saves energy by the installation of additional parallel piping on a discharge header at an oilfield to decrease system pumping head.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit hours of pump operation and the pump energy consumption.

The goal of the M&V plan is to verify the peak demand kW and annual kWh savings over the expected useful life of the equipment or modification.

Formulae and Approach

The M&V plan is a modified version of IPMVP Option A.

The application contains measurements of amps and voltage performed by the customer and witnessed by the reviewer for the pumps. The reviewer estimated the power factor to be 0.88 and 0.95 for the 700 HP and 950 HP pumps, respectively. The savings calculations indicate that the pumps operate 8,736 hours annually. The power factor estimate appears reasonable. The 3,000 HP pump has power monitoring equipment installed. All pumps are constant speed, constant volume.

To determine pre-retrofit pump kW and kWh

We will accept the kW calculations performed by the reviewer and adjust hours of operation based on the results of discussions with the customer and 7 days of monitoring the 700 HP pumps.

To determine post-retrofit pump kW and kWh

We will accept the customer measured and reviewer witnessed pump amps, volts for the 700 and 950 HP pumps. We will also accept the reviewer estimated power factors for these pumps. During the site visit, we will confirm the power monitor reading on the 3,000 HP pump. We will install motor loggers on the 700 HP pumps for a minimum of 7 days to verify the number of 700 HP pumps operating and hours of operation for each 700 HP pump. The seven day period results will be annualized, and adjusted for holidays if appropriate. If the customer has data that shows the pump hours of operation we will use that data instead of installing motor loggers.

It will also be attempted to procure logs of flow through the pumps and the common manifold. This will determine if flow decreases to the point where the fourth pump could have been deenergized in the pre retrofit condition. It will also be determined if flow increases to the point where varies to the point where the third pump will be needed. Any increases in throughput will be treated as production increases. In this case, the flow through pumps will be adjusted to pre retrofit consumption and consumption indicated through the use of pump curves and friction losses through line sizes. Diagrams will be developed indicating pre and post line size, lengths and fittings.

The formulae used will be as follows:

kW for the 700 HP and 950 HP pumps:
kW= (amps x volts x power factor x sq. root of three)/(1,000 watts/kW)

kW for the 3,000 HP pump will be read on the power monitoring equipment.

kWh = kW x hours

The energy consumption of this measure is not greatly affected by the outside air temperature. To estimate peak demand kW reduction, the expected reduction in connected kW due to the reduced pumping energy during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in the week with the hottest weekday in June, July, August, September will be determined by calculating the average kW reduction from 2 pm to 5 pm, Monday to Friday in June, July, August, September.

kW will be determined as described above. The average post retrofit kW will be subtracted from the pre retrofit kW and the peak demand reduction will be calculated.

Peak demand reduction kW= Average kW_{pre} – Average kW_{post}

Uncertainty for the savings estimate can be more fully understood by setting projected ranges on the primary variables.

Pipe Header De-Bottlenecking

- 4,000 kW pre-retrofit expected maximum demand, +/- 10% (3,600-4,400 kW)
- 8,736 hours pre retrofit expected, + 1%/- 5% (8,300-8,760)
- 6,500 GPM pre-retrofit expected, +/- 15% (5,525-7,475 GPM)

Accuracy and Equipment

The customer’s volt and amp field measurements are expected to have a measurement error of less than 7%. According to the customer, the NuFlo Measurement Systems MC-II flow meters are industrial grade instrumentation, and are expected to have an accuracy of +/- 10%. Similarly, the instrumentation for the power measurement on the 3,000 and 1,750 HP pumps (Westinghouse IQ Data Plus II) as well as the current measurement on the 950 HP pump (Cutler Hammer) are industrial grade and are expected to have an accuracy of +/- 3%. Annualizing the seven day measurement period is estimated to be +/- 10% accurate.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 20, 2007. Information on the piping system retrofit and operating conditions was collected by inspection of the water flood pumping system and by interviewing the facility representative. Pump manufacturer, model, quantities and hours of operation were verified.

Our interview with the customer revealed that production has increased significantly since the project documented in the application was completed. The water flood pumping system capacity has been increased to meet increased system flow requirements. A new 1,750 HP pump now performs the duty of the three (3) 700 HP pumps. In the current system, the 1,750 HP pump operates in parallel with the 3,000 HP and 950 HP pumps to serve the water flood piping distribution system. The seven (7) 700 HP pumps remain as back ups and are only expected to be energized when one of the larger pumps is serviced or fails.

Data was collected for 8 days to document the current operating parameters of the water flood system. Power and flow readings were manually recorded once a day from instrumentation installed on the pumping system. The 3,000 HP and 1,750 HP pumps have power meters installed. The 950 HP pump instrumentation only measures pump current on each phase. Each pump has a flow meter installed at its discharge.

Input kW for the 950 HP pump was calculated as follows:
kW= (amps x volts x power factor x sq. root of three)/(1,000 watts/kW)

System voltage for the 950 HP pump was assumed to be equal to the 1,750 HP pump that operates on the same electrical supply. The power factor was assumed to be 0.95 which is similar to the readings from the 1,750 and 3,000 HP pumps.

The instantaneous flow rate for each of the pumps was also recorded, and the three readings were added together to determine the total system flow. We calculated the average kW/GPM for the 8 day period and compared this to the data collected by the reviewer before and after the retrofit documented in the application.

The customer confirmed that the pumps operate continuously. The facility does not close for holidays.

Installation Verification

Most of the water flood piping is underground and we were able to view only a small portion of the new piping near the pump header. The facility representative verified that additional parallel piping on the discharge header was installed. We also verified that there is one 3,000 HP, one 1,750 HP and one 950 HP pump serving the water flood piping system. All three pumps were operating at the time of the site visit. There are seven 700 HP pumps. None of the 700 HP pumps was operating at the time of the site visit.

This is the only measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Process- OTHER	O			Install parallel piping takeoffs on waterflood pumping header.	1	10" Pipe takeoffs.	Physically verified new pipe at pump header and verbally verfied extent of underground piping with customer.	1.0

Scope of the Impact Assessment

The impact assessment scope is for the process/other end use measure in the SPC application covering the water flood piping retrofit. This is the only measure in this application.

Summary of Results

Based on data collected by the reviewer, before the retrofit the water flood system flow rate was 6,484 GPM and total pump power was 4,068 kW resulting in a system efficiency of 0.627 kW/GPM. After the retrofit flood system flow rate was 6,454 GPM and total pump power was 3,793 kW resulting in a system efficiency of 0.588 kW/GPM. The average flow rate from data collected for 8 days in August and September 2007 was 8,536 GPM and average total pump power was 4,227 kW resulting in a system efficiency of 0.495 kW/GPM. Table 2 is a summary of the data collected before and after the retrofit documented in the application and more recently in August and September 2007. The data measured in August and September 2007 confirms that the system efficiency remains better than that documented in the post retrofit case. We therefore accept the ex ante impacts.

The energy consumption of this measure is not greatly affected by the outside air temperature. To estimate peak demand kW reduction, the expected reduction in connected kW due to the increased pumping efficiency during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in the week with the hottest weekday in June, July, August, September was determined by calculating the average kW reduction measured pre and post retrofit.

Table 2: Summary of Data

Description	GPM	kW	kW/GPM
Baseline	6,484	4,068	0.627
Post retrofit	6,454	3,793	0.588
Data Collected Aug./Sept. 2007	8,536	4,227	0.495

- Pre and post retrofit hours of pump operation are 8,736/year.
  (8,760 hours/year –24 hours/year for service= 8,736 hours/year
- Pre-retrofit demand is 4,068 kW.
- Annual pre-retrofit energy consumption is 35,538,048 kWh/hr.

  4,068 kW x 8,736 hours= 35,538,048 kWh/hr.
- Post-retrofit demand is 3,793 kW.
- Annual post-retrofit energy consumption is 33,135,648 kWh/hr.

  3,793 kW x 8,736 hours= 33,135,648 kWh/hr.
- The resulting annual kWh savings is 35,538,048 kWh/yr – 33,135,648 kWh/yr = 2,402,400 kWh/yr

Summer peak demand reduction impacts were estimated by subtracting the pre and post retrofit demand data. Average demand reduction is 275 kW.

- The demand reduction is 275 kW
  4,068 kW – 3,793 kW = 275 kW

The ex post kW demand reduction and annual kWh savings are essentially the same as the ex ante estimate. Although the operating conditions of the water flood pumping system have changed significantly since the installation of the measure documented in the application (i.e. increased flow with a different pumping arrangement), we determined that the system operating efficiency exceeds that documented in the application. Some of the increased system efficiency is due to projects documented in SPC applications submitted after the completion of this project. Therefore, no additional ex post savings impacts are being credited to this project.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application ($650,000) is from the invoice for the work performed for the project and is an accurate reflection of the project cost. In addition to saving energy, the benefits of the project were a more reliable pumping system with better flow characteristics. Participation in the 2004/2005 SPC Program has not encouraged the customer to perform any other energy efficiency projects without participating in an incentive program.

Seven of the old pumps remain on-site and the pre-retrofit pump type and quantities were physically verified. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measure.

7. Impact Results

The engineering realization rate for this application is 1.00 for demand kW reduction and 1.00 for energy savings kWh. A summary of the realization rate is shown in Table 3.

Table 3: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	275.0	2,406,450	-
SPC Installation Report (ex ante)	275.0	2,406,450	-
Impact Evaluation (ex post)	275.0	2,402,400	-
Engineering Realization Rate	1.00	1.00	NA

Utility billing data for the site was provided in the application. For the period January 2004 to December 2004, pre-retrofit annual consumption was 137,315,928 kWh. Peak demand was 16,704 kW. Table 4 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility provided numbers.

Table 4: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	16,704	137,315,928
Baseline End Use	4,068	35,538,048
Ex ante Savings	275	2,406,450
Ex Post Savings	275	2,402,400

Table 5 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 1.6% decrease in total meter kW, a 6.8% decrease in pumping end use kW, a 1.8% decrease in total meter kWh, and a 6.8% decrease in pumping end use kWh. The ex post results showed a 1.6% decrease in total meter kW, a 6.8% decrease in pumping end use kW, a 1.7% decrease in total meter kWh, and a 6.8% decrease in pumping end use kWh.

Table 5: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	1.6%	1.8%	1.6%	1.7%
Baseline End Use %	6.8%	6.8%	6.8%	6.8%

With a cost of $650,000 and a $192,516 incentive, the project had a 1.46 year simple payback based on the ex ante calculations. The ex post savings estimate for the project are essentially the same, and the estimated simple payback is equal. A summary of the economic parameters for the project is shown in Table 6. The customer has continued to make changes to the water flood pumping system since the completion of the project documented in the application. Many of the changes to the water flood system have been documented in SPC applications submitted later. Our analysis has shown that the water flood pumping system efficiency is still better than that documented in this application. However, the multi-year impacts, shown in Table 6 below, are expected to remain constant over the life of the equipment

Table 6: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	11/28/2004	$650,000	275.0	2,406,450	0	$312,839	$192,516	1.46	2.08
SPC Program Review (Ex Post)	9/28/2007	$650,000	275.0	2,402,400	0	$312,312	$192,516	1.46	2.08

This project can be defined as a Process Overhaul according to the California Public Utilities Commission *Energy Efficiency Policy Manual, with a useful life of 20* years.

A summary of the multi-year reporting requirements is given in Table 7.

Table 7: Multi Year Reporting Table

Program ID	**SPC 2004 Application # A050**
Program Name	**2004-2005 SPC Application**

Year	Calendar Year	Ex-Ante Gross Program Projected kWh Savings	Ex post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program Projected Peak kW Reduction	Ex-Post Gross Evalaution Projected Peak kW Reduction	Ex-Ante Gross Program Projected Therm Savings	Ex post Gross Evaluation Confirmed Program Therm Savings
1	2004	300,806	300,300	0	0	0	0
2	2005	2,406,450	2,402,400	275	275	0	0
3	2006	2,406,450	2,402,400	275	275	0	0
4	2007	2,406,450	2,402,400	275	275	0	0
5	2008	2,406,450	2,402,400	275	275	0	0
6	2009	2,406,450	2,402,400	275	275	0	0
7	2010	2,406,450	2,402,400	275	275	0	0
8	2011	2,406,450	2,402,400	275	275	0	0
9	2012	2,406,450	2,402,400	275	275	0	0
10	2013	2,406,450	2,402,400	275	275	0	0
11	2014	2,406,450	2,402,400	275	275	0	0
12	2015	2,406,450	2,402,400	275	275	0	0
13	2016	2,406,450	2,402,400	275	275	0	0
14	2017	2,406,450	2,402,400	275	275	0	0
15	2018	2,406,450	2,402,400	275	275	0	0
16	2019	2,406,450	2,402,400	275	275	0	0
17	2020	2,406,450	2,402,400	275	275	0	0
18	2021	2,406,450	2,402,400	275	275	0	0
19	2022	2,406,450	2,402,400	275	275	0	0
20	2023	2,406,450	2,402,400	275	275	0	0
Total	**2004 - 23**	**46,023,356**	**45,945,900**				

FINAL SITE REPORT

SITE A051a (#04-181) US Ind IMPACT EVALUATION
SAMPLE CELL: BACKUP TIER: 3 END USE: Lighting

Measure	Lighting and Lighting Controls Retrofit
Site Description	Distribution Facility

1. Measure Description

The application documents numerous lighting measures including:

- Replacing high bay 400 watt and 250 watt high pressure sodium fixtures with 8 lamp, T-8 fluorescent lamp fixtures.
- Retrofitting "first generation" T8 lamps and electronic ballasts with "third generation" T8 lamps and electronic ballasts.
- Installing of screw in compact fluorescent lamps.
- Installing manually operated bypass timers on some of the fixtures to reduce lighting hours of operation.
- Installing occupancy sensors for selected T8 lighting.

2. Summary of the Ex Ante Calculations

There are a total of seven lighting sub measures. Four of the measures use a calculated approach and three of the measures are itemized.

The calculated measures use a simple pre-retrofit and post-retrofit algorithm using fixture connected loads and hours of operation for the ex ante calculations. The calculations were originally performed by the energy efficiency service provider. The reviewer made several adjustments to the calculations including changing fixture counts, changing fixture wattage, moving a sub measure from the itemized to the calculated subset, and making adjustments to the annual hours of operation.

For the calculated measures, the ex ante baseline is the existing system connected load and hours of operation, and is in accordance with the SPC Program guidelines. Pre-retrofit and post-retrofit calculations of lighting loads and energy use were performed using the following formulae:

kW = Fixture watts / 1,000 w/kW x Fixture quantity
kWh = kW x hours

The ex ante calculations for the itemized measures are typically based on the Express Efficiency work papers.

According to the installation report, the approved ex ante savings are 1,139,113 kWh and demand reduction is 141.3 kW. These values substantially agree with the tracking system.

Approximately 70% of the ex ante energy savings and 65% of the demand reduction are associated with the retrofit of 557 high bay 400 watt and 250 watt high pressure sodium lamp fixtures with 8 lamp, T8 fluorescent lamps. The evaluation will focus on these measures.

The occupancy sensors and screw in compact fluorescent lamps are itemized measures. The ex ante calculations for the itemized measures are typically based on the Express Efficiency work papers.

The ex ante impacts for the high-bay fixtures were calculated as follows:

- Lighting Efficiency- 400 watt HPS fixtures:
  Pre-retrofit hours of operation were 8,760 hrs/year.
  Pre-retrofit wattage was 465 watts per fixture
  Post-retrofit wattage was 216 watts per fixture
  Lighting demand reduction is:
  (0.465 kW-0.216 kW) x 290 fixtures = 72.21 kW
  Lighting efficiency savings are:
  72.21 kW x 8,760 hours = 632,560 kWh
  This calculation does not agree with the figure shown in the installation report. The reviewer made an error when making a manual adjustment to the LE 1 lighting calculation spreadsheet. The reviewer deleted the savings associated with some of the 400 watt fixtures when adjusting the LE 1 spreadsheet to account for the post installation findings concerning the lighting control system. The installation report shows 522,577 kWh savings and 59.7 kW demand reduction for the measure.

- Lighting Efficiency 250 watt HPS fixtures:
  Pre-retrofit hours of operation were 8,760 hrs/year.
  Pre-retrofit wattage was 295 watts per fixture
  Post-retrofit wattage was 216 watts per fixture
  Lighting demand reduction is:
  (0.295 kW-0.216 kW) x 265 fixtures = 20.935 kW
  Additionally, two 250 watt fixtures were permanently removed
  Lighting demand reduction is :
  (0.295 kW) x 2 fixtures = 0.59 kW
  Lighting efficiency savings are:
  (20.935 kW + 0.59 kW) x 8,760 hours = 188,559 kWh
  This calculation agrees with the figures shown in the installation report.

- Total ex ante energy savings and demand reduction for the high bay lighting retrofit only: 81.2 kW, 711,136 kWh reported ex ante,
(93.7 kW, 821,119 kWh corrected ex post)

3. Comments on the Ex Ante Calculations

The ex ante calculations were performed according the SPC Program guidelines using the lighting fixture wattages from the SPC lighting wattage tables for the new 8 lamp T8 fixtures, the existing 250 watt and 400 watt HPS. The calculation shows 8,760 hours of operation for the lighting fixtures before the retrofit. There appears to be an error in the savings calculation for the 400 watt fixtures.

4. Measurement & Verification Plan

There are numerous lighting measures documented in the application. Approximately 70% of the ex ante energy savings and 65% of the demand reduction are associated with the retrofit of 557 high bay 400 watt and 250 watt high pressure sodium lamp fixtures with 8 lamp, T8 fluorescent lamp fixtures. Two 250 watt high bay fixtures were removed. The evaluation will focus on these measures.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture quantities and hours of operation. The pre-retrofit and post-retrofit connected loads associated with various fixture types are adequately quantified in the SPC lighting wattage tables.

According to the application, 290 fixtures with 400-watt high pressure sodium lamps were replaced with 290 fixtures with 8 lamp, T8 fluorescent lamp fixtures and 267 fixtures with 250-watt high pressure sodium lamps were replaced with 265 fixtures with 8 lamp, T8 fluorescent lamp fixtures. The project saves energy through the installation of lighting fixtures with lower power draw.

The goal of the M&V plan is to estimate the actual peak kW reduction and annual kWh savings over the expected useful lives of the measures, through quantifying hours of operation, fixture quantities, and fixture wattages.

Formulae and Approach

The M&V plan proposed is a modified version of IPMVP Option A.

For this application, the pre-retrofit fixture types, quantities and hours of operation will be verified with the facility representative. The post-retrofit fixture quantities and fixture types will be physically verified during the site visit.

If we are unable to determine the hours of operation by interviewing facility representatives, we will install Hobo lighting loggers throughout the high-bay area in representative areas for a minimum of 7 days to verify the post retrofit hours of operation. These loggers measure light intensity and will be used to record lighting status (on or off). The loggers will be set to record light intensity every 90 seconds.

Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Summer peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x ((energized $hours_{pre}$ - energized $hours_{post}$)) / energized $hours_{pre}$) during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, during the week with the hottest day in June, July, August, or September.

Thus, to estimate peak demand kW reduction, the reduction in connected kW due to the increased lighting efficiency will be added to the post-retrofit connected load multiplied by the percent of energized time according to the above formulae. The derivation or extrapolation of the average percent of time energized used in the above formulae, for both the average peak demand period and the coincident peak demand periods, will be described.

If deemed necessary to determine hours of operation, monitoring with light loggers will require twelve (12) sensors. However, additional loggers may be required, based on usage and traffic patterns. The use of twelve sampling points is generally consistent with SPC program documentation from March 2001 (Appendix E, Sampling); this document suggests guidelines for determining sampling point requirements necessary to achieve an 80% confidence interval with 20% precision (using a coefficient of variation of 0.5). Random sampling may also be able to be employed, labeling fixtures sequentially according to their location, and randomly selecting from the total number of fixtures using a random number generator. The light loggers would be placed so as to be unaffected by fixtures not on motion sensors or by ambient outside light.

The lighting loggers would be left in place for a period of 7 days. Attention will be given to the time period for monitoring, in order to avoid periods of irregular usage patterns (e.g., during holidays or breaks). While longer periods might be preferable, these periods are appropriate given the scope of the evaluation and reported/expected usage characteristics.

The greatest uncertainties in the ex ante savings estimate are associated with the lighting fixture quantities and the pre-retrofit and post-retrofit lighting fixture hours of operation. The pre-retrofit and post-retrofit connected loads associated with various fixture types are adequately quantified in the SPC lighting wattage tables.

Uncertainty for the savings estimate for the high bay fixture retrofit can be more fully understood by establishing projected ranges on the primary variables, as follows:

- 555 fixtures expected, minimum 500, maximum 610 (+/- 10%)
- 8,760 hours /year expected/reported, minimum 7,884 hours, maximum 8,760 hours (-10%)

If lighting hours are not constant, there may be a small potential source of error introduced by annualizing estimates from short monitoring periods. This error is estimated at a maximum of + /- 5% and is not included in the analysis of uncertainty due to its size.

Accuracy and Equipment

If deemed necessary, Hobo data loggers will be used to verify the lighting hours of operation. The logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers will be set to sample light intensity every 90 seconds and for the purposes of the evaluation are considered to be 95% accurate for light levels where reviewed data is deemed reasonable.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on October 16, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representatives. "As Built" construction drawings were reviewed to determine the type and quantity of lighting fixtures in the high bay area before the retrofit. The area with the high-bay lighting is a single level 325,000 ft^2 conditioned space that sorts goods for distribution. The building has few windows. There are skylights on the roof. The building is occupied continuously, however most activity occurs between 3 p.m. and 8 a.m. Monday-Friday. Maximum occupancy is approximately 450 employees at any given time. The facility does not close and always remains occupied, although occupancy may be lower during major holiday periods. The facility representative confirmed that the lights in the high bay area always remain on since the area is occupied continuously. We found no reason to install lighting loggers since the high bay lights are on continuously.

Installation Verification

Based on the "as built" construction drawings, we confirmed that there were 290 fixtures with 400-watt high pressure sodium lamps and 267 fixtures with 250-watt high pressure sodium lamps in the high bay area before the retrofit. We physically verified that there are now 555 eight-lamp T-8 fluorescent fixtures in the high-bay area. We also verified that the fixture lamps are General Electric four foot 32 watt T8 part # F32T8XL/SPX41 ECO 32W. We were unable to verify the ballast type.

We reviewed the complete list of lighting measures with the facility representative and verified that the type of measures listed had actually been installed. We did not however verify the quantities listed in the application for the other measures. Based on the installed high-bay fixtures, the verification realization rate for this project is 1.0. A verification summary is shown in Table 5 below.

Scope of the Impact Assessment

The impact assessment scope is for the high-bay lighting end use measure in the SPC application covering the lighting efficiency retrofit. This is the only measure evaluated in this application.

Summary of Results

We determined during the site visit that the high bay lighting fixtures remain on continuously. Very few burned out lights were observed during the site visit. The facility has a maintenance department and burned out lights are regularly replaced. Therefore, there was no adjustment to the lighting energy consumption due to burned out lamps.

The ex ante calculations were performed using the verified operating schedule and lighting fixture wattage from the SPC tables for the 250 and 400 watt high pressure sodium fixtures and the post retrofit 8 lamp T-8 fixtures.

The ex post impacts for the high-bay lighting retrofit are calculated as follows:

- Pre-retrofit hours of operation were 8,760 hrs/year.
- Pre-retrofit demand was:
  (0.465 kW per lamp x 290 fixtures) +(0.295 kW per lamp x 267 fixtures) = 213.615 kW
- Pre-retrofit annual kWh usage was:
  213.615 kW x 8,760 hrs/yr = 1,871,267 kWh/yr
- Post-retrofit hours of operation are 8,760 hrs/year
- Post-retrofit demand is (0.216 kW per eight-lamp fixture) x 555 fixtures = 119.88 kW
- Annual post retrofit kWh usage is:
  119.88 kW x 8,760 hrs/yr = 1,050,148 kWh/yr
- The resulting annual kWh savings is 1,871,267 kWh/yr – 1,050,148 kWh/yr = 821,119 kWh/yr.

Summer peak kW impacts were estimated by subtracting post-retrofit demand kW from pre-retrofit demand kW.

- Peak kW demand reduction is:
  213.615 kW – 119.88 kW = 93.7 kW.
- The engineering realization rates for this measure are 1.15 for demand kW reduction and 1.15 for energy savings kWh.
  93.7 kW/81.2 kW = 1.15
  821,119 kWh/yr / 711,136 kWh/yr= 1.15

The realization rates are applied to the ex ante energy savings and demand reduction for all lighting end use measures in the application.

- Applying the engineering realization rates for this application of 1.15 for demand kW reduction and 1.15 for energy savings kWh to the total lighting project yields a demand reduction of 162 kW and an annual energy savings of 1,599,642 kWh
  1.15 x 141.3 kW = 162.5 kW
  1.15 x 1,139,113 kWh = 1,309,979 kWh

A summary of the realization rate is shown in Table 4.

Utility billing data for the site is was provided by the Utility. For the period January 2006-December 2006 the Site annual energy use was 9,278,280 kWh and peak demand was 1,440 kW. Table 1 summarizes the total metered use and the baseline end use energy, the ex ante savings and the ex post calculation results for the high bay lighting retrofit.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use for the high bay lighting retrofit, for both the ex ante and ex post savings calculations. The ex ante results estimated a 5.6% decrease in total meter kW, a 38% decrease in lighting end use kW (error in calculation as noted above), an 7.7% decrease in total meter kWh, and a 38.0% decrease in lighting end use kWh. The ex post results showed a 6.5% decrease in total meter kW, a 43.9% decrease in lighting end use kW, an 8.8% decrease in total meter kWh, and a 43.9% decrease in lighting end use kWh.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1,440	9,278,280
Baseline End Use	213.6	1,871,267
Ex ante Savings	81.2	711,136
Ex Post Savings	93.7	821,119

Baseline end use, ex ante and ex post savings are for the high-bay lighting retrofit ors only, not the entire lighting project.

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	5.6%	7.7%	6.5%	8.8%
Baseline End Use %	38.0%	38.0%	43.9%	43.9%

Baseline end use % and total meter %, ex ante and ex post savings are for the high-bay lighting retrofit only, not the entire lighting project.

6. Additional Evaluation Findings

The ex post kW demand reduction and annual kWh savings are greater than the ex ante estimate because the ex ante estimate appears to have an error. The installation report "Summary of Approved Measures" shows 81.2 kW demand reduction for the high bay lighting retrofit and 711,136 kWh energy savings. The reviewer deleted the savings associated with some of the 400 watt fixtures when adjusting the LE 1 spread sheet to account for the post installation findings concerning the lighting control system. The ex post corrected values for this measure are 93.7 kW demand reduction and 821,119 kWh annual savings.

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. In addition to saving energy, the benefits of the project are better quality of lighting and increased light levels in some areas. One drawback of the project has been an increase in maintenance associated with the need to replace fluorescent lamps and ballasts. Each fixture now has eight lamps and two ballasts, where before the retrofit each fixture had one lamp and one ballast. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program has not encouraged them to perform any other energy efficiency projects for which they did not participate in an incentive program.

We were able to verify the pre-retrofit lighting fixture type, quantities and hours of operation from the "as built" construction drawings and discussions with the customer's representative. We are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $706,994 and a $56,908 incentive, the project had a 4.4 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 3.8 years. A summary of the economic parameters for the project is shown in Table 3.

7. Impact Results

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	2/9/2005	$706,994	141.3	1,139,113	0	$148,085	$56,908	4.39	4.77
SPC Program Review (Ex Post)	10/22/2007	$706,994	162.5	1,309,979	0	$170,297	$56,908	3.82	4.15

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	141.3	1,139,113	-
SPC Installation Report (ex ante)	141.3	1,139,113	-
Impact Evaluation (ex post)	162.5	1,309,979	-
Engineering Realization Rate	1.15	1.15	NA

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Notes	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Lighting	L		•Retrofit high bay 400 watt and 250 watt high pressure sodium fixtures with 8 lamp, T-8 fluorescent lamp fixtures. •Installing manually operated bypass timers on some of the fixtures to reduce lighting hours of operation. •Retrofitting "first generation" T8 lamps and electronic ballasts with "third generation" T8 lamps and electronic ballasts. •Installing of screw in compact fluorescent lamps. •Installing occupancy sensors for selected T8 lighting.			555	Eight lamp, high-bay, T-8 fixtures.	Physically verified the installation of the eight lamp T8 fixtures in the high-bay area. Verbally verified the other lighting measure installation with the facility representative.	1.0

Table 6: Multi Year Reporting Table

Year	Calendar Year	Ex-Ante Gross Program Projected kWh Savings	Ex post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program Projected Peak kW Reduction	Ex-Post Gross Evalaution Projected Peak kW Reduction	Ex-Ante Gross Program Projected Therm Savings	Ex postGross Evaluation Confirmed Program Therm Savings
1	2004	0	0	0	0	0	0
2	2005	1,139,113	1,309,979	141	163	0	0
3	2006	1,139,113	1,309,979	141	163	0	0
4	2007	1,139,113	1,309,979	141	163	0	0
5	2008	1,139,113	1,309,979	141	163	0	0
6	2009	1,139,113	1,309,979	141	163	0	0
7	2010	1,139,113	1,309,979	141	163	0	0
8	2011	1,139,113	1,309,979	141	163	0	0
9	2012	1,139,113	1,309,979	141	163	0	0
10	2013	1,139,113	1,309,979	141	163	0	0
11	2014	1,139,113	1,309,979	141	163	0	0
12	2015	1,139,113	1,309,979	141	163	0	0
13	2016	1,139,113	1,309,979	141	163	0	0
14	2017	1,139,113	1,309,979	141	163	0	0
15	2018	1,139,113	1,309,979	141	163	0	0
16	2019	1,139,113	1,309,979	141	163	0	0
17	2020	1,139,113	1,309,979	141	163	0	0
18	2021	0	0	0	0	0	0
19	2022	0	0	0	0	0	0
20	2023	0	0	0	0	0	0
Totals	**2004-2023**	**18,225,808**	**20,959,664**				

FINAL SITE REPORT

SITE A052 (xxxx-04) Jaz IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 2 END USE: Other

Measure	1. VSD for HVAC fans 2. CO_2 System to Replace RO System 3. Hot Water DI System Load Shifting
Site Description	Semiconductor Manufacturing Facility

1. Measure Description

The customer is implementing three measures to reduce the energy and demand load for their semiconductor manufacturing process.

Measure #1 is for the installation of variable speed drives (VSDs) on four HVAC fan motors. The VSDs were installed on one (1) 75 HP fan motor, one (1) 100 HP fan motor, one (1) 125 HP fan motor, and one (1) 150 HP fan motor.

Measure #2 is for the installation of a CO_2 system to replace a RO system. The existing RO system requires one 15 HP pump to circulate the RO water, four (4) UV light units, an ozonator, and instrumentation to operate the system. In addition, 30 gpm of RO water must be tempered from 68 ºF to 58 ºF using chilled water. The proposed CO_2 system is able to accomplish the required re-ionization without any of the ancillary equipment above.

Measure #3 is for the shifting of load currently met by one hot water DI system to a second existing hot water DI system. The system currently being used is greatly oversized and cannot modulate down to meet current demand requirements. Instead the excess water conditioned by this unit is being wasted.

2. Summary of the Ex Ante Calculations

Measure #1 is an itemized measure. No kW or kWh savings calculations were provided. The basis of the incentive payment was the itemized incentive rate in the Measure Savings Worksheet. The ex ante calculations for the itemized measures are typically based on the Express Efficiency work papers. The Express Efficiency work papers state that the impacts for the installation of VFDs on HVAC fan motors are 753.0 kWh/HP and 0 kW demand reduction. Multiplying 450 HP by 753 kWh/HP yields 338,850 kWh. This value agrees with the Installation Report.

For Measure #2, the demand and energy savings were calculated using a simple algorithm with pre and post retrofit equipment operating conditions. The pre retrofit system required the operation of one (1) 15 HP pump, four (4) UV units, one (1) ozonator, and instrumentation. In addition, the water must be cooled from 68 ºF to 58 ºF using a heat exchanger and a chilled water loop. The demand and energy consumption for the pump, UV units, ozonator, and instrumentation were determined from measured current draw for each piece of equipment. The chiller energy use was determined using an efficiency of 1.0 kW/ton for the chiller. The post retrofit system does not require any of the ancillary equipment listed above.

Pre Retrofit Equipment

Equipment	Qty	V	I	Hrs	kW	kWh
15 HP Pump	1	480	12.5	8,760	9.3	81,468
UV Units	4	115	6.5	8,760	4.9	42,565
Ozonator	1	115	2.5	8,760	0.5	4,093
Instrumentation	1	115	2	8,760	0.4	3,274
Total					15.0	131,400

Pre Retrofit Cooling Energy Consumption

Flow	Initial Temp	Chilled Temp	Cooling Load	Eff	kW	kWh
30 gpm	68 ºF	58 ºF	12.5 tons	1 kW/ton	12.5	109,500

The above equipment results in a total pre retrofit demand of 27.5 kW and usage of 240,900 kWh.

Post Retrofit Equipment

Equipment	Qty	V	I	Hrs	kW	kWh
CO_2 Re-ionizer	1	115	3.2	8,760	0.6	5,256

The post-retrofit equipment has a demand of 0.6 kW and a usage of 5,256 kWh per year. Subtracting the post retrofit equipment demand and annual energy consumption from the pre retrofit equipment demand and annual energy consumption results in a demand reduction of 26.9 kW and an annual energy usage savings of 235,644 kWh.

For Measure #3, the demand and energy savings were calculated using a simple algorithm with the existing and proposed equipment operating conditions. The pre retrofit system required the operation of two (2) 25 HP pumps and one (1) UV unit. In addition,180 gpm of water was cooled from 90 ºF to 70 ºF and 5 gpm of water was chilled from 150 ºF to 70 ºF using a heat exchanger and a chilled water loop. The demand and energy consumption for the pump and UV units was determined from measured current draw for each piece of equipment. The chiller energy use was determined using an efficiency of 1.0 kW/ton for the chiller. The proposed system does not require any of the ancillary equipment listed above.

Pre Retrofit Equipment

Equipment	Qty	V	I	Hrs	kW	kWh
25 HP Pumps	2	480	18	8,760	26.9	235,644
UV Units	1	--	--	8,760	5	43,800
Total					31.9	279,444

Pre Retrofit Cooling Energy Consumption

Flow	Initial Temp	Chilled Temp	Cooling Load	Cooling Eff	kW	kWh
180 gpm	90 ºF	70 ºF	150 tons	1 kW/ton	150	1,314,000
5 gpm	150 ºF	70 ºF	16.7 tons	1 kW/ton	16.7	146,292
Total					166.7	1,460,292

The above equipment results in a total pre retrofit demand of 198.6 kW and annual usage of 1,739,736 kWh.

Proposed Additional Cooling Loads on Second DI Station

Flow	Initial Temp	Chilled Temp	Cooling Load	Cooling Eff	kW	kWh
18 gpm	90F	70F	15.0 tons	1 kW/ton	15.0	131,400

The above equipment has a post-retrofit demand of 15.0 kW and a usage of 131,400 kWh per year. Subtracting the post retrofit equipment demand and annual energy consumption from the pre retrofit equipment demand and annual energy consumption results in a total demand reduction of 183.6 kW and an annual energy usage savings of 1,608,336 kWh.

The total ex ante impacts are 2,182,830 kWh annual energy savings with a demand reduction of 210.5 kW. The values in the Installation Report agree with those in the tracking system. Measures 2 and 3 were combined in the utility tracking system.

3. Comments on the Ex Ante Calculations

Measure #1 is an itemized measure. No kW or kWh savings calculations were provided. The ex ante calculations for the itemized measures are typically based on the Express Efficiency work papers. The Express Efficiency work papers state that the impacts for the installation of VFDs on HVAC fan motors are 753.0 kWh/HP and 0 kW demand reduction. No credit is taken for any demand reduction due to the installation of the VFDs on the fan motors, as per the workpapers. This is a conservative assumption.

The savings for the CO_2 re-ionizer installation and hot DI water station re-piping projects were determined using customer supplied spreadsheets. Savings were determined by comparing the existing measured power consumption for all removed equipment with the nameplate power demand values for the post-retrofit equipment. Additional savings were obtained by removing load on the chilled water loop, which is served by a chiller with an estimated efficiency of 1 kW/ton.

In the customer supplied calculations, a power factor of over 90% was used to determine the demand of the 15 HP and 25 HP pumps. This value seems high; a more typical value is 0.85. In addition, it appears that the single phase equipment had the demand and energy usage calculated incorrectly. These errors are corrected and presented below.

Measure #2 Adjusted Pre Retrofit Equipment

Equipment	Qty	V	I	PF	Hrs	kW	kWh
15 HP Pump	1	480	12.5	0.85	8,760	8.8	77,289
UV Units	4	115	6.5	1.0	8,760	3.0	26,192
Ozonator	1	115	2.5	1.0	8,760	0.3	2,519
Instrumentation	1	115	2	1.0	8,760	0.2	2,015
Total						12.3	108,015

Measure #2 Adjusted Pre Retrofit Cooling Energy Consumption

Flow	Initial Temp	Chilled Temp	Cooling Load	Eff	kW	KWh
30 gpm	68 ºF	58 ºF	12.5 tons	1 kW/ton	12.5	109,500

The adjusted calculations for the above equipment results in a total pre retrofit demand of 24.8 kW and usage of 217,515 kWh.

Measure #2 Adjusted Post Retrofit Equipment

Equipment	Qty	V	I	PF	Hrs	kW	KWh
CO_2 Re-ionizer	1	115	3.2	1.0	8,760	0.4	3,224

The adjusted calculations for the post-retrofit equipment has a demand of 0.4 kW and a usage of 3,224 kWh per year. Subtracting the adjusted pre retrofit equipment demand and annual energy consumption from the adjusted post retrofit equipment demand and annual energy consumption results in a demand reduction of 24.5 kW and an annual energy usage savings of 214,292 kWh.

Measure #3 Adjusted Pre Retrofit Equipment

Equipment	Qty	V	I	PF	Hrs	kW	KWh
25 HP Pumps	1	480	18	0.85	8,760	12.7	111,297
UV Units	1	--	--	--	8,760	5	43,800
Total						17.70512	155,097

Measure #3 Adjusted Pre Retrofit Cooling Energy Consumption

Flow	Initial Temp	Chilled Temp	Cooling Load	Cooling Eff	kW	kWh
180 gpm	90 ºF	70 ºF	150 tons	1 kW/ton	150	1,314,000
5 gpm	150 ºF	70 ºF	16.7 tons	1 kW/ton	16.7	146,309
Total					166.7	1,460,309

The adjusted calculations for the above equipment results in a total pre retrofit demand of 184.4 kW and usage of 1,615,406 kWh.

Measure #3 Adjusted Additional Cooling Loads on Second DI Station

Flow	Initial Temp	Chilled Temp	Cooling Load	Cooling Eff	kW	kWh
18 gpm	90F	70F	15.0 tons	1 kW/ton	15.0	131,400

The adjusted calculations for the post-retrofit equipment has a demand of 15.0 kW and a usage of 131,400 kWh per year. Subtracting the adjusted pre retrofit equipment demand

and annual energy consumption from the adjusted post retrofit equipment demand and annual energy consumption results in a demand reduction of 169.4 kW and an annual energy usage savings of 1,484,006 kWh.

The total adjusted ex ante impacts are 2,037,147 kWh annual energy savings with a demand reduction of 193.9 kW.

4. Measurement & Verification Plan

The facility is a 2-story, industrial facility with a floor area of approximately 240,000 sq. ft. Approximately 220,000 sq. ft. is conditioned. The facility is normally occupied and in production continuously, with peak occupancy occurring weekdays from 8:00 a.m. to 5:00 p.m.

According to the application, before the VFD installation, the HVAC fans were constant speed with no indicated flow control method. The RO system required one 15 HP pump, four (4) UV units, one (1) ozonator, and instrumentation to operate the system. The hot water station required two (2) 25 HP pumps and one 5 kW UV unit to operate. A significant portion of the energy associated with the RO system and the hot DI water station is associated with chilled water usage.

The post-retrofit system includes the installation of VFDs on four (4) AHU fans, the installation of a CO_2 re-ionization system, and the re-piping and removal of a hot water DI station. The installation of the CO_2 re-ionization system and removal of the hot water DI station reduce energy use through equipment elimination as well as reduced chilled water demands.

The goal of the M&V plan is to estimate the actual kWh savings and demand reduction associated with the installation of the VFDs on the four (4) AHU fans, the installation of a CO_2 re-ionization system to replace a RO system, and the hot water DI station removal and re-piping, over the useful life of this equipment.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. The AHU motors and pump motors in question are not expected to consume a large percentage of the facility's total usage. Also, the usage of the motors is not expected to remain consistent enough for single point measurements to be representative of the average usage.

Seasonal variation is expected to be predictable and two weeks should be sufficient to calibrate an energy savings model; however, a longer period would more fully capture actual variations and the persistence of savings. Interval data on a 15-minute or less basis, preferably during the summer months of June to September, would be needed to more accurately determine coincident peak period demand savings.

Pre-retrofit and post-retrofit calculations of demand and energy loads will be calculated using the following formulae:

For the AHU VFDs:

Peak coincident kW Savings = kW at maximum Outdoor Air Temperature (either measured or predicted if the max OAT does not occur during the measurement period)

AHU fan measured input power (kW) with corresponding outdoor air temperature will be used to create an AHU input power curve unique to each air handler. An input power formula as a function of outdoor air temperature will be developed. This formula will be used in a spreadsheet bin analysis. The basic calculation is the summation of:

AHU kWh $_{(bin\ temp)}$ = Calculated kW $_{(bin\ temp)}$ x hours/yr $_{(bin\ temp)}$

For the CO_2 re-ionizer installation:

Peak coincident kW Savings = pump motor kW + UV unit kW + ozonator kW + instrumentation kW + heat load x chiller efficiency – CO_2 re-ionizer kW

Average kW Savings = pump motor kW + UV unit kW + ozonator kW + instrumentation kW + heat load x average chiller efficiency – CO_2 re-ionizer kW

kWh Savings = Average kW Savings x hours of operation

For the Hot Water DI station Re-pipe:

Peak coincident kW Savings = pump motor kW + UV unit kW + (removed DI station heat load - added heat load on secondary DI station) x chiller efficiency

Average kW Savings = pump motor kW + UV unit kW + (removed DI station heat load - added heat load on secondary DI station) x average chiller efficiency

kWh Savings = Average kW Savings x hours of operation

The majority of the savings are from the CO_2 re-ionizer and hot water DI station re-pipe projects. Therefore, the evaluation will focus on these projects if possible. Within these projects, nearly 80% of the savings is associated with the reduction in chilled water usage. Therefore, this aspect of these projects will be particularly examined. Care will be taken to determine the pre-retrofit chilled water usage and compare it with post-retrofit chilled water usage. In addition, the chilled water system will be examined to determine the total kW/ton usage for chilled water production, including chillers, cooling towers, pumps, inclusive of any VFDs on this system.

The post-retrofit energy consumption for the re-piped hot water DI station will be verified by collecting no less than two weeks of data from the customer's EMS software package. The collected data from the EMS software will then be used to determine annual usage.

If the customer's EMS data are unavailable or incomplete, the post-retrofit energy consumption for the hot water DI station will be verified through instantaneous measurements of power consumption of the pumps and UV equipment associated with the remaining hot DI water station. The spot measurements will be taken using a Fluke 41B power meter. In addition, the chilled water consumption for the hot DI water station will be examined.

The post-retrofit energy consumption of the CO_2 reionizer will also be verified using the Fluke 41B power meter. If the power consumption cannot be verified, the model number will be recorded and manufacturer will be contacted to determine power consumption.

The post-retrofit energy consumption for the AHU VFDs will be verified by collecting no less than two weeks of data from the customers EMS software package. The collected data from the EMS software will then be used in conjunction with local temperature data to determine annual usage.

If the customers EMS data is unavailable or incomplete, the post-retrofit energy consumption for the AHU VFDs will be verified by installing Hobo FlexSmart data loggers with WattNode WNA-3D-480-P watt-hour transducers and Magnalab SCT-1250-200 current transformers on the power supplied to the VFD of no less than one (1) AHU fan. The energy consumption of the fans will be logged with a sampling interval of no greater than 2 minutes, for a minimum of 14 days to verify the post-retrofit energy consumption. In addition, the outdoor air temperature and relative humidity at the facility will be monitored using at least one (1) Hobo H8 logger. The logged kWh will then be used in conjunction with temperature and occupancy effects to determine the annual usage.

Uncertainty for the savings estimate for the AHU VFDs, CO_2 Re-ionizer, and hot DI water station re-pipe projects can be more fully understood by setting projected ranges on the primary variables.

For the AHU VFDs

- 338,850 kWh expected, maximum of 1,186,205 kWh, minimum of 167,437 kWh (+250.1%, -50.6 %, based on judgment of deviation from expected hours of operation, full load kW, and average kW load factors)

For the CO_2 Re-ionizer Installation

- 24.9 kW expected, maximum of 29.5 kW, minimum of 20.3 kW (±18.5%, based on judgment of deviation from expected equipment peak and average kW values)

- 218,124 kWh expected, maximum of 258,431 kWh, minimum of 176,367 kWh (+18.5%, -19.1%, based on judgment of deviation from expected hours of operation, full load kW, and average kW load factors, and chiller efficiency)

For the Hot Water DI Station Re-pipe

- 183.6 kW expected, maximum of 237.3 kW, minimum of 129.9 kW (±29.2%, based on judgment of deviation from expected equipment peak and average kW values)
- 1,608,336 kWh expected, maximum of 2,078,766kWh, minimum of 1,131,082 kWh (+29.2%, -29.7%, based on judgment of deviation from expected hours of operation, full load kW, and average kW load factors, and chiller efficiency)

For the Three (3) Improvements Combined

- 2,165,310 kWh expected, maximum of 3,076,665 kWh, minimum of 1,788,943 kWh (+42.1%, -17.4%, based on above information)

Accuracy

The Hobo FlexSmart loggers have a resolution of ±10 seconds. The WattNode Watt-Hour transducers have an accuracy of ±0.45%+0.05%FS, and the Magnelab SCT-1250-200 current transformers have an accuracy of ±1.5%. The kWh loggers have a combined accuracy of ±2.0%+0.05%FS. The Onset current transformers have an accuracy of ±5%FS. The Hobo H8 current loggers have an accuracy of ±3%. The current loggers have a combined accuracy of ±8%. The Hobo H8 temperature and relative humidity loggers have an accuracy of ±1.3 ºF (within the range of –4 ºF to 104 ºF) for temperature and ±5% for relative humidity.

The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to Microsoft Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 21, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the post-retrofit VFDs, CO_2 system, and the hot DI water station and piping. Four HVAC VFDs and one CO_2 system were found to be installed. In addition, one hot water DI station was found to have been removed with the load re-piped to another hot DI water station.

Installation Verification

For the fan motor VFD installation project the facility representative verified that prior to the installation of the fan motors operated at constant speed with flow controlled by discharge dampers. The installation of the four HVAC fan motor VFDs was physically verified.

For the CO_2 system project, the facility representative verified that prior to the installation of the CO_2 system, a RO system provided the same functionality for the system. The installation of the CO_2 system was physically verified.

For the hot DI water re-pipe project the facility representative verified that prior to the installation of the piping, an additional hot DI water station was required to run to meet the demand. The installation of the hot DI water piping system was physically verified.

The facility representative stated that the retrofit was completed in June-July of 2005.

The verification arte is 1.00. A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
OTHER-HVAC VFD	O			VFD INSTALLATION ON FOUR HVAC FAN MOTORS	4	1-75 HP FAN VFD, 1-100 HP FAN VFD, 1-125 HP FAN VFD, 1-150 HP FAN VFD	PHYSICALLY VERIFIED INSTALLATION OF FAN VFDS	1.00
OTHER-CO2 SYSTEM	O			INSTALLATION OF CO2 SYSTEM TO REPLACE RO SYSTEM	1	CO2 SYSTEM	PHYSICALLY VERIFIED INSTALLATION OF CO2 SYSTEM	1.00
OTHER-HOT DI WATER STATION REPIPE	O			REPIPE HOT DI WATER STATION	1	PROCESS PIPING	PHYSICALLY VERIFIED INSTALLATION OF HOT DI WATER PIPING	1.00

Scope of the Impact Assessment

The impact assessment scope is for the Other category, covering HVAC VFDs and Other Custom SPC end use measures. These are the only measures in this application.

Summary of Results

The four HVAC fans were inspected. It was determined that the units operate at a constant speed throughout the year. The VFDs on the units were all set to operate at a constant 47 Hz throughout the year. Demand measurements were taken at two units. Brake horsepower (BHP) values were included in the original analysis, and the recorded kW measurements corresponded with the BHP from the original analysis. For the pre-retrofit system, it was determined that the system had flow modulated through the use of discharge dampers. Savings then could be determined by comparing the power consumption at equivalent flow rates through the use of typical power curves.

One CO_2 system was inspected. The CO_2 system consisted of a compressed gas tanks and a controller to modulate the injection of the CO_2 into the process water. The purpose of this was to “dirty” up the ultra-pure water as required for the process. The power consumption of the unit could not be verified, however, the power consumption listed in the original analysis is consistent with expected values for a PLC control module. The demand and energy consumption of the unit was compared to the energy consumption of the RO system that was required in the pre-retrofit equipment. No RO equipment was on operation, therefore, the pre-retrofit operation could not be verified. However, system diagrams were examined to verify the information presented in the original calculations. Based on determined operation, no adjustment was made to the adjusted ex ante calculations presented above.

The hot DI water re-pipe project was also inspected. It was determined that the hot DI water station for this project was removed as described. In addition, process piping had been installed underneath the floor across the facility. This piping allowed the load previously served by the removed hot DI water station to be shifted to a second hot DI water station with excess capacity. Pre-retrofit and post-retrofit system diagrams were examined to verify the operating characteristics of the hot DI water station. It was determined that the equipment listed heats DI water to the temperature required by the process being served. Once the hot water is utilized, it is returned to a common DI water loop that is then cooled to 70F. In addition to the energy and demand savings presented in this analysis, significant gas usage reduction benefits were also realized. The temperature of the DI water was verified throughout the process loop and was found to be consistent with the original analysis. In addition, it was observed that the units could not be modulated below a minimum flow rate to verify the savings level. The customer was also able to present information to verify the chilled water efficiency. Based on that information the presented level of 1.0 kW/ton was reasonable.

Based on determined operation, no adjustments were made to the adjusted ex ante calculations for this measure.

The customer representative stated that the HVAC fans, the CO_2 system, and the hot DI water stations operate 24 hours per day, 365 days per year.

The facility representative stated that this facility operates typically 24 hours per day, seven days per week. Occupancy is heavier during the weekdays, with an expected occupancy of approximately 480 people. During weekend shift, occupancy is lighter, but still expected to be approximately 320 people.

The fan motors and VFDs as well as the CO_2 system and hot DI water stations are expected to operate 8,760 hours per year. Therefore, at the summer peak hour, between 2 pm and 5 pm on weekdays, all equipment is expected to operate.

The ex post impacts are calculated in Table 2 below:

Table 2: HVAC VFD Energy and Demand Formulae

Pre-Retrofit Demand kW_{peak} = Pre-Retrofit (kW_{AHU79} + Pre-Retrofit kW_{AHU80} + Pre-Retrofit kW_{AHU95} + Pre-Retrofit kW_{AHU99})
= 71.2 kW + 52.7 kW + 93.6 kW + 75.1 kW
= 292.6 kW

Post-Retrofit Demand kW_{peak} = Post-Retrofit (kW_{AHU79} + Pre-Retrofit kW_{AHU80} + Pre-Retrofit kW_{AHU95} + Pre-Retrofit kW_{AHU99})
= 39.9 kW + 29.5 kW + 52.8 kW + 42.3 kW
= 164.5 kW

Peak kW Savings = Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak}
= 292.6 kW – 164.5 kW
= 128.1 kW

Pre-Retrofit Energy kWh = Pre-Retrofit Peak kW x Hours of Operation
= 292.6 kW x 8,760 hrs
= 2,563,140 kWh

Pre-Retrofit Energy kWh = Pre-Retrofit Peak kW x Hours of Operation
= 164.4 kW x 8,760 hrs
= 1,441,195 kWh

kWh Savings = Pre-Retrofit kWh – Post-Retrofit kWh
= 2,563,140 kWh/yr – 1,441,195 kWh/yr
= 1,121,945 kWh/yr

The adjusted ex ante savings for Measure 2 and Measure 3 determined above are added to these values for total savings in the realization rate summary below.

The ex post energy reduction is greater than the ex ante estimate. This is due primarily to the VFD retrofit project. To determine the savings, the original analysis used utility prescribed hours, kW/hp and kWh/hp savings. For these typical savings values, it is assumed that no kW savings will be experienced at peak condition, because this peak condition is expected to coincide with the warmest temperatures of the year, during which typically, HVAC VFDs will be running at or near full speed. However, it was found that these units actually operate at a constant speed throughout the year; therefore, the kW savings will be experienced during the peak conditions. In addition, the kWh/hp savings are based on a typical load profile and hours of operation for a variety of buildings. This facility operates 8,760 hours per year, much greater than a typical building would operate.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the contractor estimates for the work performed for the project. The customer did not identify any drawbacks or non-energy benefits associated with the equipment. Also, the customer did not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer stated that it is likely that participation in the 2004/2005 SPC program did encourage them to complete this and other retrofit projects. Specifically, they have completed more than 30 energy efficiency projects since this one was implemented. The customer representative stated that many had been implemented under other energy efficiency programs, however, it is likely about 1/3 were implemented without utility assistance.

We were unable to physically verify the pre-retrofit HVAC fan, RO system, or hot DI water station operating characteristics or hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

7. Impact Results

Based on the ex ante savings of 210.5 kW and 2,182,830 kWh the engineering realization rate for this application is 1.53 for demand savings and 1.29 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 3.

Table 3: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	210.5	2,182,830	-
SPC Installation Report (ex ante)	210.5	2,182,830	-
Impact Evaluation (ex post)	321.9	2,820,242	-
Engineering Realization Rate	1.53	1.29	N/A

Utility billing data for the site was reviewed. In the 12-month period from January 2006 - December 2006 (post-retrofit), the facility consumed 146,161,458 kWh. Peak demand was 20,232.0 kW in July 2006. Table 4 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 4: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	20,232.0	146,161,458
Baseline End Use	501.8	146,161,458
Ex ante Savings	210.5	2,182,830
Ex Post Savings	321.9	2,820,242

Table 5 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 1.0% decrease in total meter kW, a 41.9% decrease in the end use kW, a 1.5% decrease in total meter kWh, and a 1.5% decrease in the end use kWh. The ex post results showed a 1.6% decrease in total meter kW, a 64.2% decrease in the end use kW, a 1.9% decrease in total meter kWh, and a 1.9% decrease the end use kWh.

Table 5: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	1.0%	1.5%	1.6%	1.9%
Baseline End Use %	41.9%	1.5%	64.2%	1.9%

With a cost of $194,000 and a $87,282 incentive, the project had a 0.38 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 0.29 years. A summary of the economic parameters for the project is shown in Table 6.

Table 6: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), ($1.10/therm) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	4/19/2004	$194,000	210.5	2,182,830	-	$283,768	$87,282	0.38	0.68
SPC Program Review (Ex Post)	9/27/2007	$194,000	321.9	2,820,242	-	$366,631	$87,282	0.29	0.53

It was determined that the fan VFD project was defined as Variable Frequency Drive project in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the VFD system was assumed to have a useful life of fifteen (15) years.

It was determined that the CO2 system installation and hot DI water station projects were defined as Custom Measures-SPC projects in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the two systems were assumed to have a useful life of fifteen (15) years.

A summary of the multi-year reporting requirements is given in Table 7. Because this measure was installed approximately June 2005 the energy savings in year #1 (2004) are assumed to be 50% of the expected annual savings for this measure and the energy savings in year #2 (2005) are assumed to be 100% of the expected annual savings for this measure. In addition, no peak savings are assumed to occur during year #15 (2020).

Table 7: Multi-Year Reporting Requirements

Program ID:		**001 Application # A052**					
Program Name:		**SPC 04-05 Evaluation**					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004	-	-	-	-	-	-
2	2005	1,091,415	1,410,121	210.5	321.9	-	-
3	2006	2,182,830	2,820,242	210.5	321.9	-	-
4	2007	2,182,830	2,820,242	210.5	321.9	-	-
5	2008	2,182,830	2,820,242	210.5	321.9	-	-
6	2009	2,182,830	2,820,242	210.5	321.9	-	-
7	2010	2,182,830	2,820,242	210.5	321.9	-	-
8	2011	2,182,830	2,820,242	210.5	321.9	-	-
9	2012	2,182,830	2,820,242	210.5	321.9	-	-
10	2013	2,182,830	2,820,242	210.5	321.9	-	-
11	2014	2,182,830	2,820,242	210.5	321.9	-	-
12	2015	2,182,830	2,820,242	210.5	321.9	-	-
13	2016	2,182,830	2,820,242	210.5	321.9	-	-
14	2017	2,182,830	2,820,242	210.5	321.9	-	-
15	2018	2,182,830	2,820,242	210.5	321.9	-	-
16	2019	2,182,830	2,820,242	210.5	321.9	-	-
17	2020	1,091,415	1,410,121	-	-	-	-
18	2021	-	-	-	-	-	-
19	2022	-	-	-	-	-	-
20	2023	-	-	-	-	-	-
TOTAL	**2004-2023**	32,742,450	42,303,629			-	-

FINAL REPORT

SITE A053 (xxxx-04) Wate IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 1 END USE: Other

Measure	Installation of Seventeen (17) Variable Volume Injection Molders to Replace Seventeen (17) Standard Hydraulic Drive Injection Molders
Site Description	Plastics Manufacturing Facility

1. Measure Description

Seventeen (17) new injection molders were installed. The new molders were manufactured by JSW and are model EIII. Three (3) of the new injection molders have a capacity of 165 tons, eleven (11) have a capacity of 245 tons, and the remaining three (3) have a capacity of 310 tons. The energy efficient feature of these units is the variable volume hydraulic pump. A variable volume pump automatically reduces the flow of hydraulic fluid whenever demand is reduced during the injection cycle.

The new injection molders are replacing one (1) 150-ton, four (4) 200-ton, nine (9) 300-ton, two (2) 440-ton, and one (1) 500-ton injection molders. Van Dorn manufactured the one (1) 500-ton and two (2) of the 200-ton injection molders. The remaining injection molders were manufactured by JSW. All of the replaced injection molders included a standard hydraulic pump and operating controls. A typical hydraulically operated injection molder has a pump with a bypass valve to redirect any unused capacity back to the reservoir. Full flow and power is required at all times with bypass control.

2. Summary of the Ex Ante Calculations

The SPC calculation software for High Efficiency Injection Molders was used to determine the annual savings. The SPC High Efficiency Injection Molder Calculator provides estimates of the energy and demand of the pre-installation and post-installation equipment, using equations that are based on energy use per pound of plastic. The energy use per pound of plastic is based, per the 2004 SPC Procedures Manual, on measured performance data which accounts for the type of machine, variations in part size, production rates, and cycle time.

The existing injection-molding machine was used as the baseline. In both the pre-retrofit and post-retrofit replacement cases, the pre-retrofit production rate was used.

For convenience this project is broken down into six measures. Measure #1 is the installation of one (1) new 165-ton injection molder to replace one (1) existing 150-ton molder with a production rate of 145 pounds per hour. Measure #2 is the installation of two (2) new 165-ton injection molders to replace two (2) existing 200-ton molders, each with a production rate of 178 pounds per hour. Measure #3 is the installation of two (2) new 245-ton injection molders to replace two (2) existing 200-ton molders, each with a production rate of 178 pounds per hour. Measure #4 is the installation of nine (9) 245-ton molders to replace nine (9) existing 300-ton molders, each with a production rate of 307 pounds per hour. Measure #5 is the installation of two (2) new 310-ton molders to replace two (2) existing 310-ton molders, each with a production rate of 323 pounds per hour.

Measure #6 is the installation of one (1) new 310-ton molder to replace one (1) existing 500-ton molder with a production rate of 339 pounds per hour.

Notable inputs and parameters used by the 2004 SPC calculator for each measure are:

	Measure #1	**Measure #2**	**Measure #3**	**Measure #4**	**Measure #5**	**Measure #6**
Existing Size (ton)	150	200	200	300	310	500
Proposed Size (ton)	165	165	245	245	310	310
Quantity	1	2	2	9	2	1
Production Rate (lb/hr/molder)	145	178	178	307	323	339
Existing Specific Demand (kW/lb/hr)	0.422	0.422	0.422	0.422	0.422	0.422
Proposed Specific Demand (kW/lb/hr)	0.240	0.240	0.240	0.240	0.240	0.240
Operating Hours	7,862	7,862	7,862	7,862	7,862	7,862
Existing Sp. Energy Use (kWh/lb)	0.380	0.380	0.380	0.380	0.380	0.380
Proposed Sp. Energy Use (kWh/lb)	0.216	0.216	0.216	0.216	0.216	0.216

The ex ante demand results determined by the 2004 SCP calculator are:

	Measure #1	**Measure #2**	**Measure #3**	**Measure #4**	**Measure #5**	**Measure #6**
Existing Demand (kW)	61.2	150.1	150.1	1,165.3	272.5	143
Proposed Demand (kW)	34.9	85.6	85.6	664.2	155.3	81.5
Demand Savings (kW)	26.3	64.6	64.6	501.3	117.2	61.5

The ex ante usage results determined by the 2004 SCP calculator are:

	Measure #1	Measure #2	Measure #3	Measure #4	Measure #5	Measure #6
Existing Usage (kWh)	432,731	1,062,429	1,062,429	8,245,762	1,927,891	1,011,695
Proposed Usage (kWh)	246,610	605,470	605,470	4,699,197	1,098,690	576,557
Usage Savings (kWh)	186,121	456,959	456,959	3,546,564	829,200	435,138

The combined ex ante results determined by the 2004 SCP calculator are:

Pre-Replacement Usage -	1,942.2 kW	13,742,937 kWh
Post-Replacement Usage -	1,107.1 kW	7,831,994 kWh
Peak Summer Impact & Annual Savings -	835.0 kW	5,910,941 kWh

These are listed in the utility tracking system and substantially agree with the ex ante numbers in the Installation Report Review (IRR).

3. Comments on the Ex Ante Calculations

The ex ante calculations were performed using the SPC Calculator. The energy saving results are in agreement with values generated using the formula outlined in the SPC manual based on the equipment size and production rates provided.

Energy Savings = [(0.91 – 0.55) kWh/kg x 4,605 lbs/hr x 7,862 hrs/yr / 2.2 lb/kg)]

The SPC Guidelines do not provide a method for calculating demand savings. However, the pre-retrofit and post-retrofit calculated demand for the injection molders is consistent with the formulae:

Pre-Retrofit kW = 0.422 kW/(lb/hr) x 4,605 lbs/hr

Post-Retrofit kW = 0.240 kW/(lb/hr) x 4,605 lbs/hr

An alternative appropriate method to determine demand savings is below and results in an estimated savings of 752.2 kW or 90.0% of the SPC calculated amount.

Demand Savings = [(0.91 – 0.55) kWh/kg / 2.2 lbs/kg] x 4,605 lb/hr

4. Measurement & Verification Plan

The customer operates a 120,000 sq. ft. facility for the manufacturing of uniquely designed plastic parts for use in pools, spas, and bathtubs. Within this facility, approximately 40,000 sq. ft is office space, which is conditioned, and the remaining 80,000 sq. ft. is unconditioned production space. Many of its products are made through the use of injection molding machines. In normal operation, the facility is expected to be in operation for three shifts per day, seven days per week for nine months of the year. For the remaining three months per year production is expected to operate 24 hours per day, five days per week.

The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction due to the installation of the seventeen (17) injection molders with variable volume hydraulic drives to replace the seventeen (17) injection molders with standard hydraulic drive, over the useful life of the new equipment.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. The injection molders in question are not expected to consume a large percentage of the facility's total usage. Also, the usage of the injection molders is not expected to remain consistent enough for single point measurements to be representative of the average usage. There is not expected to be significant seasonal variation and two weeks should be sufficient for comparison; however, a longer period would more fully capture actual variations and the persistence of savings. Interval data on a 15-minute or less basis, preferably during the summer months of June to September, would be needed to accurately determine coincident peak period demand savings.

To estimate peak demand kW for the new machine, the metered kWh logged during continuous weekday afternoon periods will be used to determine an average production kW. The average kW should be appropriate because cycle times should be short compared to the typical 15-minute period over which billing demand is determined. These operating kW data points will then be adjusted based on any differences in pre-retrofit and post-retrofit production levels.

Pre-retrofit and post-retrofit calculations of injection molder loads and energy use will be calculated using the following formulae:

<u>Post-installation</u>

kW = kWh / hours (during a continuous production run on a weekday afternoon)

$$\text{kWh} = \frac{\text{metered kWh x production weeks per year x pre-installation production}}{\text{metered weeks x metered production}}$$

<u>Pre-installation</u>

kW = ex ante kW

kWh = ex ante kWh = ex ante kW x ex ante hours of operation

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit production rate and equipment information. The original equipment has been removed and cannot be observed nor metered, therefore, focus will be placed on this equipment during the interview with the customer representative. A typical method for determining the energy and demand associated with an injection molder with a standard hydraulic pump would be:

kW = motor hp x motor load factor x 0.746 kW/hp / motor efficiency

kWh = kW x operating hours

The most significant variables to be quantified are the pre-retrofit and post-retrofit hours of operation. Pre-retrofit hours will be confirmed with the site personnel to verify that the production hours listed in the application (7,862 hours per year) were valid. Appropriate modifications for the savings calculations will be made to the pre-retrofit usage figures if required, in order to establish a realistic baseline for energy use.

We will physically verify the installation of the variable volume hydraulic drives during the onsite visit. We will verify post-retrofit energy consumption by installing Hobo FlexSmart data loggers with WattNode WNA-3D-480-P Watt-hour transducers and Magnalab SCT-1250-200 or SCT-1250-600 current transformers on the motors of no less than seven (7) injection molders. Special care will be taken to ensure at least one molder from each measure above is metered. Also, measure #4 will have no less than two (2) injection molders logged due to the larger sample size. The energy consumption of the injection molders will be logged with a sampling delay of no greater than 1 second, for a minimum of 1 day to verify the post-retrofit energy consumption. In addition, the production level for the logged period will be verified with the customer representative. Preferably, production levels by hour will be logged. If this is not possible, average daily production rates will be obtained. The logged kWh per unit output will then be used to make any adjustments to post installation usage, as appropriate.

The ex ante savings estimate has several areas of significant uncertainty. The SPC calculator uses scaling factors to determine the kW/(lb/hr) and kWh/(lb/yr) values. Per the 2004 SPC Procedures Manual, these values are determined to be "typical" values based on compiled information from a large variety of injection molders. A large uncertainty is associated with comparing the pre-retrofit and post-retrofit injection molders to an unknown "typical" injection molder. Additional uncertainty is associated with the hours of operation and production level of the injection molders.

Uncertainty for the savings estimate for the injection molder retrofit can be more fully understood by setting projected ranges on the primary variables.

<u>For the Pre-Retrofit Injection Molders</u>

- Standard hydraulic injection molder kW/(lb/hr) of 0.422 kW/(lb/hr), maximum of 0.528 kW/(lb/hr), minimum of 0.317 kW/(lb/hr) (±25%, based on judgment of deviation from typical standard hydraulic injection molder in SPC calculator)

<u>For the Post-Retrofit Injection Molders</u>

- Variable volume injection molder kW/(lb/hr) of 0.240 kW/(lb/hr), maximum of 0.300 kW/(lb/hr), minimum of 0.180 kW/(lb/hr) (±25%, based on judgment of deviation from typical standard hydraulic injection molder in SPC calculator)

For the Injection Molder Retrofit

- 6,290 hours post-retrofit expected operation, minimum of 6,000 hours, maximum of 8,648 hours (-25%, +10%, based on judgment of use for site type)
- Production rate of 4,605 lb/hr, minimum 4,145 lb/hr, maximum of 5,066 lb/hr (±10%, based on judgment of use for production method)
- 835.4 kW expected savings, minimum 270.3 kW, maximum 1,401 kW (±67.7%, based on pre-retrofit injection molder expected deviation, post-retrofit injection molder expected deviation, and propagation of error method)
- 5,910,940 kWh expected savings, minimum 1,263,061 kWh, maximum 10,356,928 kWh (-78.6%, +75.2%, based pre-retrofit injection molder expected deviation, post-retrofit injection molder expected deviation, and propagation of error method)

Accuracy and Equipment

The Hobo FlexSmart loggers have a resolution of ±10 seconds. The WattNode Watt-Hour transducers have an accuracy of ±0.45%+0.05%FS. The Magnelab SCT-1250-200 and SCT-1250-600 current transformers have an accuracy of ±1.5%.

The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to Microsoft Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 4, 2007. Information on the retrofit equipment and operating conditions was collected by inspection and by interviewing the facility representative. Five kW/kWh loggers were installed on five machines to measure power consumption, and data were logged for approximately one-half to one hour for each machine on September 4, 2007. Only two of the five machines produced useable data. Additionally, motor on/off loggers were installed on the main pump motors of five machines to measure machine operation for the period of September 4 through September 12, 2007.

5.1. Installation Verification

The facility representative verified that the pre-retrofit machines were standard injection molders. It was physically verified that the new machines were variable volume injection molders. The facility representative stated that the retrofit was completed in approximately July 2004.

This is the only measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Injection Molding	O	Install Variable Volume Injection Molding Machines to Replace Standard Hydraulic Machines	17	Variable Volume Injection Molding Machines	Physically verified installation of a sample of machines	1.00

5.2. Scope of the Impact Assessment:

The impact assessment scope is for the replacement of seventeen (17) standard injection molders with variable volume injection molders. This is the only measure in this application.

5.3. Summary of Results:

Three (3) Hobo Wattnode dataloggers were installed on three of the machines on September 4, 2007 to measure the power consumption. Power consumption for the machines is relatively constant, thus a shorter metering period was chosen to measure power consumption. Motor on/off data loggers were installed on five machines for the period of September 4 through September 12, 2007 to measure the operating hours of the pumps for the machines. The facility representative stated that the monitoring period was representative of normal facility operation.

Power consumption data for one of the injection molders is shown in Table 2, and machine operation time is shown in Table 3.

Table 2: Power Consumption Data

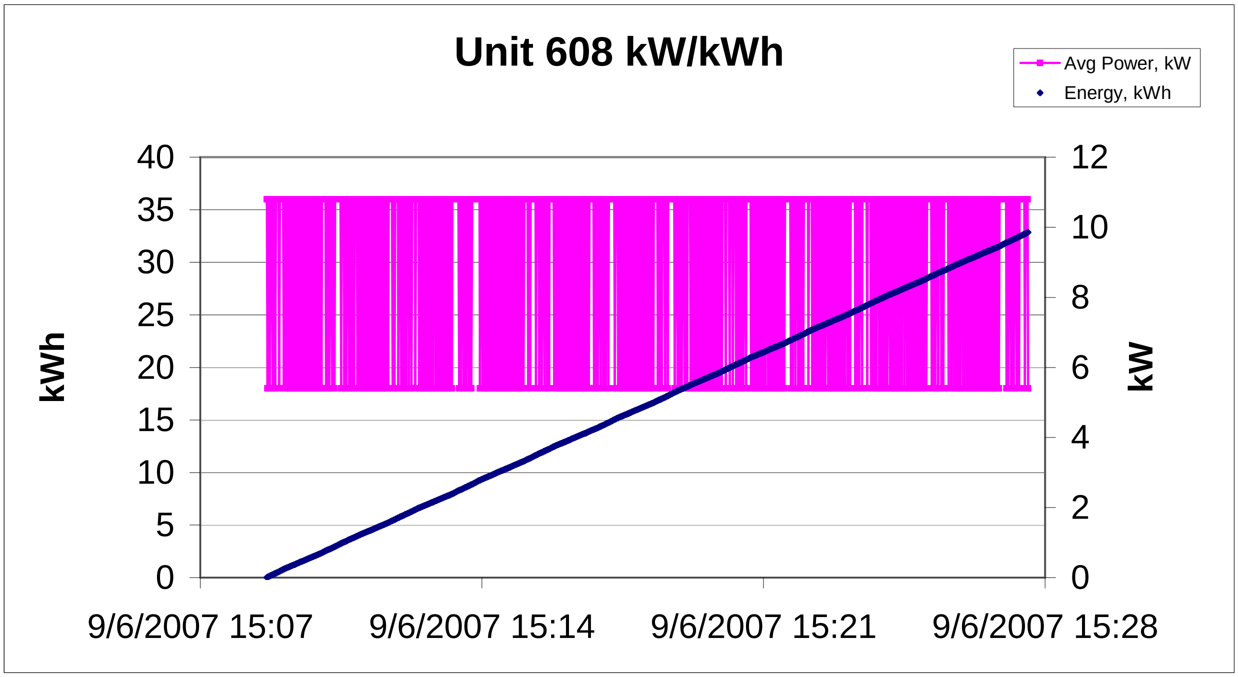


Table 3: Operation Time

Machine #	Total Logged Time (hours)	Time Motor On (hours)	Work Hours	% Motor On
216	186.08	100.49	138.08	73%
302	removed-maintenance			
303	169.82	60.07	121.82	49%
508	138.84	40.16	90.84	44%
608	138.35	67.08	90.35	74%
	Weighted Average:			**61%**

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected loads.

Annual hours of operation are based on a three-month schedule of twenty-four hours per day and five days per week, and a nine-month schedule of twenty-four hours per day and seven days per week. Per the site representative, the usage of the machines is much greater during this nine-month period, estimated at 90% during the first and second shifts and 50% during the third shift.

The logged data was taken during the twenty-four hours per day, five days per week schedule. The weighted average percent motor on times from Table 3 was adjusted to account for the greater usage during the busy nine-month period. The average percentage used in the calculations is 72.7%.

The customer was not able to provide specific data on the production rate of the individual machines during the period of logged data. He stated that the production for the individual machines was not tracked. Based on the consistency in the trended data, it was assumed that each machine produced the same part throughout the logging period as was produced during the site visit. In addition, during the site visit, the site representative estimated that the 178 lb/hr used in the original analysis was close to the production capacity of each machine, which was similar to the current production level for machine 608. Machine 302 was estimated to have a production rate of 60% based on observations during the site visit as well as discussion with the site representative.

The ex post impacts are calculated in Table 4 below:

Table 4: Energy and Demand Formulae

The following formulas include all affected machines combined.

Annual Hours Machines On	= Adjusted % On x Facility Operation Hours = 72.7% x 8,112 hours = 5,896 hours per year
Pre-Retrofit Demand kW_{peak}	= Ex Ante Specific Demand x Production Rate = 0.422 kWh/lb x 3,454 lbs/hr = 1,456.6 kW
Post-Retrofit Demand kW_{peak}	= Metered Specific Demand x Production Rate = 0.213 kWh/lb x 3,454 lbs/hr = 734.1 kW
Peak kW Savings	= Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak} = 1,456.6 kW – 734.1 kW = 722.5 kW
Pre-Retrofit kWh	= Ex Ante Specific Energy x Production Rate x Hours =0.380 kWh/lb x 3,454 lbs/hr x 5,896 hours/yr = 7,729,296 kWh/yr (allowing for rounding)
Post-Retrofit kWh	= Metered Specific Energy x Production Rate x Hours = 0.164 kWh/lb x 3,454 lbs/hr x 5,896 hours/yr = 3,339,158 kWh/yr (allowing for rounding)
kWh Savings	= Pre-Retrofit kWh – Post-Retrofit kWh = 7,729,296 kWh/yr – 3,339,158 kWh/yr = 4,390,138 kWh/yr

The calculations have some

The ex post energy savings and demand reduction values are less than the ex ante energy savings because the ex ante calculations overestimated the number of hours that the injection molders are operating as well as the production rate.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the vendor invoice for the work performed for the project and is an accurate reflection of the project cost. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program has not encouraged them to perform any other energy efficiency projects for which they did not participate in an incentive program.

We were unable to physically verify the pre-retrofit equipment or hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. Based on the measured data and discussions with the facility representative, the level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

7. Impact Results

Based on the ex ante savings of 5,910,940 kWh, the engineering realization rate for this application is 0.74 for energy savings (kWh) and 0.87 for demand savings (kW). A summary of the realization rate is shown in Table 5.

Table 5: Realization Rate Summary

Savings	kW	kWh	Therm
SPC Tracking System	835.0	5,910,940	-
SPC Installation Report (ex ante)	835.4	5,910,940	-
Impact Evaluation (ex post)	722.5	4,390,138	-
Engineering Realization Rate	0.87	0.74	NA

In the original calculations, the annual hours of actual machine operation were estimated to be 7,862 hours per year. Based on the logged data, on average the machines are actually running for 5,896 hours per year.

Utility billing data for the site was reviewed. Annual usage prior to the retrofit was 11,504,358 kWh. Peak demand was 1,869.6 kW. Table 6 summarizes the total metered use available, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 6: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1,869.6	11,504,358
Baseline End Use	1,682.6	10,353,922
Ex ante Savings	835.0	5,910,940
Ex Post Savings	722.5	4,390,138

Table 7 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations.

Table 7: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	44.7%	51.4%	38.6%	38.2%
Baseline End Use %	49.6%	57.1%	42.9%	42.4%

With a cost of $1,852,000 and a $472,875 incentive, the project had a 1.79 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 2.42 years. A summary of the economic parameters for the project is shown in Table 8.

Table 8: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	8/2/2004	$1,852,000	835.0	5,910,940	0	$768,422	$472,875	1.79	2.41
SPC Program Review (Ex Post)	9/27/2007	$1,852,000	722.5	4,390,138	0	$570,718	$472,875	2.42	3.25

It was determined that the variable volume injection molder project was defined as an Extrusion Equipment measure in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the injection molders were assumed to have a useful life of fifteen (15) years. A summary of the multi-year reporting requirements is given in Table 9. Because this measure was installed in July of 2004 the energy savings in year #1 (2004) are assumed to be 58.3% of the expected annual savings for this measure.

Table 9: Multi-Year Reporting Requirements

Program ID:		Application # 04-xxxx - A053					
Program Name:		**SPC 04-05 Evaluation**					
Year	**Calendar Year**	**Ex-ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004	3,448,048	2,560,914	835	722.54	0	0
2	2005	5,910,940	4,390,138	835	722.54	0	0
3	2006	5,910,940	4,390,138	835	722.54	0	0
4	2007	5,910,940	4,390,138	835	722.54	0	0
5	2008	5,910,940	4,390,138	835	722.54	0	0
6	2009	5,910,940	4,390,138	835	722.54	0	0
7	2010	5,910,940	4,390,138	835	722.54	0	0
8	2011	5,910,940	4,390,138	835	722.54	0	0
9	2012	5,910,940	4,390,138	835	722.54	0	0
10	2013	5,910,940	4,390,138	835	722.54	0	0
11	2014	5,910,940	4,390,138	835	722.54	0	0
12	2015	5,910,940	4,390,138	835	722.54	0	0
13	2016	5,910,940	4,390,138	835	722.54	0	0
14	2017	5,910,940	4,390,138	835	722.54	0	0
15	2018	5,910,940	4,390,138	835	722.54	0	0
16	2019	2,462,892	1,829,224	835	722.54	0	0
17	2020						
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	88,664,100	65,852,071				

Depending on timing, kW savings may not materialize in the final year of useful life (2019).

FINAL SITE REPORT

SITE A054 (xxxx-04) UPMI IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 3 END USE: Other

Measure	Conversion of 1,500 ton Injection Molder from Standard Hydraulic Drive to Electric Drive
Site Description	Plastics Manufacturing Facility

1. Measure Description

An existing 1,500-ton plastic injection molder was converted from standard hydraulic drive to electric drive. The molder was manufactured by Cincinnati Milacron and is a model Maxima VL1500. The energy efficient feature of this unit is the electric drive. An electric drive injection molder uses a variable frequency drive (VFD) to modulate the motor speed as needed. A typical hydraulically operated injection molder has a pump with a bypass valve to redirect any unused capacity back to the reservoir. Full flow and power is required at all times with bypass control.

2. Summary of the Ex Ante Calculations

The SPC calculation software for High Efficiency Injection Molders was used to determine the annual savings. The SPC High Efficiency Injection Molder Calculator provides estimates of the energy and demand of the pre-installation and post-installation equipment, using equations that are based on energy use per pound of plastic. The energy use per pound of plastic is based, per the 2004 SPC Procedures Manual, on measured performance data which accounts for the type of machine, variations in part size, production rates, and cycle time.

The existing injection-molding machine was used as the baseline, which is consistent with the SPC Guidelines. In both the pre-retrofit and post-retrofit replacement cases, the pre-retrofit production rate was used.

Notable inputs and parameters used by the calculator are:

<u>Pre-Retrofit Existing Equipment and Production</u>
Manufacturer and Size – Cincinnati Milacron 1,500 ton standard hydraulic machine
Average Production Rate – 466 lbs/hr
Annual Operating Hours – 8,000
Production Rate - 0.311 lbs/ton (466/1,500)
Specific Energy Use – 0.91 kWh/kg

<u>Post-Retrofit Equipment and Production</u>
Manufacturer and Size – Cincinnati Milacron 1,500 ton electric drive machine
Average Production Rate – 466 lbs/hr
Annual Operating Hours – 8,000
Production Rate - 0.311 lbs/ton (466/1,500)
Specific Energy Use – 0.20 kWh/kg

The ex ante results determined by the 2004 SCP calculator are:

Pre-Replacement Usage -	196.5 kW	1,415,118 kWh
Post-Replacement Usage -	42.3 kW	304,327 kWh
Peak Summer Impact & Annual Savings -	154.3 kW	1,110,792 kWh

The ex ante savings in the Installation Report Review substantially agree with the utility tracking system. However, the tracking system has an incorrect description of the measure (chiller) and an incorrect end use category (H for HVACR or AC&R)

3. Comments on the Ex Ante Calculations

The ex ante calculations were performed using the SPC Calculator. The energy saving results are in agreement with values generated using the formula outlined in the SPC manual based on the equipment size and production rates provided. However, a factor of approximately 92.3% was included. No justification or explanation of this factor is given.

Energy Savings = [(0.91 – 0.20) kWh/kg x 466 lbs/hr x 8,000 hrs/yr x 0.923 / 2.2 lb/kg)]

Additionally, the pre-retrofit and post-retrofit calculated energy usage of the injection molders is consistent with the formulae:

Pre-Retrofit kWh = 0.380 kWh/lb x 466 lb/hr x 8,000 hr/yr

Post-Retrofit kWh = 0.0816 kWh/lb x 466 lb/hr x 8,000 hr/yr

The SPC Guidelines do not provide a method for calculating demand savings. However, the pre-retrofit and post-retrofit calculated demand for the injection molders is consistent with the formulae:

Pre-Retrofit kW = 0.422 kW/(lb/hr) x 466 lb/hr

Post-Retrofit kW = 0.091 kW/(lb/hr) x 466 lb/hr

An alternative appropriate method to determine demand savings is below and results in an estimated savings of 150.4 kW (97.5% of the SPC calculated amount).

Demand Savings = [(0.91 – 0.20) kWh/kg / 2.2 lbs/kg] x 466 lb/hr

4. Measurement & Verification Plan

The customer operates an approximately 100,000 sq. ft. facility for the manufacturing of custom, job-specific plastic parts. Approximately 10,000 sq. ft. of this facility is office space, which is conditioned; the remaining 90,000 sq. ft. is production area, and is not conditioned. Many of the products are made through the use of injection molding machines. In normal operation, the facility is expected to be in operation for three shifts per day, for approximately 363 days per year. According to the application, the pre-retrofit production rate was 466 lb/hr. Because of the widely varying requirements associated with each specific customer's part, the production rate can vary greatly;

however, the site representative thought 466 lb/hr was a reasonable average production rate for this machine.

The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction due to the retrofit of the 1,500 ton injection molder from standard hydraulic drive to electric drive.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. The injection molder in question is not expected to consume a large percentage of the facility's total usage. Also, the usage of the injection molder is not expected to remain consistent enough for single point measurements to be representative of the average usage. There is not expected to be significant seasonal variation and two weeks should be sufficient for comparison; however, a longer period would more fully capture actual variations and the persistence of savings. Interval data on a 15-minute or less basis, preferably during the summer months of June to September, would be needed to accurately determine coincident peak period demand savings.

To estimate peak demand for the new machine, the metered kWh logged during continuous weekday afternoon periods will be used to determine an average production kW. The average kW should be appropriate, because cycle times should be short compared to the typical 15-minute period over which billing demand is determined. These operating kW data points will then be adjusted based on any differences in pre-retrofit and post-retrofit production levels.

Pre-retrofit and post-retrofit calculations of injection molder loads and energy use will be calculated using the following formulae:

<u>Post-installation</u>

kW = kWh / hours (during a continuous production run on a weekday afternoon)

$$\text{kWh} = \frac{\text{metered kWh x production weeks per year x pre-installation production}}{\text{metered weeks x metered production}}$$

<u>Pre-installation</u>

kW = ex ante kW

kWh = ex ante kWh = ex ante kW x ex ante hours of operation

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit production rate and equipment information. The original equipment has been removed and cannot be observed nor metered, therefore, focus will be placed on this equipment during the interview with the customer representative. A typical method for determining the energy and demand associated with an injection molder with a standard hydraulic pump would be:

kW = motor hp x motor load factor x 0.746 kW/hp / motor efficiency

kWh = kW x operating hours

The most significant variables to be quantified are the pre-retrofit and post-retrofit hours of operation. Pre-retrofit hours will be confirmed with the site personnel to verify that the production hours listed in the application (8,000 hours per year) were valid. Appropriate modifications for the savings calculations will be made to the pre-retrofit usage figures if required, in order to establish a realistic baseline for energy use.

We will physically verify the installation of the electric drive during the onsite visit. We will verify post-retrofit energy consumption by installing Hobo FlexSmart data loggers with WattNode WNA-3D-480-P Watt-hour transducers and Magnalab SCT-1250-200 current transformers on the motor. The energy consumption of the injection molder will be logged with a sampling delay of no greater than 2 minutes, for a minimum of 14 days to verify the post-retrofit energy consumption. In addition, the production level for the logged period will be verified with the customer representative. Preferably, production levels by hour will be logged. If this is not feasible, daily production rates will be obtained. The logged kWh per unit output will then be used to make any adjustments to post installation usage, as appropriate.

The ex ante savings estimate has several areas of significant uncertainty. The SPC calculator uses scaling factors to determine the kW/(lb/hr) and kWh/(lb/yr) values. Per the 2004 SPC Procedures Manual, these values are determined to be “typical” values based on compiled information from a large variety of injection molders. A large uncertainty is associated with comparing the pre-retrofit and post-retrofit injection molders to an unknown “typical” injection molder. Additional uncertainty is associated with the hours of operation and production level of the injection molders.

Uncertainty for the savings estimate for the injection molder retrofit can be more fully understood by setting projected ranges on the primary variables.

For the Pre-Retrofit Injection Molder

- Standard hydraulic injection molder kW/(lb/hr) of 0.422 kW/(lb/hr), maximum of 0.528 kW/(lb/hr), minimum of 0.317 kW/(lb/hr) (±25%, based on judgment of deviation from typical standard hydraulic injection molder in SPC calculator)
- Standard hydraulic injection molder kWh/lb of 0.380 kWh/lb, maximum of 0.474 kWh/lb, minimum of 0.285 kWh/lb (±25%, based on judgment of deviation from typical standard hydraulic injection molder in SPC calculator)

For the Post-Retrofit Injection Molder

- Electric drive injection molder kW/(lb/hr) of 0.091 kW/(lb/hr), maximum of 0.114 kW/(lb/hr), minimum of 0.068 kW/(lb/hr) (±25%, based on judgment of deviation from typical standard hydraulic injection molder in SPC calculator)
- Electric drive injection molder kWh/(lb/hr) of 0.0816 kW/(lb/hr), maximum of 0.102 kWh/(lb/hr), minimum of 0.0612 kWh/(lb/hr) (±25%, based on judgment of deviation from typical standard hydraulic injection molder in SPC calculator)

For the Injection Molder Retrofit

- 8,000 hours post-retrofit expected operation, minimum of 6,000 hours, maximum of 8,700 hours (-25%, +8.8%, based on judgment of use for site type)
- Production rate of 466 lb/hr, minimum 419.1 lb/hr, maximum of 512.6 lb/hr (±10%, based on judgment of use for production method)
- 154.3 kW expected savings, minimum 101.7 kW, maximum 206.9 (±34.1%, based on pre-retrofit injection molder expected deviation, post-retrofit injection molder expected deviation, and propagation of error method)
- 1,110,792 kWh expected savings, minimum 640,757 kWh, maximum 1,502,163 kWh (-42.3%, +35.2%, based pre-retrofit injection molder expected deviation, post-retrofit injection molder expected deviation, and propagation of error method)

Accuracy

The Hobo FlexSmart loggers have a time accuracy of ±10 seconds. The WattNode Watt-Hour transducers have an accuracy of ±0.45%+0.05%FS, and the Magnelab SCT-1250-200 current transformers have an accuracy of ±1.5%.

The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to Microsoft Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 24, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the injection molder and by interviewing the facility representative. One set of 600A current transformers and data loggers were installed on the input phases for the injection molder with a sampling frequency of one (1) minute.

5.1. Installation Verification

The facility representative verified that the pre-retrofit injection molder had a standard hydraulic drive.

It was physically verified that the retrofit unit was a Cincinnati Milacron Maxima VL1500. It was determined that the post-retrofit machine installed was a hybrid machine as opposed to the all-electric drive unit specified in the application. For the installed hybrid machine, the platen end of the machine was controlled by a hydraulic system, which included one motor connected to a variable volume pump. A separate motor with a VFD controlled the extruder screw. The facility representative stated that the retrofit was completed in July 2004.

These are the only measures in this application. The verification realization rate for this project is 1.00. A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
PROCESS-INJECTION MOLDER	O			Replace one 400T standard hydraulic drive injection molder with one 1100T variable volume injection molder	1	1100T Variable Volume Injection Molder	Physically verified installation of 1100T variable volume injection molder	1.00

5.2. Scope of the Impact Assessment:

The impact assessment scope is for the injection molder retrofit measure in the SPC application. This is the only measure in this application.

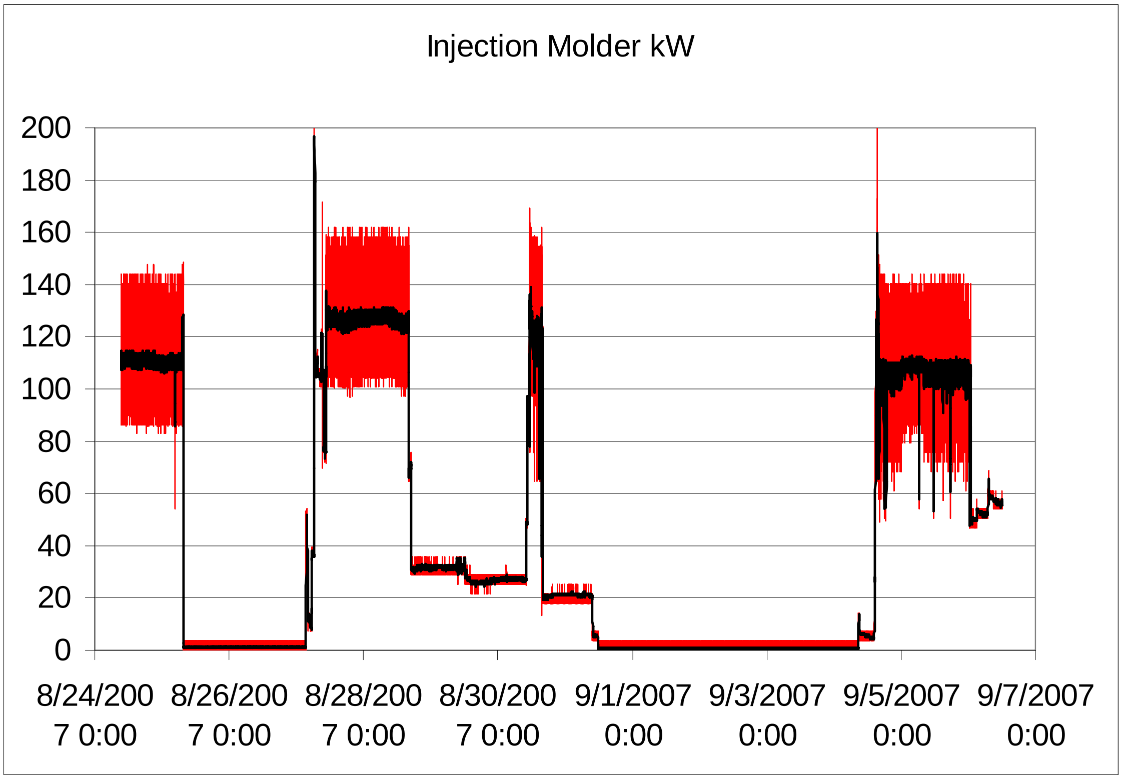
5.3. Summary of Results:

One (1) Hobo Wattnode was installed on the injection molder for 14 days (from August 24, 2006-September 6, 2007) to measure the operating hours and power consumption of the retrofit injection molder. It was found that on average, during the metered period the injection molder operated 33.8% of the time for an expected 2,872 hours per year compared to the 8,000 hours per year assumed in the ex ante calculations. However, the facility representative stated that the operation of the injection molder is extremely variable, with the metered time being lighter than usual. A more typical value for operating time is 45%-50% of the facility's annual hours. The midpoint (47.5%) would result in annual operation of 4,036 hours per year.

The facility representative stated that this facility operates 24 hours per day. In addition, this facility is in production throughout the year except for 11 holidays.

It was determined from the Hobo kWh logger and the Hobo 600A current logger that the demand of the injection molder varies significantly over time, even if production level is held relatively constant. For the time period from 9:30 AM on August 27 to 4:00 PM on August 28, the 1-minute average demand of the injection molder varied from 97.2 kW to 162.0 kW. However, this fluctuation smoothes out very quickly as the sampling period is increased. If a 5-minute average kW is used to determine the demand of this injection molder, the range is only 121 kW to 131 kW. With a 15-minute average kW, the range is reduced further to 124 kW to 131 kW. The injection molder power draw is shown in Figure 1.

Figure 1: Hobo kWh Logger Results



To accurately represent the kWh/lb and kW/(lb/hr), the customer tracked the production level throughout the metering process. This was then used on a daily basis to determine an average kW/(lb/hr). In addition, the total production during the metered time period and total energy usage during the metered time period was used to determine an overall average kWh/lb. These values are presented in Table 2. The kW/(lb/hr) and kWh/lb values were then used to determine an adjusted peak kW and annual kWh based on the pre-retrofit production rate.

Table 2: Daily Production and Usage Values

Date	Production Hours	Qty	kg	Average lb/hr	kWh	Average Production kW	Average kW-h/lb
8/24/07 to 9/6/07	172.5	6036	22,499	287	13,350.1	111.2	0.27
Total	172.5	**6,036**	**22,499**	287	**13,350**		
Average							0.270

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load, with an adjustment for the pre-retrofit production level of 466 lb/hr. The average kW of the machine was used to account for the probability of the peak occurring during the facility peak.

The ex post impacts are calculated in Table 3 below:

Table 3: Energy and Demand Formulae

Pre-Retrofit Demand kW_{peak} = Pre-Retrofit Demand Rate x Pre-retrofit Production
= 0.4218 kW/ (lb/hr) x 466 lb/hr
= 196.5 kW (ex ante calculations)

Post-Retrofit Demand kW_{peak} = Post-Retrofit Demand Rate x Pre-retrofit Production
= 0.270 kW/ (lb/hr) x 466 lb/hr
= 125.7 kW

Peak kW Savings = Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak}
= 196.5 kW – 125.7 kW
= 70.8 kW

Pre-Retrofit kWh = Pre-Retrofit Energy Rate x Pre-Retrofit Production x Post-retrofit Hours
= 0.3796 kWh/lb x 466 lb/hr x 4,036hours/yr
= 713,857 kWh/yr (allowing for rounding and based upon hourly use reduction)

Post-Retrofit kWh = Post-Retrofit Energy Rate x Pre-Retrofit Production x Post-retrofit Hours
=0.27 kWh/lb x 466 lb/hr x 4,036 hours/yr
= 507,213 kWh/yr (allowing for rounding)

kWh Savings = Pre-Retrofit kWh – Post-Retrofit kWh
= 713,857 kWh/yr – 507,213 kWh/yr
= 206,644 kWh/yr

The ex post kW demand reduction is less than the ex ante estimate because the ex ante calculations underestimated the demand associated with the new injection molder.

The ex post energy savings is less than the ex ante energy savings because the ex ante calculations underestimated the average demand associated with the new injection molder and overestimated the annual hours of operation.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is an accurate reflection of the project cost. In addition to saving energy, the post-retrofit injection molder is better able to control injection rate, resulting in less waste. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. However, they again stated that the work varies considerably throughout the year. The customer's participation in the 2004/2005 SPC Program has not encouraged them to perform any other energy efficiency projects.

We were unable to physically verify the pre-retrofit injection molder type, production level, or hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

7. Impact Results

Based on the ex ante savings of 154.3 kW and 1,110,792 kWh the engineering realization rate for this application is 0.46 for kW reduction and 0.19 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 4.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	154.3	1,110,792	-
SPC Installation Report (ex ante)	154.3	1,110,792	-
Impact Evaluation (ex post)	70.8	206,644	-
Engineering Realization Rate	0.46	0.19	NA

Utility billing data for the site was reviewed. In the 12-month period from January 2003 – December 2003 (pre-retrofit), the facility consumed 8,516,940 kWh. Peak demand was 1,920.0 kW in September 2003. Table 5 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 5: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1,920.0	8,516,940
Baseline End Use	196.5	1,415,118
Ex ante Savings	154.3	1,110,792
Ex Post Savings	70.8	206,644

Table 6 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 8.0% decrease in total meter kW, a 78.5% decrease in the injection molder end use kW, a 13.0% decrease in total meter kWh, and a 78.5% decrease in the injection molder end use kWh. The ex post results showed a 3.7% decrease in total meter kW, a 36.0% decrease in the injection molder end use kW, a 2.4% decrease in total meter kWh, and a 14.6% decrease in the injection molder end use kWh.

Table 6: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	8.0%	13.0%	3.7%	2.4%
Baseline End Use %	78.5%	78.5%	36.0%	14.6%

With a cost of $130,000 and a $65,000 incentive, the project had a 0.45 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 2.42 years. A summary of the economic parameters for the project is shown in Table 7.

Table 7: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	4/19/2007	$130,000	154.3	1,110,792	0	$144,403	$65,000	0.45	0.90
SPC Program Review (Ex Post)	9/26/2007	$130,000	70.8	206,644	0	$26,864	$65,000	2.42	4.84

It was determined that the injection molder replacement project was defined as a Miscellaneous Measure-Extrusion Equipment in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the injection molders were assumed to have a useful life of fifteen (15) years. A summary of the multi-year reporting requirements is given in Table 8. Because this measure was installed in August but not in operation until November of 2004, the energy savings in year #1 (2004) are assumed to be 2/12 of the expected annual savings for this measure. In addition, no peak savings are expected for the fist year (2004).

Table 8: Multi-Year Reporting Requirements

Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	185,132	34,441				
2	2005	1,110,792	206,644	154.3	70.8		
3	2006	1,110,792	206,644	154.3	70.8		
4	2007	1,110,792	206,644	154.3	70.8		
5	2008	1,110,792	206,644	154.3	70.8		
6	2009	1,110,792	206,644	154.3	70.8		
7	2010	1,110,792	206,644	154.3	70.8		
8	2011	1,110,792	206,644	154.3	70.8		
9	2012	1,110,792	206,644	154.3	70.8		
10	2013	1,110,792	206,644	154.3	70.8		
11	2014	1,110,792	206,644	154.3	70.8		
12	2015	1,110,792	206,644	154.3	70.8		
13	2016	1,110,792	206,644	154.3	70.8		
14	2017	1,110,792	206,644	154.3	70.8		
15	2018	1,110,792	206,644	154.3	70.8		
16	2019	925,660	172,203	154.3	70.8		
17	2020						
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	16,661,880	3,099,653				

FINAL REPORT

SITE A055 (2004-xxxx) Hy2 IMPACT EVALUATION
SAMPLE CELL: TIER: 2 END USE: Other

Measure	Replace manual thermostats with occupancy-based thermostats
Site Description	Hotel

1. Measure Description

Replace 557 manual thermostats in hotel guestrooms with occupancy-based programmable thermostats.

2. Summary of the Ex Ante Calculations

According to the Installation Report Review, the ex ante estimate of annual savings is 2,279,801 kWh, 0 kW, and 0 therms. This agrees with the utility tracking system.

The ex ante savings calculations are prescriptive and itemized, based on the Express Efficiency setback programmable thermostat workpaper. The workpaper dictates savings of 4,093 kWh/year and 1,095 therms/year per thermostat.

The assumptions for these workpaper savings are:

- Regular office hours = 7 am - 6 pm, Monday - Friday
- Base case system runs continuously due to lack of controls
- Fan is in AUTO mode
- Occupied hrs/yr = 11 hr/day x 5 day/wk x 52.14 wk/yr = 2,870 hr/yr
- AC Capacity = 10.0 tons
- Overall AC efficiency = 1.3 kW/ton average without fans
- 500 sf/ton size
- Size of heating = 250 kBtu/hr
- Overall heating efficiency = 70%
- Total cfm = 5,000
- Fan hp = 3
- Fixed outside air (20%)
- Located in San Jose (uses ASHRAE bin weather data)

With these assumptions, the workpapers use weather bin data to estimate the base case energy consumed for heating and cooling. The weather bin data is separated into occupied and unoccupied periods. Using setback temperatures for the unoccupied periods, the occupancy-based energy consumption is calculated. There are some additional calculations to approximate “warm up” periods and “cool down” periods. The difference between the base case energy use and the occupancy-based energy use is the energy savings.

The kWh savings reported are consistent with workpaper prescribed value per unit. However, the gas savings in therms is reported to be 0, whereas the workpaper indicates 1,095 therms per year per unit.

The project file lists the total cost of this measure as $93,001. The tracking system notes an incentive of $30,078. It is unclear how the incentive was calculated. The category was listed as H for HVAC in the utility tracking system; this category is now AC&R. The proper category for this measure is “Other”.

3. Comments on the Ex Ante Calculations

The ex ante savings are based on the SCE workpapers for setback programmable thermostats in a small commercial application. These savings are not applicable to the occupancy-based programmable thermostats used in this project because:

- The technology is not the same. The occupancy-based thermostats operate much differently than the standard programmable thermostat.
- Weather data is used for San Jose, which is different than weather in the subject location. This is a weather sensitive measure, and location is important to the accuracy of savings.
- A hotel has very different occupancy patterns and usage than the typical small commercial application. A hotel guestroom is very dissimilar to a small retail or office building.
- The work paper calculations are based on small split system AC units. This hotel facility is cooled by a central chiller plant.
- The work paper calculates savings for heating accomplished by small furnaces. This hotel has a central plant hot water boiler used for space heating. This project does not claim therm savings or electric heat savings, but there will be both electrical and therm savings associated with heating; these will be different (and likely lower for therms) than those savings identified in the work papers.
- The ex ante savings assumed that the space is occupied during typical office hours and unoccupied during nights and weekends. The occupancy-based programmable thermostats used in hotel guestrooms will follow a much different occupancy pattern.

In short, the deemed savings used to estimate the ex ante impacts are not appropriate for this project. The evaluated savings are not expected to have any relation to the ex ante claims. The ex ante savings calculation approach will not be utilized for ex post savings.

4. Measurement & Verification Plan

The goal of the measurement and verification (M&V) plan is to determine peak kW, kWh, and therm savings over the life of the measure by establishing the effect the occupancy-based programmable thermostats have on heating, cooling, and fan energy use in guest rooms.

This facility is a hotel, with 557 fan-coil units (FCUs) in 536 guest rooms. The building contains a total of 423,500 sf; of which 287,279 sf is guestroom space, including corridors. Cooling for the building is provided by two, 400-ton water-cooled chillers. More details on the central cooling plant will be collected during the site visit.

Heating for the building is provided by a central hot water boiler system. Details on this system will be collected during the site visit and used in ex post savings calculations.

There are a total of 557 in-room fan coil units (FCUs). The FCUs are 1/20-hp each and are rated for 300 cfm of air flow. The supply air register is 13"x 7.5". The chilled water coil in each FCU is rated at 0.49 ton to 1.0 ton cooling capacity. The nameplate heating coil capacity is 11,300 Btu/hr.

Formulae and Approach

IPMVP M&V Option A (Partially Measured Retrofit Isolation) will be used to estimate the impacts resulting from this project.

Limited information was provided for this facility; therefore, the final ex post savings approach cannot be entirely determined until the site visit is conducted. The basic method will involve a monitoring approach to determine the difference between the baseline and new heating, cooling, and fan energy consumption.

Ideally, a minimum of four base case (reference) rooms will be monitored; these will be evenly divided between building faces. The occupancy-based thermostat will be set to operate in manual mode for these rooms, thus simulating the pre-retrofit conditions. Additionally, four or more rooms evenly divided by building exposures will be monitored with the new occupancy-based thermostats fully functional. To the extent possible, ground floor and top floor rooms will be monitored in proportions representative to the total number of rooms.

The basic parameters that will be monitored, if permitted by facility staff and physical constraints, are relayed in Table 1.

Table 1: Onsite Data Collection and Verification Monitoring Parameters

Measured Parameter	Description	Interval / Length
Supply air temperature	Thermocouple logger in FCU	5 minute interval
Return air / room temperature	Thermocouple logger in FCU	5 minute interval
Fan on/off	Time of Use (TOU) motor logger	Continuous
Fan load	Amp logger measuring fan energy usage	5 minute interval
Outside air temp	Utilize EMS to trend or NOAA weather station	15 minute interval if available via EMS or hour if via NOAA
Room rental status	Customer to provide daily rental status of rooms during measurement period	Daily

Table 2: Onsite Data Collection and Verification

Data Element	Proposed Means of Collecting Data
Chilled water plant performance	Estimate chiller plant efficiency based on equipment and age of plant. A typical plant of this type will operate between 0.8 and 1.2 kW/ton. Estimates may be through manufacturer or EMS data.
Boiler nameplate data, and service records data	Visual Inspection and data provided by contact
Cooling coil capacity	Nameplate or review of documentation
Heating coil capacity	Nameplate or review of documentation
Fan capacity	Nameplate or review of documentation
Average monthly occupancy	Provided by contact

The measured supply air temperature and return air temperature will be used to calculate the temperature difference (ΔT) across the cooling and heating coils. The supply air temperature will be used to determine when an FCU is in heating or cooling mode.

FCU airflow will be determined from nameplate data or documentation if possible. If information on the unit can be found, fan power will be used to estimate the typical airflow for that size unit. Spot readings from vane anemometers during operation at various fan speeds will be used to validate this data.

Boiler efficiency will be obtained from the nameplate (if available) or recent service documentation. Chiller plant efficiency will be estimated based on the equipment, operation, and age of the plant. Fan power will be determined from monitored data and/or nameplate data.

Each monitored room will have heating energy, cooling energy, cooling peak demand, fan energy, and fan peak demand calculated for each interval. Each interval will be aggregated for each day. The rooms will be grouped as base case unrented, base case rented, post case unrented, and post case rented. Daily consumption values for each group of rooms will be combined. Savings will be calculated by the consumption differences between the base case and post case for both rented and unrented periods. The savings results will be regressed against weather data for the monitoring period to determine the correlation of outside air temperature and savings. Using weather correlations and typical annual occupancy data, the annual savings will be estimated.

The following equations will be used to calculate the energy values from the measured data.

Heating Energy:

$$\text{therm/day} = \sum_{i=1}^{288}\left[\frac{(\Delta T)(\text{FCU cfm})(1.1)}{(\text{boiler efficiency})}\right] x \frac{\text{therm}}{100{,}000\ \text{Btu}} \qquad \text{Eqn. 1}$$

Cooling Energy:

$$\text{kWh/day}_{\text{cooling}} = \sum_{i=1}^{288}\left[\frac{(\Delta T)(1.08)(\text{FCU cfm})(\text{chiller plant kW/ton})}{(12{,}000\ \text{Btu/ton})}\right] \qquad \text{Eqn. 2}$$

$$\text{Peak kW}_{\text{cooling}} = \sum_{i=1}^{36}\left[\frac{(\Delta T)(1.08)(\text{FCU cfm})(\text{chiller plant kW/ton})}{(12{,}000\ \text{Btu/ton})}\right] \div 36 \qquad \text{Eqn. 3}$$

i = each 5-minute interval of the measurement period

Fan Energy:

kWh/day = directly measured Eqn. 4

Peak kW = average of directly measured values during the peak period (2pm- 5pm) Eqn. 5

Each interval that the fan is not running, kWh and kW will equal 0. Peak demand kW will be calculated using the average kW values over the entire peak period.

Uncertainty for the savings estimates can be more fully understood by setting projected ranges on the primary variables.

Occupancy Rates

- Guest room occupancy: 75% expected, 50% minimum, 90% maximum (+20% maximum, -33% minimum)

Heating Energy Savings

- Annual average time pre-retrofit: 5% expected, 2% minimum, 10% maximum (+100% maximum, - 60 % minimum)
- Annual average time post-retrofit: 2% expected, 1% minimum, 5% maximum (+150% maximum, -50% minimum)
- therms saved: 20,000 expected, 5,000 minimum, 40,000 maximum (+100% maximum, -75% minimum) based on extrapolating from summer run time percentages to the entire year

Cooling Energy Savings

- Annual average time pre-retrofit: 20% expected, 10% minimum, 28% maximum (+40% maximum, -100% minimum)
- Annual average time post-retrofit: 10% expected, 5% minimum, 23% maximum (+130% maximum, -50% minimum)
- Average temp difference 15°F expected, minimum 6°F, maximum 18°F (includes -60% and +20%)

Fan Energy Savings

- % time pre-retrofit: 32% expected, 16% minimum, 64% maximum (±100%)
- % time post-retrofit: 20% expected, 10% minimum hours, 30% maximum hours (±100%) based on expected operations
- Size: 0.053 kWx 557 FCUs, 29.5kW expected, minimum 20 kW, 40 kW (includes +/-50% for hi-low operation)
- 120,000 kWh expected: minimum 100,000, maximum 200,000 kWh (based on -20%, +66.7% for extrapolating from summer run time percentages to the entire year)

This uncertainty analysis shows that time of operation of fans, heating, and cooling along with extrapolation from summer run time percentages to full year estimates, comprise the largest uncertainties to savings estimates. Attention will be primarily directed in the implementation of the M&V plan to capturing operating time percentages accurately.

There may be other small potential sources of error introduced; these exist for a variety of reasons, such as variances in rooms monitored. The greatest source of error results due to the measurement of on times being conducted during the late summer. The smaller errors are estimated at a maximum of ±10% in aggregate. The larger error sources can significantly affect savings.

Accuracy and Equipment

The spot electrical measurements are to be performed with a Wavetek Meterman, AC38, digital multimeter with and accuracy of 1.2%. Monitoring of electrical equipment will be performed with Dent DATApro logger, which uses a PC serial interface for data transfer; all data will be exported to a MS Excel format. These loggers have a resolution of 1 minute, and, for the purposes of the evaluation, are 1.5% accurate (including current transformers, or CTs).

Monitoring of temperatures will be performed with HOBO Temperature Data Loggers, with an estimated accuracy of ±0.33°F.

Other collected data and reported data are considered to be 95% accurate, where the reviewed data is deemed reasonable.

Annualizing the cooling run time data and the fan run time data from a monitoring period is projected to result in a possible error in the final results of ±15%.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 17, 2007. Information was collected from equipment nameplate, spot power checks, and interviews with hotel staff. Several guest rooms were entered to examine FCUs and thermostat setpoints. However, hotel staff refused to allow equipment monitoring. Data was instead collected from thermostat software. Some modifications from the M&V plan were therefore necessary. These changes are discussed in this section of the report.

Installation Verification

Two guest rooms were surveyed during the on-site visit; both had occupancy-sensor programmable thermostats installed. Each guest room thermostat is connected to a central computer system, and is monitored by Inncontrol II software. The software communicates the room's rental status with the thermostats. Door sensors and occupancy sensors in the guestroom are used to determine activity in guest rooms. When a guest room door is closed, the occupancy sensor looks for activity in the room. If there is room activity, the thermostat enters occupied mode, wherein the thermostat operates within a ±2°F temperature range of the set target temperature. If the door is closed and the room has no activity for a period of 10 minutes, the thermostat reverts to its unoccupied mode. If the room is rented and unoccupied the temperature is allowed to swing within ±5°F of the target temperature set point. If the room is unrented and unoccupied, the temperature is allowed to swing within ±10°F of the target temperature set point. The limits of the allowable set points and ranges are 50°F and 90°F.

The verification realization rate for this project is 1.0. A verification summary is shown in Table 8 below.

Summary of Results

The hotel staff would not allow any installation of monitoring equipment. The guestrooms FCUs and thermostats are connected to a computer program. This program records all activities in each guestroom. As an alternate to monitoring data, hotel staff was able to provide printouts from the Inncontrol II system for several guest rooms. The printouts were for four rooms from September 13, 2007 to September 17, 2007 and an additional four rooms October 8, 2007 to October 15, 2007. The OA_{db} during these periods ranged from 54°F to 84°F. The printouts included room rental status, occupancy, actual room temperature, allowable temperature window, and FCU activity (heating, cooling and fan). The data provided was more detailed than monitoring equipment could have provided. Unfortunately, the only format that could be provided was graphical printouts. This data was manually entered into an Excel file for analysis. In addition to not allowing monitoring equipment to be installed, the hotel staff refused to allow any of the guestrooms thermostat settings to be changed. Therefore no data could be collected to simulate base case manual thermostats. Adjustments were made from the data that was collected to account for this change.

According to hotel staff, one chiller is sufficient for a majority of the year and the stand-by chiller operates only a few days out of the year. The chilled water is supplied through a single primary loop system. Heat rejection for the central plant is provided by two evaporative cooling towers. The majority of the equipment, including the chillers and cooling towers, are original to the 20 year-old building. It is estimated that the cooling plant operates at an efficiency of 1.0 kW/ton.

Heating for the building is provided by three identical hot water boilers. The boilers each have a rated output capacity of 1.258 MMBtu/hr and a nameplate efficiency of 83.9%. The boilers are shut off when the outside air temperature (OA_{db}) is greater than 60°F. Therefore, heating is not provided to guestrooms when outside air is greater than 60°F.

Ex ante calculations use an assumed FCU fan motor horsepower. This is a factor that was verified during the on-site visit. Ex ante savings utilized a nameplate capacity of 1/20-hp, and a demand of 0.053kW for calculations. The on-site survey found that the nameplate capacity is 1/20-hp. The new thermostats control the fan motors at three speeds (high, medium, and low). Spot readings were taken at all three speeds, providing 0.055 kW, 0.0415 kW, 0.028 kW, respectively. The fan speed is determined by the thermostat set point and room temperature. The manual thermostats had manual fan control options. Therefore, it is not possible to simulate the manual thermostat fan speed, and determine the time spent at each particular speed. For ex post calculations, the medium speed power was used (0.415 kW).

The data provided includes several useful parameters for the ex post analysis including rental status, occupancy, and FCU activity. Initially, correlations between OA_{db} and FCU activity were analyzed. A majority of the guests are business travelers and guestrooms are typically vacant during the day. Vacant rooms enter a temperature setback so a correlation to OA_{db} and FCU activity is not useful. Instead, FCU activity was related to OA_{db} in terms of room occupancy. By splitting data into occupied and unoccupied periods, the following correlations were calculated:

Figure 1: Percent Time Cooling in Occupied Rooms (monitoring data)

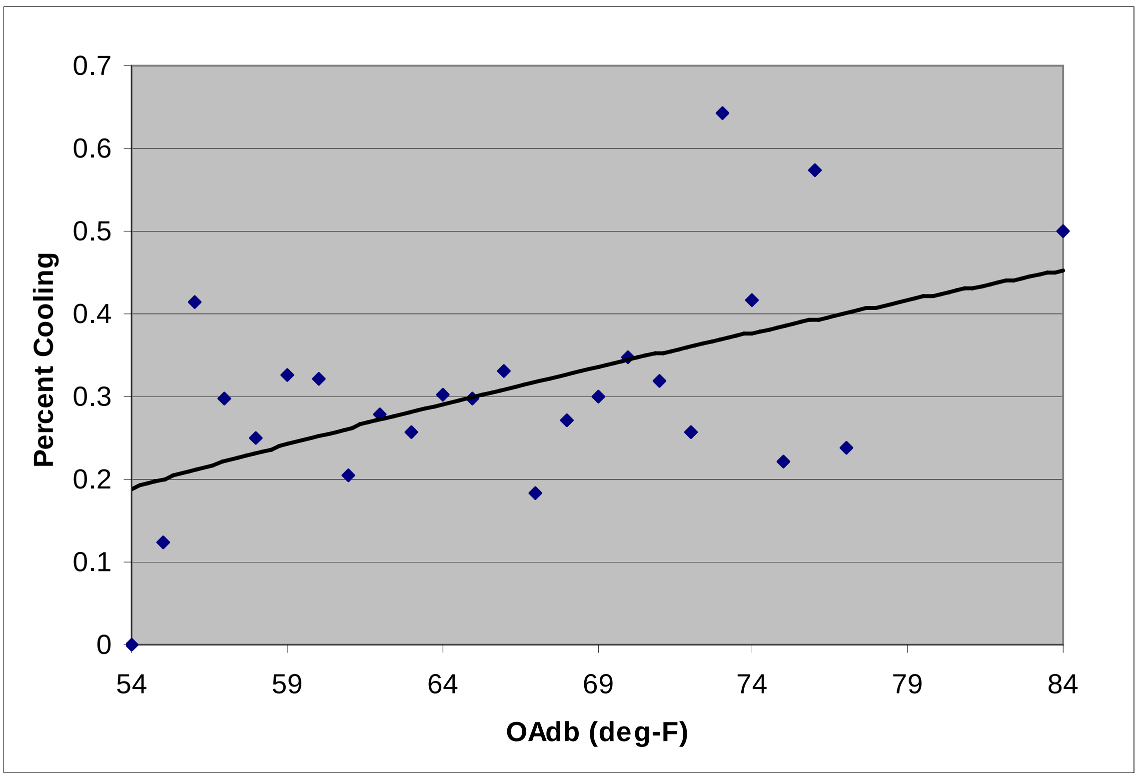


Figure 2: Percent Time Fan only in Occupied Rooms (monitoring data)

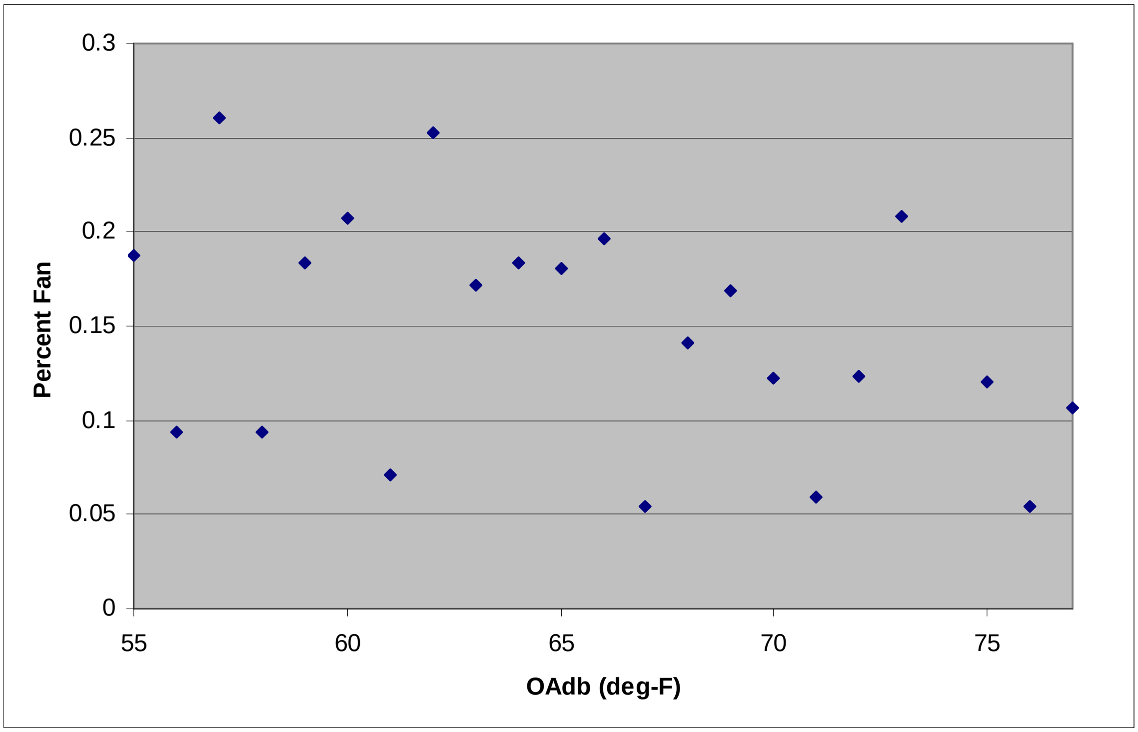


Figure 3: Percent Time Cooling in Unoccupied Rooms (monitoring data)

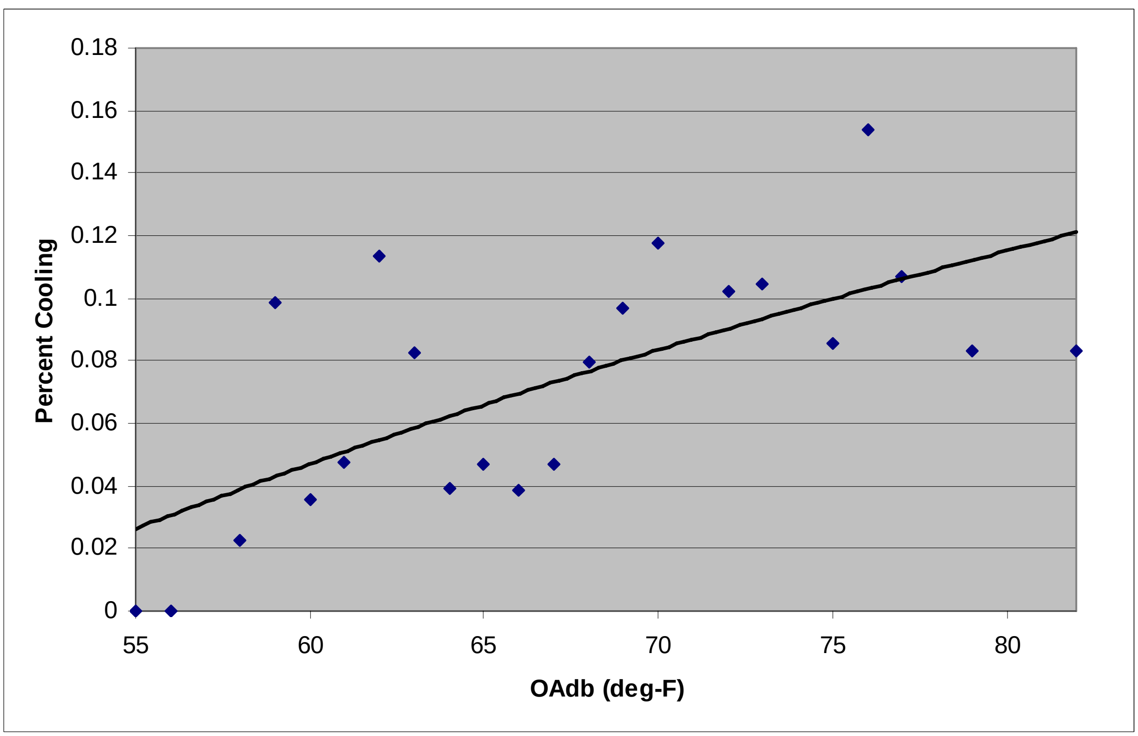
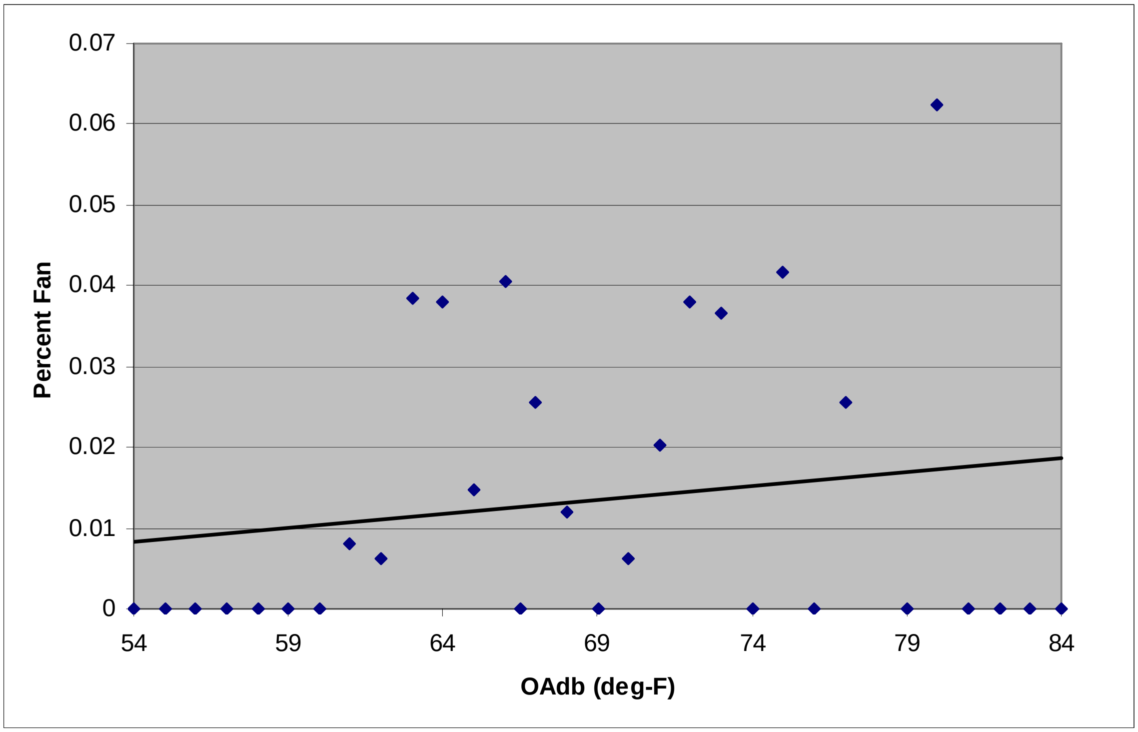


Figure 4: Percent Time Fan Only in Unoccupied Rooms (monitoring data)



Cooling correlations:

$$\text{percent cooling}_{\text{occupied}} = 0.5968\ln(OA_{db}) - 2.1915 \qquad \text{Eq. 6}$$

$$\text{percent cooling}_{\text{unoccupied}} = 0.237\ln(OA_{db}) - 0.9235 \qquad \text{Eq. 7}$$

Fan only correlations:

$$\text{percent fan}_{\text{unoccupied}} = 0.0003(OA_{db}) - 0.0105 \qquad \text{Eq. 8}$$

$$\text{percent fan}_{\text{occupied}} = 0.1472 \qquad \text{Eq. 9}$$

Minimal data related to heating was collected. Therefore, monitoring data from another site with identical thermostatic controls and similar FCUs are used with the same air flow. Heating savings are not a large contributor to overall savings and using heating correlations from another similar site will introduce some inaccuracy, but relative to the entire savings, this will be minimal. The site is located in a climate zone which has mild conditions and heating is minimal. Also, cooler OA temperatures are at night, when most heating is needed. Room occupancy in rented rooms is high during nighttime period, so savings are low.

The ex post savings analysis uses hourly TMY OA_{db} data for the relevant climate zone. For each hour, average FCU activity is calculated. Guest room FCUs have four factors that are calculated for each interval, percent cooling, percent fan only, percent heating, percent total fan. The percent fan only is while the fan is running without heating or cooling. The percent total fan is the percent that the fan is running, independent of other FCU activity. Each interval calculates the FCU activity for guest rooms with respect to occupancy and control type.

As previously mentioned, the FCU activity data provided by hotel staff included guest room rental status as well as room occupancy. When analyzing guest room data with respect to FCU activity, it was apparent that there is a stronger correlation to room occupancy than rental status. Therefore, all of the percent cooling, percent fan, and percent heating factors are calculated based on room occupancy. Room occupancy in rented rooms is summarized in Table 3. Rooms that are not rented are assumed to be unoccupied. It should be noted that there is lower occupancy during off-peak periods, and this is considered in ex post calculations. Monthly hotel occupancy rates were used to calculate the percentage of rooms that will be occupied and unoccupied for each hourly interval. Monthly occupancy rates are summarized in Table 4.

Table 3: Percent of Occupancy in Rented rooms

Period	Percent occupancy
Off Peak	56.2%
Peak	31.3%
Average	**43.8%**

Table 4: Typical Monthly Average Occupancy Rate

Month	Average Occupancy
Jan	70.7%
Feb	72.4 %
Mar	76.0%
Apr	76.6%
May	73.2%
Jun	77.5%
Jul	79.6%
Aug	75.4%
Sep	74.6%
Oct	71.8%
Nov	70.7%
Dec	60.9%
Average	**73.3%**

Table 5: Base Case, Manual Thermostat Activity during Occupied Periods

Parameter	Equation	Restrictions	Source
% cooling	$\% \text{ cooling} = 0.5968 \ln(OA_{db}) - 2.1915$	OA_{db}>55°F	Occupied
% fan only	$\% \text{ fan} = 0.1472$	none	Occupied
% heating	$\% \text{ heating} = (0.0001\,OA_{db}^{2}) - (0.0101\,OA_{db}) + 0.3798$	OA_{db}<60°F	monitoring data from other site
% fan (total)	$\% \text{ fan total} = \% \text{ cooling} + \% \text{ fan} + \% \text{ heating}$	none	sum of all FCU activity

Table 6: Base Case, Manual Thermostat Activity during Unoccupied Periods

Parameter	Equation	Restrictions	Source
% cooling	$\% \text{ cooling} = 0.237 \ln(OA_{db}) - 0.9235$	OA_{db}>55°F	Unoccupied
% fan only	$\% \text{ fan} = 0.0003(OA_{db}) - 0.0105$	none	unoccupied
% heating	$\% \text{ heating} = (0.0001\,OA_{db}^{2}) - (0.0101\,OA_{db}) + 0.3798$	OA_{db}<60°F	monitoring data from other site
% fan (total)	$\% \text{ fan total} = \% \text{ cooling} + \% \text{ fan} + \% \text{ heating}$	none	sum of all FCU activity

Table 7: Post Case, Setback Thermostat Activity during Occupied Periods

Parameter	Equation	Restrictions	Source
% cooling	$\% \text{ cooling} = 0.5968 \ln(OA_{db}) - 2.1915$	OA_{db}>55°F	occupied
% fan only	$\text{percent fan}_{unoccupied} = 0.0003(OA_{db}) - 0.0105$	none	occupied
% heating	$\% \text{ heating} = 0.033$	OA_{db}<60°F	Monitoring data from other site
% fan (total)	$\% \text{ fan total} = \% \text{ cooling} + \% \text{ fan} + \% \text{ heating}$	none	Sum of all FCU activity

Table 8: Post Case, Setback Thermostat Activity during Unoccupied Periods

Parameter	Equation	Restrictions	Source
% cooling	$\%\ \text{cooling} = 0.5968\ \ln(OA_{db}) - 2.1915$	OA_{db}>55°F	unoccupied
% fan only	$\text{percent fan}_{\text{unoccupied}} = 0.0003(OA_{db}) - 0.0105$	none	unoccupied
% heating	$\%\ \text{heating} = 0.022$	OA_{db}<60°F	Monitoring data from other site
% fan (total)	$\%\ \text{fan total} = \%\ \text{cooling} + \%\ \text{fan} + \%\ \text{heating}$	none	Sum of all FCU activity

The ex post savings analysis calculates energy consumption for each TMY hourly interval based on the equations above. Using Equations 1 through 5, the energy consumption for all rooms is:

Heating energy consumption (therms) for occupied rooms:

$$= (557\ \text{FCUs})(\text{room occ rate})(\%\ \text{heating}_{\text{occupied}})\left[\frac{(\Delta T)(\text{FCU airflow})(1.1)}{(\text{boiler efficiency})}\right]\frac{\text{therm}}{100{,}000\ \text{Btu}} \qquad \text{Eq. 10}$$

Heating energy consumption (therms) for unoccupied rooms:

$$= (557\ \text{FCUs})(1 - \text{room occ rate})(\%\ \text{heating}_{\text{unoccupied}})\left[\frac{(\Delta T)(\text{FCU airflow})(1.1)}{(\text{boiler efficiency})}\right]\frac{\text{therm}}{100{,}000\ \text{Btu}} \qquad \text{Eq. 11}$$

Cooling energy consumption (kWh) for occupied rooms:

$$= (557\ \text{FCUs})(\text{room occ rate})(\%\ \text{cooling}_{\text{occupied}})\left[\frac{(\Delta T)(1.08)(\text{FCU cfm})(\text{chiller plant kW/ton})}{(12{,}000\ \text{Btu/ton})}\right] \qquad \text{Eq. 12}$$

Cooling energy consumption (kWh) for unoccupied rooms:

Eq.13

$$= (557\ \text{FCUs})(1 - \text{room occ rate})(\%\ \text{cooling}_{\text{unoccupied}})\left[\frac{(\Delta T)(1.08)(\text{FCU cfm})(\text{chiller plant kW/ton})}{(12{,}000\ \text{Btu/ton})}\right]$$

Fan energy consumption (kWh) for occupied rooms:

$$= (557\ \text{FCUs})(\text{room occ rate})(0.0415\ \text{kW/fan})(\%\ \text{fan}_{\text{occupied}}) \qquad \text{Eq. 14}$$

Fan energy consumption (kWh) for unoccupied rooms:

$$= (557\ \text{FCUs})(1 - \text{room occ rate})(0.0415\ \text{kW/fan})(\%\ \text{fan}_{\text{unoccupied}}) \qquad \text{Eq. 15}$$

Peak demand is calculated as the average kW during peak periods. Peak demand reduction is the difference between the calculated demand during peak periods for pre-retrofit and setback scenarios. Similarly, the energy savings is the difference between the energy consumption before the occupancy-based thermostats were installed and with the occupancy thermostats in operation. A summary of the ex post savings results are in Tables11 through 17.

The engineering realization rate for this application is 0.15 for kWh energy savings. A summary of the realization rate is shown in Table 18.

Table 9: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1,453.4	6,677,228
Baseline End Use	116.2	626,506
Ex Ante Savings	-	2,279,801
Ex Post Savings	52.7	331,907

Table 10: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	-	34.1%	3.6%	5.0%
Baseline End Use %	-	363.9%	45.4%	53.0%

6. Additional Evaluation Findings

As previously mentioned the ex ante savings are not applicable for this measure. Ex ante savings values are very high value when compared to the total meter values. The ex post savings values are based on actual guest room data. Hotel staff refused to allow monitoring of FCU equipment, and accuracy of the data collected was limited. However, the data that was provided offered insight to factors that would not have been revealed under the existing M&V plan. Specifically, the hotel room occupancy as it relates to FCU activity in rented rooms was particularly revealing. The M&V approach would have linked the FCU activity to room rental status, not occupancy. As this measure is geared towards saving energy in rooms while they are unoccupied, this allows for a much more accurate way to view heating, cooling and fan operation.

There are some factors in the ex post analysis that contribute to the uncertainty of the savings. The best estimates were applied to minimize the propagation of uncertainty in ex post savings calculations. One of these factors is the time spent at a particular fan speed. This will relate to the weighted average fan power. The median value of 0.415 kW was used (with a possible range of ±50%). Other factors that cannot be accounted for are yearly fluctuations from TMY weather data and hotel occupancy. A summary of possible ranges of the primary variables is provided in Section 4.

7. Impact Results

Table 11: Annual Average Rental and Occupancy Rates

Rental rate	73.3%
Occupied	38.2%
Unoccupied	61.8%

Table 12: Actual FCU Activity

FCU Activity	data unoccupied	data occupied
Percent cooling	5.4%	24.2%
Percent fan	0.8%	14.7%
Percent heating	1.2%	0.8%

Table 13: Annual Average Extrapolated FCU Activity, Manual Thermostats

FCU Activity	Occupied	Unoccupied
Percent cooling	24.2%	24.2%
Percent fan only	14.7%	14.7%
Percent heating	4.5%	5.0%
Percent fan total	43.4%	43.9%

Table 14: Annual Average Extrapolated FCU Activity, Setback Thermostats

FCU Activity	Occupied	Unoccupied
Percent cooling	24.2%	5.4%
Percent fan	14.7%	0.8%
Percent heating	1.3%	2.2%
Percent fan total	40.2%	8.5%

Table 15: Annual Average Extrapolated Energy consumption, Occupied Periods

Consumption	Base	Post	Reduction
cooling (kWh)	185,712	185,712	0
heating (therms)	12,831	3,680	9,151
fan (kWh)	90,911	32,492	58,419
peak (kW)	54.6	46.8	7.7

Table 16: Annual Average Extrapolated Energy consumption, Unoccupied Periods

Consumption	Base	Post	reduction
cooling (kWh)	293,132	65,518	227,614
heating (therms)	14,257	6,333	7,923
fan (kWh)	56,752	10,878	45,873
peak (kW)	61.6	16.6	45.0

Table 17: Annual Average Extrapolated Energy consumption, Totals

Consumption	Base	Post	reduction
cooling (kWh)	478,845	251,230	227,614
heating (therms)	27,087	10,013	17,075
fan (kWh)	147,662	43,370	104,292
peak (kW)	116.2	63.5	52.7
Total kWh	**626,507**	**294,600**	**331,907**

Table 18: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	-	2,279,801	-
SPC Installation Report (ex ante)	-	2,279,801	-
Impact Evaluation (ex post)	52.7	331,907	17,075
Engineering Realization Rate	-	0.15	-

Table 19: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings, $ ($0.13/kWh, $1.10/therm)	SPC Incentive, $	Simple Payback w/ incentive, yrs
Installation Approved Amount (Ex Ante)	3/2/2005	$93,001	0	2,279,801	0	296,374	30,078	0.2
SPC Program Review (Ex Post)	11/2/2005	$93,001	52.7	331,907	17,075	61,930	30,078	1.0

Table 20: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
HVAC OCCUPANCY SENSOR	O - Other			INNCOM e4 Smart Digital Thermostat	557	INNCOM e4 Smart Digital Thermostat	Physically inspected several guest rooms, and made sure units were in use	1.0

Table 21: Multiple Year Reporting Summary

Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program MW Savings	Ex-Post Gross Evaluation Projected Peak MW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	1,899,834	276,589		52.7		14,229
3	2006	2,279,801	331,907		52.7		17,075
4	2007	2,279,801	331,907		52.7		17,075
5	2008	2,279,801	331,907		52.7		17,075
6	2009	2,279,801	331,907		52.7		17,075
7	2010	2,279,801	331,907		52.7		17,075
8	2011	2,279,801	331,907		52.7		17,075
9	2012	2,279,801	331,907		52.7		17,075
10	2013	2,279,801	331,907		52.7		17,075
11	2014	2,279,801	331,907		52.7		17,075
12	2015	2,279,801	331,907		52.7		17,075
13	2016	379,967	55,318				2,846
14	2017						
15	2018						
16	2019						
17	2020						
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	25,077,811	3,650,977				187,825

FINAL SITE REPORT

SITE A056 (04-470) Prim IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 1 END USE: /Other

Measure	Comprehensive Air Compressor System Retrofit
Site Description	Manufacturing

1. Measure Description

Retrofit compressed air system. Replace two 300 HP single stage lubricant injected rotary screw compressors with one 300 HP two stage lubricant injected rotary screw VFD driven compressor and one 300 HP two stage lubricant injected rotary screw load/unload controlled compressor. Replace one 350 HP single stage lubricant injected rotary screw compressor with one 350 HP two stage lubricant injected rotary screw compressor. Separate manufacturing area into three zones. Install new distribution piping, intermediate pressure controllers, sequencing controller, and 50,000 gallons of air storage.

2. Summary of the Ex Ante Calculations

The ex ante calculations were performed using values from data submitted with the application, manufacturer's specifications, and methodologies based on the Department of Energy's Compressed Air Challenge (CAC).

In the installation report the reviewer noted that the installed measures were different than what had been submitted in the original application. Only one of the new 300 HP compressors was installed with a VFD where both the new 300 HP compressors were originally expected to have VFDs. Another one of the existing 350 HP compressors failed and was replaced with a high efficiency compressor of equal capacity. One of the compressors originally slated for replacement was retained due to increased production. The energy savings calculations were adjusted accordingly. The reviewer's calculations show that the compressed air plant operates 8,400 hours annually.

According to the installation report, the average baseline efficiency was 0.314039 kW/CFM. The average measured post installation efficiency was 0.199645 kW/CFM. The average pre retrofit flow was 7,266.58 CFM.

The annual kWh savings were calculated as follows:
(0.314039 kW/CFM- 0.199645 kW/CFM) x 7,266.58 CFM x 8,400 hours = 6,982,527 kWh.

The demand reduction calculation is not shown in the calculation but it is implied to have come from an AIRMASTER+ simulation that used the actual pre-retrofit air consumption measured to estimate the demand impacts. The analysis was complicated by the fact that the post installation air flow had increased. We are unable to duplicate the demand reduction calculation but it appears to be reasonable.

The average kW impact based on the ex ante calculations would be 831 kW, derived as follows:
(0.314039 kW/CFM- 0.199645 kW/CFM) x 7,266.58 CFM = 831 kW.

The ex ante peak demand reduction is shown as 238 kW. This equates to 29% (238 kW/831 kW) of the average demand reduction and seems reasonable.

The Installation Report states that the ex ante savings are 6,982,527 kWh annually and demand reduction is 238 kW. These values agree with the tracking system data.

3. Comments on the Ex Ante Calculations

The ex ante calculations were performed using methodologies based on the Department of Energy's Compressed Air Challenge (CAC). The reviewer did a good job of presenting the calculations in a transparent and comprehensible format. The reviewer made an effort to verify the pre-retrofit and post-retrofit conditions and to ensure that the calculations were an accurate reflection of the installed equipment. The reviewer required that post installation data be collected by the customer. Eight days of post installation data were collected. The reviewer noted that air consumption had increased during the post retrofit monitoring period, but used the pre retrofit air consumption to calculate the ex ante impact.

4. Measurement & Verification Plan

According to the application, prior to the retrofit there were eight air compressors operating to satisfy the main plant demand. Two new 300 HP compressors were added to the system, and one of the existing compressors was relegated as a backup unit. While the project was under construction, one of the existing compressors failed and was replaced with a new high efficiency compressor of equal capacity.

The application states that a lack of a common control for the eight existing compressors created operating conflicts with the independent compressor controls. Each compressor tried to modulate around its individual set point, however, since each was receiving a control signal from different points in a dynamic system, they received different pressure signals.

As the compressors satisfied plant demands, each compressor started to modulate (reduce output), while not significantly reducing energy consumption. This was the single largest factor in the pre retrofit system inefficiency.

The application provides an estimated air usage profile that shows the compressed air plant operating 24 hours/day, 7 days per week, shutting down for two weeks in July, and December (approximately 8,400 hours annually).

The project saves energy with the installation of a central “common” control system that will automatically add “base load” (not modulating) compressors as required, and use a VFD compressor in a permanent “trim” position. Additional savings are associated with higher efficiency compressors, new distribution piping, intermediate pressure controllers and the additional storage capacity.

According to the customer’s representative, there have been significant changes to the plant since the project was completed. Approximately 12 months ago, a 300 HP compressor was added to the system to meet increased capacity needs. Two (2) months ago, two 350 HP compressors were added to the system to meet the demands of a new building adjacent to the existing plant.

The customer’s representative stated that the project that is documented in this application included the installation of a central monitoring and control system. The control system logs the air flow at 4 flow stations and kW consumption at each compressor.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit hours of operation, air usage profile, and the compressor energy consumption.

The goal of the M&V plan is to verify the kW and kWh consumed by the compressed air system at the completion of the project documented in the application and prior to the changes to the system after the project was completed, as discussed above, over the useful life of the measure.

Formulae and Approach

The M&V plan is a modified version of IPMVP Option B.

The installation contractor monitored the compressor kW and air consumption for approximately 7 days prior to the retrofit. A summary of the data is included in the application. During this period the average air flow was 7,266.58 scfm and the average power was 2,294 kW. This equates to 0.316 kW/scfm. The reviewer made some minor adjustments to the baseline and the application documents state that the baseline is 0.314039 kW/scfm.

We will obtain stored data on the customer’s control system for a 7 day period following the completion of the project and before the changes to the system noted above. The customer stated that the control system measures air flow and kW in 10 second intervals. The data will be averaged and the post retrofit kW/scfm calculated.

The energy consumption of this measure is not greatly affected by the outside air temperature. To estimate peak demand kW reduction, the expected reduction in connected kW due to the increased compressor efficiency during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in the week with the hottest weekday in June, July, August, September will be determined by calculating the average kW reduction from 2 pm to 5 pm, Monday to Friday during the 7 day period.

The formulae and methodology for the calculations are summarized as follows:

To determine post-retrofit compressor kW/scfm

Average the kW and scfm readings over a 168 hour (7 days) period.
Calculate average kW/scfm for 168 hours.

Estimate the annual post retrofit kWh

Multiply the 168 hour kW/scfm x average cfm (pre-retrofit) x 52.14 weeks/year to obtain annual kWh (accounting for holidays and plant shutdowns if appropriate).

Estimate the annual pre retrofit kWh

Multiply the 168 hour kW/scfm (pre-retrofit) x average cfm (pre-retrofit) x 52.14 weeks/year to obtain annual kWh (accounting for holidays and plant shutdowns if appropriate).

Estimate the annual savings kWh
=
Subtract the post retrofit annual kWh from the pre retrofit kWh.

Estimate peak demand kW reduction

Accept the ex ante result as a baseline and adjust in proportion to the engineering realization rate for annual kWh.

Uncertainty for the savings estimate can be more fully understood by setting projected ranges on the primary variables.

<u>Air Compressor Retrofit</u>

- 2,294 kW pre-retrofit expected maximum demand, + 20% / - 20% (1,835-2,752 kW)
- 8,400 operating hours pre retrofit expected, +4% / - 10% (7,560-8,760 hours)
- Air usage: 7,300 cfm average +/- 30% (5,110-9,490 cfm)

Accuracy and Equipment
The customer’s EMON power measurement has error of less than 3%. The customer’s air flow measurement instrumentation manufactured by Sage, has an error of 5 to 10 %. Annualizing the seven day measurement period is estimated to be +/- 10% accurate.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 14, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the air compressor system and by interviewing the facility representative. Air compressor make, model, quantities and hours of operation were verified. We also verified that the distribution piping had been replaced and that intermediate pressure controllers, a sequencing controller, and 50,000 gallons of air storage were installed.

We had anticipated obtaining monitoring data for the compressed air system from a period prior to the installation of the additional air compressors described above. Unfortunately, the customer's data collection system did not archive the data from this time period. The customer provided 168 hours of monitoring data for the compressed air system beginning on Thursday October 4, 2007 and ending Wednesday October 10, 2007. Power consumption and air flow was measured on the system in 10 second intervals. The customer stated that this period is an accurate representation of the current facility operation. We used this data for the ex post analysis.

The building is occupied continuously and the compressed air system is always energized except during holidays. Maximum occupancy is approximately 250 employees at any given time. The facility is closed 9 holidays annually.

Installation Verification

The facility representative verified that two 300 HP single stage lubricant injected rotary screw compressors were replaced with one 300 HP two stage lubricant injected rotary screw VFD driven compressor and one 300 HP two stage lubricant injected rotary screw load/unload controlled compressor. We verified that both the new compressors are Ingersoll Rand Model SSR-EPE300-25, and one of the compressors is VFD driven. We also verified the installation of the new distribution piping, intermediate pressure controllers, a sequencing controller, and 50,000 gallons of air storage.

These are the only measures in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 6 below.

Scope of the Impact Assessment

The impact assessment scope is for the process/other end use measure in the SPC application covering the air compressor system retrofit. These are the only measures in this application.

Summary of Results

Power consumption and air flow data for the compressed air system was obtained from the customer. The data was provided in 10 second intervals for 168 hours, beginning at 12 a.m. on October 4, 2007. Input power ranged from 2,211 kW to 2,667 kW, with an average of 2,559.1 kW. Total system output ranged from 9,007 scfm to 29,638 scfm, with an average of 12,410.4 scfm. The average system efficiency over the 168 hour period was 0.2062 kW/scfm. A summary of the data is shown in Table 1.

Table 1: Summary of Monitoring Data October 4-October 10, 2007

		Total kW from Compressors			Total SCFM from Compressors			Average System Efficiency
Day	Date	Min.	Avg.	Max.	Min.	Avg.	Max.	kW/SCFM
Thursday	10/4/07	2,299.6	2,550.1	2,640.9	9,115	12,435	21,216	0.2051
Friday	10/5/07	2,337.3	2,563.7	2,651.8	9,473	12,541	29,638	0.2044
Saturday	10/6/07	2,330.7	2,571.0	2,664.7	9,279	12,631	16,109	0.2035
Sunday	10/7/07	2,338.9	2,563.1	2,660.3	9,007	12,527	28,883	0.2046
Monday	10/8/07	2,211.1	2,534.6	2,652.9	8,756	12,068	18,997	0.2100
Tuesday	10/9/07	2,255.4	2,565.4	2,661.8	9,030	12,219	29,040	0.2100
Wednesday	10/10/07	2,336.4	2,566.0	2,667.1	9,183	12,452	15,688	0.2061
Average			**2,559.1**			**12,410.4**		**0.206208**

The facility representative stated that the period monitored was reflective of average facility operation.

- The pre-retrofit baseline compressor system efficiency was 0.314039 kW/scfm.

- The annual hours of operation are 8,544 hours/year:
  (365 days-9 days) x 24 hours/day = 8,544 hours/year

- The ex post kWh impacts are 6,694,759 kWh/year:
  (0.314039 kW/scfm-0.206208 kW/scfm) x 7,266.58 scfm x 8,544 hours/year = 6,694,759 kWh/year

Summer peak demand reduction impacts were estimated by using the ex ante result as a baseline and adjusting in proportion to the engineering realization rate for annual kWh. The ex post demand reduction is 228 kW
238 kW x (6,694,759 kWh/6,982,527 kWh) = 228 kW.

The engineering realization rate for this application is 0.96 for demand kW reduction and 0.96 for energy savings kWh. A summary of the realization rate is shown in Table 5.

Utility billing data for the site was provided in the application. For the period January 2006 to December 2006, pre-retrofit annual consumption was 61,470,732 kWh. Peak demand was 7,459 kW. Table 2 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility provided numbers.

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 3.2% decrease in total meter kW, a 10.4% decrease in compressor end use kW, a 11.4% decrease in total meter kWh, and a 35.8% decrease in compressor system end use kWh. The ex post results showed a 3.1% decrease in total meter kW, a 10% decrease in compressor end use kW, a 10.9% decrease in total meter kWh, and a 34.3% decrease in compressor end use kWh.

Table 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	7,459	61,470,732
Baseline End Use	2,282	19,497,318
Ex ante Savings	238	6,982,527
Ex Post Savings	228	6,694,759

Table 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	3.2%	11.4%	3.1%	10.9%
Baseline End Use %	10.4%	35.8%	10.0%	34.3%

6. Additional Evaluation Findings

We determined that the ex post annual kWh and demand kW are less than the ex ante because the system efficiency measured from October 4-October 10, 2007 is approximately 3% less (0.206208 kW/scfm vs. 0.199645) than the data measured at the completion of the project in September 2005.

The facility representative stated that the cost estimate provided in the application ($1,355,273) is from the invoice for the work performed for the project and is an accurate reflection of the project cost. In addition to saving energy, the benefits of the project are quieter compressor operation and a more constant pressure in the compressed air line.

There have been significant changes to the plant since the project was completed. Approximately 12 months ago, a 300 HP compressor was added to the system to meet increased capacity needs. Two months ago, two 350 HP compressors were added to the system to meet the demands of a new building adjacent to the existing plant. The ex post analysis has shown that the system efficiency documented in the application has essentially remained the same as it was at the completion of the project documented in the application evaluated.

Participation in the 2004/2005 SPC Program has not encouraged the customer to perform any other energy efficiency projects without participating in an incentive program.

The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measure.

With a cost of $1,355,273 and a $500,000 incentive, the project had a 0.94 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 0.98 years. A summary of the economic parameters for the project is shown in Table 4.

The customer has continued to make changes to the compressed air system since the completion of the project documented in the application. Some of the changes to the compressed air system have been documented in SPC applications submitted after this measure was installed. Our analysis has shown that the compressed air system efficiency has remained essentially equal to that documented in this application and therefore the multi-year impacts, shown in Table 7 below, are expected to remain constant over the life of the equipment.

7. Impact Results

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	9/9/2005	$1,355,273	238.0	6,982,527	0	$907,729	$500,000	0.94	1.49
SPC Program Review (Ex Post)	8/18/2007	$1,355,273	228.0	6,694,759	0	$870,319	$500,000	0.98	1.56

Table 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	238.0	6,982,527	-
SPC Installation Report (ex ante)	238.0	6,982,527	-
Impact Evaluation (ex post)	228.0	6,694,759	-
Engineering Realization Rate	0.96	0.96	NA

Table 6: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Process- OTHER	O			Replace two 300 HP rotary screw air compressors with one VFD driven 300 HP rotary screw air compressor and one 300 HP load unload compressor. Install new distribution piping, intermediate pressure controllers, sequencing controller, and 50,000 gallons of air storage	2	Ingersoll Rand Model SSR-EPE300-25 Compressors, Custom PLC for sequencing control, new piping, 50,000 gallon storage tank .	Physically verified compressor quantity and model, PLC sequencer, piping and storarge installation.	1.0

Table 7: Multi Year Reporting Table

Program ID	**SPC 2005 Application # A056**
Program Name	**2004-2005 SPC Application**

Year	Calendar Year	Ex-Ante Gross Program Projected kWh Savings	Ex post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program Projected Peak kW Reduction	Ex-Post Gross Evalaution Projected Peak kW Reduction	Ex-Ante Gross Program Projected Therm Savings	Ex post Gross Evaluation Confirmed Program Therm Savings
1	2004	0	0	0	0	0	0
2	2005	1,745,632	1,673,690	0	0	0	0
3	2006	6,982,527	6,694,759	238	228	0	0
4	2007	6,982,527	6,694,759	238	228	0	0
5	2008	6,982,527	6,694,759	238	228	0	0
6	2009	6,982,527	6,694,759	238	228	0	0
7	2010	6,982,527	6,694,759	238	228	0	0
8	2011	6,982,527	6,694,759	238	228	0	0
9	2012	6,982,527	6,694,759	238	228	0	0
10	2013	6,982,527	6,694,759	238	228	0	0
11	2014	6,982,527	6,694,759	238	228	0	0
12	2015	6,982,527	6,694,759	238	228	0	0
13	2016	6,982,527	6,694,759	238	228	0	0
14	2017	6,982,527	6,694,759	238	228	0	0
15	2018	6,982,527	6,694,759	238	228	0	0
16	2019	6,982,527	6,694,759	238	228	0	0
17	2020	5,236,895	5,021,069	238	228	0	0
18	2021					0	0
19	2022					0	0
20	2023					0	0
Totals	2004 - 23	104,737,905	100,421,385				

FINAL REPORT

SITE A057 (04-xxxx) CityofH IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: Lighting

Measure	1. Fixture Replacement 2. Occupancy Sensors
Site Description	Hospital (multiple buildings)

1. Measure Description

The customer completed a lighting replacement including over 8,000 fixtures and an occupancy sensor controls project that included over 5,000 fixtures. Both projects were completed in various locations throughout the facility (approximately 100 buildings). The project is broken down into two (2) calculated measures that received rebates through the SPC program. The installation report review dated July 2, 2005 identified them as measures M1 and M2, which were Lighting Replacement and Occupancy Sensor Controls, respectively.

Measure 1 is the replacement project that encompasses numerous buildings in their compound. A majority of the project includes replacing 1st Generation T-8 fluorescent fixtures with more efficient 3rd Generation T-8 fixtures. In addition, some incandescent fixtures were replaced with compact fluorescent fixtures of various sizes.

Measure 2 is the installation of both wall and ceiling mounted occupancy sensors in numerous rooms throughout their compound, including restrooms, hallways, offices, break rooms, conference rooms, and other intermittent use rooms.

The fixture retrofits and replacements save energy through increased efficacy and the occupancy sensors reduce energy usage through reduced hours of operation.

2. Summary of the Ex Ante Calculations

For these two calculated measures, a simple pre-retrofit and post-retrofit algorithm using fixture connected loads and hours of operation was used for the ex ante calculations. The calculation was performed using a customized spreadsheet. The SPC calculator was not used. Lighting fixture watts used in the calculation agree with the values in the SPC lighting fixture wattage tables. The ex ante calculation assumed annual hours of lighting operation from 2,080 to 8,736 hours of operation, depending on space type. Reduction in operation hours due to the occupancy sensors ranged from 15% to 45% depending on space type.

The ex ante baseline is the existing system connected load and hours of operation, and is in accordance with the SPC Program guidelines. Pre-retrofit and post-retrofit calculations of lighting loads and energy use were performed using the following formulae:

kW = Fixture watts / 1,000 W/kW x Fixture quantity kW Saved = kW pre-replacement – kW post-replacement

kWh Reduction for Fixture Replacement = kW Saved x Operating hours

kWh Reduction for Occupancy Sensors = kW x Operating hours x Percent off

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load. Note that the number below was obtained from the final spreadsheet, but does not match the number given on the Installation Report Review (86.9 Peak kW savings).

Peak kW savings is 658.4 kW – 572.7 kW = 85.7 kW

Note that these savings were split between the fixture replacement and occupancy sensor measures. However, the total amount should actually be attributed entirely to the fixture replacement in the ex ante calculations. Demand savings were not calculated due to the reduction in hours of use.

Average demand savings may be a useful estimate of kW savings due to the occupancy sensors. This number is calculated using the annual kWh savings due to the occupancy sensors divided by the weighted average annual hours of operation. Average demand savings (kWh / hours) for the occupancy sensors amounts to approximately 115 kW, calculated using the following formula.

Average kW savings is 463,930 kWh / 4,010 hours = 115.7 kW

Energy savings were calculated using the above formulas and a range of operating hours and fixture wattages depending on the particular space type.

The resulting total ex ante annual kWh savings is 365,671 kWh/yr + 463,930 kWh/yr= 829,601 kWh/yr.

This figure and 86.9 kW demand savings agree with the utility tracking system.

3. Comments on the Ex Ante Calculations

The ex ante calculations were performed according the SPC Program guidelines using customized spreadsheets, lighting fixture wattages equal to those shown in the SPC lighting wattage tables, and a percent reduction in operating hours comparable to those shown in the SPC Program Guidelines.

4. Measurement & Verification Plan

This facility is a medical campus that includes approximately 100 buildings. The hours of occupancy vary by space, ranging from 24/7 down to typical daytime office hours. Periods of peak occupancy are expected to occur Mondays through Fridays from 7:00 AM to 11:00 PM.

The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction due to the installation of fixtures to replace less efficient fixtures or to lower usage with occupancy sensor controls.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A – Partially Measured Retrofit Isolation. Fixture wattages are sufficiently defined in SPC standard wattage tables and manufacturer information. In addition, there is not expected to be significant seasonal variation, and two weeks should be sufficient for comparison; however, a longer period would more fully capture actual variations and the persistence of savings. Interval data on a 15-minute or less basis, preferably during the summer months of June to September, would be needed to accurately determine coincident peak period demand savings.

Pre-retrofit and post-retrofit calculations of lighting demand and energy usage will be calculated using the following formulae:

kW = Fixture watts / 1,000 watts / kW x Fixture quantity x Percent energized during peak demand period

kWh = kW x Operating hours x Percent energized

The most significant variables to be quantified are the pre-retrofit and post-retrofit hours of operation. Pre-retrofit hours will be confirmed with the site personnel to verify that the facility hours have not changed since the implementation of these measures.

For this application, we propose to verify the pre-retrofit fixture types, quantities and hours of operation with the facility representative. In addition, the new fixtures and occupancy sensors will be verified because these projects have a large degree of uncertainty associated with the hours of operation.

We will install no less than twenty-four (24) Hobo H8 Light Loggers throughout the facility in representative areas for the listed measures for a minimum of 7 days to verify the post retrofit hours of operation. These optically triggered loggers record lighting status (on or off).

The hours of operation determined from these loggers will then be used, along with the customer's description of hours of operation, to determine reasonable hours of operation for the areas not specifically metered.

Uncertainty for the savings estimate for the lighting retrofit can be more fully understood by setting projected ranges on the primary variables.

Pre-Retrofit

Fixture Replacement

- Total fixture demand of 521.22 kW, maximum of 539.67 kW, minimum of 502.76 kW (+/- 3.5%, based on judgment of deviation from typical fixture wattages in SPC standard wattage table).
- Total fixture energy use of 2,261,810 kWh, maximum of 2,670,068 kWh, minimum of 1,853,552 kWh (+/- 18.1%, based on judgment of deviation from listed space hours of use).

Occupancy Sensors

- Total fixture demand of 296.7 kW, maximum of 402.6 kW, minimum of 190.7 kW (+/- 35.7%, based on judgment of deviation from typical reduction in hours from the SPC occupancy sensor reduction table).

- Total fixture energy use of 1,189,596 kWh, maximum of 1,492,884 kWh, minimum of 886,307 kWh (+/- 25.5%, based on judgment of deviation from listed space hours of use).

Post-Retrofit

Fixture Replacement

- Total fixture demand of 435.51 kW, maximum of 450.97 kW, minimum of 420.06 kW (+/- 3.5%, based on judgment of deviation from typical fixture wattages in SPC standard wattage table).

- Total fixture energy use of 1,896,145 kWh, maximum of 2,239,136 kWh, minimum of 1,553,154 kWh (+/- 18.1%, based on judgment of deviation from listed space hours of use).

Occupancy Sensors

- Total fixture demand of 181.0 kW, maximum of 339.5 kW, minimum of 69.8 kW (+ 87.6%, - 61.4%, based on judgment of deviation from typical reduction in hours from the SPC occupancy sensor reduction table).

- Total energy use of 725,653 kWh, maximum of 1,334,943 kWh, minimum of 318,381 kWh (+ 84.0%, - 56.1%, based on judgment of deviation from listed space hours of use).

Savings

Fixture Replacement

- 85.70 kW expected savings, maximum 109.77 kW, minimum 61.63 kW (+/- 28.1%, based on pre and post-retrofit fixture expected deviation, and propagation of error method).

- 365,666 kWh expected savings, maximum 488,846 kWh, minimum 242,485 kWh (+/- 33.7%, based on pre and post-retrofit fixture expected deviation, and propagation of error method).

Occupancy Sensors

- 115.7 kW expected savings, maximum 217.1 kW, minimum 44.6 kW (+ 87.6%, - 61.4%, based on judgment of deviation from typical reduction in hours from the SPC occupancy sensor reduction table).

- Total energy use of 463,942 kWh, maximum of 853,488 kWh, minimum of 203,555 kWh (+ 84.0%, - 56.1%, based on judgment of deviation from listed space hours of use).

Total Combined

- 201.4 kW expected savings, maximum 305.6 kW, minimum 126.4 kW (+ 51.7%, - 37.3%, based on judgment of deviation from typical reduction in hours from the SPC occupancy sensor reduction table). Note this is more than what was shown on the Installation Report Review, due to the addition of demand savings attributed to the occupancy sensors.

- Total energy use of 829,608 kWh, maximum of 1,238,166 kWh, minimum of 541,554 kWh (+ 49.2%, - 34.7%, based on judgment of deviation from listed space hours of use).

Accuracy

The Hobo H8 lighting dataloggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable. The SPC lighting wattage tables and field verified fixture counts are considered to be 100% accurate.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate. The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 12, 2007. Information on the retrofit equipment and operating conditions was collected by inspection and by interviewing the facility representative. Lighting schedules were obtained using lighting on/off data loggers in a representative sample of buildings/spaces.

Installation Verification

The facility representative verified that the pre-retrofit fixtures were older first generation T-8 fixtures and did not have occupancy sensors.

It was physically verified (in a representative sample) that the new light fixtures were third generation T-8 fixtures and that occupancy sensors were installed. Not all spaces included in the project were visited, due to the large quantity of fixtures, rooms and buildings. The facility representative stated that the retrofit was completed by May 2005.

These are the only measures in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Lighting Retrofit	L	Replace older T8 fluorescent fixtures with new generation T8 fixtures. Install occupancy sensors in numerous buildings and rooms	Numerous	T8 Light Fixtures and Occupancy Sensors	Physically verified installation of a sample of fixtures and occupancy sensors	1.00

Scope of the Impact Assessment:

The impact assessment scope is for the installation of new T8 fixtures and occupancy sensors. These are the only measures in this application.

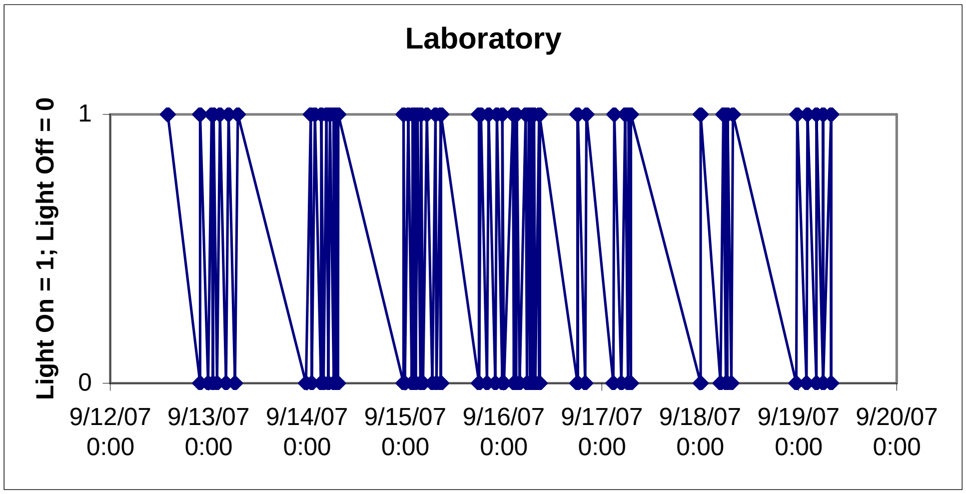
Summary of Results:

Hobo lighting on-off data loggers were placed in four buildings within the facility compound. Within each building, loggers were placed in five different rooms for a period of one week. Note that due to time constraints with the facility representative, only twenty total data loggers could be placed at the facility. A majority of the spaces were laboratories and offices, which comprised the most commonly sampled space. The facility representative stated that the monitoring period and buildings/spaces sampled is representative of normal facility operations. The facility representative stated that in general, portions of the buildings are occupied from approximately 7:00 a.m. to 6:00 p.m., 5 days per week. Some areas are occupied twenty-four hours per day, seven days per week.

Three of the twenty data-loggers indicated the lights were on the entire monitoring period, which is unlikely based on the facility/space usage and schedule. It is possible that the data was compromised by security lighting and/or other light sources. These data points were removed from the analysis. In addition, one logger was removed from its logging location by others and was not able to be recovered.

During the onsite visit it was determined that the vast majority of the fixtures being served by the occupancy sensors were in office space or laboratories. In addition, the majority of these spaces were served by multiple occupants. None of the spaces that had occupancy sensors installed had the lights off at the time of the verification. Based on the logged data, the fixtures with occupancy sensors only operated 4.7% less than fixtures without occupancy sensors. This is much less than predicted in the original analysis. A sample of data from a data-logger that was placed in a laboratory is shown in Figure 1.

Figure 1: Lighting On-Off Data Logging Results



For the fixture replacement project, the demand reduction was calculated by subtracting the total post-retrofit fixture demand from the total pre-retrofit fixture demand. The energy savings were calculated by multiplying this demand reduction by the hours of operation for fixtures without occupancy sensors as determined from the logged data.

For the occupancy sensor project, the energy savings was determined by multiplying the total demand of the fixtures by the hours of operation of fixtures without occupancy sensors as determined from the logged data and the average percent reduction in hours experienced by fixtures with occupancy sensors as observed from the logged data. The demand reduction was determined by dividing the energy savings by the original hours of operation of fixtures without occupancy sensors.

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load.

The ex post impacts are calculated in Figure 2 below:

Figure 2: Energy and Demand Formulae

Fixture Replacement

Pre-Retrofit Demand kW_{peak} = Existing Fixture Wattage x Number of Fixtures / 1,000

Post-Retrofit Demand kW_{peak} = New Fixture Wattage x Number of Fixtures / 1,000

Peak kW Savings = Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak}
= 560.66 kW – 474.96 kW = 85.70 kW

Pre-Retrofit kWh = Pre-Retrofit Demand x Hours
= 560.66 kW x 4,215 hours
= 2,363,421 kWh/yr (allowing for rounding)

Post-Retrofit kWh = Post-Retrofit Demand x Hours
= 474.96 kW x 4,215 hours
= 2,002,163 kWh/yr (allowing for rounding)

kWh Savings = Pre-Retrofit kWh – Post-Retrofit kWh
= 2,363,421 kWh/yr – 2,002,162 kWh/yr
= 361,258 kWh/yr

Occupancy Sensors

Pre-Retrofit kWh = Pre-Retrofit Demand x Hours
= 297.64 kW x 4,215 hours
= 1,254,690 kWh/yr (allowing for rounding)

Post-Retrofit kWh = Pre-Retrofit Demand x (Hours – Hours x % Reduction)
= 297.64 kW x (4,215 hours – 4,215 hours x 4.7%)
= 1,195,352 kWh/yr (allowing for rounding)

kWh Savings = Pre-Retrofit kWh – Post-Retrofit kWh
= 1,254,690 kWh/yr – 1,195,352 kWh/yr
= 59,338 kWh/yr

Peak kW Savings = Occupancy Sensor kWh Savings / Hours of Operation
= 59,338 kWh / 4,215 hours
= 14.08 kW

Total Savings

Peak kW Savings = 99.78 kW
kWh Savings = 420,596 kWh

Peak kW savings for the occupancy sensors is calculated above as average demand savings, but in the case of occupancy sensors can be assumed as peak demand savings.

The ex post energy savings is less than the ex ante energy savings because the ex ante calculations overestimated the average lighting on-hour reduction due to the occupancy sensor installation. The ex post demand savings are more than the ex ante demand savings because the ex ante calculations did not account for any demand reduction attributed to the occupancy sensors.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the vendor invoices for the work performed for the project and is an accurate reflection of the project cost. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program has not encouraged them to perform any other energy efficiency projects for which they did not participate in an incentive program.

We were unable to physically verify the pre-retrofit equipment or hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. Based on the collected data and discussions with the facility representative, the level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

7. Impact Results

Based on the ex ante savings of 829,601 kWh, the engineering realization rate for this application is 0.51 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 2.

Table 2: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	86.9	829,601	-
SPC Installation Report (ex ante)	86.9	829,601	-
Impact Evaluation (ex post)	99.8	420,596	-
Engineering Realization Rate	1.15	0.51	NA

Utility billing data for the site was reviewed. Annual usage prior to the retrofit was 41,357,827 kWh. Peak demand was 7,776 kW. Table 3 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 3: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	7,776.0	41,357,827
Baseline End Use	560.7	2,363,421
Ex ante Savings	86.9	829,601
Ex Post Savings	99.8	420,596

Table 4 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations.

Table 4: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	1.1%	2.0%	1.3%	1.0%
Baseline End Use %	15.5%	35.1%	17.8%	17.8%

With a cost of $185,990 and a $41,480 incentive, the project had a 1.34 year simple payback based on the ex ante calculations. Based on the number of fixture replacements and occupancy sensors, it appears that the project cost given in the tracking data is low. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 2.64 years. A summary of the economic parameters for the project is shown in Table 5.

Table 5: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	7/2/2005	$185,990	86.9	829,601	0	$107,848	$41,480	1.34	1.72
SPC Program Review (Ex Post)	9/25/2007	$185,990	99.8	420,596	0	$54,677	$41,480	2.64	3.40

It was determined that the lighting fixture replacement and occupancy sensor project was defined as Fluorescent Fixture – T8 and Occupancy Sensor measures in the California Public Utilities Commission *Energy Efficiency Policy Manual*. Therefore, the T8 fixtures were assumed to have a useful life of sixteen (16) years, while the occupancy sensors were assumed to have a useful life of eight (8) years. A summary of the multi-year reporting requirements is given in Table 6. Because this measure was installed by May of 2005, the energy savings in year #1 (2005) are assumed to be 41.7% of the expected annual savings for this measure. The table reflects the varying kWh savings due to the different lives of the lighting measures. (The kW demand savings were not adjusted).

Table 6: Multi-Year Reporting Requirements

Program ID:		**Application # 04-002**					
Program Name:		**SPC 04-05 Evaluation**					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004						
2	2005	345,667	175,248	86.9	99.78		
3	2006	829,601	420,596	86.9	99.78		
4	2007	829,601	420,596	86.9	99.78		
5	2008	829,601	420,596	86.9	99.78		
6	2009	829,601	420,596	86.9	99.78		
7	2010	829,601	420,596	86.9	99.78		
8	2011	829,601	420,596	86.9	99.78		
9	2012	829,601	420,596	86.9	99.78		
10	2013	636,297	395,872	86.9	99.78		
11	2014	365,671	361,258	86.9	85.70		
12	2015	365,671	361,258	86.9	85.70		
13	2016	365,671	361,258	86.9	85.70		
14	2017	365,671	361,258	86.9	85.70		
15	2018	365,671	361,258	86.9	85.70		
16	2019	365,671	361,258	86.9	85.70		
17	2020	365,671	361,258	86.9	85.70		
18	2021	213,308	210,734				
19	2022						
20	2023						
TOTAL	**2004-2023**	9,562,176	6,254,836				

FINAL SITE REPORT

SITE A058 (04-xxxx) Deut IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: Process/Other

Measure	Comprehensive Air Compressor System Retrofit
Site Description	Manufacturing

1. Measure Description

The customer implemented three measures to reduce energy consumption at their plant. The primary measure (M1) involved replacing one (1) 150 HP single stage lubricant injected rotary screw compressor with one (1) 100 HP single stage lubricant injected rotary screw VFD driven compressor. Measure #2 (M2) was the installation of an intermediate pressure controller, and measure #3 (M3) was the replacement of a non-cycling refrigerated dryer with a cycling refrigerated dryer and adding 3,800 gallons of air storage.

2. Summary of the Ex Ante Calculations

The project sponsor submitted pre-retrofit monitored data with the application, which was used in combination with generic efficiencies, manufacturer specifications, measured data, and compressor information as inputs to DOE's Compressed Air Challenge AIRMaster+ simulation model, in order to determine the estimated electrical usage of the baseline and proposed compressed air systems. The estimated annual energy savings for the compressor replacement, intermediate pressure controller, and dryer retrofit, based on the reviewer's calculations, totals 599,304 kWh (554,517 kWh, 38,428 kWh, and 6,358 kWh respectively).

The Installation Report states that the ex ante savings are 599,304 kWh annually and demand reduction is 61.3 kW. These values agree with the utility tracking system data.

The reviewer noted that the project was installed as submitted in the application and the ex ante savings were accepted without post installation monitoring.

3. Comments on the Ex Ante Calculations

The ex ante calculations were performed using Air Master+. The project sponsor submitted pre retrofit monitored data with the application and the reviewer used this data for the Air Master+ simulation.

The reviewer noted that the project was installed as submitted in the application and the ex ante savings were accepted without post installation monitoring.

4. Measurement & Verification Plan

This project involves the replacement of a modulating rotary screw compressor with a VSD rotary screw compressor, the installation of an intermediate pressure controller, and the replacement of a non-cycling refrigerated dryer with a cycling refrigerated unit. Prior to the retrofit there were two 150 HP compressors. One compressor was utilized at a time with the other unit acting as a backup. In the post retrofit system, one of the 150 HP compressors was replaced by a VSD controlled 100 HP rotary screw compressor. Energy savings are realized by the higher efficiency of the VSD unit at part-load conditions, the reduction of artificial demand based on lower system operating pressures as a result of the intermediate pressure controllers, and the reduction in energy use and pressure drop based on the installation of the cycling dryer.

The ex ante calculations estimated that the annual savings associated with compressor retrofit are 554,517 kWh and demand reduction is 61.3 kW. This is 93% of the total project kWh savings. Therefore, this evaluation will focus on this measure and the ex ante savings for the intermediate pressure controller and dryer retrofit will be assumed acceptable (38,428 kWh, and 6,358 kWh respectively).

The application estimates that the plant operates 8,400 hours annually.

The goal of the M&V plan is to estimate the actual annual electricity savings realized with the measure over the useful life of the equipment, in order to compare these values with the initial ex ante estimations.

The plan is to verify the kW and kWh consumed, which may be able to be derived from the air usage profile and pre-retrofit and post-retrofit hours of operation. Compressor unloading curves for the pre-retrofit and post-retrofit compressors will be used to estimate annual energy consumption and peak demand reduction from the air usage profiles.

Formulae and Approach

For this application, it is proposed to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. The electrical usage is expected to be consistent and predictable based on instantaneous measurements as well as monthly and annual system reports.

For this application, the pre-retrofit compressor usage and characteristics will be verified with the facility representative. Power monitoring equipment will be installed on the new compressor for a minimum of 7 days, in order to verify the post retrofit hours of operation and power usage. Power will be measured in 5 minute intervals (or less) and averaged for each hour to determine average hourly kW. Power measurements for the new compressor will then be multiplied by the annual hours of operation to determine the annual kWh.

Using the measured average hourly kW, we will calculate the average hourly air usage profile of the new compressor for seven days using performance data for the VFD compressor (% of compressor capacity vs. % full load power, based on data available from the manufacturer and/or from the DOE Compressed Air Challenge). The air usage profile determined for the new VFD compressor will be adjusted if necessary based on changes in production or equipment served as described above.

The pre-retrofit kW and kWh will be calculated based on performance data for the pre-retrofit compressor (which used inlet modulation control), as determined from the performance data (% of compressor capacity vs. % full load power) from the DOE Compressed Air Challenge.

The energy consumption of this measure is not greatly affected by the outside air temperature. To estimate peak demand kW reduction, the expected reduction in connected kW due to the increased compressor efficiency during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in the week with the hottest weekday in June, July, August, September will be determined by calculating the average kW reduction from 2 pm to 5 pm, Monday to Friday during the 7 day period.

If kW measurements cannot be taken, we will request that the customer log readings from the compressor control panel on an hourly basis showing the air flow and air compressor kW for a 24 hour period. We will then use this data to annualize compressor performance.

The formulae and methodology for the calculations are summarized as follows:

To determine post-retrofit compressor kW and kWh:

1.) Measure kW in 5 minute (or less) intervals.
2.) Calculate average kW for each hour for 168 hours (7 days):
3.) Average the kW readings over the one hour period.
4.) Calculate the average kWh for each hour in the 168 hour period:
    Hourly kWh= Average hourly kW x 1 hour
5.) Calculate kWh for the 168 hour period: Sum the 168 hourly results
6.) Estimate the annual kWh: Multiply the 168 hour result x 52.14 weeks/year to obtain annual kWh (accounting for holidays if appropriate).
7.) Calculate the average peak kW from the monitoring results between 2 p.m. to 5 p.m., Monday to Friday, during the monitoring period.

To determine pre-retrofit compressor kW and kWh:

1.) Obtain the maximum capacity of the new air compressor and maximum input power from the manufacturer’s representative.
2.) Determine the average hourly acfm from VFD compressor performance data (% capacity versus % power) and adjust for changes in equipment/production/schedules if necessary.

3.) Utilizing performance data from the DOE Compressed Air Challenge (CAC) and manufacturer's data (maximum capacity of the old air compressors and maximum input power) stated in the application, determine the average hourly kW for 168 hours for the pre-retrofit compressor. This will be determined from CAC performance data and based on the hourly air usage profile developed above.
4.) Calculate the average kWh for each hour in the 168 hour period:

Hourly kWh= Average hourly kW x 1 hour

5.) Calculate kWh for the 168 hour period: Sum the hourly results
6.) Estimate the annual kWh: Multiply the 168 hour result x 52.14 weeks/year to obtain annual kWh (accounting for holidays if appropriate).
7.) Calculate the average peak kW from the CAC performance data based on the hourly air usage profile developed above, between 2 p.m. to 5 p.m., Monday to Friday during the monitoring period.

The average peak kW and the kWh values from the post-retrofit analysis will be subtracted from the pre-retrofit analysis values resulting in the ex post impact (kW and kWh savings).

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit hours of operation, air usage profile, and the compressor energy consumption.

Uncertainty for the savings estimate can be more fully understood by setting projected ranges on the primary variables.

Air Compressor Retrofit

- 95 kW pre-retrofit expected average maximum demand, + / - 30% (67-124 kW)
- 8,400 operating hours pre retrofit expected, +4%/- 10% (7,560-8,760 hours)
- Air usage: 215 cfm average +/- 30% (150-280 cfm)

Accuracy and Equipment

The Dent Elite Pro power monitors have a measurement error of less than 1%. The accompanying current transducers (CTs) have a measurement error of 2 to 5 % depending on the size needed for the compressor and the CT manufacturer. The compressor performance data is estimated to be +/- 5% accurate. Annualizing the seven day measurement period is estimated to be +/- 10% accurate.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 13, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the air compressor system and by interviewing the facility representative. Air compressor make, model, quantities and hours of operation were verified. Power consumption was measured on the new VFD driven air compressor in 30 second intervals over a 168 hour period.

The building is occupied continuously from midnight Sunday to midnight Friday. According to the facility representative, the new VFD driven air compressor is not shut down when the facility is unoccupied and generally operates continuously. Since the project was installed, air consumption at the facility has increased significantly. A second 200 HP VFD driven air compressor was added approximately 12 months ago. The new 200 HP compressor is now the lead compressor and the 100 HP compressor acts as the trim machine. Maximum occupancy is approximately 200 employees at any given time. The facility is closed 9 holidays annually but the air compressor system is continuously energized.

Installation Verification

The facility representative verified that prior to the retrofit, there were two 150 HP compressors. One compressor was utilized at a time with the other unit acting as a backup. In the post retrofit system, one of the 150 HP compressors was replaced by the VSD controlled 100 HP rotary screw compressor. The new 100 HP compressor is a Ingersoll Rand Nirvana model IRN100H-CC, rated at 429 CFM at 125 psig and 86 kW input. As noted above, a second VFD driven air compressor (200 HP) has been added since the completion of the project documented in the application.

We also verified that the 3,800 gallon receiver and intermediate pressure controller were installed. The refrigerated air dryer capacity has been increased to accommodate the increased demand for compressed air. The new dryer is a cycling air dryer. These are the only measures in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Process- OTHER	O			Replace one 150 HP rotary screw air compressor with a VFD driven 100 HP rotary screw air compressor. Install intermediate presure controller and cycling refrigerated dryer.	1	Ingersoll Rand IRN 100H-CC	Physically verified compressor model, and intermediate pressure controller. A new cycling dryer has been installed due to the increase in compressed air usage at the facility.	1.0

Scope of the Impact Assessment

The impact assessment scope is for the process/other end use measure in the SPC application covering the air compressor retrofit. These are the only measures in this application.

Summary of Results

Compressor power consumption on the 100 HP VFD driven compressor was measured in 30 second intervals with the Dent Elite logger. Data was analyzed for 168 hours, from September 5, 2007- September 11, 2007. Input power ranged from zero to 97 kW, with an average of 63 kW. The 100 HP compressor operated for approximately160 hours out of the 168 hour period analyzed.

Although the air compressor system capacity has increased significantly with the addition of the 200 HP VFD driven compressor, the 100 HP VFD driven compressor still operates as a trim compressor. The ex post evaluation compares the current duty and energy consumption of the 100 HP VFD driven compressor with the 150 HP inlet modulated compressor that it replaced.

The facility representative stated that the period monitored was reflective of average operation. Therefore, there was no adjustment to the energy consumption.

We calculated the ex post impacts based on data measured in each 30 second interval instead of based on a one hour average of the measured data as described in Section 4 above, as this interval data is more precise.

The pre-retrofit system had two inlet modulated 150 HP Sullair LS-20S compressors. According to documentation provided by the reviewer in the application, the 150 HP Sullair LS-20S is rated at 683 CFM at 125 psig and 140.7 kW input. The new 100 HP compressor is a Ingersoll Rand Nirvana model IRN100H-CC, rated at 429 CFM at 125 psig and 85.8 kW. Input power to the new VFD driven compressor was measured in 30 second intervals. Table 2 shows the analysis for the first 15 minutes of the monitoring period.

Table 2: Sample of the Analysis for 15 minutes 9/5/2007

Record	Record	Chan 5	New 100 HP VSD			Old 150 HP Inlet modulated				Savings	
Date	End Time	Avg. KW	% max kW	% max scfm	SCFM	SCFM	% Max SCFM	% max kW	kW	kW	kWh
9/5/2007	0:00:00	52.7	61%	60%	273	273	40%	82%	115.4	62.7	0.52
9/5/2007	0:00:30	51.5	60%	58%	267	267	39%	82%	115.0	63.5	0.53
9/5/2007	0:01:00	51.2	60%	58%	265	265	39%	82%	114.9	63.6	0.53
9/5/2007	0:01:30	50.0	58%	57%	258	258	38%	81%	114.5	64.5	0.54
9/5/2007	0:02:00	50.3	59%	57%	260	260	38%	81%	114.6	64.3	0.54
9/5/2007	0:02:30	51.5	60%	58%	267	267	39%	82%	115.0	63.4	0.53
9/5/2007	0:03:00	52.2	61%	59%	270	270	40%	82%	115.2	63.0	0.53
9/5/2007	0:03:30	51.5	60%	58%	267	267	39%	82%	115.0	63.5	0.53
9/5/2007	0:04:00	50.4	59%	57%	261	261	38%	81%	114.6	64.2	0.54
9/5/2007	0:04:30	50.3	59%	57%	260	260	38%	81%	114.6	64.3	0.54
9/5/2007	0:05:00	50.7	59%	57%	262	262	38%	82%	114.7	64.0	0.53
9/5/2007	0:05:30	50.5	59%	57%	261	261	38%	81%	114.6	64.1	0.53
9/5/2007	0:06:00	50.5	59%	57%	261	261	38%	81%	114.6	64.1	0.53
9/5/2007	0:06:30	51.3	60%	58%	266	266	39%	82%	114.9	63.6	0.53
9/5/2007	0:07:00	49.7	58%	56%	257	257	38%	81%	114.4	64.6	0.54
9/5/2007	0:07:30	48.9	57%	55%	252	252	37%	81%	114.1	65.2	0.54
9/5/2007	0:08:00	50.2	58%	57%	259	259	38%	81%	114.5	64.3	0.54
9/5/2007	0:08:30	51.4	60%	58%	266	266	39%	82%	115.0	63.5	0.53
9/5/2007	0:09:00	51.8	60%	59%	269	269	39%	82%	115.1	63.3	0.53
9/5/2007	0:09:30	51.7	60%	59%	268	268	39%	82%	115.0	63.3	0.53
9/5/2007	0:10:00	51.5	60%	58%	267	267	39%	82%	115.0	63.5	0.53
9/5/2007	0:10:30	48.9	57%	55%	252	252	37%	81%	114.1	65.2	0.54
9/5/2007	0:11:00	46.8	55%	53%	241	241	35%	81%	113.4	66.6	0.55
9/5/2007	0:11:30	47.1	55%	53%	242	242	35%	81%	113.5	66.4	0.55
9/5/2007	0:12:00	49.3	57%	56%	254	254	37%	81%	114.2	65.0	0.54
9/5/2007	0:12:30	51.3	60%	58%	266	266	39%	82%	114.9	63.6	0.53
9/5/2007	0:13:00	52.8	62%	60%	274	274	40%	82%	115.4	62.6	0.52
9/5/2007	0:13:30	53.3	62%	61%	277	277	41%	82%	115.6	62.3	0.52
9/5/2007	0:14:00	53.2	62%	60%	276	276	40%	82%	115.6	62.3	0.52
9/5/2007	0:14:30	52.5	61%	60%	272	272	40%	82%	115.3	62.8	0.52
9/5/2007	0:15:00	52.0	61%	59%	270	270	39%	82%	115.2	63.1	0.53

The following is a description of how the analysis was performed for the first 30 second interval:

- The average power was 52.7 kW for the first 30 second interval. This is 61% (52.7 kW/85.8 kW) of the maximum kW for the 100 HP compressor.
- Using the compressor performance data and CAC performance data for a VSD compressor shown in Table 3, we calculated that the compressor was operating at 60% of maximum CFM (273 SCFM= 60% x 457 CFM).
- Using the compressor performance data and CAC performance data for an inlet modulated compressor shown in Table 3, we calculated that the base case 150 HP inlet modulated compressor would have been operating at 40% of maximum CFM (273 SCFM/683 SCFM).
- At 40% of maximum CFM, the inlet modulated compressor would consume 82% of maximum kW (Table 3). 82% x 140.7 kW = 115.4 kW.
- The demand reduction for this 30 second interval is 115.4 kW-52.7 kW= 62.7 kW.
- The kWh savings for this 30 second interval are 62.7 kW/(120 intervals per hour) = 0.52 kWh.

Summary of results for the 168 hour and the annualized period:

- This analysis was performed for each 30 second interval and the results were added together. For the 168 hour period, the total savings were 10,643.25 kWh.
- The annual savings associated with the compressor retrofit are 10,643.25 kWh/week x 52.14 weeks per year = 554,939 kWh.
- We accepted the ex ante savings estimates for the intermediate pressure controller and dryer retrofit (38,428 kWh and 6,358 kWh respectively). Total ex post savings are 599,725 kWh (554,939 kWh + 38,428 kWh + 6,358 kWh).
- Summer peak demand reduction impacts were estimated by averaging the demand reduction for the time period 2 pm to 5 pm, Monday to Friday. Average demand reduction is 60.3 kW.

Table 3: Air Compressor Control Comparison

% of Compressor Capacity	Modulation (Inlet Valve) % FL Power	Variable Frequency Drive % FL Power
100	100.0	100.0
95	98.5	95.2
90	97.0	90.4
85	95.5	85.6
80	94.0	80.8
75	92.5	76.0
70	91.0	71.2
65	89.5	66.4
60	88.0	61.6
55	86.5	56.8
50	85.0	52.0
45	83.5	47.2
40	82.0	42.4
35	80.5	37.6
30	79.0	32.8
25	77.5	28.0
20	76.0	23.2
15	74.5	18.4
10	73.0	13.6
5	71.5	8.8
0	70.0	4.0

Values from the Compressed Air Challenge Workshop Sponsored by the US Department of Energy

6. Additional Evaluation Findings

The ex post kW demand reduction and annual kWh savings are essentially identical to the ex ante. The facility representative stated that the cost estimate provided in the application ($76,585) is from the invoice for the work performed for the project and is an accurate reflection of the project cost. In addition to saving energy, the benefits of the project are quieter compressor operation, increased system reliability and a more constant pressure in the compressed air line. The customer does not anticipate any changes to operation that will affect energy. Participation in the 2004/2005 SPC Program has not encouraged the customer to perform any other energy efficiency projects without participating in an incentive program.

The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measure.

7. Impact Results

The engineering realization rate for this application is 0.98 for demand kW reduction and 1.00 for energy savings kWh. A summary of the realization rate is shown in Table 4.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	61.3	599,304	-
SPC Installation Report (ex ante)	61.3	599,304	-
Impact Evaluation (ex post)	60.3	599,725	-
Engineering Realization Rate	0.98	1.00	NA

Utility billing data for the site was provided by the utility company. For the period January 2004 to December 2004, pre-retrofit annual consumption was 6,933,588 kWh. Peak demand was 1,248 kW. Table 5 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility provided numbers.

Table 5: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1,248	6,933,588
Baseline End Use	123	948,174
Ex ante Savings	61.3	599,304
Ex Post Savings	60.3	599,725

Table 6 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 4.9% decrease in total meter kW, a 49.8% decrease in compressor end use kW, a 8.6% decrease in total meter kWh, and a 63.2% decrease in compressor end use kWh. The ex post results showed a 4.8% decrease in total meter kW, a 49.0%

decrease in compressor end use kW, a 8.6% decrease in total meter kWh, and a 63.3% decrease in compressor end use kWh.

Table 6: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	4.9%	8.6%	4.8%	8.6%
Baseline End Use %	49.8%	63.2%	49.0%	63.3%

With a cost of $76,585 and a $38,293 incentive, the project had a 0.5 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is equal to the ex ante, and the estimated simple payback is the same. A summary of the economic parameters for the project is shown in Table 7. The customer stated that they have no reason to believe that the operation of the facility will change in the foreseeable future, therefore the multi-year impacts, shown in Table 8 below, are expected to remain constant over the life of the equipment.

Table 7: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	9/13/2004	$76,585	61.3	599,304	0	$77,910	$38,293	0.49	0.98
SPC Program Review (Ex Post)	9/26/2007	$76,585	60.3	599,725	0	$77,964	$38,293	0.49	0.98

It was determined that the compressor modifications can be considered as a process overhaul. In the California Public Utilities Commission Energy Efficiency Policy Manual, a useful life of 20 years is given.

A summary of the multi-year reporting requirements is given in Table 8.

Table 8: Multi Year Reporting Table

Program ID	**SPC 2005 Application # A058**
Program Name	**2004-2005 SPC Application**

Year	Calendar Year	Ex-Ante Gross Program Projected kWh Savings	Ex post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program Projected Peak kW Reduction	Ex-Post Gross Evaluation Projected Peak kW Reduction	Ex-Ante Gross Program Projected Therm Savings	Ex post Gross Evaluation Confirmed Program Therm Savings
1	2004	299,652	299,863	61	60		
2	2005	599,304	599,725	61	60		
3	2006	599,304	599,725	61	60		
4	2007	599,304	599,725	61	60		
5	2008	599,304	599,725	61	60		
6	2009	599,304	599,725	61	60		
7	2010	599,304	599,725	61	60		
8	2011	599,304	599,725	61	60		
9	2012	599,304	599,725	61	60		
10	2013	599,304	599,725	61	60		
11	2014	599,304	599,725	61	60		
12	2015	599,304	599,725	61	60		
13	2016	599,304	599,725	61	60		
14	2017	599,304	599,725	61	60		
15	2018	599,304	599,725	61	60		
16	2019	299,652	299,863				
17	2020						
18	2021						
19	2022						
20	2023						
Total	2004-2023	8,989,560	8,995,875				

FINAL SITE REPORT

SITE A059 (2004-xxx) Hele **IMPACT EVALUATION**
SAMPLE CELL: ORIGINAL TIER: 5 END USE: Other

Measure	Air Compressor System Retrofit
Site Description	Manufacturing

1. Measure Description

This project involves the redesign of the compressed air piping distribution system, the installation of a 2,200 gallon receiver, the replacement of a mist eliminator and the installation of a sequencing controller to control three existing 60 HP modulating rotary screw compressors.

2. Summary of the Ex Ante Calculations

According to documentation in the application, the energy savings and incentive calculations were performed by the IOU's engineer. The IOU engineer used an average compressed air flow of 350 cfm and compressor demand of 135 kW for the facility baseline. The baseline CASE Index (explained below) is 156. The CASE Index methodology, in conjunction with monitored data, was used to estimate the post retrofit energy consumption and incentive. The project sponsor was required to submit 1-week of monitored post retrofit data (flow and kW) to support the savings estimate in the installation report.

Compressed Air Supply Efficiency (CASE) Index

The CASE Index was based on a May 2004 California Energy Commission PIER Program Consultant Report 500-04-037 titled: "Industrial Compressed Air Supply System Efficiency". This methodology of evaluating the overall efficiency of a compressed air system was used in the analysis. The CASE Index is defined as:

CASE Index = (Average cfm x 60) / (Average kW)

The CASE Index is a value from 0 to 300. According to the documentation, based on one week of monitoring, the average flow at the facility was 350 cfm and the average compressor power was 135 kW, which resulted in a CASE Index for the baseline operation of 156. According to the research paper, on average, modern efficiently designed compressed air systems which operate properly should have a CASE Index of at least 250.

Following the completion of the project, the application documents indicate that the reviewer analyzed the post retrofit data and the savings were adjusted. The pre and post retrofit data were not included in the documents we received for the project, so the reviewer was contacted to obtain this information. Contrary to what is implied in the application, the reviewer advised that compressed air flow data was very difficult to obtain and was not measured or recorded for this project (implying that the only measured data was the pre and post compressor kW). The reviewer stated that the customer's contractor attempted to measure compressed air flow but was unsuccessful. The reviewer further advised that they assumed (and the project sponsor concurred) that there were no significant changes to the production levels at the facility before and after the retrofit. The reviewer stated that, assuming the compressed air usage of the facility remained steady, all of the measured differences in pre and post retrofit energy consumption were the result of the measures documented in the application (new control system, new storage tanks, flow control, and piping).

Additional details of the methodology utilized for the ex ante analysis were provided by the reviewer.

Assuming steady production between the pre and post intervals, the savings and incentive were based on the pre and post installation measured kW data. The average kW for the baseline system was approximately 111 kW. The average kW for the post retrofit system was approximately 65.6 kW. The average kW reduction was 45.4 kW. The hours of operation for the compressor air system were estimated to be 7,196 hours annually based on the pre and post data and the stated production hours of the facility.

The annual savings were calculated to be 326,698 kWh with a demand reduction of 45.4 kW.

111 kW-65.6 kW = 45.4 kW
45.4 kW x 7,196 hrs/yr = 326,698 kWh

The Installation Report states that the ex ante savings are 326,698 kWh annually and demand reduction is 45.4 kW. These values agree with the tracking system data.

3. Comments on the Ex Ante Calculations

According to the documentation in the application, the ex ante calculations were performed using the CASE Index methodology. The documents state that the CASE Index inputs were developed using actual measurements of pre and post retrofit system airflow and compressor kW. Recent discussions with the reviewer revealed that they were unable to obtain measurements of compressed air flow before or after the retrofit, and only measured compressor kW, assuming that the compressed air flow was equal before and after the retrofit. Pre and post retrofit data was measured for less than 3.5 days from Thursday morning to Sunday afternoon in both cases. There were more than 8 months between the pre and post retrofit measurements. While the assumption that air flow before and after the retrofit was equal may be true, this is not an ideal approach to providing credible ex ante analysis.

The ex ante analysis and supporting documentation has failed to establish an ex post verifiable baseline for the pre or post retrofit system performance. The only certainty is that, based on the measured data, the energy consumption of the system was reduced after the retrofit.

4. Measurement & Verification Plan

The goal of the M&V plan is to estimate the actual annual electricity savings realized with the measure over the useful life of the equipment.

We will accept the ex ante kWh savings and demand reduction since we are unable to verify the assumption that the compressed air usage before the retrofit was equal to the compressed air usage after the retrofit.

Formulae and Approach

For this application, it is proposed to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation.

For this project we will verify the current hours of operation of the compressed air system. We will also attempt to verify the current and past levels of production (upon which the ex ante savings are based) and the relative use of compressed air based on the experience and opinions of the facility representatives. We will adjust the ex ante impacts proportionally if any of these parameters are found to be different than those documented in the application.

The greatest uncertainties in the ex ante savings estimate are associated with………

Uncertainty for the savings estimate can be more fully understood by setting projected ranges on the primary variables.

<u>Air Compressor Retrofit</u>

- 7,200 operating hours pre retrofit expected, +/- 15% (6,120-8,280 hours)
- 7,200 operating hours post retrofit expected, +/- 15% (6,120-8,280 hours)
- Air usage as related to production level, 1 expected (+/- 25%) (0.75-1.25 post retrofit)

Accuracy and Equipment

The ex post analysis is subjective because it will be based on the opinions and experience of the customer's representative. The accuracy of the subjective evaluation of the ex ante analysis is expected to be +/- 25%.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 21, 2007. Information on the retrofit equipment and operating conditions were collected by inspection of the air compressor system and by interviewing the facility representative. Air compressor, sequencing controller and mist eliminator make, model, quantities and hours of operation were verified. We also verified that the compressed air distribution piping had been replaced.

Our interview with the facility representative revealed that when the project documented in the application was completed there were 5 production lines at the facility. Approximately 12 months after the completion of the project, 2 of the production lines were eliminated. The facility representative estimates that compressed air usage has been reduced by 25-30%.

At the time of the site visit, 2 of the 3 remaining production lines were shut down. These two lines are being retooled. One of the lines is expected to be running by the end of November 2007 and the other in January 2008. The compressed air system consists of three inlet modulated 60 HP rotary screw compressors. One of the three air compressors had been removed from the facility for repairs. The sequencing controller was bypassed and a single air compressor was energized to serve the one operating production line. The facility representative stated that they will restore the compressed air system to automatic mode (and the sequencing controller will be enabled) when the second production line is running.

The building is occupied 24 hours per day Monday-Friday, and also operates about 25% of Saturdays. The facility is closed 8 holidays annually. The facility representative advised that the compressed air system is de-energized when the facility is unoccupied.

Installation Verification

We verified the installation of the distribution piping, the 2,200 gallon receiver, the Quincy mist eliminator and the ConservAIR sequencing controller. We also verified that there are three 60 HP Ingersoll Rand SSR-EP60 air compressors rated at 240 CFM at 125 psig (one compressor was off site for repairs at the time of the site visit). These compressors were operational before and after the retrofit.

These are the only measures in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Process- OTHER	O			Install 2,200 gallon receiver, sequencing controller, mist eliminator. Replace compressed air distribution piping.	1	ConservAIR sequencing controller, Pressure Vessel Technologies 2,200 gal. Tank, Quincy ME-800 mist eliminator.	Physically verified 2,200 gallon receiver, sequencing controller, mist eliminator and distribution piping.	1.0

Scope of the Impact Assessment

The impact assessment scope is for the 'Other' end use measure in the SPC application covering the air compressor retrofit. This is the only measures in this application.

Summary of Results

- Pre and post retrofit hours of compressor operation are 6,378/year.
  (5 days/week + (1/4) Saturdays) x 52.14 weeks/year x 24 hours/day – (8 holidays x 24 hours/day) = 6,378 hours/year.

- Percent of ex ante annual hours of operation is 88.6%
  6,378 hours/ 7,196 hours= 0.886.

- Expected compressed air usage when all three production lines are operating: 75% of usage at the time of the retrofit based on the opinion and experience of the site representative.

- Ex post adjusted annual kWh impact: 217,090 kWh.
  326,698 kWh x 0.886 x 0.75 = 217,090 kWh

- Ex post adjusted demand reduction impact: 34 kW.
  45.4 kWh x 0.75 = 34 kW

6. Additional Evaluation Findings

The ex post kW demand reduction is less than the ex ante estimate because we determined that the compressed air usage for the facility has decreased with the elimination of 2 production lines. The ex post energy savings are less than the ex ante energy savings for the same reason. In addition, we determined that the hours of operation of the plant are less than those shown in the ex ante analysis.

The facility representative stated that the cost estimate provided in the application ($200,698) is from the invoice for the work performed for the project and is an accurate reflection of the project cost. In addition to saving energy, the benefits of the project are a more constant pressure in the compressed air line and more reliable delivery of compressed air to the end users. The customer is currently retooling 2 of the 3 production lines and the impact on the energy savings and demand reduction cannot be estimated at this time. Participation in the 2004/2005 SPC Program has not encouraged the customer to perform any other energy efficiency projects without participating in an incentive program.

The level of M&V employed at this site is not sufficient to accurately determine the impacts of the installed measure. The lack of a well documented ex ante analysis has proven to be a hindrance to accurately assessing the impacts for this project. A more robust evaluation would have been possible had the project sponsor been successful in measuring compressed air flow and compressor power as was originally proposed for the project.

7. Impact Results

The engineering realization rate for this application is 0.75 for demand kW reduction and 0.66 for energy savings kWh. A summary of the realization rate is shown in Table 2.

Table 2: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	45.4	326,698	-
SPC Installation Report (ex ante)	45.4	326,698	-
Impact Evaluation (ex post)	34.0	217,090	-
Engineering Realization Rate	0.75	0.66	NA

Utility billing data for the site was provided in the application. For the period January 2004 to December 2004, pre-retrofit annual consumption was 2,452,753 kWh. Peak demand was 563 kW. Table 3 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility provided numbers.

Table 3: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	563	2,452,753
Baseline End Use	111	798,756
Ex ante Savings	45.4	326,698
Ex Post Savings	34	217,090

Table 4 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 8.1% decrease in total meter kW, a 40.9% decrease in compressor end use kW, a 13.3% decrease in total meter kWh, and a 40.9% decrease in compressor end use kWh. The ex post results showed a 6.0% decrease in total meter kW, a 30.6% decrease in compressor end use kW, a 8.9% decrease in total meter kWh, and a 27.2% decrease in compressor end use kWh.

Table 4: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	8.1%	13.3%	6.0%	8.9%
Baseline End Use %	40.9%	40.9%	30.6%	27.2%

With a cost of $200,698 and a $26,136 incentive, the project had a 4.7 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 7.1 years. A summary of the economic parameters for the project is shown in Table 5.

Table 5: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	9/13/2004	$200,698	45.4	326,698	0	$42,471	$26,136	4.11	4.73
SPC Program Review (Ex Post)	9/25/2007	$200,698	34.0	217,090	0	$28,222	$26,136	6.19	7.11

It was determined that the compressed air projects were defined as a Custom Project under the SPC program according to the California Public Utilities Commission *Energy Efficiency Policy Manual*, and are therefore assumed to have a useful life of 15 years.

A summary of the multi-year reporting requirements is given in Table 6. The customer advised that 2 of the 3 production lines are currently being re-tooled. At this point they do not anticipate a significant change in compressed air demand but the impacts of the new production lines will not be known until early 2008, therefore the multi-year impacts, shown in Table 6 below, are shown to be constant over the life of the equipment. However, because this measure was installed by September 2004, the energy savings in year #1 (2004) are assumed to be 33.3% of the expected annual savings for this measure.

Table 6: Multi Year Reporting Table

Program ID:			Application # A059				
Program Name:			**SPC 04-05 Evaluation**				
Year	**Calendar Year**	**Ex-Ante Gross Program Projected kWh Savings**	**Ex post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program Projected Peak kW Reduction**	**Ex-Post Gross Evalaution Projected Peak kW Reduction**	**Ex-Ante Gross Program Projected Therm Savings**	**Ex post Gross Evaluation Confirmed Program Therm Savings**
1	2004	81,675	54,273	-	-		
2	2005	326,698	217,090	45.4	34.0		
3	2006	326,698	217,090	45.4	34.0		
4	2007	326,698	217,090	45.4	34.0		
5	2008	326,698	217,090	45.4	34.0		
6	2009	326,698	217,090	45.4	34.0		
7	2010	326,698	217,090	45.4	34.0		
8	2011	326,698	217,090	45.4	34.0		
9	2012	326,698	217,090	45.4	34.0		
10	2013	326,698	217,090	45.4	34.0		
11	2014	326,698	217,090	45.4	34.0		
12	2015	326,698	217,090	45.4	34.0		
13	2016	326,698	217,090	45.4	34.0		
14	2017	326,698	217,090	45.4	34.0		
15	2018	326,698	217,090	45.4	34.0		
16	2019	326,698	217,090	45.4	34.0		
17	2020	326,698	217,090	45.4	34.0		
18	2021	326,698	217,090	45.4	34.0		
19	2022	326,698	217,090	45.4	34.0		
20	2023	326,698	217,090	45.4	34.0		
TOTAL	**2004-2023**	6,288,937	4,178,983				

FINAL REPORT

SITE A060 (2004-659) Felc/crow IMPACT EVALUATION
SAMPLE CELL: TIER: 3 END USE: Other

Measure	Replace manual thermostats with occupancy based thermostats
Site Description	Hotel

1. Measure Description

Replace 350 manual thermostats in hotel guestrooms with occupancy-based programmable thermostats.

2. Summary of the Ex Ante Calculations

According to the Installation Report Review, the ex ante estimate of annual savings is 1,432,550 kWh, 0 kW, and 0 therms.

The ex ante savings calculations are based on the Express Efficiency setback programmable thermostat workpapers. The workpapers dictate savings of 4,093 kWh/year and 1,095 therms /year per thermostat. The assumptions for these workpaper savings are:

- Regular office hours = 7 am - 6 pm, Monday - Friday
- Base case system runs continuously due to lack of controls
- Fan is in AUTO mode
- Occupied hrs/yr = 11 hr/day x 5 day/wk x 52.14 wk/yr = 2,870 hr/yr
- AC Capacity = 10.0 tons
- Overall AC efficiency = 1.3 kW/ton average without fans
- 500 sf/ton size
- Size of heating = 250 kBtu/hr
- Overall heating efficiency = 70%
- Total cfm = 5,000
- Fan hp = 3
- Fixed outside air (20%)
- Located in San Jose (uses ASHRAE bin weather data)

With these assumptions, the workpapers use weather bin data to estimate the base case energy consumed for heating and cooling. The weather bin data is separated into occupied and unoccupied periods. Using setback temperatures for the unoccupied periods, the occupancy-based energy consumption is calculated. There are some additional calculations to approximate “warm up” periods and “cool down” periods. The difference of the base case energy use and the occupancy-based energy use is the energy savings.

The electrical savings reported agree with the workpapers; however, the gas savings are reported as 0, which are not in agreement with the workpapers. The savings and incentive agree with the figures in the utility tracking system.

The project file lists the total cost of this measure as $109,780. The tracking system notes an incentive of $18,900. It is unclear how the incentive was calculated. The category was listed as H for HVAC in the utility tracking system; this category is now AC&R. The proper category for this measure is “Other”.

3. Comments on the Ex Ante Calculations

The ex ante savings are based on the workpapers which prescribe savings for setback programmable thermostats in a small commercial application. These savings are not applicable to the occupancy based programmable thermostats used in this project because:

- the technology is not the same. The occupancy based thermostats operate much differently than a standard programmable thermostat, and
- the facility type has completely different occupancy patterns and usage than the typical small commercial application. A hotel guestroom is very dissimilar to a small retail or office building. The workpaper calculations are based on small split AC units. The hotel guestrooms are cooled and heated by heat pumps. The ex ante savings assumed that the space is occupied during typical office hours and unoccupied during nights and weekends, which is clearly at odds with hotel guest rooms which are occupied overnight and on weekends. The occupancy based programmable thermostats are used in hotel guestrooms, and will follow a much different occupancy pattern.

In short, the deemed savings used to estimate the ex ante impacts are not appropriate for this project. We do not expect the evaluated savings to have any relation to the ex ante claims. The ex ante savings calculation approach will not be utilized for ex post savings.

4. Measurement & Verification Plan

The goal of the measurement and verification (M&V) plan is to determine peak kW and kWh savings over the life of the measure by establishing the effect the occupancy based programmable thermostats have on heating, cooling, and fan energy use in guest rooms.

This facility is a hotel, with 350 heat pumps in 335 guestrooms. According to the utility tracking system the building contains a total of 176,240 sq ft.

Cooling and heating for the building is provided by heat pumps. Standard rooms have one heat pump, while larger rooms have two heat pumps. These are water source units. Details about heat pump capacity and compressor staging will be collected during the site visit.

Two, 650-ton cooling towers provide a heat sink and heat rejection for the heat pumps' source water. Each cooling tower is equipped with two (2) 10-hp VFD controlled fans and two (2) 5-hp circulation pumps.

Formulae and Approach

IPMVP M&V Option A (Partially Measured Retrofit Isolation) will be used to estimate the impacts resulting from this project.

Limited information was provided for this facility; therefore, the final ex post savings approach cannot be completely determined until the site visit is conducted. The basic method will involve a monitoring approach to determine the difference between the baseline and post retrofit heat pump / HVAC system energy consumption.

Ideally, a minimum of four base case (reference) rooms will be monitored; these will be evenly divided between building faces. The occupancy based thermostat will be set to operate in manual mode for these rooms, thus simulating the pre-retrofit conditions. Additionally, four or more rooms evenly divided by building exposures will be monitored with the new occupancy based thermostats fully functional. To the extent possible, ground floor and top floor rooms will be monitored in proportions representative to the total number of rooms.

The basic parameters that will be monitored, if permitted by facility staff and physical constraints, are:

Table 1: Monitoring Parameters

Measured Parameter	**Description**	**Interval / Length**
Heat pump load	kW logger measuring heat pump energy usage (or amp logger with assumed power factor based on spot measurements)	5 minute interval (or 0.5 / 1 minute interval)
Room rental status	Customer to provide daily rental status of rooms during measurement period	Daily
Average monthly occupancy	Customer to provide typical monthly rental status of guestrooms	Monthly

Each interval of the heat pump load (in terms of average kW) will be aggregated for each day. The rooms will be grouped as base case unrented, base case rented, post case unrented, and post case rented. Savings will be calculated by the consumption differences between the base case and post case for both rented and unrented periods. The savings results will be regressed against weather data for the monitoring period to determine the correlation of outside air temperature and savings. Using weather correlations and typical annual occupancy data, the annual savings will be estimated.

For each interval, the average power will be calculated using the average amps over the interval. The equation will be adjusted using a factor of 1.73 if heat pumps are three phase.

$$\text{kW} = (\text{amp})(\text{volts})(\text{powerfactor}) \qquad \text{Eqn. 1}$$

The energy consumed in each interval will be summed for an entire day. Peak kW will be derived from average kW over peak periods. Peak demand period is defined, as the period from 2 pm to 5 pm during the hottest weekday periods during the summer months (Monday to Friday, June to September).

$$\text{kWh/day} = \sum_{i=1}^{288}(\text{kW}_i) \qquad \text{Eqn. 2}$$

Where 288 represents 12 five minute intervals over 24 hours

$$\text{Peak kW} = \frac{\sum \text{kWh}_{\text{peak}}}{\text{peak period}} \qquad \text{Eqn. 3}$$

Uncertainty for the savings estimates can be more fully understood by setting projected ranges on the primary variables.

Heating Pump Energy Savings

- guest room occupancy: 75% expected, 50% minimum, 90% maximum (+20% maximum , - 33 % minimum)
- Average energy savings per heat pump: 600 kWh expected, 250 minimum, 1,200 maximum (+ 100 % maximum, - 58.3% minimum)
- Average heat pump peak demand reduction: 0.08 kW expected, 0.04 minimum, 0.2 kW maximum (+ 150 % maximum, - 50% minimum)

The largest source of uncertainty is the average heat pump load in unrented rooms. During unrented periods, the programmable thermostats enter a deep setback, so the largest portion of savings is expected, along with the largest uncertainty as to the magnitude of these savings. A primary focus of implementing the M&V plan will be to understand and quantify the actual savings in unrented rooms.

Extrapolation from the late summer monitoring period to full year estimates also contribute to uncertainties to savings estimates.

There may be other small potential sources of uncertainty introduced in the ex post savings for a variety of reasons, such as hotel guest behavior in the monitoring rooms. It is difficult to identify whether the monitoring rooms will represent typical guest rooms.

Another possible source of uncertainty is in equipment operation. It is assumed that the heat pumps in the monitoring rooms will be representative of the hotel. It is possible that source water valves could be clogged or other problems might exist that could cause heat pumps to run longer or with increased load.

These smaller errors are estimated at a maximum of + /- 10% in aggregate.

Accuracy and Equipment

The spot electrical measurements are to be performed with a Wavetek Meterman AC38 digital multimeter with an accuracy of 1.2%. Monitoring of electrical equipment will be performed with Dent DATApro loggers, which use a PC serial interface for data transfer. All data will be exported to MS Excel format. These loggers have a resolution of one minute and, for the purposes of the evaluation, are 1.5% accurate (including CT).

Other collected data and reported data are considered to be 95% accurate where reviewed data is deemed reasonable.

Annualizing the heat pump load data from the 4 week monitoring period is projected to result in a possible error in the final results of +/- 15 %.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 18, 2007. Information was collected from equipment nameplates, spot power checks, and interviews with hotel staff. Several guest rooms were entered to examine heat pumps and thermostat setpoints. Six (6) heat pumps were monitored.

Installation Verification

All of the eight guest rooms that were surveyed had occupancy-sensor programmable thermostats installed. Door sensors and occupancy sensors are used to determine activity in guest rooms. When a guest room door is closed, the occupancy sensor looks for activity in the room. If there is room activity, the thermostat operates in its rented-occupied mode, in which the thermostat operates within a 2°F temperature range of the set target temperature. If the door is closed and the room has no activity for a period of 10 minutes, the thermostat reverts to its rented-unoccupied mode, during which the temperature is allowed to swing within five degrees of the target temperature setpoint. If there is no activity in the room for a period of 14 hours, the thermostat enters its un-rented mode. In this mode, the temperature is allowed to swing from 65°F to 80°F.

The verification realization rate for this project is 1.0. A verification summary is shown in Table 6 below.

Summary of Results

As outlined in Section 4, the ex ante savings calculations cannot be utilized for ex post savings. The basic methodology outlined in the M&V section of this report was used for ex post analysis.

Heat Pumps

The water source heat pumps have a rated capacity of 13,600 Btu/hr of cooling and ARI heating capacity of 17,000 Btu/hr. The blower has a rating flow of 420 cfm. The heat pumps are 21 years old. The units are single phase. The nameplate FLA is 5.4 amps.

Occupancy

From interviews with hotel staff it was determined that there are only minor fluctuations in the occupancy rates. The primary clients at the hotel are business travelers. Therefore, there is a decrease in occupancy around holiday and weekend periods. Occupancy fluctuations on a monthly basis are negligible. The typical monthly occupancy rate of 75% is used for ex post calculations.

Monitoring Data

Heat pumps in six hotel guest rooms were monitored. The heat pump total amps were monitored at 5 minute intervals. Three of the guestrooms thermostats were set to operate in a manual mode to simulate the activity of the old base case manual thermostats that were replaced. Another three rooms operated with the occupancy setback functions enabled. Monitoring took place from September 18th, 2007 to October 18th, 2007. During that period the dry bulb outside air temperature (OA_{db}) ranged from 87°F to 54°F. While the full effects of heating were not monitored, enough data was collected to determine the appropriate relationship of OA_{db} and heat pump loads.

Savings Calculations

Five minute interval amp data was used to calculate power. The heat pumps are single phase. The power factor is assumed to be 0.8. The voltage was measured to be 277 V. Average power for each interval is calculated by equation 1.

$$kW = (amp)(volts)(powerfactor) \quad \text{Eqn. 1}$$

The monitoring data was compiled into two groups, pre-retrofit manual thermostats and setback enabled thermostats. The compiled data was inspected as a function of the OA_{db}

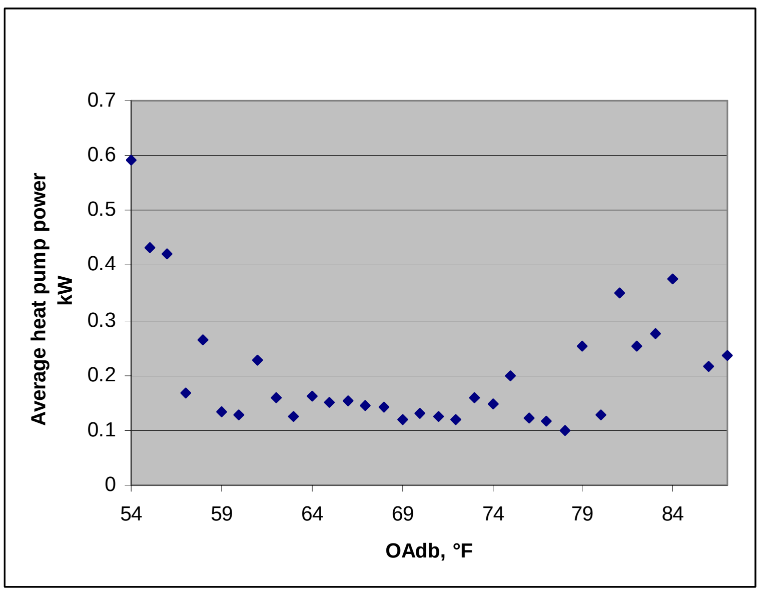
and rental status. The rental status of the room had large effects on heat pump power use for both base case rooms and post case rooms. Hotel policy is for the cleaning staff turn off the thermostat in un-rented rooms. This practice was clear from the monitoring data. However, on occasion, the hotel staff forgot to turn off a thermostat and the monitored data showed the heat pumps operating. There is no correlation between OA_{db} and the periods that unrented rooms have their thermostat in operation. Therefore, based on monitoring data, the average power in all unrented rooms was averaged to account for guest rooms that have the thermostats functioning. Unrented room heat pump average power is calculated using equations 4 and 5.

$$kW_{base,vacant} = (0.00598 kW/heat\ pump) \qquad \text{Eqn. 4}$$

$$kW_{post,vacant} = (0.003627 kW/heat\ pump) \qquad \text{Eqn. 5}$$

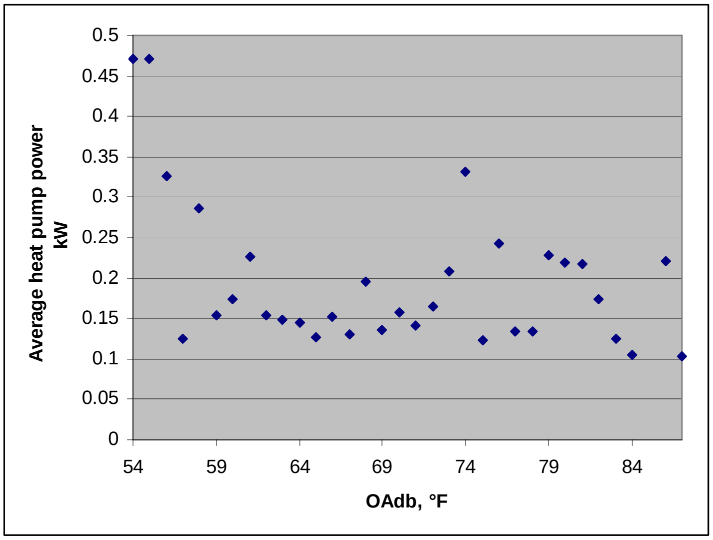
For rented rooms, a correlation with OA_{db} was used to determine heat pump average power. This is illustrated in Figure 1 and 2. Equations 6 and 7 represent this correlation and are used in ex post savings.

Figure 1: Average Power in Rented Reference Rooms (monitoring data)



$$kW_{base,\ rented} = (0.00096)(OA_{db}^{\ 2}) - (0.1366)(OA_{db}) + (4.9847) \qquad \text{Eqn. 6}$$

Figure 2: Average Power in Rented Base Case Rooms (monitoring data)



$$kW_{post,rented} = (0.000424)(OA_{db}^{2}) - (0.0631)(OA_{db}) + (2.507)$$ Eqn. 7

Using TMY[1] data for climate zone 8, the ex post analysis calculates the expected average power based on an hourly period. The average power is based on equations 4, 5, 6 and 7. The average hourly power is multiplied by 350 heat pumps and occupancy rate to calculate the total average power for all rooms. The energy consumption for all rooms is the summation of the total average power for all hours. The energy saving is the difference between base case and post case room energy consumption. The peak demand reduction is the average power reduction during the peak periods of 2 pm to 5 pm during the hottest weekday periods during the summer months (Monday to Friday, June to September). Incorporating all guest rooms and the occupancy rates, the ex post equations are:

$$kW_{base,vacant} = (1 - 0.75)(0.00598 kW/heat\ pump)(350 heat\ pumps)$$ Eqn. 8

$$kW_{post,vacant} = (1 - 0.75)(0.003627 kW/heat\ pump)(350 heat\ pumps)$$ Eqn. 9

$$kW_{base,rented} = \left((0.00096)(OA_{db}^{2}) - (0.1366)(OA_{db}) + (4.9847)\right)(0.75)(350 heat\ pumps)$$ Eqn. 10

[1] TMY data are published by ASHRAE and use 30-year averages to represent typical weather data for specific locales. This is appropriate for annualizing the savings since the savings will be anticipated for more than the first year.

$$kW_{post,rented} = \left((0.000424)(OA_{db}{}^{2}) - (0.0631)(OA_{db}) + (2.507)\right)(0.75)(350 heat\ \ pumps)$$

Eqn. 11

Table 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	480.0	13,286,558
Baseline End Use	63.1	691,551
Ex ante Savings	0.0	1,432,550
Ex Post Savings	16.39	100,930

Table 3: Percent Savings and Demand reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	0.0%	10.8%	3.4%	0.8%
Baseline End Use %	0.0%	207.2%	26.0%	14.6%

6. Additional Evaluation Findings

Ex post energy savings are significantly lower than the ex ante savings. As discussed in Section 3, the deemed savings values used in the ex ante calculation are not applicable for this measure.

The ex post savings are low, primarily because the measure is not being used to its full capability. Hotel staff shut off thermostats in unrented rooms while cleaning, both in the pre retrofit and post retrofit case. Therefore, essentially no heating or cooling is provided in unrented rooms. The exception to this is the time periods between guest checkout and room cleaning. It was also noticed that on occasion, hotel staff forget to turn off thermostats in un-rented rooms. By shutting off the thermostats in un-rented rooms, the thermostat is not allowed to operate in the fashion for which it was designed. The thermostat still enters the unoccupied-rented setback, but rooms will never be allowed to enter the unoccupied-vacant setback.

The ex ante savings did not claim demand reduction. Many of the hotel guests travel on business and are not in hotel rooms during peak periods. Peak demand reductions were accounted for in the ex post savings analysis. A majority of the demand reduction was achieved in rooms that are rented, as un-rented rooms have the thermostats turned off.

As summarized in Tables 2 and 3, the peak demand reduction is 16.1 kW. This is estimated to be about 26% of the baseline peak demand.

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. With a cost of $109,780 and a $18,900 incentive, the project has a 5.9 month simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 83.2 months. A summary of the economic parameters for the project is shown in Table 4.

There are several, non-energy related benefits from installing the occupancy based programmable thermostats. The existing thermostats were outdated in appearance, while the new units are considered attractive to hotel guests. Also, there is a better response time and smaller temperature swings with the new thermostats, thereby improving comfort.

7. Impact Results

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh)	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	4/6/2005	$109,780	0	1,432,550	0	$186,232	$18,900	0.49	0.59
SPC Program Review (Ex Post)	11/2/2007	$109,780	16.39	100,930	0	$13,121	$18,900	6.93	8.37

Table 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	-	1,432,550	-
SPC Installation Report (ex ante)	-	1,432,550	-
Impact Evaluation (ex post)	16.39	100,930	-
Engineering Realization Rate	NA	0.070	NA

Table 6: Installation Verification Summary

Measure Description	End-Use Category	Other Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
HVAC OCCUPANCY SENSOR	O - Other	INNCOM e4 Smart Digital Thermostat	350	INNCOM e4 Smart Digital Thermostat	Physically inspected several guest rooms and made sure units were functioning	1.0

Table 7: Multi Year Reporting Table

Program ID:		**A060**					
Program Name:		**SPC 04-05 Evaluation**					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004						
2	2005	1,074,413	75,698	-	16.39	-	-
3	2006	1,432,550	100,930	-	16.39	-	-
4	2007	1,432,550	100,930	-	16.39	-	-
5	2008	1,432,550	100,930	-	16.39	-	-
6	2009	1,432,550	100,930	-	16.39	-	-
7	2010	1,432,550	100,930	-	16.39	-	-
8	2011	1,432,550	100,930	-	16.39	-	-
9	2012	1,432,550	100,930	-	16.39	-	-
10	2013	1,432,550	100,930	-	16.39	-	-
11	2014	1,432,550	100,930	-	16.39	-	-
12	2015	1,432,550	100,930	-	16.39	-	-
13	2016	358,138	25,233			-	-
14	2017						
15	2018						
16	2019						
17	2020						
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	15,758,050	1,110,230				

SITE A061 (2004-660) Doub IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 2 END USE: Other

Measure	Replace manual thermostats with occupancy based thermostats
Site Description	Hotel

1. Measure Description

Replace 476 manual thermostats in hotel guestrooms with occupancy-based programmable thermostats.

2. Summary of the Ex Ante Calculations

According to the Installation Report Review (IRR), the ex ante estimate of annual savings is 2,279,801 kWh, 0 kW, and 0 therms.

The utility tracking system notes savings of 1,948,268 kWh, consistent with the prescribed savings in the workpaper.

Neither the IRR nor the utility tracking system note any thermal savings.

The ex ante savings calculations are based on the Express Efficiency setback programmable thermostat work paper. The work paper dictates savings of 4,093 kWh/year and 1,095 therms/year per thermostat. The assumptions used to develop these work paper savings are:

- Regular office hours = 7 am - 6 pm, Monday - Friday
- Base case system runs continuously due to lack of controls
- Fan is in AUTO mode
- Occupied hrs/yr = 11 hr/day x 5 day/wk x 52.14 wk/yr = 2,870 hr/yr
- AC Capacity = 10.0 tons
- Overall AC efficiency = 1.3 kW/ton average without fans
- 500 sf/ton size
- Size of heating = 250 kBtu/hr
- Overall heating efficiency = 70%
- Total cfm = 5,000
- Fan hp = 3
- Fixed outside air (20%)
- Located in San Jose (uses ASHRAE bin weather data)

With these assumptions, the work papers use weather bin data to estimate the base case energy consumed for heating and cooling. The weather bin data is separated into occupied and unoccupied periods. Using setback temperatures for the unoccupied periods, the occupancy-based energy consumption is calculated. There are some additional calculations to approximate "warm up" periods and "cool down" periods. The difference between the base case energy use and the occupancy-based energy use is the energy savings.

The project file lists the total cost of this measure as $116,401. The tracking system notes an incentive of $25,704. It is unclear how the incentive was calculated. The category was listed as H for HVAC in the utility tracking system; this category is now AC&R. The proper category for this measure is "Other".

3. Comments on the Ex Ante Calculations

The ex ante savings are based on the work papers for setback programmable thermostats in a small commercial application. These savings are not applicable to the occupancy-based programmable thermostats used in this project because:

- The technology is not the same. The occupancy-based thermostats operate much differently than the standard programmable thermostat.
- Weather data is used for San Jose, which is different than weather in the subject location. This is a weather sensitive measure, and location is important to the accuracy of savings.
- Hotels have different occupancy patterns and usage than the typical small commercial application. A hotel guestroom is very dissimilar to a small retail or office building.
- The work paper calculations are based on small split system AC units. This hotel facility is cooled by a central chiller plant.
- The work paper calculates savings for heating accomplished by small furnaces. This hotel has individual electric resistance heaters on each fan coil unit (FCU).
- The ex ante savings assumed that the space is occupied during typical office hours and unoccupied during nights and weekends. The occupancy-based programmable thermostats used in hotel guestrooms will follow a much different occupancy pattern.

In short, the deemed savings used to estimate the ex ante impacts are not appropriate for this project. The evaluated savings are not expected to have any relation to the ex ante claims. The ex ante savings calculation approach will not be utilized for ex post savings.

4. Measurement & Verification Plan

The goal of the measurement and verification (M&V) plan is to determine peak kW and annual kWh savings over the life of the measure by establishing the effect the occupancy based programmable thermostats have on heating, cooling, and fan energy use in the hotel guest rooms.

The building contains a total of 345,000 sf including approximately 162,235 sf of guestroom spaces. Cooling for the building is provided by a central plant chilled water loop supplied by two (2) 360-ton water-cooled chillers. Small fan coil units (FCUs) in each guestroom use cold water from the chilled water loop to cool the air in the room. More details about the central cooling plant will be collected during the site visit.

Heating for the building is provided by electric resistance strip heating elements. Each guestroom heating unit has a rated capacity of 1.5 kW to 2.0 kW. Spot readings as well as continuous monitoring will be conducted onsite to confirm these values.

There are a total of 476 guestroom fan coil units (FCUs). The FCU motors are each 1/20-hp and the output of each fan is rated at 300 cfm. The chilled water coil in each FCU is rated at 0.68-ton cooling capacity. The fan power at different operating speeds will be collected during the site visit.

Formulae and Approach

IPMVP M&V Option A (Partially Measured Retrofit Isolation) will be used to estimate the impacts resulting from this project.

Limited information was provided for this facility; therefore, the final ex post savings approach can not be entirely determined until the site visit. The basic method will involve a monitoring approach to determine the difference between the baseline and new heating, cooling, and fan energy consumption.

Ideally, a minimum of four base case (reference) rooms will be monitored; these will be evenly divided between building faces. The occupancy based thermostat will be set to operate in manual mode for these rooms, thus simulating the pre-retrofit conditions. According to technical support staff, the thermostat should indirectly have this capability by turning off sensors. Additionally, four or more rooms with fully functioning occupancy based thermostats will be monitored. To the extent possible, ground floor and top floor rooms will be monitored in proportions representative to the total number of rooms. The basic parameters that will be monitored, if permitted by facility staff and physical constraints, are shown in Table 1 and Table 2.

Table 1: Onsite monitoring parameters

Measured Parameter	Description	Interval / Length
Supply air temperature	Thermocouple logger in FCU	5 minute interval
Return air / room temperature	Thermocouple logger in FCU	5 minute interval
Temperature indicators	Determine appropriate supply air temperatures that indicate FCU heating or cooling modes	Spot measurements
Fan on/off	TOU motor logger	Continuous
Fan load	Amp logger measuring fan energy usage	5 minute interval
Outside air temp	Utilize EMS to trend or NOAA weather station	15 minute interval if available via EMS or hour if via NOAA
Room rental status	Customer to provide daily rental status of rooms during measurement period	Daily

Table 2: Additional Onsite data to collect

Data Element	Proposed Means of Collecting Data
Chilled water plant performance	Estimate chiller plant efficiency based on equipment and age of plant. A typical plant of this type will operate between 0.8 and 1.2 kW/ton. Estimates may be through manufacturer or EMS data.
Cooling coil capacity	Nameplate or review of documentation
Heating element capacity	Nameplate, review of documentation, or spot check
Fan capacity	Nameplate or review of documentation
Average monthly occupancy	Provided by contact

The measured supply air temperature and return air temperature will be used to calculate the temperature differential (ΔT) across the cooling coils. The supply air temperature will be used to determine when an FCU is in heating or cooling mode.

FCU airflow will be determined from nameplate data or documentation if possible. If information on the unit can be found, fan power will be used to estimate the typical airflow for that size unit. Spot readings from vane anemometers during operation at various fan speeds may be used to validate this data.

Each monitored room will have heating energy, cooling energy, cooling peak demand, fan energy, and fan peak demand calculated for each interval. Each interval will be aggregated for each day. The rooms will be grouped as base case unrented, base case rented, post case unrented, and post case rented. The daily consumption values of each group of rooms will be combined. Savings will be calculated by the consumption differences between the base case and post case for both rented and unrented periods. The savings results will be regressed against weather data for the monitoring period to determine the correlation between outside air temperature and savings. Using weather correlations and typical annual occupancy data, the annual savings will be estimated.

The following equations will be used to calculate the energy values from the measured data.

Heating Energy:

$$\text{kWh/day} = \sum_{i=1}^{288}\left[\frac{(\text{element load}_i)}{(12\text{ intervals/hr})}\right] \qquad \text{Eq. 1}$$

Where the element load = 0 while not heating and element load = element capacity while heating.

Cooling Energy:

$$\text{kWh/day}_{\text{cooling}} = \sum_{i=1}^{288}\left[\frac{(\Delta T)(1.08)(\text{FCU cfm})(\text{chiller plant kW/ton})}{(12{,}000\text{ BTUs/ton})}\right] \qquad \text{Eq. 2}$$

$$\text{Peak kW}_{\text{cooling}} = \sum_{i=1}^{36}\left[\frac{(\Delta T)(1.08)(\text{FCU cfm})(\text{chiller plant kW/ton})}{(12{,}000\text{ BTUs/ton})}\right] \div 36 \qquad \text{Eq. 3}$$

i = each 5-minute interval of the measurement period; peak kW measured as average from 2 pm to 5 pm

Fan Energy:

kWh/day = directly measured Eq. 4

Peak kW = average during peak period Eq. 5

Each interval that the fan is not running, kWh and kW will equal 0. Peak demand kW will be calculated as the average kW values over the entire peak period.

Uncertainty for the savings estimates can be more fully understood by setting projected ranges on the primary variables.

Heating Energy Savings

- guest room occupancy: 75% expected, 50% minimum, 90% maximum (+20% maximum , -33% minimum)
- base runtime: 5% expected, 2% minimum, 15% maximum (+200% maximum , -60% minimum)
- time post retrofit: 314 expected, 200 minimum hours, 1,000 maximum hours (+200%, -35%) based on estimates of operation
- Capacity 1.5 kW expected, minimum 1.2 kW, maximum 1.7 kW (includes -20% and +13% for size of heating element)
- 100,000 kWh expected, minimum 50,000 kWh, maximum 180,000 kWh based on extrapolating from summer run time percentages to the entire year

Cooling Energy Savings

- guest room occupancy: 75% expected, 50% minimum, 90% maximum (+20% maximum , -33% minimum)
- time pre retrofit: 1,287 expected, 900 minimum, 1,600 maximum (+25%, -25%)
- time post retrofit: 916 expected, 600 minimum hours, 1200 maximum hours (+30%, -30%) based on estimates of operation
- Temp difference Average 12°F expected, minimum 6°F kW, maximum 15°F (includes -50% and +25%)
- 100,000 kWh expected, minimum 75,000 kWh, maximum 200,000 kWh based on extrapolating from summer run time percentages to the entire year

Fan Energy Savings

- guest room occupancy: 75% expected, 50% minimum, 90% maximum (+20% maximum , -33 % minimum)
- % time pre retrofit: 25% expected, 8% minimum, 75% maximum (±200%)
- % time post retrofit: 14.1% expected, 7% minimum hours, 28% maximum hours (±100%) based on expected operations
- Size: 476 x 0.043 kW expected (20 kW), maximum 476 x 0.053 kW (25 kW) for hi low operation)
- 110,000 kWh expected, minimum 88,000, maximum 132,000 kWh (based on 20% for extrapolating from summer run time percentages to the entire year)

This uncertainty analysis shows that time of operation of fan and heating elements, along with extrapolation from summer run time percentages to full year estimates, comprise the largest uncertainties to savings estimates. Attention will be primarily directed in the implementation of the M&V plan to capturing operating time percentages accurately.

There may be other small potential sources of error introduced, for a variety of reasons, such as variances in rooms monitored. The greatest source of error results due to the measurement being conducted during the late summer. These smaller errors are estimated at a maximum of ±10% in aggregate. The larger error sources can significantly affect savings.

Accuracy and Equipment

The spot electrical measurements are to be performed with a Wavetek Meterman, AC38, digital multimeter with and accuracy of 1.2%. Monitoring of electrical equipment will be performed with Dent DATApro logger, that uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format. These loggers have a resolution of 1 minute and for the purposes of the evaluation are 1.5% accurate (including CT).

Monitoring of temperatures will be performed with HOBO Temperature Data Logger, with an estimated accuracy of ±0.33°F.

Other collected data and reported data are considered to be 95% accurate where reviewed data is deemed reasonable.

Annualizing the cooling run time data and the fan run time data from the 4 week monitoring period is projected to result in a possible error in the final results of ±5%.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 18, 2007. Information was collected from equipment nameplates, spot power checks, and interviews with hotel staff. Several guest rooms were entered to examine FCUs and thermostat set points. Four guest rooms were monitored. Some of the guest room FCUs were oriented in a way that made installing data loggers impossible. Also, hotel occupancy was high and there were limited vacant rooms to sample. Another problem encountered was that simulating the base case operation was not possible. Originally, tech support at the thermostat manufacturer advised us that it would be possible to simulate manual operation by jumping out the occupancy sensor, but during the site visit it was determined that the thermostat model installed at this site does not have that capability.

Installation Verification

Eight guest rooms were surveyed during the on-site visit; all rooms had occupancy-sensor programmable thermostats installed. The thermostats have an allowable set point range between 65°F and 80°F. Each thermostat is equipped with an occupancy sensor and a door sensor which are used to determine activity in guest rooms. When a guest room door is closed, the occupancy sensor looks for activity in the room. If room activity is detected, the thermostat enters its occupied mode, in which the thermostat operates within a two-degree temperature range of the set target temperature. If the door is closed and no activity is detected for a period of 8 minutes, the thermostat reverts to its unoccupied mode, which allows the room temperature to swing to a prescribed shallow setback. If there continues to be no activity in the room for a period of 15 hours, the room enters an unsold room mode. In this mode the temperature is allowed to swing to a prescribed deep setback temperature.

The verification realization rate for this project is 1.0. A verification summary is shown in Table 14 below.

Summary of Results

Cooling for the building is provided by two, 360-ton water-cooled chillers. One chiller operates at a time, and the chillers cycle every 12 hours. The chilled water is distributed through a single primary loop system. Chilled water is circulated by four, 30-hp constant speed pumps. Heat rejection for the central chiller plant is provided by two evaporative cooling towers. The majority of the equipment, including the chillers and cooling towers, are original to the 22 year-old building.

Heating for guest rooms is provided by electric resistance heaters. Nameplate data could not be collected. Spot readings were taken and revealed a heating element power draw of 1.25 kW.

Nameplate fan power is 0.5-hp with a current of 0.3 amps at 277 volts. The previously existing thermostats controlled fans to 3 speeds and were entirely manual. The new thermostats control the fan to two speeds. Based on monitoring data the fan typically operates on high speed at a power of 0.290 kW.

The ex post savings analysis uses hourly TMY data for the appropriate climate zone. Each hourly interval calculates the FCU activity based on OA_{db} and occupancy rates. The equations for FCU activity were developed from monitoring data and correlations found at similar hotel sites in the same geographical area. Typical occupancy for this hotel is 75% from March through June and 70% the rest of the year.

The M&V monitoring plan was to monitor FCU supply air temperature in conjunction with FCU amps. However, the FCU configuration did not allow for temperature measurement. FCU units are above the ceiling tiles with limited workspace, and the supply air flow was not accessible. Therefore, cooling and heating runtimes were estimated with an alternate approach.

Baseline FCU activity could not be collected from monitoring, therefore, weather correlations from an analysis at a similar site[1] was used to estimate the heating and cooling with manual thermostats, cooling and fan only runtimes, as well as heating data. A summary of weather correlations and the source is provided in Table 3 through Table 6.

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[1] SPC 0405 Evaluation Site A011

Table 3: Base Case, Manual Thermostats, FCU Activity, Rented Rooms

Parameter	Equation	Restriction	Eq	Source
% cooling	$= 0.0302e^{0.0306xOA_{db}}$	OA_{db}>55°F	6	Monitoring data from a similar site
% heating	$= (0.000148 \times OAT^{2} - 0.0221 \times OA_{db} + 0.8569)$	OA_{db}<65°F	7	Monitoring data from a similar site
% fan only	$= \%\ \ cooling + \%\ \ post\ \ fan + \%\ \ heating$	None	8	Monitoring data
% fan (total)	$= \%\ \ cooling + \%\ \ fan + \%\ \ heating$	None	9	Sum of FCU activity

Table 4: Base Case, Manual Thermostats, FCU Activity, Unrented Rooms

Parameter	Equation	Restriction	Eq	Source
% cooling	$= 0.0302e^{0.0306xOA_{db}}$	OA_{db}>55°F	10	Monitoring data from a similar site
% heating	$= 0.33$	OA_{db}<65°F	11	Monitoring data from a similar site
% fan only	$= \%\ \ cooling + \%\ \ post\ \ fan + \%\ \ heating$	none	12	Monitoring data
% fan (total)	$= \%\ \ cooling + \%\ \ fan + \%\ \ heating$	none	13	Sum of FCU activity

Table 5: Post Case, Occupancy-Based Thermostats, FCU Activity, Rented Rooms

Parameter	Equation	Restriction	Eq	Source
% cooling	$= 0.00055OA_{db}^{2} - 0.0731OA_{db} + 2.59$	OA_{db}>55°F	14	Monitoring data
% heating	0.033	OA_{db}<65°F	15	Monitoring data from a similar site
% fan only	0.107	none	16	Monitoring data
% fan (total)	$= \%\ \ cooling + \%\ \ fan + \%\ \ heating$	none	17	Sum of FCU activity

Table 6: Post Case, Occupancy-Based Thermostats, FCU Activity, Unrented Rooms

Parameter	Equation	Restriction	Eq	Source
% cooling	$= 0.00564 OA_{db} - 0.3003$	OA_{db}>55°F	18	Monitoring data
% heating	0.022	OA_{db}<65°F	19	Monitoring data from a similar site
% fan only	=0.0312	none	20	Monitoring data
% fan (total)	$= \%\ cooling + \%\ \ fan + \%\ \ heating$	none	21	Sum of FCU activity

Using these equations, the FCU activity is calculated for each hourly interval. These equations are used to calculate the energy savings and demand reduction.

Heating energy consumption (kWh) for rented rooms:

$$= (476\text{FCUs})(\text{room occ rate})(\%\ \text{heating}_{\text{occupied}})(\text{element capacity}) \qquad \text{Eq. 22}$$

Heating energy consumption (kWh) for unrented rooms:

$$= (476\text{FCUs})(1 - \text{room occ rate})(\%\ \text{heating}_{\text{unoccupied}})(\text{element capacity}) \qquad \text{Eq. 23}$$

Cooling energy consumption (kWh) for rented rooms:

$$= (476\ \text{FCUs})(\text{room occ rate})(\%\ \text{cooling}_{\text{occupied}})\left[\frac{(\Delta\text{T})(1.08)(\text{FC U cfm})(\text{chiller plant kW/ton})}{(12{,}000\ \text{Btu/ton})}\right] \qquad \text{Eq. 24}$$

Cooling energy consumption (kWh) for unrented rooms:

$$= (476\ \text{FCUs})(1 - \text{room occ rate})(\%\ \text{cooling}_{\text{unoccupied}})\left[\frac{(\Delta\text{T})(1.08)(\text{FC U cfm})(\text{chiller plant kW/ton})}{(12{,}000\ \text{Btu/ton})}\right]$$

Eq.25

Fan energy consumption (kWh) for occupied rooms:

$$= (476\ \text{FCUs})(\text{room occ rate})(\text{fan power})(\%\ \text{fan}_{\text{occupied}}) \qquad \text{Eq. 26}$$

Fan energy consumption (kWh) for unoccupied rooms:

$$= (476\ \text{FCUs})(1\text{-}\ \text{room occ rate})(\text{fan power})(\%\ \text{fan}_{\text{unoccupied}}) \qquad \text{Eq. 27}$$

Peak demand is calculated as the average kW during peak period. Peak demand reduction is the difference between the calculated demand during peak periods for pre-retrofit and setback scenarios. Similarly, the energy savings is the difference between the energy consumption before the occupancy-based thermostats were installed and with the occupancy thermostats in operation. A summary of the ex post savings results are in Tables 11 through 17.

Table 7: Total Meter, Ex Ante, Ex Post Results

	Peak kW	Annual kWh
Total Meter	920.0	4,977,618
Baseline End Use	134.7	988,085
Ex Ante Savings	-	1,948,268
Ex Post Savings	38.0	369,271

Table 8: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	-	39.1%	4.1%	7.4%
Baseline End Use %	-	197.2%	28.2%	37.4%

6. Additional Evaluation Findings

As previously mentioned, the ex ante savings are not applicable for this measure. In Table 7 it can be seen that claimed ex ante kWh savings are far greater then the calculated baseline end use (Table 7). Therefore, the ex ante savings claim appears unrealistic and grossly overstated.

The ex post savings values are based on actual guest room data, where possible. Monitoring data at this hotel could not be used to identify heating vs OA_{db} correlations, or any baseline values. Therefore weather correlations developed for an evaluation of similar measures at a similar hotel[1] that had similar FCU systems, room sizes and occupancy patterns were used. The FCU activity is based on actual weather correlations. Even though these hotels are in different climate zones, the same correlations can be applied to both, and savings at each can be calculated using local TMY data. By using correlations from another site, additional uncertainty is introduced. However, these sites are similar, and based on the data that was collected, the performance and weather correlations are appropriate.

There are some factors in the ex post analysis that contribute to the uncertainty of the savings. The best estimates were applied to minimize the propagation of uncertainty in ex post savings calculations. One of these factors is the time spent at a particular fan speed. This will relate to the average fan power. The median value of 0.290 kW was used (with a possible range of ±50%). Other factors that cannot be accounted for are yearly fluctuations from TMY weather data and hotel occupancy. A summary of possible ranges of the primary variables is provided in Section 4.

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. With a cost of $116,401 and a $25,704 incentive, the project had a 0.36 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is significantly lower than ex ante, and the estimated simple payback is 1.9 years. A summary of the economic parameters for the project is shown in Table 6.

There are several positive, non-energy benefits from installing the occupancy based programmable thermostats. The existing thermostats were outdated in appearance, while the new units are considered attractive to hotel guests. Also, there is a better response time and smaller temperature swings with the new thermostats, thereby improving comfort.

7. Impact Results

Table 9: Ex Post Heating Savings

Baseline average on-time in heating mode	5.5%
Post average on-time in heating mode	2.3%
Heating capacity (kW)	1.25
Energy savings (kWh/yr)	164,561

Table 10: Ex Post Cooling Savings

Baseline average on-time in cooling mode	18.1%
Post average on-time in cooling mode	12.5%
FCU air flow rate (cfm)	300
FCU ΔT (°F)	15
Annual average chilled-water system efficiency (kW/ton)	1.0
Energy savings (kWh/yr)	97,786
Peak demand reduction (kW)	21.1

Table 11: Ex Post Fan Savings

Baseline average fan on	32.2%
Post average fan on	23.3%
Energy savings (kWh/yr)	106,924
Peak demand reduction (kW)	16.9

Table 12: Realization Rate Summary

	kW	kWh	therms
SPC Tracking System	-	1,948,268	-
SPC Installation Report (ex ante)	-	1,948,268	-
Impact Evaluation (ex post)	38.0	369,271	-
Engineering Realization Rate	-	0.1895	-

Table 13: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh)	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	11/9/2004	$116,401	0.0	1,948,268	0	$253,274.84	25,704.00	0.36	0.46
SPC Program Review (Ex Post)	11/27/2007	$116,401	38.0	369,271	0	$48,005.23	25,704.00	1.89	2.42

Table 14: Installed Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
HVAC OCCUPANCY SENSOR	O - Other	INNCOM e4 Smart Digital Thermostat	476	SensorStat DDC II by Onity Inc, occupancy-based thermostat	Physically inspected several guest rooms, and made sure units were in use	1

Table 15: Multiple Year Reporting Summary

Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	324,711	61,545				
2	2005	1,948,268	369,271	0	38.0		
3	2006	1,948,268	369,271	0	38.0		
4	2007	1,948,268	369,271	0	38.0		
5	2008	1,948,268	369,271	0	38.0		
6	2009	1,948,268	369,271	0	38.0		
7	2010	1,948,268	369,271	0	38.0		
8	2011	1,948,268	369,271	0	38.0		
9	2012	1,948,268	369,271	0	38.0		
10	2013	1,948,268	369,271	0	38.0		
11	2014	1,948,268	369,271	0	38.0		
12	2015	1,623,557	307,726	0	38.0		
13	2016						
14	2017						
15	2018						
16	2019						
17	2020						
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	21,430,948	4,061,981				

FINAL SITE REPORT

SITE A062 (0-784) Gyps   IMPACT EVALUATION
SAMPLE CELL: ORIGINAL   TIER: 4   END USE: Other

Measure	Comprehensive Air Compressor System Retrofit
Site Description	Manufacturing

1. Measure Description

This project involves the replacement of one 150 HP modulating and one 150 HP variable displacement rotary screw compressor with one 150 HP load/unload and one 175 HP VSD rotary screw compressor. The project also involves the addition of approximately 1,000 gallons of compressed air storage capacity.

2. Summary of the Ex Ante Calculations

The applicant calculated the estimated annual baseline compressor energy kWh usage using AirMaster+ software. Inputs to the software were based on known runtime hours, actual loading profiles, measured data (airflow and compressor energy), and actual/manufacturer performance curves. The reviewer verified the AirMaster+ inputs, including manufacturer specifications, measured data, and compressor information supplied by the applicant, in order to determine the estimated electrical usage of the baseline and proposed compressed air systems.

The annual energy savings resulting from the receiver retrofit (918 kWh) were included in the AirMaster+ report but not in the application summary. The reviewer added these additional savings to the application. During the post installation inspection, the reviewer found that the project was installed as proposed and the ex ante savings were approved.

The Installation Report Review (IRR) states that the ex ante savings are 418,497 kWh annually and demand reduction is 5.6 kW. These values agree with the tracking system data.

3. Comments on the Ex Ante Calculations

The ex ante calculations were performed using Air Master+. The project sponsor submitted pre retrofit monitored data with the application and the reviewer used this data for the Air Master+ simulation.

The reviewer noted that the project was installed as submitted in the application and the ex ante savings were accepted without post installation monitoring.

4. Measurement & Verification Plan

In the pre retrofit system, one of the modulating compressors was base-loaded and the variable displacement compressor acted as the trim machine. The other modulating compressor was used for backup. In the post retrofit system, the load/unload 150 HP compressor is base-loaded and the VSD controlled rotary screw compressor acts as the trim machine. The variable displacement unit was retained for backup purposes. Energy savings are realized by the higher efficiency of the replacement compressors, the higher efficiency of the VSD unit at part-load conditions, and the reduction of spikes in airflow demand based on the installation of larger receiver capacity.

The application states that the compressed air plant operates continuously.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit hours of operation, air usage profile, and the compressor energy consumption.

The goal of the M&V plan is to verify the kW and kWh consumed, which may be able to be derived from the air usage profile and pre-retrofit and post-retrofit hours of operation. Compressor unloading curves for the pre-retrofit and post-retrofit compressors will be used to estimate annual energy consumption and peak demand reduction from the air usage profiles.

Formulae and Approach

The M&V plan is a modified version of IPMVP Option A.

For this application, the pre-retrofit compressor usage and characteristics will be verified with the facility representative.

Power monitoring equipment will be installed on the new compressors for a minimum of 7 days, in order to verify the post retrofit hours of operation and power usage. Power will be measured in 2 minute intervals (or less) and averaged for each hour to determine average hourly kW.

Power measurements for the new compressors will be annualized to determine the annual kWh.

Using the measured average hourly kW, we will calculate the average hourly air usage profile of the new compressors for seven days using performance data for the VFD and load/unload compressors (% of compressor capacity vs. % full load power, based on data available from the manufacturer and / or from the DOE Compressed Air Challenge).

The pre-retrofit kW and kWh will be calculated based on performance data for the pre-retrofit compressors, which used inlet modulation control, utilizing the performance data

(% of compressor capacity vs. % full load power) from the DOE Compressed Air Challenge.

The energy consumption of this measure is not greatly affected by the outside air temperature. To estimate peak demand kW reduction, the expected reduction in connected kW due to the increased compressor efficiency during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in the week with the hottest weekday in June, July, August, September will be determined by calculating the average kW reduction from 2 pm to 5 pm, Monday to Friday during the 7 day period.

If kW measurements cannot be taken, we will request that the customer log readings from the compressor control panels on an hourly basis showing the air flow and air compressor kW for a 24 hour period. We will then use this data to annualize compressor performance.

The formulae and methodology for the calculations are summarized as follows:

To determine post-retrofit compressor kW and kWh

Measure kW in 5 minute (or less) intervals.

Calculate average kW for each hour for 168 hours (7 days):
Average the kW readings over the one hour period.

Calculate the average kWh for each hour in the 168 hour period:
Hourly kWh= Average hourly kW x 1 hour

Calculate kWh for the 168 hour period:
Sum the 168 hourly results

Estimate the annual kWh:
Multiply the 168 hour result x 52.14 weeks/year to obtain annual kWh (accounting for holidays if appropriate).

Calculate the average peak kW from the monitoring results between 2 p.m. to 5 p.m., Monday to Friday during the monitoring period.

To determine pre-retrofit compressor kW and kWh

Obtain the maximum capacity of the new air compressors and maximum input power from the manufacturer's representative. Determine the average hourly acfm from VFD and load/unload compressor performance data (% capacity versus % power) and adjust for changes in equipment/production/schedules if necessary.

Utilizing performance data from the DOE Compressed Air Challenge (CAC) and manufacturer's data (maximum capacity of the old air compressors and maximum input power) stated in the application, determine the average hourly kW for 168 hours for the pre-retrofit compressors. This will be determined from CAC performance data and based on the hourly air usage profile developed above.

Calculate the average kWh for each hour in the 168 hour period:
Hourly kWh= Average hourly kW x 1 hour

Calculate kWh for the 168 hour period:
Sum the hourly results

Estimate the annual kWh:
Multiply the 168 hour result x 52.14 weeks/year to obtain annual kWh (accounting for holidays if appropriate).

Calculate the average peak kW from the CAC performance data based on the hourly air usage profile developed above, between 2 p.m. to 5 p.m., Monday to Friday during the monitoring period.

The average peak kW and the kWh figures from the post-retrofit analysis will be subtracted from the pre-retrofit analysis and the result will be the ex post impact (kW and kWh savings).

Uncertainty for the savings estimate can be more fully understood by setting projected ranges on the primary variables.

Air Compressor Retrofit

- 275 kW pre-retrofit expected average maximum demand, + / - 25% (206-343 kW)
- 8,760 operating hours pre retrofit expected, +0%/- 15% (7,446-8,760 hours)
- Air usage: 1,200 cfm average +/- 30% (840-1,560 cfm)

Accuracy and Equipment

The Dent Elite Pro power monitors have a measurement error of less than 1%. The accompanying current transducers (CTs) have a measurement error of 2 to 5 % depending on the size needed for the compressor and the CT manufacturer. The compressor performance data is estimated to be +/- 5% accurate. Annualizing the seven day measurement period is estimated to be +/- 10% accurate.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 14, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the air compressor system and by interviewing the facility representative. Air compressor make, model, quantities and hours of operation were verified.

According to the facility representative, the new VFD driven air compressor developed operational problems shortly after the installation was completed. Approximately 12 months ago, the variable speed drive stopped operating and the compressor is no longer in use. The compressor manufacturer will not replace the drive under warranty and the facility representative stated that it is unlikely that the compressor will be repaired. The customer is using a rental compressor and the load/unload compressor to meet the plant demand. The customer is currently evaluating options for the compressed air system. It is possible that both compressors may be replaced in the near future.

Maximum occupancy is approximately 300 employees at any given time. The facility is occupied continuously from midnight Sunday to midnight Friday. The plant also operates approximately 25% of Saturdays. The facility is closed 2 holidays annually and the air compressor system is de-energized when the facility is unoccupied.

Installation Verification

The facility representative verified that prior to the retrofit, there was one Sullair 150 HP modulating and one Sullair 150 HP variable displacement rotary screw compressor. In the post retrofit system, the variable displacement 150 HP compressor was replaced by the VSD controlled 175 HP rotary screw compressor. The 150 HP modulating compressor was replaced by the 150 HP load/unload compressor. The new non-functioning 175 HP compressor is a Gardner Denver model VS870302EGJ753, rated at 870 CFM at 110 psig. The new load/unload 150 HP compressor is a Gardner Denver model ST150EBQ99M rated at 760 CFM at 100 psig (0.164 kW/acfm).

These are the only measures in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 5 below.

Scope of the Impact Assessment

The impact assessment scope is for the process/other end use measure in the SPC application covering the air compressor retrofit. These are the only measures in this application.

Summary of Results

The ex ante calculations were based on the variable displacement 150 HP compressor being replaced by the VSD controlled 175 HP rotary screw compressor and the 150 HP modulating compressor being replaced by the 150 HP load/unload compressor. The ex ante calculations assumed that the VSD compressor would act as the lead compressor until it reached maximum capacity. When it reached maximum capacity, the load/unload compressor would be enabled and the VSD compressor would act as the trim compressor. Most of the energy savings associated with the project were associated with the staging of the compressors to utilize the superior part load performance of the VSD compressor. As discussed above, the VSD compressor has failed and is not likely to be replaced. Therefore most of the ex ante savings are not being realized for this project.

The customer confirmed that the compressed air system essentially operates the same as before the retrofit. The new load/unload compressor is now functioning as the lead compressor and is fully loaded when the facility is operating. The rental compressor acts as the lag compressor. The system operation is not significantly different than before the retrofit documented in the application was performed.

We obtained performance data for the new load/unload compressor and the inlet modulated compressor that it replaced. The new load/unload compressor is marginally more efficient than the inlet modulated compressor. The ex post evaluation focuses on this difference in efficiency.

The pre-retrofit system inlet modulated 150 HP Sullair LS20S 150 H compressor has a full load efficiency of 0.174 kW/acfm at 100 psig. The post-retrofit system load/unload 150 HP Gardner Denver model ST150EBQ99M has a full load efficiency of 0.164 kW/acfm at 760 CFM and 100 psig. According to the customer, the new load/unload compressor is now functioning as the lead compressor and is fully loaded when the facility is operating. The ex post analysis was performed as follows:

- Pre and post retrofit hours of compressor operation are 6,521 hours/year. (52.14 weeks/year x 5 days/week + 13 Saturdays/year -2 holidays/year) x 24 hours/day= 6,521 hours/year.
- Pre-retrofit demand is 132.24 kW.

  760 acfm x 0.174 kW/acfm= 132.24 kW
- Pre-retrofit energy consumption is 862,337 kWh/yr.

  132.24 kW x 6,521 hours/yr = 862,337 kWh/yr
- Post-retrofit demand is 124.64 kW.

  760 acfm x 0.164 kW/acfm= 124.64 kW
- Post-retrofit energy consumption is 812,777 kWh/yr.

  124.64 kW x 6,521 hours/yr.= 812,777 kWh/yr
- The resulting annual kWh savings is 862,337 kWh/yr – 812,777 kWh/yr = 49,560 kWh/yr
- The demand reduction is 132.24 kW-124.64 kW= 7.6 kW

Utility billing data for the site was obtained from the IOU. For the period January 2004 to December 2004, pre-retrofit annual consumption was 12,767,778 kWh. Peak demand was 2,080 kW. Table 1 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility provided data.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 0.3% decrease in total meter kW, a 4.2% decrease in compressor end use kW, a 3.3% decrease in total meter kWh, and a 48.5% decrease in compressor end use kWh. The ex post results showed a 0.4% decrease in total meter kW, a 5.7% decrease in compressor end use kW, a 0.4% decrease in total meter kWh, and a 5.7% decrease in compressor end use kWh.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	2,080	12,767,778
Baseline End Use	132	862,337
Ex ante Savings	5.6	418,497
Ex Post Savings	7.6	49,560

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	0.3%	3.3%	0.4%	0.4%
Baseline End Use %	4.2%	48.5%	5.7%	5.7%

6. Additional Evaluation Findings

The ex post kW demand reduction is slightly higher than the ex ante estimate because we determined the increased efficiency of the load/unload compressor was higher than that used in the ex ante savings. The ex post energy savings are less than the ex ante energy savings because we found that the VSD driven compressor which provides most of the ex ante savings is no longer operating and is unlikely to be repaired.

The facility representative stated that the cost estimate provided in the application ($134,270) is from the invoice for the work performed for the project and is an accurate reflection of the project cost. The customer is very disappointed with the failure of the VSD compressor. The customer is currently investigating options to redesign the compressed air system and it not possible at this time to know how that may affect the energy consumption of the compressed air system. Participation in the 2004/2005 SPC Program has not encouraged the customer to perform any other energy efficiency projects without participating in an incentive program.

The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measure.

With a cost of $134,270 and a $33,480 incentive, the project had a 1.8 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 15.6 years. A summary of the economic parameters for the project is shown in Table 3. The customer stated that they have no reason to believe that the operation of the facility will change in the foreseeable future, therefore the multi-year impacts, shown in Table 6 below, are expected to remain constant over the life of the remaining load/unload compressor.

7. Impact Results

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	9/13/2004	$134,270	5.6	418,497	0	$54,405	$33,480	1.85	2.47
SPC Program Review (Ex Post)	8/18/2007	$134,270	7.6	49,560	0	$6,443	$33,480	15.64	20.84

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	5.6	418,497	-
SPC Installation Report (ex ante)	5.6	418,497	-
Impact Evaluation (ex post)	7.6	49,560	-
Engineering Realization Rate	1.36	0.12	NA

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Process- OTHER	O			Replace two 150 HP rotary screw air compressors with one 175 HP VFD driven and one 150 HP load/unload rotary screw air compressor.	2	Gardner Denver VS 870 302 EGJ753, Gardner Denver ST 150 EBQ99M	Physically verified compressor quantity and model.	1.0

Table 6: Multi Year Reporting Table

Program ID	SPC 2005 Application # A062
Program Name	2004-2005 SPC Application

Year	Calendar Year	Ex-ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	209,249	24,780	6	8		
3	2006	418,497	49,560	6	8		
4	2007	418,497	49,560	6	8		
5	2008	418,497	49,560	6	8		
6	2009	418,497	49,560	6	8		
7	2010	418,497	49,560	6	8		
8	2011	418,497	49,560	6	8		
9	2012	418,497	49,560	6	8		
10	2013	418,497	49,560	6	8		
11	2014	418,497	49,560	6	8		
12	2015	418,497	49,560	6	8		
13	2016	418,497	49,560	6	8		
14	2017	418,497	49,560	6	8		
15	2018	418,497	49,560	6	8		
16	2019	418,497	49,560	6	8		
17	2020	418,497	49,560	6	8		
18	2021	418,497	49,560	6	8		
19	2022	418,497	49,560	6	8		
20	2023	418,497	49,560	6	8		
TOTAL	**2004-2023**	7,742,195	916,860				

FINAL REPORT

SITE A063 (2004 – xxxx) Alum IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: Lighting

Measure	Lighting Fixture Replacement and Installation of Occupancy Sensors
Site Description	Industrial Manufacturing Facility

1. Measure Description

The customer completed a lighting retrofit for various locations throughout their facility. The retrofit project is broken down into nine (9) itemized measures (labeled I1-I9) and eight (8) calculated measures (labeled (C1-C8).

Measure I1 is the installation of twenty-three (23) 14 to 26 watt screw-in CFLs to replace twenty-three (23) incandescent bulbs. Measure I2 is the installation of thirteen (13) 14 to 26 watt screw-in CFLs with reflectors to replace thirteen (13) incandescent bulbs. Measure I3 is the installation of four (4) 2 foot T8 fixtures to replace four (4) 2 foot T12 fixtures. Measure I4 is the installation of five hundred sixty-two (562) 4foot T8 fixtures to replace five hundred sixty-two (562) T12 fixtures. Measure I5 is the de-lamping of three hundred fifty (350) 4 foot T8 fixtures. Measure I6 is the installation of three hundred ninety-eight (398) high bay T8 fixtures. Measure I7 is the installation of four (4) wall-mounted occupancy sensors. Measure I8 is the installation of twenty-two (22) ceiling-mounted occupancy sensors. Measure I9 is the installation of fourteen (14) LED exit signs.

Measure C1 is the installation of eight (8) 2-lamp 4 foot T8 fixtures to replace eight (8) 400 watt high-pressure sodium fixtures. Measure C2 is the installation of three (3) 100 watt pulse-start metal halide fixtures to replace three (3) 500 watt quartz fixtures. Measure C3 is the installation of twenty-three (23) 8-lamp T5 fixtures to replace twenty-three (23) 1000 watt metal halide fixtures. Measure C4 is the installation of three (3) 2-lamp T5 fixtures to replace three (3) 500 watt incandescent fixtures. Measure C5 is the installation of four (4) 2-lamp T8 fixtures to replace four (4) 500 watt incandescent fixtures. Measure C6 is the installation of seven (7) 2-lamp T8 fixtures to replace seven (7) 500 watt incandescent fixtures. Measure C7 is the installation of twenty-nine (29) 250 watt metal halide fixtures to replace twenty-nine (29) 400 watt high-pressure sodium fixtures. Measure C8 is the installation of ten (10) 100 watt metal halide fixtures to replace ten (10) 250 watt mercury vapor fixtures.

The fixture retrofits save energy through increased efficacy and the occupancy sensors reduce energy usage through reduced hours of operation.

2. Summary of the Ex Ante Calculations

The ex ante calculations were performed using a combination of itemized and calculated savings. For the calculated measures, a simple pre-retrofit and post-retrofit algorithm, using fixture connected loads and hours of operation, was used to determine the demand and energy savings. The estimated savings are presented in Table 1.

Table 1: Energy and Demand Savings for Calculated Measures

Measure	Description	Qty	Pre-Retrofit Fixture Watts	Post-Retrofit Fixture Watts	kW Savings	Hours	Utility kWh Savings
C1	T8 Replacing HPS400	8	465	58	3.3	4,992	16,254
C2	MH100PS replacing 500W Qtz	3	500	128	1.1	4,992	5,572
C3	8L T5 replacing MH1000W	23	1,080	468	14.1	4,992	70,268
C4	2L T5 replacing 500W Inc.	3	500	117	1.1	4,992	5,736
C5	2L T8 replacing 500W Inc.	4	500	58	1.8	4,992	8,826
C6	2L T8 replacing 500W Inc.	7	500	58	3.1*	4,992	15,446
C7	250W MH replacing HPS400W	29	465	270	5.7	4,368	24,701
C8	100W MH replacing 250W MV	10	290	128	1.6	4,368	7,076
Total					**31.8**		**153,880**

*In the submitted utility workpapers, this measure was given a 1.8kW savings value. This appears to be a typographical error duplicating the savings for the previous measure.

For the itemized measures, savings were estimated based on utility defined standard fixture replacement wattage savings tables to determine the various measure savings. The itemized savings values are shown in Table 2.

Table 2: Energy and Demand Savings for Itemized Measures

Measure	Description	Qty	Standard Watt Savings Value	Standard kWh Savings Value	Utility kW Savings	Utility kWh Savings
I1	14-26W Screw-in CFL	23	49.5	231.908	1.14	5,334
I2	14-26W Screw-in CFL w/reflec.	13	49.5	231.908	0.64	3,015
I3	T8 L&E ballast-2 foot	4	10.0	46.382	0.04	185.5
I4	T8 L&E ballast-4 foot	562	11.0	50.13	6.18	28,173
I5	T8 or T5-4 foot delamping	350	43.0	201.455	15.05	70,509
I6	Interior High Bay Fixture	398	224.0	896	89.15	356,608
I7	Wall box occ. Sensor	4	89.0	416.965	0.36	1,668
I8	Ceiling occ. Sensor	22	305.0	1428.93	6.71	31,436
I9	LED Exit Sign	14	42.4	351.36	0.59	4,919
Total					**119.9**	**501,847**

The calculated and itemized measures combined result in a total demand and energy savings of 151.6 kW and 655,727 kWh. These figures are noted in the Installation Report Review and in the utility tracking system.

3. Comments on the Ex Ante Calculations

The ex ante calculations were performed using a combination of calculated and itemized approaches. For the calculated measures, the savings were determined using fixture quantities and wattages consistent with the SPC standard wattage tables for the existing and proposed fixtures. For the itemized measures, savings were determined using utility defined standard fixture replacement wattage savings tables. The savings for itemized measures could likely have been more accurately calculated using the customer supplied pre and post retrofit fixture types and hours of operation; however, they could not be calculated due to the incomplete descriptions used.

Hours of operation for the calculated measures were based on 4,992 hours of operation for indoor fixtures and 4,368 hours per year for outdoor fixtures. Hours of operation for the itemized measures were determined using the utility defined kWh and kW savings values.

Using the ex ante baseline as the pre-retrofit system, the pre-retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

<u>Measure C1: T8 Replacing HPS400, for a lighting fixture example</u>

kW = Fixture watts / 1,000 watts/kW x fixture quantity

kWh = kW x Operating hours

The ex ante impacts were calculated as follows:

> Pre-retrofit hours of operation were 4,992 hrs/year.
> Pre-retrofit wattage was 465 watts per fixture x 8 fixtures = 3.72 kW
> Annual kWh usage was 3.72 kW x 4,992 hrs/yr = 18,570 kWh/yr.
>
> Post-retrofit hours of operation were 4,992 hrs/year.
> Post-retrofit wattage is 58 watts per fixture x 8 fixtures = 0.464 kW
> Annual kWh usage is 0.464 kW x 4,992hrs/yr = 2,316 kWh/yr

The resulting annual kWh savings is 18,570 kWh/yr – 2,316 kWh/yr = 16,254 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load.

Peak kW savings is 3.72 kW – 0.464 kW = 3.26 kW

Measure I7 Wall Occupancy Sensors (using a calculated approach)

Measure I7 was calculated using an itemized approach; however, this measure could also have been calculated using the method below.

kW = Fixture watts / 1,000 watt/kW x fixture quantity

kWh = kW x Operating hours

kW = (# of Fixtures) * (kW per Fixture) * (Diversity Factor)

Diversity Factor = % the lights are on after installation of occupancy sensors.

kWh = (# of Fixtures) * (kW per Fixture) * (OpHrsPre – OpHrsPost)

Summer peak impacts are estimated by subtracting post-retrofit from pre-retrofit connected load.

4. Measurement & Verification Plan

This facility is a 135,000 sf industrial manufacturing facility used for the production of precision aluminum castings for use in the automotive and aerospace industry. This facility is expected to be occupied 24 hours per day Monday through Friday and occasionally on Saturdays. Periods of peak occupancy are expected to occur Mondays through Fridays from 7:00 AM to 11:00 PM. Approximately 10,000 sf is office space and is conditioned. The remaining 125,000 sf is unconditioned. This facility has few windows but does have some skylights.

The goal of the M&V plan is to estimate the peak kW and annual kWh reduction due to the replacement of less efficient fixtures and lower usage due to occupancy sensors, over the expected useful lives of these measures.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. The lighting fixtures in question are not expected to consume a large percentage of the facility's total usage. Fixture wattages are expected to be sufficiently defined from SPC standard wattage tables and manufacturer information. In addition, there is not expected to be significant seasonal variation and two weeks should be sufficient for comparison; however, a longer period would more fully capture actual variations and the persistence of savings. Interval data on a 15-minute or less basis, preferably during the summer months of June to September, would be helpful to determine coincident peak period demand savings.

Pre-retrofit and post-retrofit calculations of lighting demand and energy usage will be calculated using the following formulae:

kW = Fixture watts / 1,000 watts/kW x fixture quantity x percent energized during peak demand period

kWh = kW x Operating hours x Percent energized

The most significant variables to be quantified are the pre-retrofit and post-retrofit hours of operation. Pre-retrofit hours will be confirmed with the site personnel to verify that the facility hours have not changed since the implementation of these measures.

In addition, nearly 77% of the kWh savings are attributed to itemized measures. The facility representative will be interviewed to determine, if possible, the pre-retrofit fixture quantities and type. Appropriate modifications for the savings calculations will be made to the pre-retrofit usage figures if required, in order to establish a realistic baseline for energy use.

For this application, we propose to verify the pre-retrofit fixture types, quantities and hours of operation with the facility representative. Specifically, measures I5, I6, and C3 will be examined. These three measures account for 76% of the kWh savings attributed to this application. In addition, the occupancy sensors projects I7 and I8 will be verified because these projects have a large degree of uncertainty associated with both the fixture wattage as well as the hours of operation.

We will install no less than fifteen (15) Hobo H8 light loggers in throughout the facility in representative areas for the three measures for a minimum of 14 days to verify the post retrofit hours of operation. These optical loggers record lighting status (on/off).

The hours of operation determined from these loggers will then be used, along with customer's description of hours of operation, to determine reasonable hours of operation for the areas not specifically metered.

Uncertainty for the savings estimate for the lighting retrofit can be more fully understood by setting projected ranges on the primary variables.

<u>For the Pre-Retrofit Fixtures</u>

- Total fixture demand of 375.2 kW, maximum of 427.8 kW, minimum of 323.9 kW (+14.0%, -13.7%, based on judgment of deviation from typical fixture wattages in SPC standard wattage table and expected ranges of error from standard kW savings values for)

<u>For the Post-Retrofit Fixtures</u>

- Total fixture demand of 223.6 kW, maximum of 254.0 kW, minimum of 193.8 kW (+13.6%, -13.3%, based on judgment of deviation from typical fixture wattages in SPC standard wattage table and expected ranges of error from standard kW savings values)

<u>For the Lighting Retrofit</u>

- 151.6 kW expected savings, maximum 212.3 kW, minimum 92.3 kW (+40.1%, -39.1%, based on pre and post-retrofit fixture expected deviation, and propagation of error method)

- 655,729 kWh expected savings, maximum 926,175 kWh, minimum 392,230 kWh (+41.2%, -40.2%, based on pre and post-retrofit fixture expected deviation, and propagation of error method

Accuracy

The Hobo H8 light on/off loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable. The SPC lighting wattage tables and field verified fixture counts are considered to be 100% accurate.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate. The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 5, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Eight (8) lighting on/off loggers were installed throughout the manufacturing facility.

Installation Verification

For the high-bay retrofit measure, the facility representative verified that the pre-retrofit lighting fixtures were 400W high-pressure sodium. Per the utility installation report, 374 fixtures were replaced with high bay fluorescent fixtures. This was confirmed through discussion with the customer representative. The installation of the 398 post-retrofit high-bay fluorescent fixtures was physically verified.

For the T8 fixture delamping measure, the facility representative verified that the observed fixtures were installed as part of the T8 retrofit project, and involved delamping. The removal of the 350 lamps was physically verified.

For the 8-lamp T5HO retrofit measure, the facility representative verified that the pre-retrofit lighting fixtures were 1000 watt metal halide. Per the utility installation report, 23 fixtures were removed. This was confirmed through discussion with the customer representative. The installation of the 23 post-retrofit high-bay fluorescent fixtures was physically verified.

The facility representative stated that the retrofit occurred in July through August of 2004.

Fourteen additional lighting retrofit projects were completed at this facility. The other measures were observed during the on-site verification, but not investigated in depth.

The verification realization rate for each of the projects verified is 1.0. A verification summary is shown in Table 3 below.

Table 3: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING	L		INTERIOR HIGH-BAY RETROFIT		398	4 OR 6 LAMP T8 HIGH BAY FIXTURES	PHYSICALLY VERIFIED FIXTURES FOR QUANTITY AND TYPE	1.0
LIGHTING	L		T8 WITH DELAMPING		350	T8 FIXTURES DELAMPED	PHYSICALLY VERIFIED FIXTURES FOR QUANTITY AND TYPE	1.0
LIGHTING	L		8L T5 TO REPLACE 1000 WATT METAL HALIDE		23	8 LAMP T5HO FIXTURES	PHYSICALLY VERIFIED FIXTURES FOR QUANTITY AND TYPE	1.0

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measures in the SPC application. These were the only measures in this application.

Summary of Results

Eight Hobo light on/off loggers were installed on representative areas of the manufacturing facility for 12 days (from August 23, 2007-September 4, 2007) to measure the operating hours of a representative sample of the retrofit lighting fixtures.

The facility representative stated that this facility operates typically 24 hours per day, five days per week. In addition, Saturday shifts are operated as needed to fill production demands. The first shift is the largest shift with an expected occupancy of around 90 workers. During the second and the third shifts the occupancy is much low, at between 5 to 10 workers. During this period, lighting is energized as needed. The facility representative stated that the 12-day period had been representative of normal facility operation with the exception of the holiday periods.

The customer was able to provide a list of pre-retrofit and post-retrofit fixtures. Upon examination, it was determined that the occupancy sensors were located in individual offices as well as a few small common areas. Due to the relatively small portion of the demand reduction and energy savings associated with these fixtures, no loggers were placed to better evaluate these measures (I7 and I8). Instead, the number and type of fixtures connected to the sensors was recorded. The fixture wattages were determined from the SPC standard wattage tables. Standard percent savings values from the SPC Program Procedures Manual were used.

Table 4: Occupancy Sensor Savings

Sensor	Fixture Qty	Fixture	Qty	kW each	Area	% Savings	kW Saved	Hours per Year	kWh Savings
Wall	8	4' 2L T8	2	0.06	Office	30%	0.03	3,983	134
Wall	10	4' 2L T8	4	0.06	Office	30%	0.07	3,983	268
Wall	31	4' 2L T8	4	0.06	Office	30%	0.07	3,983	268
Wall	56	4' 2L T8	4	0.06	Lunch	25%	0.06	3,983	223
Ceiling	9	4' 2L T8	8	0.06	Conference	35%	0.16	3,983	625
Ceiling	21	4' 2L T8	2	0.06	Engineering	15%	0.02	3,983	67
Ceiling	22	4' 2L T8	12	0.06	Customer Service	15%	0.10	3,983	402
Ceiling	24	4' 2L T8	4	0.06	Offices	30%	0.07	3,983	268
Ceiling	33	4' 2L T8	4	0.06	Computer Rm	45%	0.10	3,983	402
Ceiling	48	4' 2L T8	8	0.06	QC Lab	45%	0.20	3,983	803
Ceiling	49	4' 2L T8	8	0.06	Back Lab	45%	0.20	3,983	803
Ceiling	57	4' 2L T8	8	0.06	Office	30%	0.13	3,983	535
Ceiling	72	4' 2L T8	4	0.06	Office	30%	0.07	3,983	268
Ceiling	82	4' 2L T8	6	0.06	Offices	30%	0.10	3,983	402
Total							**1.15**		**4,573**

The eight Hobo light on/off loggers were placed at various locations throughout the production area of the facility. The production area comprised the vast majority of the footprint of the building, as well as being the area where the vast majority of the fixtures were installed. Measures I5, I6, and C3, which account for 76% of the kWh savings, involved fixtures on the production floor.

The fixture type and quantity for these measures was consistent with the original application.

To accurately represent the hours of operation, the light fixtures must be broken down into two categories: interior and exterior. The majority of the fixtures are interior lights, which are expected to operate on a similar schedule. A small portion of the fixtures are exterior lights, and operate only during evening hours. In the ex ante calculations, the exterior lights were expected to operate 4,368 hours per year. The site representative stated that that was a reasonable value. Based on the logged data, it was determined that the interior light fixtures operated on average 53.0% of the time during Monday-Saturday hours. The fixtures were not found to operate on Sundays. In addition, the metering period included a holiday, during which the light fixtures were not found to operate. Based on this operating schedule, the fixtures are expected to operate 3,983 hours per year (24 hours/day x 6 days/week x 52.14 weeks/year x 53.0%). A description of the operating hours can be found in Table 5 below.

Table 5: Hobo Light On/Off Logger Results

Location	%Time Running	Location	%Time Running
Maintenance	44.4%	Die Trim	67.7%
Die Repair	49.3%	Stock Prep	45.0%
Chip and Mill	56.3%	Inspection	56.8%
Forge Shop	51.9%		
Average			**53.0%**
Hours per year of operation			**3,983**

Using the hours of operation presented above, the customer list of pre-retrofit and post-retrofit fixtures, and the SPC standard wattage tables, the savings could be accurately determined.

These results are summarized in Table 6.

Table 6: Revised Energy and Demand Savings for Calculated and Itemized Measures

Measure	Description	Pre-Retrofit Qty	Pre-Retrofit Fixture Watts	Post-Retrofit Qty	Post-Retrofit Fixture Watts	kW Savings	Hours	Utility kWh Savings
C1	T8 Replacing HPS400	8	465	8	58	3.3	3,983	12,969
C2	MH100PS replacing 500W Qtz	3	500	3	128	1.1	3,983	4,445
C3	8L T5 replacing MH1000W	23	1,080	23	468	14.1	3,983	56,067
C4	2L T5 replacing 500W Inc.	3	500	3	117	1.1	3,983	4,577
C5	2L T8 replacing 500W Inc.	4	500	4	58	1.8	3,983	7,042
C6	2L T8 replacing 500W Inc.	7	500	7	58	3.1	3,983	12,324
C7	250W MH replacing HPS400W	29	465	29	270	5.7	4,368	24,701
C8	100W MH replacing 250W MV	10	290	10	128	1.6	4,368	7,076
Total Calculated Measures						**31.7**		**129,200**
I1	14-26W Screw-in CFL	23	81[1]	23	17[1]	1.5	4,101[1]	6,037
I2	14-26W Screw-in CFL w/reflec.	13	76[1]	13	15	0.8	4,032[1]	3,185
I3	T8 L&E ballast-2 foot	4	28[2]	4	17[2]	0.05	3,983	123
I4	T8 L&E ballast-4 foot	562	36[2]	562	28[2]	4.5	3,983	17,908
I5	T8 or T5-4 foot delamping	350	28[2]	350	0	9.8	3,983	39,035
I6	Interior High Bay Fixture	374	465[2]	398	241[2]	78.0	3,983	310,654
I7	Wall box occ. sensor	4	196[1,2]	4	140[1,2]	0.2	3,983	892
I8	Ceiling occ. sensor	22	239[1,2]	22	162[1,2]	1.7	3,983	6,707
I9	LED Exit Sign	14	30[1,2]	14	9[2]	0.3	8,760	2,575
Total Itemized Measures						**96.8**		**387,178**
Total						**128.5**		**516,378**

[1] Indicates values determined through a weighted average of individual fixture information
[2] Indicates values determined from discussion with customer representative and SPC standard wattage tables.

During daytime hours it was found that all units operated, therefore, at the summer peak hour, between 2 pm and 5 pm on the hottest weekdays, all lighting fixtures are expected to be in operation.

The ex post impacts are calculated as in Table 7 below, which details one measure.

Table 7: Energy and Demand Formulae Example for Fixture Replacement (I6)

Pre-Retrofit Demand kW_{peak}	= Pre-Retrofit Fixture Wattage x Pre-retrofit Fixture Qty = 0.465 kW/Fixture x 374 Fixtures = 173.9 kW
Post-Retrofit Demand kW_{peak}	= Post-Retrofit Fixture Wattage x Post-retrofit Fixture Qty = 0.241 kW/Fixture x 398 Fixtures = 95.9 kW
Peak kW Savings	= Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak} = 173.9 kW – 95.9 kW = 78.0 kW
Pre-Retrofit kWh	= Pre-Retrofit Demand kW_{peak} x Pre-retrofit Hours = 173.9 kW x 3,983 hours/year = 692,711 kWh/yr
Post-Retrofit kWh	= Post-Retrofit Demand kW_{peak} x Post-retrofit Hours = 95.9 kW x 3,983 hours/year = 382,056 kWh/yr
kWh Savings	= Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak} = 692,711 kWh/yr – 382,056 kWh/yr = 310,654 kWh/yr

The ex post kW demand reduction is greater than the ex ante estimate, as it was found that the "typical demand savings" value assumed by the utility overestimated the demand reduction in itemized measures I4 through I9.

The ex post energy savings are also less than the ex ante energy savings due to the overestimation of demand reduction as well as the overestimated hours of operation used in the ex ante calculations.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. In addition to saving energy, the new fixtures were described as having a better quality of light. The customer did not give any drawbacks associated with the new equipment. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program has not encouraged them to perform any other energy efficiency projects for which they did not participate in an incentive program. However, they have completed a compressed air retrofit project with the assistance of utility incentive programs.

We were unable to physically verify the pre-retrofit lighting fixture type, quantity and hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

7. Impact Results

Based on the ex ante savings of 150.4 kW and 655,729 kWh the engineering realization rate for this application is 0.85 for kW reduction and 0.78 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 8.

Table 8: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	150.4	655,728	-
SPC Installation Report (ex ante)	150.4	655,728	-
Impact Evaluation (ex post)	128.5	516,378	-
Engineering Realization Rate	0.85	0.79	N/A

Utility billing data for the site was reviewed. In the 12-month period from January 2003 - December 2003 (pre-retrofit), the facility consumed 4,351,627 kWh. Peak demand was 1,356.8 kW in March 2003. Table 9 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 9: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1,356.8	4,351,627
Baseline End Use	259.6	1,042,516
Ex ante Savings	150.4	655,728
Ex Post Savings	128.5	516,378

Table 10 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed an 11.1% decrease in total meter kW, a 57.9% decrease in lighting end use kW, a 15.1% decrease in total meter kWh, and a 62.9% decrease in lighting end use kWh. The ex post results showed a 9.5% decrease in total meter kW, a 49.5% decrease in lighting end use kW, an 11.9% decrease in total meter kWh, and a 49.5% decrease in lighting end use kWh.

Table 10: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	11.1%	15.1%	9.5%	11.9%
Baseline End Use %	57.9%	62.9%	49.5%	49.5%

With a cost of $118,500 and a $41,509 incentive, the project had a 0.90 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 1.15 years. A summary of the economic parameters for the project is shown in Table 11.

Table 11: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), ($0.80/therm) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	5/11/2004	$118,500	150.4	655,728	-	$85,245	$41,509	0.90	1.39
SPC Program Review (Ex Post)	9/14/2007	$118,500	128.5	516,378	-	$67,129	$41,509	1.15	1.77

A useful life for each measure was determined using the information form the California Public Utilities Commission *Energy Efficiency Policy Manual*. A summary of the measure category and effective useful lives is given in Table 12.

Table 12: Measure Effective Useful Life

Measure	Description	Category	Useful Life
C1	T8 Replacing HPS400	Fluorescent Fixture-T8	16
C2	MH100PS replacing 500W Qtz	HID Fixture	16
C3	8L T5 replacing MH1000W	High Output T5 Fixture	16
C4	2L T5 replacing 500W Inc.	High Efficiency Lighting	16
C5	2L T8 replacing 500W Inc.	Fluorescent Fixture-T8	16
C6	2L T8 replacing 500W Inc.	Fluorescent Fixture-T8	16
C7	250W MH replacing HPS400W	HID Fixture	16
C8	100W MH replacing 250W MV	HID Fixture	16
I1	14-26W Screw-in CFL	CF-Screw-in Replacement Lamp	8
I2	14-26W Screw-in CFL w/reflec.	CF-Screw-in Replacement Lamp	8
I3	T8 L&E ballast-2 foot	Fixture: T8 Lamp and Electronic Ballast	16
I4	T8 L&E ballast-4 foot	Fixture: T8 Lamp and Electronic Ballast	16
I5	T8 or T5-4 foot delamping	Delamping/Fixture Modification/Removal	16
I6	Interior High Bay Fixture	High Efficiency Lighting	16
I7	Wall box occ. sensor	Occupancy Sensor	8
I8	Ceiling occ. sensor	Occupancy Sensor	8
I9	LED Exit Sign	Exit Sign	16

A summary of the multi-year reporting requirements is given in Table 13. Because this measure was installed in approximately August of 2004, the energy savings in year #1 (2004) are assumed to be 1/3 of the expected annual savings for this measure. In addition, no peak savings are assumed to occur in this year.

Table 13: Multi-Year Reporting Requirements

Program Name:		SPC 04-05 Evaluation, Site A063					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	218,576	172,126	-	-	-	-
2	2005	655,728	516,378	150.4	128.5	-	-
3	2006	655,728	516,378	150.4	128.5	-	-
4	2007	655,728	516,378	150.4	128.5	-	-
5	2008	655,728	516,378	150.4	128.5	-	-
6	2009	655,728	516,378	150.4	128.5	-	-
7	2010	655,728	516,378	150.4	128.5	-	-
8	2011	655,728	516,378	150.4	128.5	-	-
9	2012	641,910	510,771	147.4	127.1	-	-
10	2013	614,275	499,557	141.5	124.4	-	-
11	2014	614,275	499,557	141.5	124.4	-	-
12	2015	614,275	499,557	141.5	124.4	-	-
13	2016	614,275	499,557	141.5	124.4	-	-
14	2017	614,275	499,557	141.5	124.4	-	-
15	2018	614,275	499,557	141.5	124.4	-	-
16	2019	614,275	499,557	141.5	124.4	-	-
17	2020	409,517	333,038	141.5	124.4	-	-
18	2021	-	-	-	-	-	-
19	2022	-	-	-	-	-	-
20	2023	-	-	-	-	-	-
TOTAL	**2004-2023**	10,160,025	8,127,486			-	-

FINAL REPORT

SITE A064 (0450-04) Edwa IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 5 END USE: Lighting

Measure	T5 Lighting Retrofit
Site Description	Medical Manufacturing Facility

1. Measure Description

Replace one hundred eighty-eight (188) 250 watt metal halide fixtures with one hundred eighty-eight (188) three (3) lamp T5 fluorescent fixtures.

2. Summary of the Ex Ante Calculations

A simple pre-retrofit and post-retrofit algorithm using fixture connected loads and hours of operation was used for the ex ante calculations. The pre-retrofit lighting fixture watts used in the calculation agree with the values in the SPC lighting fixture wattage tables. The post-retrofit lighting fixtures could not be found in the SPC lighting fixture wattage tables, however, the fixture watts used in the calculation are reasonable when compared to typical manufacturer specifications. The hours of operation were not provided; however, these are assumed to be 4,289.5 hours per year.

The ex ante baseline is the existing system connected load and hours of operation, and is in accordance with the SPC Program guidelines. Pre-retrofit and post-retrofit calculations of lighting loads and energy use were performed using the following formulae:

kW = Fixture watts / 1,000 watts / kW x fixture quantity

kWh = kW x operating hours

The ex ante impacts were calculated as follows:

> Pre-retrofit hours of operation were 4,289.5 hrs/year.
> Pre-retrofit wattage was 295 watts per lamp x 188 lamps = 55.5 kW
> Annual kWh usage was 55.5 kW x 4,289.5 hrs/yr = 238,067 kWh/yr.
>
> Post-retrofit hours of operation were 4,289.5 hrs/year.
> Post-retrofit wattage is 105 watts per fixture x 188 fixtures = 19.8 kW
> Annual kWh usage is 19.8 kW x 4,289.5 hrs/yr = 84,932 kWh/yr

The resulting annual kWh savings is 238,067 kWh/yr – 84,932 kWh/yr = 153,135 kWh/yr (153,102 kWh/yr in the Installation Report Review and in the utility tracking system).

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load.

Peak kW savings is 55.5 kW – 19.8 kW = 35.7 kW (35.7 in the Installation Report Review and 36.0 in the utility tracking system).

3. Comments on the Ex Ante Calculations

No calculations were provided in the application The calculations were duplicated as closely as possible using descriptions of equipment found in the application.

No make or model number was provided in the application for the pre-retrofit fixtures. However, it was stated that the fixtures were 250 watt metal halide. Based on the Table of Standard Fixture Wattages provided in Appendix B of the 2004 SPC Procedures Manual, a 250 W metal halide fixture has a typical demand of 0.295 kW/fixture.

Per the application, the proposed fixtures included three (3) 22.5" GE Biax T5 U-tube bulbs and Sylvania Quicktronic instant start electronic ballasts. No model number was specified for the ballast, nor was the number of ballasts per fixture specified. Therefore, it was assumed that there was one ballast per fixture to power the three T5 U-tube bulbs. Within the Quicktronic line, several ballast met this criteria, and depending on the voltage input and the ballast factor selected, the demand per ballast ranged from 99 watts fixture to 110 watts per fixture. If a demand of 105 W per fixture is used, the resulting savings are consistent with the reported savings.

The hours of operation were also not clearly defined in the application. The one hundred seventy-six fixtures installed in the clean room are all expected to operate thirteen (13) hours per day Monday through Friday and six and one-fourth (6.25) hours per day on Saturdays. In addition, additional hours must be added for daily cleaning, during which the lighting controls are overridden. The additional hours were not specified in the application. In addition, no hours of operation were specified for the twelve (12) fixtures installed in the packaging area. The energy savings value in the application is consistent with the average hours of operation of 4,289.5 hours per year.

Based on the fixtures and hours of operation listed above, the ex ante impacts were calculated as follows:

> Pre-retrofit hours of operation were 4,289.5 hrs/year.
> Pre-retrofit wattage was 295 watts per lamp x 188 lamps = 55.5 kW
> Annual kWh usage was 55.5 kW x 4,289.5 hrs/yr = 238,067 kWh/yr.
>
> Post-retrofit hours of operation were 4,289.5 hrs/year.
> Post-retrofit wattage is 105 watts per fixture x 188 fixtures = 19.8 kW
> Annual kWh usage is 19.8 kW x 4,289.5 hrs/yr = 84,932 kWh/yr

The resulting annual kWh savings is 238,067 kWh/yr – 84,932 kWh/yr = 153,135 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load.

Peak kW savings is 55.5 kW – 19.7 kW = 35.7 kW

4. Measurement & Verification Plan

The building is a 77,500 ft^2 conditioned office and manufacturing facility that manufactures medical products. Peak occupancy is expected to occur between 6 AM and 11 PM, Monday through Friday, with limited occupancy occurring periodically outside of that time period. According to the application, one hundred eighty-eight (188) fixtures were replaced under this retrofit. One hundred seventy-six (176) of the fixtures are located in a production clean room. The remaining twelve (12) fixtures are located in a packaging area. The pre-retrofit fixtures were 250 watt metal halide fixtures. The post-retrofit fixtures were three-lamp T-5 fluorescent fixtures. The project saves energy through the installation of lighting fixtures with a higher efficacy (more lumens per watt).

The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction due to the installation of the one hundred eighty-eight (188) three-lamp T5 fixtures to replace one hundred eighty-eight (188) 250 watt metal halide fixtures over the useful life of this retrofit.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. The lighting fixtures in question are not expected to consume a large percentage of the facility's total usage. Fixture wattages are expected to be sufficiently defined from SPC standard wattage tables and manufacturer information. In addition, there is not expected to be significant seasonal variation and two weeks should be sufficient for comparison; however, a longer period would more fully capture actual variations and the persistence of savings. Interval data on a 15-minute or less basis, preferably during the summer months of June to September, would be helpful to accurately determine coincident peak period demand savings.

Pre-retrofit and post-retrofit calculations of lighting demand and energy usage will be calculated using the following formulae:

kW = Fixture watts / 1,000 watts/kW x fixture quantity x percent energized during peak demand period

kWh = kW x Operating hours x Percent energized

The most significant variables to be quantified are the pre-retrofit and post-retrofit hours of operation. Pre-retrofit hours will be confirmed with the site personnel to verify that the production hours listed in the application (4,289) were valid. Appropriate modifications for the savings calculations will be made to the pre-retrofit usage figures if required, in order to establish a realistic baseline for energy use.

For this application, we propose to verify the pre-retrofit fixture types, quantities and hours of operation with the facility representative. In addition, we will physically verify the post-retrofit fixture quantities and fixture types during the site visit. We will install Hobo H8 Light Loggers throughout the facility in representative areas for a minimum of

14 days to verify the post retrofit hours of operation. These optically triggered loggers record lighting status (on or off).

Uncertainty for the savings estimate for the lighting retrofit can be more fully understood by setting projected ranges on the primary variables.

For the Pre-Retrofit Metal Halide Fixtures

- 250 watt metal halide demand of 0.295 kW, maximum of 0.310 kW, minimum of 0.280 kW (±5%, based on judgment of deviation from typical metal halide fixture in SPC standard wattage table)

For the Post-Retrofit T5 Fixtures

- T5 fixture demand of 0.105 kW/fixture, maximum of 0.110 kW, minimum of 0.100 kW (±5%, based on judgment of deviation from ballast manufacturers' information)

For the Lighting Retrofit

- 4,286 hours pre-retrofit and post-retrofit expected operation, minimum of 3,643 hours, maximum of 4,929 hours (±15.0%, based on judgment of use for site type)

- 35.7 kW expected savings, maximum 38.6 kW, minimum 32.8 (±8.2%, based on pre-retrofit fixture expected deviation, post-retrofit fixture expected deviation, and propagation of error method)

- 153,102 kWh expected savings, maximum 179,303 kWh, minimum 126,901 kWh (±17.1%, based on the above variables)

Accuracy

The Hobo H8 light on/off loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable. The SPC lighting wattage tables and field verified fixture counts are considered to be 100% accurate.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate. The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 21, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the fixtures and by interviewing the facility representative. One hundred eighty eight (188) three lamp T5 fixtures were found to be installed.

Installation Verification

The facility representative verified that prior to the installation of the T5 fixtures, 250 watt metal halide fixtures were in use. The installation of the T5 fixtures was physically verified during the on-site process. The facility representative stated that the retrofit was completed by September 2004.

A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING-188-3L T5 TO REPLACE 250W METAL HALIDE	L		188 3L T5 FIXTURES TO REPLACE 188 250W METAL HALIDE FIXTURES		188	3L T5 FIXTURES	PHYSICALLY VERIFIED INSTALLATION OF FIXTURES	1.0

Scope of the Impact Assessment

The impact assessment scope is for the Lighting end use measure in the SPC application. This was the only measure in this application.

Summary of Results

Two Hobo light on/off loggers were installed within the clean room area of the manufacturing facility for 22 days (from August 21, 2007-September 11, 2007) to measure the operating hours of the retrofit lighting fixtures.

The facility representative stated that this clean room operates typically from 4:00 AM to 6:00 PM, Monday through Friday. In addition, on Saturday, the clean room is expected to operate from approximately 4:00 AM to 3:00 PM. After each workday, a cleaning crew is in the room for several hours. The facility representative stated that the 12-day period had been representative of normal facility operation with the exception of the Monday holiday period.

In order to more accurately represent the pre-retrofit and post retrofit demand and energy usage as well as determine the savings, the lighting fixtures were divided into two schedules, based on the location. Twelve fixtures were located in the packaging area. In the original application the customer described the hours of operation of this location to be around 12 hours per day. This customer verified that this was correct. The clean room location consisted of 176 fixtures. Using the hours of operation determined from the installed lighting loggers, the demand and energy usage and savings values could be determined. The hours of operation are summarized in Table 2 below.

Table 2: Fixture Operating Hours

	Clean Room	Packaging Area
Number of Fixtures	176	12
Percent of Time on From Logger	64.9%	N/A
Expected Annual Operating Hours	5,516	3,086

Based on the results of the logger analysis, the fixture weighted average is 5,361.2 annual hours of operation.

The lighting fixtures are expected to operate Monday through Friday, 4:00 AM to 11:45 PM, therefore, at the summer peak hour, between 2 pm and 5 pm on the hottest weekdays, the lighting fixtures are expected to be in operation.

The ex post impacts are calculated in Figure 1 below:

Figure 1: Energy and Demand Formulae for VFD Installation

Pre-Retrofit Demand kW_{peak}	= Pre-Retrofit Fixture Wattage x Pre-retrofit Fixture Qty = 0.295 kW/Fixture x 188 Fixtures = 55.46 kW
Post-Retrofit Demand kW_{peak}	= Post-Retrofit Fixture Wattage x Post-retrofit Fixture Qty = 0.105 kW/Fixture x 188 Fixtures = 19.74 kW
Peak kW Savings	= Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak} = 55.46 kW – 19.74 kW = 35.72 kW
Pre-Retrofit kWh	= Pre-Retrofit Demand kW_{peak} x Pre-retrofit Hours = 55.46 kW x 5,361.2 hours/year = 297,332 kWh/yr
Post-Retrofit kWh	= Post-Retrofit Demand kW_{peak} x Post-retrofit Hours = 19.74 kW x 5,361.2 hours/year = 105,830 kWh/yr
kWh Savings	= Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak} = 297,332 kWh/yr – 105,830 kWh/yr = 191,502 kWh/yr

The ex post kW demand reduction is equal to the ex ante demand reduction. The post retrofit fixture type and quantity was found to be as reported The ex post energy savings are greater than the ex ante energy savings due to an underestimated value for hours of operation used in the ex ante calculations.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. The costs appear somewhat high for the number of fixtures retrofit. The customer did not identify any non-energy benefits or drawbacks associated with the new equipment. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future.

We were unable to physically verify the pre-retrofit fixture type or hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures. However, a determination of the new fixture wattage to a more accurate level could increase the accuracy of the ex post savings estimate even further.

7. Impact Results

Based on the utility tracking system savings of 36.0 kW and 153,102 kWh the engineering realization rate for this application is 0.99 for kW reduction and 1.25 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 3.

Table 3: Realization Rate Summary

	KW	KWh	Therm
SPC Tracking System	36.0	153,102	-
SPC Installation Report (ex ante)	35.7	153,102	-
Impact Evaluation (ex post)	35.7	191,502	-
Engineering Realization Rate	0.99	1.25	N/A

Utility billing data for the site was reviewed. In the 12-month period from July 2003 - June 2004 (pre-retrofit), the facility consumed 2,966,388 kWh. Peak demand was 674.9 kW in August 2003. Table 4 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 4: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	674.9	2,966,388
Baseline End Use	51.9	345,067
Ex Ante Savings	35.7	153,102
Ex Post Savings	35.7	191,502

Table 5 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 5.3% decrease in total meter kW, a 68.8% decrease in lighting end use kW, a 5.2% decrease in total meter kWh, and a 51.5% decrease in lighting end use kWh. The ex post results showed a 5.3% decrease in total meter kW, a 68.8% decrease in lighting end use kW, a 6.5% decrease in total meter kWh, and a 64.4% decrease in lighting end use kWh.

Table 5: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/ Demand Reduction	kW	kWh	kW	KWh
Total Meter %	5.3%	5.2%	5.3%	6.5%
Baseline End Use %	68.8%	51.5%	68.8%	64.4%

With a cost of $73,599 and a $7,655 incentive, the project had a 3.31 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 2.65 years. A summary of the economic parameters for the project is shown in Table 6.

Table 6: Economic Information

	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	8/5/04	$73,599	35.7	153,102	-	$19,903	$7,655	3.31	3.70
SPC Program Review (Ex Post)	9/18/07	$73,599	35.7	191,502	-	$24,895	$7,655	2.65	2.96

It was determined that the T5 lighting retrofit project was defined as a Lighting Measure-High Efficiency Lighting project in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the lighting project was assumed to have a useful life of sixteen (16) years.

A summary of the multi-year reporting requirements is given in Table 7. Because this measure was installed approximately September of 2004 the energy savings in year #1 (2004) are assumed to be 1/4 of the expected annual savings for this measure. In addition, no peak savings are assumed to occur in 2004.

Table 7: Multi-Year Reporting Requirements

Program		001 Application # A064					
Program		SPC 04-05 Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected kWh Savings	Ex-Post Gross Evaluation Confirmed kWh Savings	Ex-Ante Gross Program-Projected Peak kW Savings	Ex-Post Gross Evaluation Confirmed kW Savings	Ex-Ante Gross Program-Projected Therm Savings	Ex-Post Gross Evaluation Confirmed Therm Savings
1	2004	38,276	47,876	-	-	-	-
2	2005	153,102	191,502	35.7	35.7	-	-
3	2006	153,102	191,502	35.7	35.7	-	-
4	2007	153,102	191,502	35.7	35.7	-	-
5	2008	153,102	191,502	35.7	35.7	-	-
6	2009	153,102	191,502	35.7	35.7	-	-
7	2010	153,102	191,502	35.7	35.7	-	-
8	2011	153,102	191,502	35.7	35.7	-	-
9	2012	153,102	191,502	35.7	35.7	-	-
10	2013	153,102	191,502	35.7	35.7	-	-
11	2014	153,102	191,502	35.7	35.7	-	-
12	2015	153,102	191,502	35.7	35.7	-	-
13	2016	153,102	191,502	35.7	35.7	-	-
14	2017	153,102	191,502	35.7	35.7	-	-
15	2018	153,102	191,502	35.7	35.7	-	-
16	2019	153,102	191,502	35.7	35.7	-	-
17	2020	114,827	143,627	35.7	35.7	-	-
18	2021	-	-	-	-	-	-
19	2022	-	-	-	-	-	-
20	2023	-	-	-	-	-	-
TOTAL	2004-2023	2,449,632	3,064,035			-	-

FINAL REPORT

SITE A065 (0595-04) Irv1 IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 5 END USE: Lighting

Measure	Lighting Fixture Replacement and Installation of Occupancy Sensors
Site Description	Six (6) Multi-Story Office Buildings

1. Measure Description

The customer completed a lighting retrofit for various locations throughout their facilities. The retrofit project is broken down into seven (7) itemized measures (labeled Measure 1- Measure 7) that received incentives through the SPC program. The installation report review dated January 11, 2005 identified them as measures M1 through M7. Originally, nineteen (19) measures were submitted. Twelve of the nineteen were found not to be eligible for the SPC program because the individual facilities' connected load was below the 500 kW minimum.

Measure 1, at Site 1, is the installation of seventeen (17) LED exit signs to replace incandescent exit sign bulbs and the installation of thirty-three (33) 26 watt hardwired fluorescents to replace 120 watt incandescent bulbs. Measure 2, also at Site 1, is the installation of forty-one (41) LED exit signs to replace incandescent exit signs and the replacement of ninety-three (93) 75 watt incandescent bulbs with 26 watt hardwired fluorescents. Measure 3, at Site 2, is for the installation of five (5) LED exit signs to replace exit signs with incandescent bulbs and the replacement of twenty-eight (28) 75 watt incandescent bulbs with 15 watt compact fluorescent lamps. Measure 4, at Site 3, is the installation of twelve (12) 26 watt compact fluorescent linear hardwired fixtures to replace 120 watt incandescent bulbs, the replacement of twenty-seven (27) 67 watt incandescent bulbs with 26 watt compact fluorescent linear hardwired, the replacement of twelve (12) 67 W incandescent bulbs with 14 watt compact fluorescents, and the replacement of fifteen (15) 4 foot T12 lamps with T8 lamps. Measure 5, again at Site 4, is the installation of thirty-nine (39) compact fluorescent linear hardwired to replace incandescent bulbs. Measure 6, also at Site 4, is the installation of fourteen (14) new wall-box sensors and the installation of twenty-six (26) new ceiling mounted occupancy sensors. Measure 7, at Site 5, is the installation of twenty (20) 26 watt linear compact fluorescent hardwired to replace 75 watt incandescent bulbs, the replacement of thirty-nine (39) 100 watt incandescent bulbs with 26 watt linear compact fluorescent (hardwired), the replacement of two (2) 3 foot T12 lamps with T8 lamps, and the replacement of three (3) T12 8 foot lamps with T8 lamps.

The fixture retrofits save energy through increased efficacy and the occupancy sensors reduce energy usage through reduced hours of operation.

2. Summary of the Ex Ante Calculations

The ex ante calculations were performed using an itemized approach with defined standard fixture replacement wattage savings tables to determine the various measure savings. These savings are presented in Table 1.

Table 1: Utility Reported Energy and Demand Savings

Measure	Description	Utility kW Savings	Utility kWh Savings
1	LED Exits to replace Inc.	0.7	5,973
1	26W Fl. to replace 120W Inc.	7.1	33,395
2	26W Fl. to replace 75W Inc.	20.1	94,111
2	LED Exits to replace Inc.	1.7	14,406
3	15W Fl. to replace 75W Inc.	1.4	6,493
3	LED Exits to replace Inc.	0.2	1,757
4	26W Fl. to replace 120W Inc.	2.6	12,144
4	26W Fl. to replace 67W Inc.	5.8	27,323
4	14W Fl. to replace 67W Inc.	0.6	2,783
4	4’ T8 lamp to replace T12	0.2	752
5	26W Fl. to replace Inc.	8.4	39,466
6	Wall Occ. Sensor Installation	1.3	5,838
6	Ceiling Occ. Sensor Installation	7.9	37,152
7	26W Fl. to replace 75W Inc.	4.3	20,239
7	26W Fl. to replace 100W Inc.	8.4	39,466
7	2’ T8 lamp to replace T12	0.0	109
7	8’ T8 lamp to replace T12	0.0	127
Total		**70.9**	**341,533**

3. Comments on the Ex Ante Calculations

These numbers substantially agree with the Installation Report Review and the utility tracking system.

The ex ante calculations were performed using an itemized approach with defined standard fixture replacement wattage savings tables to determine the various measure savings. Alternatively, these savings could also have been calculated using a simple pre-retrofit and post-retrofit algorithm using fixture connected loads as determined using customer provided lists of fixture types and hours of operation for each measure, as well as the supplied manufacturers’ information for various fixtures. When fixture wattage information was not available, the SPC lighting wattage tables were used.

For check calculations, lighting hours of operation were based on 8,760 hours per year operation for exit signs, 4,700 hours per year for all other lights (per customer description of operation), and a 50% reduction in lighting hours of operation for occupancy sensor installation.

Using the ex ante baseline as the pre-retrofit system, the pre-retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

Measure 1 Exit Signs, for a lighting fixture example

kW = Fixture watts / 1,000 watts / kW x fixture quantity

kWh = kW x operating hours

The ex ante impacts were calculated as follows:

Pre-retrofit hours of operation were 8,760 hrs/year.
Pre-retrofit wattage was 40 watts per fixture x 17 lamps = 0.68 kW
Annual kWh usage was 0.680 kW x 8,760 hrs/yr = 5,956.8 kWh/yr.

Post-retrofit hours of operation were 8,760 hrs/year.
Post-retrofit wattage is 5.9 watts per fixture x 17 fixtures = 0.10 kW
Annual kWh usage is 0.100 kW x 8,760 hrs/yr = 878.6 kWh/yr

The resulting annual kWh savings is 5,956.8 kWh/yr – 878.6 kWh/yr = 5,078.2 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load.

Peak kW savings is 0.68 kW – 0.10 kW = 0.58 kW

Measure 6 Wall Occupancy Sensors

kW = Fixture watts / 1,000 watts / kW x fixture quantity

kWh = kW x operating hours

kW = (# of Fixtures) * (kW per Fixture) * (DiversityFactor)
DiversityFactor = % the lights are on after installation of occupancy sensors.
KWh = (# of Fixtures) * (kW per Fixture) * (OpHrsPre – OpHrsPost)

The ex ante impacts were calculated as follows:

Pre-retrofit hours of operation were 4,700 hrs/year.
Pre-retrofit wattage was 89.3 watts per sensor x 14 sensors = 1.25 kW
(89.3 watts per sensor from utility standard savings values)
Annual kWh usage was 1.25 kW x 4,700 hrs/yr = 5,875 kWh/yr.

Post-retrofit hours of operation were 4,700 hrs/year (2,350 on/2,350 off).
Post-retrofit wattage was 89.3 watts per sensor x 14 sensors x 0.5 Demand Factor = 0.625 kW
Annual kWh usage was 0.625 kW x 4,700 hrs/yr = 2,938.0 kWh/yr.

The resulting annual kWh savings is 5,875 kWh/yr – 2,938.0 kWh/yr = 2,937 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load.

Peak kW demand reduction is 1.25 kW – 0.625 kW = 0.625 kW

When compared to the Express Efficiency workpaper savings, the utility standard fixture replacement wattage savings tables overestimate the savings in many cases. Of the seventeen measures implemented under this rebate application, ten (10) of the measures had demand savings per fixture values that exceeded the original fixture wattage. Of the remaining seven, two (2) were occupancy sensors, for which savings could not be determined at this time. A summary of the savings associated with the measures is found in Table 2 below.

Table 2: Calculated and Utility Savings Comparison

Measure	Description	Pre-Retrofit Wattage	Post Retrofit Wattage	Calculated Wattage Savings	Utility Standard Wattage Savings	Utility savings as percent of original watts
1	LED Exits to replace Inc.	40[1]	5.9	34.1	42.4	**106%**
1	26W Fl. to replace 120W Inc.	120	26	94	216.0	**180%**
2	26W Fl. to replace 75W Inc.	75	26	49	216.0	**288%**
2	LED Exits to replace Inc.	40[1]	5.9	34.1	42.4	**106%**
3	15W Fl. to replace 75W Inc.	75	15	60	49.5	66%
3	LED Exits to replace Inc.	40[1]	5.9	34.1	42.4	**106%**
4	26W Fl. to replace 120W Inc.	120	26	94	216.0	**180%**
4	26W Fl. to replace 67W Inc.	67	26	41	216.0	**322%**
4	14W Fl. to replace 67W Inc.	67	14	53	49.5	74%
4	4' T8 lamp to replace T12	40	32	8	11.0	28%
5	26W Fl. to replace Inc.	75[2]	26	49	216.0	**288%**
6	Wall Occ. Sensor Installation	---	---	---	89.0	---
6	Ceiling Occ. Sensor Installation	---	---	---	305.0	---
7	26W Fl. to replace 75W Inc.	75	26	49	216.0	**288%**
7	26W Fl. to replace 100W Inc.	100	26	74	216.0	**216%**
7	2' T8 lamp to replace T12	27	17	8	12.0	48%
7	8' T8 lamp to replace T12	60	59	1	9.0	15%

In some cases, the workpapers may have been applied to the wrong measures.

If the savings are calculated using the fixture wattages supplied for measures 1-5 and 7, the realized savings are much less than the standard itemized savings values. The

[1] No description of pre-retrofit exit signs is given, therefore for the analysis a common fixture using two (2) 20W incandescent bulbs is used.
[2] For Measure 11, no description of pre-retrofit bulb wattage was provided, therefore, a wattage of 75W per bulb was assumed.

adjusted values are found in Table 3 below. The calculated savings are 24.9 kW and 126,981 kWh. This is a 65% reduction in demand savings and a 63% reduction in energy usage savings.

Table 3: Utility and Adjusted Energy and Demand Savings

Measure	Description	Utility kW Savings	Utility kWh Savings	Adjusted kW Savings	Adjusted kWh Savings
1	LED Exits to replace Inc.	0.7	5,973	0.6	5,078
1	26W Fl. to replace 120W Inc.	7.1	33,395	3.1	14,904
2	26W Fl. to replace 75W Inc.	20.1	94,111	4.6	21,895
2	LED Exits to replace Inc.	1.7	14,406	1.4	12,247
3	15W Fl. to replace 75W Inc.	1.4	6,493	1.7	8,072
3	LED Exits to replace Inc.	0.2	1,757	0.2	1,494
4	26W Fl. to replace 120W Inc.	2.6	12,144	1.1	5,420
4	26W Fl. to replace 67W Inc.	5.8	27,323	1.1	5,319
4	14W Fl. to replace 67W Inc.	0.6	2,783	0.6	3,056
4	4’ T8 lamp to replace T12	0.2	752	0.1	577
5	26W Fl. to replace Inc.	8.4	39,466	1.9	9,182
6	Wall Occ. Sensor Installation	1.3	5,838	1.3	2,938
6	Ceiling Occ. Sensor Installation	7.9	37,152	7.9	18,636
7	26W Fl. to replace 75W Inc.	4.3	20,239	1.0	4,591
7	26W Fl. to replace 100W Inc.	8.4	39,466	2.9	13,521
7	2’ T8 lamp to replace T12	0.0	109	0.0	94
7	8’ T8 lamp to replace T12	0.0	127	0.0	14
Total		**70.9**	**341,533**	**24.9**	**126,981**

4. Measurement & Verification Plan

Site 1 is a 568,045 sq.-ft., three building high-rise complex. According to the application, Measure 1 included the installation of seventeen (17) LED exit signs and thirty-three (33) 26 watt hardwired fluorescent fixtures. Measure 2 consisted of the installation of forty-one (41) LED exit signs and ninety-three (93) 26 watt hardwired fluorescent fixtures at this location.

The Site 2 is a 129,498 sq-ft, two-building complex. According to the application, five (5) LED exit signs and twenty-eight (28) 15 watt compact fluorescent fixtures were installed.

The Site 3 is a 310,111 sq.-ft., high-rise office building. According to the application, thirty-nine (39) 26 watt compact fluorescent linear hardwired bulbs, twelve (12) 14 watt compact fluorescent bulbs, and fifteen (15) 4-ft. T8 lamps were installed.

The Site 4 is a 366,227 sq.-ft., high-rise office building. According to the application, thirty-nine (39) compact fluorescent linear hardwired bulbs, fourteen (14) wall-box sensors, and twenty-six (26) ceiling mounted occupancy sensors were installed.

At Site 5 is a 235,536 sq.-ft., high-rise office building. According to the application, fifty-nine (59) 26 watt compact fluorescent linear hardwired bulbs, two (2) 3-ft. T8 lamps, and three (3) 8-ft. T8 lamps were installed.

The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction due to the installation of the more efficient fixtures and the occupancy sensors, over the useful life of the measure.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. The lighting fixtures in question are not expected to consume a large percentage of the facility's total usage. Fixture wattages are expected to be sufficiently defined from SPC standard wattage tables and manufacturer information and are not expected to deviate. In addition, there is not expected to be significant seasonal variation and two weeks should be sufficient for comparison; however, a longer period would more fully capture actual variations and the persistence of savings. Interval data on a 15-minute or less basis, preferably during the summer months of June to September, would be helpful to accurately determine coincident peak period demand savings.

Pre-retrofit and post-retrofit calculations of lighting demand and energy usage will be calculated using the following formulae:

kW = Fixture watts / 1,000 watts / kW x fixture quantity x percent energized during peak demand period

kWh = kW x operating hours x percent energized

The most significant variables to be quantified are the pre-retrofit and post-retrofit hours of operation. Pre-retrofit hours will be confirmed with the site personnel to verify that the facility hours have not changed since the implementation of these measures. Appropriate modifications for the savings calculations will be made to the pre-retrofit usage figures if required, in order to establish a realistic baseline for energy use.

For this application, we propose to verify the pre-retrofit fixture types, quantities and hours of operation with the facility representative. Specifically, measures 2, 4, and 6 will be evaluated in detail. These three measures account for 62% of the kWh savings attributed to this application. In addition, the occupancy sensors are included in these measures, and as such have the largest degree of uncertainty associated with the fixture wattage as well as with the hours of operation.

We will install no less than fifteen (15) Hobo H8 Light Loggers in throughout the facility in representative areas for the three measures for a minimum of 14 days to verify the post retrofit hours of operation. These optically triggered loggers record lighting status (on or off).

The hours of operation determined from these loggers will then be used, along with customer's description of hours of operation, to determine reasonable hours of operation for the areas not specifically metered.

Uncertainty for the savings estimate for the lighting retrofit can be more fully understood by setting projected ranges on the primary variables.

For the Pre-Retrofit Fixtures

- Total fixture demand of 37.8 kW, maximum of 45.9 kW, minimum of 33.8 kW (+21.3%, -10.7%, based on judgment of deviation from typical fixture wattages in SPC standard wattage table)

For the Post-Retrofit Fixtures

- Total fixture demand of 12.9 kW, maximum of 14.9 kW, minimum of 8.9 kW (-31.1%, +15.6%, based on judgment of deviation from typical fixture wattages in SPC standard wattage table)

For the Lighting Retrofit

- 24.9 kW expected savings, maximum 33.2 kW, minimum 20.4 kW (+33.3%, -18.2%, based on pre and post-retrofit fixture expected deviation, and propagation of error method)

- 126,981 kWh expected savings, maximum 167,137 kWh, minimum 102,249 kWh (+31.6%, -19.5%, based on pre and post-retrofit fixture expected deviation)

Accuracy

The Hobo H8 light on/off loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable. The SPC lighting wattage tables and field verified fixture counts are considered to be 100% accurate.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate. The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 22, 2007. The onsite verification was completed for Site 3, Site 4, and Site 1 (Building 1). Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Sixteen (16) lighting on/off loggers were installed in representative areas throughout the office buildings.

Installation Verification

At the Site 4 facility, two measures were completed. These included the installation of 39 hardwired fluorescent fixtures to replace incandescent fixtures, and the installation of 14 wall and 26 ceiling occupancy sensors. For the hardwired fluorescent retrofit project, the original project description stated that thirty-nine (39) 120 watt incandescent fixtures were removed. The facility representative confirmed that this was the case. The installation of the 39 hardwired fluorescent fixtures as well as the 14 wall and 26 ceiling occupancy sensors was physically verified.

At the Site 3 facility, two measures were completed. These included the installation of thirty-nine (39) 26 watt and twelve (12) 14 watt hardwired fluorescent fixtures to replace incandescent fixtures, and the installation of fifteen (15) T8 lamps to replace T12 lamps. For the hardwired fluorescent retrofit project the original project description stated that twelve (12) 120 W incandescent and forty (40) 67 watt incandescent fixtures were removed. The facility representative confirmed that this was the case. However, a mix of 60 watt and 75 watt fixtures were removed, with 67 watt being used as an average in the original application. The installation of the thirty-nine (39) 26 W and twelve (12) 14 watt hardwired fluorescent fixtures was physically verified.

The Site 1 (Building 1) measure was part of the Site 1 retrofit project, which included two measures. These included the installation of fifty eight (58) LED exit signs and one hundred twenty six (126) 26 W hardwired fluorescent fixtures to replace incandescent fixtures. For the hardwired fluorescent retrofit project, the original project description stated that thirty three (33) 20 W incandescent and ninety three (93) 75 watt incandescent fixtures were removed. The facility representative confirmed that this was the case. The installation of the 26 watt hardwired fluorescent fixtures and LED exit signs was physically verified for type; however, quantities were not verified due to the spread of the fixtures over the buildings.

The facility representative stated that the retrofit occurred approximately December of 2004.

Six additional lighting retrofit projects were completed under this project. The other measures were discussed with the site representative but not investigated in depth. The verification realization rate for each of the projects evaluated is 1.0. A verification summary is shown in Table 4 below.

Table 4: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING	L		LED Exits to replace Inc.		17	LED Exit Signs	PHYSICALLY VERIFIED FIXTURES FOR TYPE	1.00
LIGHTING	L		26W Fl. to replace 120W Inc.		33	26W HW Fluorescent	PHYSICALLY VERIFIED FIXTURES FOR TYPE	1.00
LIGHTING	L		26W Fl. to replace 75W Inc.		93	26W HW Fluorescent	PHYSICALLY VERIFIED FIXTURES FOR TYPE	1.00
LIGHTING	L		LED Exits to replace Inc.		41	LED Exit Signs	PHYSICALLY VERIFIED FIXTURES FOR TYPE	1.00
LIGHTING	L		26W Fl. to replace 120W Inc.		12	26W HW Fluorescent	PHYSICALLY VERIFIED FIXTURES FOR QUANTITY AND TYPE	1.00
LIGHTING	L		26W Fl. to replace 67W Inc.		27	26W HW Fluorescent	PHYSICALLY VERIFIED FIXTURES FOR QUANTITY AND TYPE	1.00
LIGHTING	L		14W Fl. to replace 67W Inc.		12	14W HW Fluorescent	PHYSICALLY VERIFIED FIXTURES FOR QUANTITY AND TYPE	1.00
LIGHTING	L		4' T8 lamp to replace T12		15	4' T8 Lamp	PHYSICALLY VERIFIED FIXTURES FOR QUANTITY AND TYPE	1.00
LIGHTING	L		26W Fl. to replace Inc.		39	26W HW Fluorescent	PHYSICALLY VERIFIED FIXTURES FOR QUANTITY AND TYPE	1.00
LIGHTING	L		Wall Occ. Sensor Installation		14	Wall Occupancy Sensor	PHYSICALLY VERIFIED FIXTURES FOR QUANTITY AND TYPE	1.00
LIGHTING	L		Ceiling Occ. Sensor Installation		26	Ceiling Occupancy Sensor	PHYSICALLY VERIFIED FIXTURES FOR QUANTITY AND TYPE	1.00

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measures in the SPC application. These were the only measure in this application.

Summary of Results

Sixteen Hobo light on/off loggers were installed on representative areas of the office buildings for 15 days (from August 22, 2007-September 5, 2007) to measure the operating hours of a representative sample of the retrofit lighting fixtures.

The facility representative stated that this facility operates typically 10-16 hours per day, five days per week. However, people have access to the building throughout the week so various fixtures may be in operation at any given time. The facility representative was not able to estimate occupancy throughout the week because the space is rented out to various tenants. However, the facility representative was able to estimate the typical occupancy of the building on a Saturday to be no greater than 25% of the normal weekday occupancy and 5-10% of the typical weekday occupancy on Sundays. The facility representative stated that the 15-day period had been representative of normal facility operation with the exception of the Monday holiday period.

In order to more accurately represent the pre-retrofit and post retrofit demand and energy usage as well as determine the savings for the entire project, the itemized measures were calculated based on a lighting retrofit list provided in the application. The customer verified that the list of fixtures was correct, and fixture wattages were determined from the SPC standard wattage tables for each type of fixture. Using the hours of operation determined from the installed lighting loggers, the demand and energy usage and savings values could be determined. These results are summarized in Table 5.

Table 5: Revised Energy and Demand Savings for Itemized Measures

Measure	Description	Fixture Qty	Pre-Retrofit Demand (W)	Post-Retrofit Demand (W)	Demand Savings (kW)	Hours of Operation	Energy Savings (kWh)
1	LED Exits to replace Inc.	17	40	5.9	0.58	8,760	5,078
1	26W Fl. to replace 120W Inc.	33	120	26	3.10	4,294	13,319
2	26W Fl. to replace 75W Inc.	93	75	26	4.56	4,294	19,566
2	LED Exits to replace Inc.	41	40	5.9	1.40	8,760	12,247
3	15W Fl. to replace 75W Inc.	28	75	15	1.68	4,294	7,213
3	LED Exits to replace Inc.	5	40	5.9	0.17	8,760	1,494
4	26W Fl. to replace 120W Inc.	12	120	26	1.13	4,294	4,843
4	26W Fl. to replace 67W Inc.	27	67	26	1.11	4,294	4,753
4	14W Fl. to replace 67W Inc.	12	67	14	0.64	4,294	2,731
4	4' T8 lamp to replace T12	15	40	32	0.12	4,294	515
5	26W Fl. to replace Inc.	39	75	26	1.91	4,294	8,205
6	Wall Occ. Sensor Installation	14	26.0	0.61	0.36	4,294	1,526
6	Ceiling Occ. Sensor Installation	26	300	119.6	4.69	8,760	41,092
7	26W Fl. to replace 75W Inc.	20	75	26	0.98	4,294	4,208
7	26W Fl. to replace 100W Inc.	39	100	26	2.89	4,294	12,392
7	2' T8 lamp to replace T12	2	27	17	0.02	4,294	86
7	8' T8 lamp to replace T12	3	60	59	0.00	4,294	13
Total					25.33		139,282

For the LED lighting retrofit projects, the fixtures were assumed to be in operation 8,760 hours per year.

The light fixtures metered were found on average to operate 57.9% of the time during Monday-Friday hours and 26.8% of the time on weekend hours. In addition, the metering period included a holiday, during which many of the light fixtures were not found to operate. The holiday period was treated as a weekend day for data analysis. Based on this operating schedule, the remaining fixtures are expected to operate 4,294 hours per year. A description of the operating hours can be found Table 6.

For fixtures connected to wall occupancy sensors, the fixtures were found to be located in janitor closets and only operate approximately 1.16% of the metered time period, or approximately 101 hours per year. To account for diversity, the hours of operation were assumed to remain at 4,294 for both the pre-retrofit and post-retrofit condition. However, the post-retrofit fixture wattage for the fixtures controlled was reduced using the equation given below:

Post Retrofit Wattage = Pre Retrofit Wattage x Hours of operation determined from metered data / Pre-retrofit hours of operation

The fixtures connected to ceiling occupancy sensors the fixtures were located in restroom areas and found to operate approximately 34.9% of the metered time period, or approximately 3,492 hours per year. A restroom area that did not have an occupancy sensor was also metered, and found to operate the entire time period. Therefore, the hours of possible operation were assumed to be 8,760. Again the same method was used for both the pre-retrofit and post-retrofit condition, with the fixture wattage reduced using the method presented above.

Table 6: Hobo Light On/Off Logger Results

Location	%Time Running	Location	%Time Running
8105-11-JR	1.3%	8001-730	40.2%
8105-09-JR	1.2%	8001-740	41.7%
8105-08-JR	1.0%	8001-145	N/A
8105-11-MR	40.6%	4695-700	64.0%
8105-09-MR	100.0%	4695-500	61.7%
8105-08-MR	39.1%	4695-1250	55.0%
8001-840	40.6%	4695-1200	56.2%
8001-880	34.2%	4695-1100	40.2%

During daytime hours it was found that all units operated, therefore, at the summer peak hour, between 2 pm and 5 pm on the hottest weekdays, all lighting fixtures are expected to be in operation.

The ex post impacts are calculated by the method shown in Table 7 below:

Table 7: Energy and Demand Formulae Example for Fixture Replacement (M1)

Pre-Retrofit Demand kW_{peak}	= Pre-Retrofit Fixture Wattage x Pre-retrofit Fixture Qty = 0.040 kW/Fixture x 17 Fixtures = 0.68 kW
Post-Retrofit Demand kW_{peak}	= Post-Retrofit Fixture Wattage x Post-retrofit Fixture Qty = 0.006 kW/Fixture x 17 Fixtures = 0.10 kW
Peak kW Savings	= Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak} = 0.68 kW – 0.10 kW = 0.58 kW
Pre-Retrofit kWh	= Pre-Retrofit Demand kW_{peak} x Pre-retrofit Hours = 0.68 kW x 8,760 hours/year = 5,957 kWh/yr
Post-Retrofit kWh	= Post-Retrofit Demand kW_{peak} x Post-retrofit Hours = 0.10 kW x 8,760 hours/year = 876 kWh/yr
kWh Savings	= Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak} = 5,957 kWh/yr – 876 kWh/yr = 5,081 kWh/yr

The ex post demand and energy savings are less than the ex ante energy savings. This is mainly due to the use of a prescribed savings itemized approach to determine the savings. When the ex post calculations are compared to the revised ax ante calculations given in Table 3 above, the energy and demand savings values are similar.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. In addition to saving energy, the new fixtures were described as having a better quality of light and increasing comfort due to lower heat output. The customer did not identify any drawbacks associated with the new equipment. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. Participation in the 2004/2005 SPC program has not encouraged the customer to perform any other energy efficiency projects for which they did not participate in an incentive program. However, they have completed several projects that did receive utility incentive. These projects included VFDs on HVAC fans, chiller retrofits, and additional lighting retrofit projects.

We were unable to physically verify the pre-retrofit lighting fixture type, quantity and hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures. However, the accuracy could be improved through detailed analysis of the pre retrofit lighting and actual wattage reductions.

7. Impact Results

Based on the ex ante savings of 70.9 kW and 341,533 kWh, the engineering realization rate for this application is 0.36 for kW reduction and 0.41 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 8.

Table 8: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	70.9	341,533	-
SPC Installation Report (ex ante)	70.9	341,533	-
Impact Evaluation (ex post)	25.3	139,282	-
Engineering Realization Rate	0.36	0.41	N/A

Utility billing data for the site was reviewed. In the 12-month period from January 2003 - December 2003 (pre-retrofit), the facilities consumed a total of 15,133,061 kWh. The sum of the peak demands for the facilities was 4,644.7. Table 9 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 9: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	4,644.7	15,133,061
Baseline End Use	1,393.4	4,539,918
Ex ante Savings	70.9	341,533
Ex Post Savings	25.3	139,282

Table 10 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 1.5% decrease in total meter kW, a 5.1% decrease in lighting end use kW, a 2.3% decrease in total meter kWh, and a 7.5% decrease in lighting end use kWh. The ex post results showed a 0.5% decrease in total meter kW, a 1.8 % decrease in lighting end use kW, a 0.9% decrease in total meter kWh, and a 3.1% decrease in lighting end use kWh.

Table 10: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	1.5%	2.3%	0.5%	0.9%
Baseline End Use %	5.1%	7.5%	1.8%	3.1%

With a cost of $46,767 and an $8,075 incentive, the project had a 0.87 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 2.14 years. A summary of the economic parameters for the project is shown in Table 11.

Table 11: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), ($1.10/therm) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	10/18/2004	$46,746	70.9	341,533	-	$44,399	$8,075	0.87	1.05
SPC Program Review (Ex Post)	9/25/2007	$46,746	25.3	139,282	-	$18,107	$8,075	2.14	2.58

A useful life for each measure was determined using the information form the California Public Utilities Commission *Energy Efficiency Policy Manual*. A summary of the measure category and effective useful lives is given in Table 12.

Table 12: Measure Effective Useful Life

Measure	Description	Category	Useful Life
1	LED Exits to replace Inc.	LED Exit Sign	16
1	26W Fl. to replace 120W Inc.	High Efficiency Lighting	16
2	26W Fl. to replace 75W Inc.	High Efficiency Lighting	16
2	LED Exits to replace Inc.	LED Exit Sign	16
3	15W Fl. to replace 75W Inc.	High Efficiency Lighting	16
3	LED Exits to replace Inc.	LED Exit Sign	16
4	26W Fl. to replace 120W Inc.	High Efficiency Lighting	16
4	26W Fl. to replace 67W Inc.	High Efficiency Lighting	16
4	14W Fl. to replace 67W Inc.	High Efficiency Lighting	16
4	4’ T8 lamp to replace T12	Fluorescent Fixture-T8	16
5	26W Fl. to replace Inc.	High Efficiency Lighting	16
6	Wall Occ. Sensor Installation	Occupancy Sensor	8
6	Ceiling Occ. Sensor Installation	Occupancy Sensor	8
7	26W Fl. to replace 75W Inc.	High Efficiency Lighting	16
7	26W Fl. to replace 100W Inc.	High Efficiency Lighting	16
7	2’ T8 lamp to replace T12	Fluorescent Fixture-T8	16
7	8’ T8 lamp to replace T12	Fluorescent Fixture-T8	16

A summary of the multi-year reporting requirements is given in Table 13. Because this measure was installed approximately December 2004, the energy savings in year #1 (2004) are assumed to be 1/12 of the expected annual savings for this measure. In addition, no peak savings are assumed to occur in this first year.

Table 13: Multi-Year Reporting Requirements

Program ID:		001 Application # A065					
Program Name:		SPC 04-05 Evaluation					
Year	Calendar Year	Ex-ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	28,461	11,607	-	-	-	-
2	2005	341,533	139,282	70.8	25.3	-	-
3	2006	341,533	139,282	70.8	25.3	-	-
4	2007	341,533	139,282	70.8	25.3	-	-
5	2008	341,533	139,282	70.8	25.3	-	-
6	2009	341,533	139,282	70.8	25.3	-	-
7	2010	341,533	139,282	70.8	25.3	-	-
8	2011	341,533	139,282	70.8	25.3	-	-
9	2012	337,951	135,730	70.8	25.3	-	-
10	2013	298,544	96,664	61.7	20.3	-	-
11	2014	298,544	96,664	61.7	20.3	-	-
12	2015	298,544	96,664	61.7	20.3	-	-
13	2016	298,544	96,664	61.7	20.3	-	-
14	2017	298,544	96,664	61.7	20.3	-	-
15	2018	298,544	96,664	61.7	20.3	-	-
16	2019	298,544	96,664	61.7	20.3	-	-
17	2020	273,665	88,609	61.7	20.3	-	-
18	2021	-	-	-	-	-	-
19	2022	-	-	-	-	-	-
20	2023	-	-	-	-	-	-
TOTAL	2004-2023	5,120,614	1,887,563			-	-

FINAL REPORT

SITE A066 (2005-xxx) Veri IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 5 END USE: Other

Measure	Install VFDs on two (2) 40 HP Cooling Tower Fans, one (1) 75 HP HVAC Fan and two (2) 25 HP HVAC Fans
Site Description	Office Tower

1. Measure Description

The customer implemented two measures to reduce the energy usage used for AC&R for an office building.

Measure #1 is the installation of VFDs on two (2) 40 HP fans on the cooling tower. Prior to the installation of the VFDs, the fans were operated as constant speed fans. The fans were cycled on and off as needed to maintain the condenser water temperature to the chiller. In the post-installation case, the fan speed is modulated continuously to maintain the condenser water loop temperature set point.

Measure #2 is the installation of VFDs on one (1) 75 HP HVAC unit fan and two (2) 25 HP HVAC unit fans. Prior to the installation the fans were modulated to the desired maximum flow through the use of discharge dampers.

2. Summary of the Ex Ante Calculations

The SPC Calculation Software for the VFD on the cooling tower fans was used to determine the impacts for measure #1. This program calculated energy and demand savings of 5.2 kW and 10,446 kWh.

Measure #2 is an itemized measure. No kW or kWh savings calculations were provided. The ex ante calculations for the itemized measures are typically based on the Express Efficiency work papers. The Express Efficiency work papers state that the impacts for the installation of VFDs on HVAC fan motors are 753.0 kWh/HP and 0 kW demand reduction. Multiplying 125 HP by 753 kWh/HP yields 94,125 kWh. This value agrees with the Installation Report.

The ex ante results are:

Measure #1-Cooling Tower VFDs:
Annual Savings - 10,446 kWh

Measure #2-HVAC Fans VFDs:
Annual Savings - 94,125 kWh

Both Measures Combined:
Annual Savings - 104,571 kWh

The totalized figures agree with the utility tracking system; however, the HVAC fan VFDs were in the wrong category. All VFDs should be in the “Other” category.

3. Comments on the Ex Ante Calculations

The impact for the cooling tower VFDs was determined using the SPC Calculation software. The VFDs on the colling tower fans result in 5.2 kW demand savings and 10,446 kWh energy savings. The SPC calculator uses simplified bin analysis based on typical chiller operation and local climate data.

Measure #2 is an itemized measure. No kW or kWh savings calculations were provided. The basis of the incentive payment was the itemized incentive rate in the Measure Savings Worksheet. The ex ante calculations for the itemized measures are typically based on the Express Efficiency work papers. The Express Efficiency work papers state that the impacts for the installation of VFDs on HVAC fan motors are 753.0 kWh/HP and 0 kW demand reduction. Multiplying 125 HP by 753 kWh/HP yields 94,125 kWh. This value agrees with the Installation Report. No credit is taken for any demand reduction due to the installation of the VFDs on the fan motors. This is a conservative assumption.

4. Measurement & Verification Plan

The facility is a multi-story office building that was constructed in 1990. The office tower has a floor area of 115,000 sq. ft. and is expected to be occupied continuously, with periods of peak occupancy occurring weekdays from 8:00 am to 5:00 pm. According to the application, before the installation, the cooling tower fans were constant speed and cycled on/off to maintain condenser water temperature setpoint. The HVAC fans were constant speed with fan outlet dampers to control flow. The post-installation system includes the installation of VFDs on cooling tower fans and HVAC fan motors, which reduces the energy consumption of the system.

The goal of the M&V plan is to estimate the actual kWh reduction due to the installation of the VFDs on the two cooling tower fans and three HVAC fans over the life of the VFDs.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A: Partially Measured Retrofit Isolation. The cooling tower fan motors and HVAC fan motors in question are not expected to consume a large percentage of the facility’s total energy usage. Also, the usage of the motors is not expected to remain consistent enough for single point measurements to be representative of the average usage.

Seasonal variation is expected to be predictable and two weeks should be sufficient to calibrate an energy savings model; however, a longer period would more fully capture actual variations and the persistence of savings.

Pre-retrofit and post-retrofit calculations of demand and energy loads will be calculated using the following formulae:

For the Cooling Tower and HVAC Fan VFDs:

Peak kW = motor full load kW x load factor

Average kW = motor full load kW x load factor x utilization factor

For the cooling tower fan VFD installation, the utilization factor is the total annual hours the fan is running divided by the total annual hours the cooling tower is in operation. For the HVAC fan VFD installation, the utilization factor is a function of the duty cycle of the fan.

kWh Savings = Average kW Savings x hours of operation

The majority of the savings are from the HVAC fan VFD installation. Therefore, the evaluation will focus on this measure.

For the cooling tower and HVAC VFD projects, the most significant variables to be quantified are the decrease in kW load factor due to the improved part load energy consumption of the fan motors with the VFDs. Site personnel will be interviewed to verify the pre-retrofit flow control method for the fan motors. Care will be taken to determine any changes in flow characteristics due to the retrofit. In addition, site personnel will be interviewed to attempt to more accurately determine annual variations and patterns in flow rates.

The post-retrofit energy consumption for the cooling tower and HVAC VFDs will be verified by collecting no less than two weeks of collected data from the customer's EMS software package. The collected data from the EMS software will then be used in conjunction with local temperature data to determine annual usage.

If the customer's EMS data is unavailable or incomplete, the post-retrofit energy consumption for the cooling tower and HVAC fan motors will be verified by installing Hobo FlexSmart data loggers with WattNode WNA-3D-480-P watt-hour transducers and Magnalab SCT-1250-200 or SCT-075-050 current transformers on the power supplied to the VFD of no less than two HVAC fans. The energy consumption of the motors will be logged with a sampling delay of no greater than 1 minute, for a minimum of 7 days to verify the post-retrofit energy consumption. In addition, the outdoor air temperature and relative humidity at the facility will be monitored using no less than one (1) Hobo H8 loggers. The logged kWh will then be used in conjunction with temperature to determine the annual usage.

Uncertainty for the savings estimate for the cooling tower and HVAC fan VFD projects can be more fully understood by setting projected ranges on the primary variables.

For the Cooling Tower Fan VFDs

- 5.2 kW expected, maximum of 13 kW, minimum of 0 kW (+250%, -100 %, based on judgment of deviation from expected hours of operation, full load kW, and average kW load factors)
- 10,446 kWh expected, maximum of 15,064 kWh, minimum of 4,362 kWh (+44.2%, -58.2 %, based on judgment of deviation from expected hours of operation, full load kW, and average kW load factors)

For the HVAC Fan VFDs

- 94,125 kWh expected for the HVAC fan VFDs, maximum of 164,034 kWh, minimum of 27,627 kWh (+74.3%, -70.6 %, based on judgment of deviation from expected hours of operation, full load kW, and average kW load factors)

For the Two Improvements Combined

- 104,571 kWh expected for the cooling tower and HVAC VFDs combined, maximum of 179,098 kWh, minimum of 31,989 kWh (+71%, -69%, based on above information)

Accuracy

The Hobo FlexSmart loggers have a resolution of ±10 seconds. The WattNode Watt-Hour transducers have an accuracy of ±0.45%+0.05%FS. The Magnelab SCT-1250-200 and the Magnelab SCT-750-050 current transformers have an accuracy of ±1.5%. The kWh loggers have a combined accuracy of ±2.0%+0.05%FS. The Onset current transformers have an accuracy of ±5%FS. The Hobo H8 current loggers have an accuracy of ±3%. The current loggers have a combined accuracy of ±8%. The Hobo H8 temperature and relative humidity loggers have an accuracy of ±1.3F (within the range of –4F to 104F) for temperature and ±5% for relative humidity.

The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to Microsoft Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 7, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the VFDs and fans and by interviewing the facility representative. Two VFDs were installed on two 40 hp cooling tower fans, and VFDs were installed on AC fans: two 25 hp and one 75 hp fans.

Installation Verification

For the VFD installation project the facility representative verified that prior to the installation of the VFDs, constant speed controls were installed, with outlet dampers used to control the flow of the AC fans and cycling used to control the flow of the cooling tower fans. The installation of the VFDs was physically verified during the on-site evaluation visit. The facility representative stated that the retrofit was completed by September 2005.

A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
INSTALL VFD'S ON TWO 25 HP FANS,ONE 75 HP FAN MOTOR, AND TWO 40 HP COOLING TOWER FANS.	O			INSTALL VFDS ON TWO 25 HP FANS, ONE 75 HP FAN MOTOR, AND TWO 40 HP COOLING TOWER FANS.	1	TWO (2) 25 HP VFDS, ONE (1) 75 HP VFD, TWO (2) 40 HP VFDS,.	PHYSICALLY VERIFIED INSTALLATION OF VFD'S	1.00
HVAC - INSTALL VFD'S ON TWO 40 HP COOLING TOWER FAN MOTORS.	H	INSTALL VFD'S ON TWO 40 HP COOLING TOWER FAN MOTORS.			2	40 HP VFD.	PHYSICALLY VERIFIED INSTALLATION OF VFD'S	1.00

Scope of the Impact Assessment

The impact assessment scope is for the HVAC and cooling tower fan VFD installations in the “Other” end use measure category. These were the only two measures in this application.

Summary of Results

Four Hobo kW loggers were installed within the facility for 20 days (from September 7, 2007-September 26, 2007). Data was successfully collected for five days (from September 7, 2007-September 12, 2007), due to the loggers being disconnected by the customer prior to completion of the evaluation. The loggers were used to measure the power levels and operating hours of the VFDs.

The facility representative stated that the cooling and ventilation fans operate typically from 5:00 AM to 8:00 PM, Monday through Friday. In addition, on Saturday, the fans are expected to operate from approximately 7:00 AM to 6:00 PM. On Sunday, the fans are expected to operate from approximately 8:00 AM to 6:00 PM. This variation from what was originally described required verification with the metered data. Based on the metered data, the AC fans were in operation from 6:00 AM to 9:00 PM weekdays, 6:00 AM to 7:00 PM Saturdays, and 7:00 AM to 9:00 PM on Sundays; the cooling tower fans were in operation from 10:00 AM to 9:00 PM every day. The facility representative stated that the 5-day period had been representative of normal facility operation.

In order to more accurately represent the pre-retrofit and post retrofit demand and energy usage as well as determine the savings, the VFDs were estimated to have a peak load factor of 80% power, which was consistent with the metered data. The hours of operation are summarized in Table 2 below.

Table 2: VFD Operating Hours

	Cooling Tower Fans	AHU Fans
Number of VFD's	2	3
Percent of Time on From Logger	43%	61%
Expected Annual Operating Hours (Each)	2,535	5,318

The cooling tower and AC VFDs are expected to operate per the schedule above. Therefore, at the summer peak hour, between 2 pm and 5 pm on weekdays, the fans are expected to be in operation.

In order to determine the load profile of the fans, the cooling tower fans and AHU fans were trended. The trended data was then parsed into 'percent of full load' categories. The percent of time at each percent load category was then summed.

For each percent load category, a percent full load flow rate was determined using the affinity laws.

This percent flow at each percent load was then used along with a typical pre-retrofit performance curve for each application. For the cooling tower fans, which cycle, the average percent full load kW was assumed to be equal to the percent load. For the AHU fans, a typical load profile for outlet damper condition was used.

The ex post impacts are calculated in Table 3 below:

Table 3: Energy and Demand Formulae for VFD Installation (Cooling Tower Fans)

Pre-Retrofit Demand kW_{peak} = Qty x Motor HP x 0.7457 / Motor Eff x Load Factor
= 2 x 40 HP x 0.7457 / 0.93 x 80%
= 51.3 kW

Post-Retrofit Demand kW_{peak} = Qty x Motor HP x 0.7457 / Motor Eff / VFD Eff x Load Factor
= 2 x 40 HP x 0.7457 / 0.93 / 0.942 x 80%
= 54.5 kW

Peak kW Savings = Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak}
= 51.3 kW – 54.5 kW
= -3.2 kW

Pre-Retrofit kWh = Pre-Retrofit kW_{peak} x (%Time at 100% load x 100% + %Time at 90% x 90% . . . %Time at 0% x 0%) x Hours per Year (%Time values determined from metered data)
= 65,452 kWh/yr

Post-Retrofit kWh = Post-Retrofit kW_{peak} x (Time at 100% load x 100% + Time at 90% x 90% . . . Time at 0% x 0%) x Hours per Year (%Time values determined from metered data)
= 19,075 kWh/yr

kWh Savings = Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak}
= 65,452 kWh/yr – 19,075 kWh/yr
= 46,377 kWh/yr

The ex post energy savings are greater than the ex ante energy savings due to an underestimated value for hours of operation used in the ex ante calculations.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. The costs appear reasonable for the size of the equipment installed. The customer did not give any non-energy benefits or drawbacks associated with the new equipment. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future.

We were unable to physically verify the pre-retrofit controls or hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

7. Impact Results

Based on the ex ante savings of 5.2 kW and 104,571 kWh, the engineering realization rate for this application is 2.79 for kW reduction and 1.20 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 4.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	5.2	104,571	-
SPC Installation Report (ex ante)	5.2	104,571	-
Impact Evaluation (ex post)	14.5	125,475	-
Engineering Realization Rate	2.79	1.20	N/A

Utility billing data for the site was reviewed. In the 12-month period from January 2004 – December 2004 (pre-retrofit), the facility consumed 1,857,152 kWh. Peak demand was 474.7 kW in March 2004. Table 5 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 5: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	474.7	1,857,152
Baseline End Use	108.0	266,077
Ex ante Savings	5.2	104,571
Ex Post Savings	14.5	125,475

Baseline is energy used by these fans only.

Table 6 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 1.1% decrease in total meter kW, a 4.8% decrease in fan end use kW, a 5.6% decrease in total meter kWh, and a 39.3% decrease in fan end use kWh. The ex post results showed a 3.1% decrease in total meter kW, a 13.4% decrease in cooling fan end use kW, a 6.8% decrease in total meter kWh, and a 47.2% decrease in cooling fan end use kWh.

Table 6: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	1.1%	5.6%	3.1%	6.8%
Baseline End Use %	4.8%	39.3%	13.4%	47.2%

With a cost of $67,884 and a $10,836 incentive, the project had a 4.20 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 3.50 years. A summary of the economic parameters for the project is shown in Table 7.

Table 7: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), ($1.10/therm) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	8/5/2004	$67,884	5.2	104,571	-	$13,594	$10,836	4.20	4.99
SPC Program Review (Ex Post)	9/26/2007	$67,884	14.5	125,475	-	$16,312	$10,836	3.50	4.16

It was determined that the VFD installation project was defined in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the variable frequency drive was assumed to have a useful life of fifteen (15) years.

A summary of the multi-year reporting requirements is given in Table 8. Because this measure was installed approximately September of 2005, the energy savings in year #2 (2005) are assumed to be 1/4 of the expected annual savings for this measure. In addition, no peak savings are assumed to occur.

Table 8: Multi-Year Reporting Requirements

Program ID:		001 Application # A066					
Program Name:		SPC 04-05 Evaluation					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004	-	-	-	-	-	-
2	2005	26,143	31,369	-	-	-	-
3	2006	104,571	125,475	5.2	14.5	-	-
4	2007	104,571	125,475	5.2	14.5	-	-
5	2008	104,571	125,475	5.2	14.5	-	-
6	2009	104,571	125,475	5.2	14.5	-	-
7	2010	104,571	125,475	5.2	14.5	-	-
8	2011	104,571	125,475	5.2	14.5	-	-
9	2012	104,571	125,475	5.2	14.5	-	-
10	2013	104,571	125,475	5.2	14.5	-	-
11	2014	104,571	125,475	5.2	14.5	-	-
12	2015	104,571	125,475	5.2	14.5	-	-
13	2016	104,571	125,475	5.2	14.5	-	-
14	2017	104,571	125,475	5.2	14.5	-	-
15	2018	104,571	125,475	5.2	14.5	-	-
16	2019	104,571	125,475	5.2	14.5	-	-
17	2020	78,428	94,106	5.2	14.5	-	-
18	2021	-	-	-	-	-	-
19	2022	-	-	-	-	-	-
20	2023	-	-	-	-	-	-
TOTAL	**2004-2023**	1,568,565	1,882,125			-	-

Final Report

SITE A067 (2005-184) Niag ---------------------------- . IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 3 END USE: Lighting

Measure	High Bay T5 Lighting Retrofit / Occupancy Sensors
Site Description	Manufacturing Plant

1. Measure Description

Replace 444 high intensity discharge fixtures utilizing 400 watt metal halide lamps with 444 fluorescent fixtures utilizing four (4) T5 lamps. Install 202 fixture mounted occupancy sensors to reduce lighting hours of operation. Remove (de-lamp) 256 metal halide fixtures.

2. Summary of the Ex Ante Calculations

The customer used the Itemized Measure Form to calculate the incentive. The original application did not include peak demand and annual energy savings, as it was submitted under the itemized approach. The original application was submitted as a Standard 2005 SPC application. The project was transferred to the Summer Initiative program, which requires peak demand and annual energy savings estimates. These were estimated by the reviewer using the itemized measures and using the SPC estimation software to calculate savings for the occupancy sensor sub-measure. Total savings was estimated to be 329.6 kW and 1,658,708.8 kWh. These are listed as the Application Approved savings amounts.

The total savings in the Installation Report Review were revised for the number of fixtures and fixture wattages found in the Post-Installation Inspection Report and given as 363.9 kW and 2,109,420 kWh. Calculated measure #1 in the Installation Report Review, Summary of Approved Measures sheet, contains “Peak Lighting Measure” savings attributed to the Summer Initiative Program; these are excluded from the SPC savings.

The balance of the savings, 278.3 kW and 1,593,851 kWh, are listed as “Other Measures” in the Installation Report Review, and agree with the utility tracking system. These are the ex ante savings for the SPC program.

The second calculated measure contains the demand and energy savings from the fixture replacement, and the savings for this measure are calculated on the Lighting Equipment Survey (LE1) sheet. Savings from 444 fixture replacements and 256 fixture removals are included in this calculation.

The savings for itemized measure #1 contains the demand and energy savings from the occupancy sensors and is stipulated based on the workpapers. The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. These workpapers note that a conversion from metal halide fixtures to high output (HO) T5 fixtures results in a wattage reduction from 0.458 kW to 0.234 kW, for a non-coincident peak reduction of 0.224 kW. Coincident peak reduction is noted as 0.205 kW and 0.210 kW for the warehouse and process industrial market sectors respectively. Energy savings are noted at 843 kWh/year and 1,504 kWh/year for the warehouse and process industrial market sectors respectively. The hours of operation are fixed in the workpapers at 3,550 and 5,300 for the warehouse and process industrial market sectors respectively.

For ceiling mounted occupancy sensors, the savings are based on the control of eight (8) fluorescent T12 fixtures, consuming 72 watts each, in an office conference room. Savings are based on a reduction from 2,210 hours/year to 1,040 hours/year (1,170 hours/year reduction). The workpaper reports 789 kWh savings (674 kWh/year plus a 17% office sector demand interactive effects factor). The non-coincident peak reduction of 0.305 kW was derived from the 0.576 kW controlled wattage and a 53% reduction in hours. Coincident peak reduction in the workpaper was noted to be 0.381 kW, which included a 1.25 demand sector interactive effects factor.

3. Comments on the Ex Ante Calculations

The ex ante savings figures can be checked for reasonableness using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation. A diversity factor of 84% is used for the calculation because this is the coincident diversity factor listed for the warehouse market sector in the workpapers. The use-reduction factor listed in the work papers is 53%. The motion sensors are located in the warehouse portion of the building at this site.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x (1 – diversity factor)

The check calculations for the main measures (involving conversion from HID fixtures and installation of motion sensors on these fixtures) were performed as follows:

- Pre-retrofit hours of operation: 6,023 hrs/yr (reported)
  Pre-retrofit wattage: 0.458 kW per fixture x 700 lamps = 320.6 kW
  Annual kWh usage: 320.6 kW x 6,023 hrs/yr = 1,930,974 kWh/yr
- Post-retrofit hours of operation for fixtures with occupancy sensors (based on an 53% use reduction factor): 6,023 hours x (1-0.53) = 2,831 hrs/year
  Post-retrofit wattage: 0.234 kW per four-lamp fixture x 242 fixtures + 0.234 kW per four-lamp fixture x 202 fixtures with motion sensors = 56.6 kW + 47.3 kW = 103.9 kW

Annual kWh usage: 56.6 kW x 6,023 hrs/yr + 47.3 kW x 2,831 hrs/yr= 474,808 kWh/yr

- The resulting annual kWh savings = 1,930,974 kWh/yr – 474,808 kWh/yr = 1,456,166 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load. This calculation was done using eight hundred (800) 400W metal halide fixtures replaced with eight hundred (800) six-lamp T5 fluorescent fixtures. The actual retrofits under SPC involved four hundred forty four (444) 400W metal halide fixtures replaced with four hundred forty four (444) four-lamp fluorescent fixtures and two hundred fifty six (256) 400W metal halide fixtures removed, with the installation of 202 occupancy sensors.

Summer peak demand reduction was calculated as follows:

- Reduction in connected kW load plus reduction in load due to motion sensor use: (0.458 kW – 0.351 kW) x 800 = 85.6 kW

Summer peak demand reduction reflecting SPC retrofits is calculated as follows:

- Reduction in connected kW load plus reduction in load due to motion sensor use: ((0.458 kW – 0.234 kW) x 444 + 0.458 kW x 256) + 47.3 kW x (1-.84) = 99.46 kW + 117.25 kW + 7.57 kW = 224.28 kW

Based upon hourly use figures obtained from site personnel, hours are expected to be higher than the average stated in the workpapers for warehouse operations, and kWh savings are thus expected to be higher. There may not be significant changes to the kW estimates, however.

In general, the savings figures in the final Implementation Report (IR) would be expected to be identical to the utility tracking system savings figures. The total savings in the Installation Report Review were given as 2,109,420 kWh/yr and 363.9 kW. Notes in the Installation Report Review and listed in the “Other” category give the savings as adjusted for the SPC program as 1,593,851 kWh and 278.3 kW, based on findings at the inspection. The utility tracking system lists these revised amounts (1,593,851 kWh and 278.3 kW), and these are used as the ex ante savings.

4. Measurement & Verification Plan

The building is a single level 400,000 sf production plant and warehouse used for water bottling and distribution. It is reported to be approximately 3 years old. The building has minimal windows, but many skylights. The building is occupied 24 hours per day, seven days a week. Occupancy is approximately 60 to 65 employees at any given time. According to the application, before the retrofit there were eight hundred (800) metal halide fixtures using 400-watt lamps. After the retrofit, there are four hundred forty four

(444) four-lamp T-5 fluorescent fixtures, two hundred and two (202) of which are controlled by individual, fixture mounted occupancy sensors. The project saves energy through the installation of lighting fixtures with a lower connected wattage and through the control of the lighting fixtures with occupancy sensors to reduce the hours of operation.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

IPMVP Option C approach should be considered. The savings reported in the utility tracking system is approximately 30% of the kWh and 10% of the kW consumed based upon the pre-retrofit building use (peak demand is approximately 2,049 kW and annual energy use approximates 5,271,000 kWh per year according to the utility billing data). Utility billing and interval data should support this approach if there are no other significant loads or other significant energy conservation activities which occurred in the months immediately following the retrofit. There is not expected to be significant seasonal variation and several months should be sufficient for comparison; however, a one to two year period would more fully capture actual variations and the persistence of savings. Interval data on a 15 minute basis during the summer months of June to September might be needed to accurately determine summer peak period demand savings since motion sensors are expected to contribute significantly to estimated peak load reduction.

If Option C cannot be used due to changes in the facility or its operation in the time periods immediately before or after the retrofit, then a modified version of IPMVP Option A can be utilized. Lighting loggers would be used to quantify hours of operation. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = $kWh_{pre} - kWh_{post}$

Summer peak demand period savings = $kW_{pre} - kW_{post}$ during the hottest periods between 2 pm to 5 pm, Monday to Friday, in June, July, August, September

To estimate the average expected peak demand kW reduction, since this measure is not weather dependent, the average of all reductions during that periods as stated above could be used.

Since actual billing and interval data will be used, whole building data should be the most accurate way to quantify the savings considering the pre retrofit conditions are uncertain. The most significant variables to be qualified are that there were no changes to operation not related to the measure which affect the pre and post retrofit energy usage.

Uncertainty for the savings estimate for the production facility fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables.

Uncertainty with utility billings

- kWh: 1,593,851 kWh expected; 1,577,912 kWh minimum; 2,390,777 kWh maximum (+50% for additional hours, - 1% for utility metering)
- kW: 278 kW expected , 264 kW minimum , 292 kW maximum hours (+/- 5 % based on extrapolating to actual hottest day period)

Uncertainty from changes in schedules and other energy use increases / decreases

- kWh: 1,593,851 kWh expected; 1,514,158 kWh minimum; 1,673,544 kWh maximum (+/- 5% for additional equipment or energy saving measures)
- kW: 278 kW expected , 264 kW minimum , 292 kW maximum hours (+/- 5% for additional equipment or energy saving measures and based on extrapolating to actual hottest day period)

Uncertainty in light logger measurements

- kWh: 1,593,851 kWh expected; 1,514,158 kWh minimum; 1,673,544 kWh maximum (+/- 5% for uncertainty in lighting logger measurements)

Accuracy and Equipment

The light loggers to be used are Dent TOU-L Lighting Smart*logger* dataloggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Annualizing that data from a 7 to 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

The utility meters capture 15 minute interval data and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Annualizing the kW data to the hottest summer period is projected to result in a possible error in the final results of +/- 5 %.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on June 5, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Lighting fixture quantities and hours of operation were verified.

The building is occupied around the clock seven days a week. The facility has 65 employees, and the average occupancy during the day is 60 employees. The facility is closed one holiday annually for the company soccer tournament.

Installation Verification

The facility representative verified that the metal halide fixtures were replaced on a one for one basis, with the exception of 256 fixtures that were removed. It was physically verified that there were 250 four-lamp T-5 fluorescent fixtures without occupancy sensors and 203 four-lamp T-5 fixtures with occupancy sensors installed in the facility. These counts fall within the 5% expected uncertainty for fixture count. The retrofit was completed in September 2005.

The installation of T5s and motion sensors, are the only measures in this application. The verification realization rate for this project is 1.02 (453/444). A verification summary is shown in Table 5 below.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measures in the SPC application covering the lighting efficiency retrofit. These are the only measures in this application. The savings from the fixtures that was credited to the Summer Lighting Incentive Program will be excluded from the analysis.

Summary of Results

The facility representative stated that the building is occupied continuously. All lights in the production area are on when the building is occupied. The lights in the warehouse area are never manually de-energized, and are energized by the occupancy sensors only.

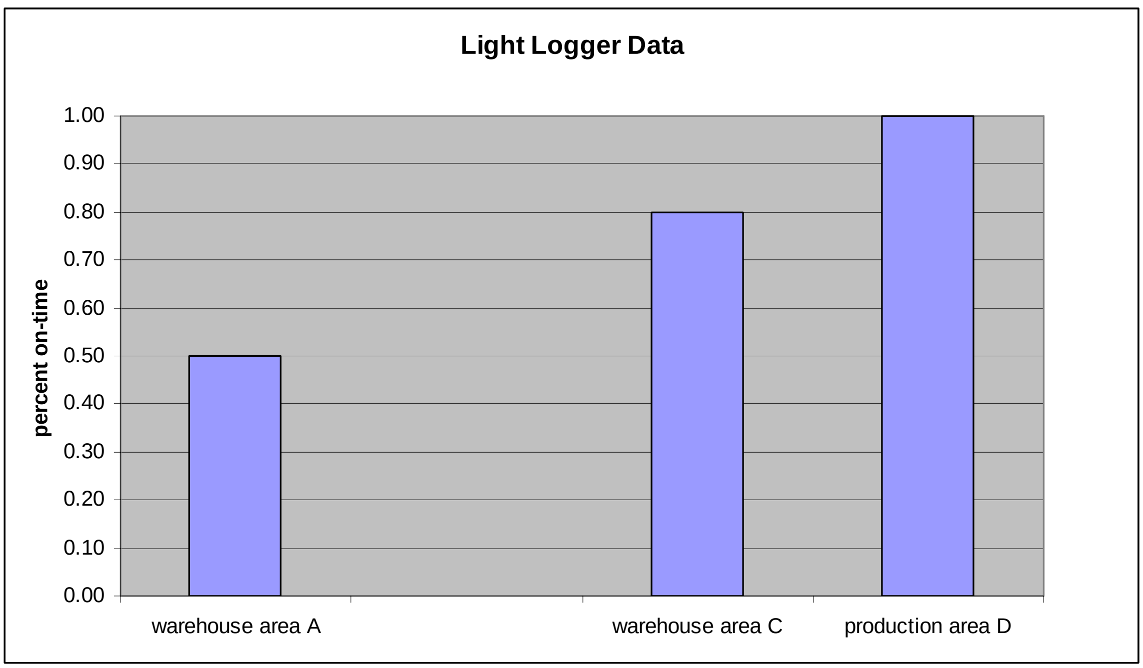
Very few burned out lights were observed during the site visit. Burned out lights are regularly replaced. Therefore, there was no adjustment to the lighting energy consumption due to burned out lamps.

All lights are expected to be operating during the peak demand period defined as the hottest periods during the weekdays between 2 pm to 5 pm, Monday to Friday in June, July, August or September.

The electricity end-uses at this facility are lighting, forklift charging, injection molders, blow molders, and compressed air. The facility representative stated that there was a significant expansion in production (additional injection and blow molding machines coming online) at the same time as the lighting retrofit so billing analysis will not be used for this site. The presence of summer initiative lighting measures also prevents the isolation of the SPC funded measures using bill analysis.

The light loggers were installed in four locations at the plant. It was not possible to install additional lighting loggers due to staff time limitations at the site. Three loggers were installed inside fixtures in the warehouse area and one inside a fixture in the production area. One of the loggers (in warehouse area B) was not able to be retrieved because pallets of water prevented the boom lift from getting close enough to the fixture. The on-time of the fixtures was recorded between 12:00 AM on 6/6/07 and 11:59 PM on 6/26/07. The percent on-time during this time period is shown for each of the fixtures in Figure 1 below. The average percent on-time was 1.0 for the production area, 0.80 for the southeast warehouse area, and 0.50 in the northwest warehouse area during this 21 day period. The percent on-time of the loggers in the warehouse area are averaged and applied to all the occupancy-sensor controlled fixtures in the warehouse area.

Figure 1: Light Logger Data at Site A067



The ex ante calculations were revised after the evaluation site visit to reflect actual hours of operation and the actual number of fixtures installed. The hours of operation are listed as 6,023 hrs/yr in the ex ante calculation. Our on-site interview revealed that the facility is operational 8742 hours per year (closed only for one holiday).

The total fixture wattage is calculated using the per fixture wattages prescribed in the SPC program documentation.

- Pre-retrofit hours of operation were 8,742 hrs/year.
  Pre-retrofit wattage for the 400W metal halide fixtures was 0.458 kW per fixture x 700 lamps = 320.6 kW. (453 replacements, 247 removed)
  Annual kWh usage was 320.6 kW x 8,742 hrs/yr = 2,802,685 kWh/yr.
- Post-retrofit hours of operation are 8,742 hours x (100%) = 8,742 hrs/year for the production area T5 fixtures and 8,742 hours x (65%) = 5,682 hrs/year for the warehouse area T5 fixtures.
  Post-retrofit wattage is 0.234 kW per four-lamp T5 fixture x 250 fixtures in the production area + 0.234 kW per four-lamp T5 fixture x 203 fixtures in the warehouse area = 58.5 kW + 47.5 kW = 106.0 kW.
  Annual kWh usage is the power draw multiplied by the annual hours of use = (58.5 kW x 8,742 hrs/yr for the production area + 47.502 kW x 5,682 hrs/yr for the warehouse area = 781,328 kWh/yr.
- The resulting annual kWh savings is 2,802,685 kWh/yr – 781,328 kWh/yr = 2,021,358 kWh/yr.

Summer peak impacts were estimated by subtracting post-retrofit load from pre-retrofit load. The load includes connected load and the diversity factor adjusted savings for occupancy sensor use.

Summer peak demand reduction is calculated as follows:

- Pre-retrofit kW load (metal halide connected) minus Post-retrofit kW load (T5 connected + T5 diversity) is (320.6 kW) – (106 kW – 16.6 kW) = 231 kW.

The demand reduction of 16.6 kW is the actual measured weekday 12 pm to 7 pm demand reduction as sensed by the occupancy sensors.

Utility billing data for the site was obtained from the utility billing data. The earliest available data was from December 2004; one year of pre-retrofit data was not available. The retrofit occurred in August 2005, but no savings are visible in the billing data because additional production equipment came online at the same time. Annual consumption in 2005 was 5,271,900 kWh. Peak demand was 2049 kW in the summer of 2005. No pre-retrofit baseline usage was listed in the application. Table 1 summarizes the total metered use, the baseline end use energy (calculated energy use of the 700 pre-retrofit fixtures), the revised ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 13.6% decrease in total meter kW, a 86.8% decrease in lighting end use kW, a 30.2% decrease in total meter kWh, and a 56.9% decrease in lighting end use kWh. These high savings were due to the overestimation of the motion sensor savings, in part because the workpapers did not accurately represent the fixtures installed, and in part because the energy savings were calculated to be about double what the workpapers indicated. The ex post results showed an 11.3% decrease in total meter kW, a 72.1% decrease in lighting end use kW, a 38.3% decrease in total meter kWh, and a 72.1% decrease in lighting end use kWh.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	2049	5,271,900
Baseline End Use	320.6	2,802,685
Ex Ante Savings	278.3	1,593,851
Ex Post Savings	231.2	2,021,358

Note: Baseline end use is for the affected lighting fixtures only.

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	13.6%	30.2%	11.3%	38.3%
Baseline End Use %	86.8%	56.9%	72.1%	72.1%

6. Additional Evaluation Findings

The ex post kW demand reduction is lower than the ex ante estimate because the motion sensor demand reduction was based on the workpapers which assume a (per unit) controlled wattage of 0.576, much higher than the wattage actually controlled (0.234), and they assume an overall use factor of 47%, yielding more savings than the measured use reduction factor of 65% in the warehouse area.

The ex post energy savings are greater than the ex ante energy savings because of the longer hours of operation in the ex post calculations. (We found at the site visit that the facility in operation 24 hours a day all year long, closed only for one annual holiday.)

In addition to saving energy, the employees notice that lighting quality is greatly improved and the increased lumen levels on the production floor allow the facility to meet minimum lumen levels required by their customers for a food processing facility. The customer anticipates expansion of the bottling line that will increase energy consumption in the near future. Participation in the 2004/2005 SPC Program has encouraged the customer to install high efficiency production equipment, high pressure to low pressure compressed air recovery system, and VFD drives through a rebate program.

7. Impact Results

The pre-retrofit lighting fixture type, quantities and hours of operation were unable to physically verified. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With the motion sensor cost of $15,968, non-peak lighting cost of $32,470 and a $24,219 incentive, the project had a 0.12 year simple payback based on the ex ante calculations. Because the non-reimbursed expense for the project and the project savings are very similar in the ex ante case and the ex post case the simple payback is 0.09 years for the ex post case. A summary of the economic parameters for the project is shown in Table 3.

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	8/30/2005	$48,439	278.3	1,593,851	0	$207,201	$24,219	0.12	0.23
SPC Program Review (Ex Post)	6/11/2007	$48,439	231.2	2,021,358	0	$262,776	$24,219	0.09	0.18

The engineering realization rate for this application is 0.83 for demand kW reduction and 1.27 for energy savings kWh. According to the installation report, the ex ante savings are 1,593,851 kWh annually and demand reduction is 278.3 kW. These figures are identical to those in the tracking system. A summary of the realization rate is shown in Table 4.

The Installation Verification Summary is shown in Table 5 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 6.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	278.3	1,593,851	-
SPC Installation Report (ex ante)	278.3	1,593,851	-
Impact Evaluation (ex post)	231.2	2,021,358	-
Engineering Realization Rate	0.83	1.27	NA

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Replace 444 400W metal halide fixtures with 444 4-lamp HO T5 fluorescent fixtures and delamp 256 400W metal halide fixtures. Also add 202 occupancy sensors.		453	4 lamp T-5 HO fixtures and occupancy sensors	Physically verified lamp type and quantity.	1.02

Table 6: Multi Year Reporting Table

Program ID Program Name		SPC 2004 Application # A067 2004 – 2005 SPC Evaluation					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004						
2	2005	398,463	505,340				
3	2006	1,593,851	2,021,358	278	231		
4	2007	1,593,851	2,021,358	278	231		
5	2008	1,593,851	2,021,358	278	231		
6	2009	1,593,851	2,021,358	278	231		
7	2010	1,593,851	2,021,358	278	231		
8	2011	1,593,851	2,021,358	278	231		
9	2012	1,593,851	2,021,358	278	231		
10	2013	1,593,851	2,021,358	278	231		
11	2014	1,593,851	2,021,358	278	231		
12	2015	1,593,851	2,021,358	278	231		
13	2016	1,593,851	2,021,358	278	231		
14	2017	1,593,851	2,021,358	278	231		
15	2018	1,593,851	2,021,358	278	231		
16	2019	1,593,851	2,021,358	278	231		
17	2020	1,593,851	2,021,358	278	231		
18	2021	1,195,388	1,516,019	278	231		
19	2022						
20	2023						
TOTA	**2005-2024**	25,501,616	32,341,728				

Lighting measures with 16 year life

Final Report

SITE A068 IMPACT EVALUATION

SAMPLE CELL: ORIGINAL TIER: 2 END USE: Lighting

Measure	High Bay T5 Lighting Retrofit / Occupancy Sensors
Site Description	Warehouse

1. Measure Description

Replace fixtures using 437 three-foot T12 lamps and 1,686 four-foot T12 lamps with fixtures using T5 lamps; remove 117 four-foot and 100 eight-foot T12 lamps; replace 465 HID fixtures with four-lamp high output (HO) T5 fixtures; install four (4) wall box occupancy sensors; install 724 ceiling mounted occupancy sensors; install 175 photocells; and install three (3) LED exit signs.

2. Summary of the Ex Ante Calculations

The total ex ante kW demand and kWh savings submitted were 428.7 kW and 1,934,306.26 kWh in the Installation Report Review.

The customer submitted all retrofits as itemized measures. No calculations of demand or energy savings were provided. However, a printout indicating that the savings were generated by the SPC Track/SelfGen2002 software program was included in the application paperwork. This printout is consistent with the ex ante savings and the incentive.

The Itemized Measure Application Form also was included in the application paperwork and correctly shows the incentive for the project.

The ex ante savings for the itemized measures are typically based on the Express Efficiency workpapers.

Measure E-L22 covers conversion from 3 foot fixtures (using two T12 lamps and energy saving ballasts) to 3 foot fixtures (using two T8 lamps and electronic ballasts). The total installed wattage drops from 0.068 kW to 0.042 kW for a noncoincident demand savings of 0.013 kW per lamp. Coincident demand savings for the warehouse market sector is 0.012 kW and annual kWh savings of 49 kWh per lamp, based upon 3,550 annual operating hours and a 0.84 coincident diversity factor.

The workpapers section E-L23 measure covers conversion from 4 foot fixtures (using T12 lamps and energy saving ballasts) to 4 foot fixtures (using T8 lamps and electronic ballasts). The average of the two lamp fixture and three lamp fixture savings is used as the basis of the per fixture savings of .009 kW. Coincident demand savings for the warehouse market sector is 0.008 kW and annual kWh savings of 34 kWh per lamp, based upon 3,550 annual operating hours and a 0.84 coincident diversity factor

Section E-L19 covers removal of four foot lamps. The original fixture wattage is based on T-12, 34-watt lamps in fixtures employing energy savings ballasts and assumes removal of one lamp and its associated ballast. The work paper indicates the total wattage drops from 0.115 kW to 0.072 kW with a noncoincidental demand savings of 0.043 kW per lamp. The coincident kW and kWh savings are listed as 0.039 kW and 162 kWh for a warehouse application.

In section E – L20, the savings for a similar conversion from three to two 8 foot lamps (with the associated ballast removed) is provided, assuming an original T-12 lamp wattage of 60 watts powered by energy saving ballasts. After removal of 1 lamp and ballast, the total installed wattage drops from 0.205 kW to 0.126 kW with noncoincident demand savings of 0.079 kW per lamp. The coincident kW and kWh savings are listed as 0.072 kW and 297 kWh for a warehouse application.

Section H – L292 covers savings from replacement of metal halide (MH) HID fixtures to high bay, high output (HO) T5 or T8 fluorescent fixtures and lamps. The workpapers assume metal halide fixture wattage (with ballast) at 0.458 kW, four lamp HO T5 system wattage at 0.234 kW, and a total wattage drop from 0.458 kW to 0.234 kW per fixture for a non-coincident peak reduction of 0.224 kW per fixture. Coincident peak reduction is noted as 0.205 kW and kWh savings is noted as 843 kWh/year based on a warehouse market sector with the assumed operation hours and diversity factor. Note that for T8 lamps, the workpaper states that T8s can be incorporated by presuming that replacement fixture will have proportionately more lamps to match the light output of the similar T5 fixture.

In workpapers section J – L83, wall box mounted occupancy sensors, the workpaper documents savings based on the control of three (3) 4 foot 2 lamp fluorescent fixtures with 34 watt T-12 lamps, consuming 72 watts each including the ballast, in a private office. Savings are based on a reduction of usage from 2,550 hours/year to 1,500 hours/year (1,050 hours/year reduction). The workpaper reports a total of 266 kWh per fixture savings, which includes a 17% office sector energy interactive effects factor). The non-coincident peak reduction of 0.089 kW was derived from the 0.216 kW controlled wattage and a 41% reduction in hours. Coincident peak reduction was reported at 0.111 kW, which includes a 1.25 average office sector Demand Interactive Effects factor.

In section J – L83 for ceiling or wall mounted occupancy sensors, the workpaper documents savings based on the control of eight (8) 4 foot 2 lamp fluorescent fixtures with 34 watt T-12 lamps, consuming 72 watts each including the ballast, in an office conference room. Savings are based on a reduction of usage from 2,210 hours/year to 1,040 hours/year (1,170 hours/year reduction). The workpaper reports a total of 789 kWh savings for all sectors (674 kWh/year plus a 17% office sector energy interactive effects factor). The non-coincident peak reduction of 0.305 kW was derived from the 0.576 kW controlled wattage and a 53% reduction in hours. Coincident peak reduction was reported at 0.381 kW, which includes a 1.25 average office sector Demand Interactive Effects factor.

For installation of photocells, section K – L36 considers outside lights automatically controlled by a photocell in conjunction with a time clock. In this scenario, exterior lights operate 4,100 hours per year. Without the photocell, the time clock would operate the light for an additional 280 hours per year (approximately 3 months for 3 additional hours per day). For the savings calculation, the photocell is assumed to control four 70-watt (95 watts each including ballast) high pressure sodium lamps. The noncoincident demand savings are 0.380 kW when controls shut off equipment. The coincident demand savings are0.0 kW and the energy savings for all market sectors are 106 kWh per year.

In section M – L137, the workpapers establish savings from installation of high efficiency LED exit signs, assuming replacement of older signs containing two 20-watt incandescent lamps. Total installed wattage drops from 0.040 kW to 0.004 kW. The noncoincident demand savings are 0.036 kW per LED fixture; with a 1.18 Demand Interactive Effects factor, the noncoincident demand savings are 0.042 kW. Fire code requires exit signs to operate all year - 8760 hrs/yr. The savings are calculated as 0.036 kW x 8,760 hours/year x 1.114 = 351 kWh per year. The calculation includes 11.4% average Energy Interactive Effects. Coincident demand savings are 0.042 kW x 1.0 = 0.042 kW.

3. Comments on the Ex Ante Calculations

Calculations of energy savings resulting from the installed measures were not detailed. All supporting calculation documentation did not appear to be included in the application paperwork for this site. The savings from each itemized measure were shown in the printout generated by the SPC Track/SelfGen2002 software program.

The increased savings did not alter the incentive, as the incentive was based on fixed incentive rates.

The ex ante savings are shown in the Measure Savings Worksheet; the ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. The calculations performed with figures from those workpapers did not result in the kW and kWh savings listed for many sub-measures. The greatest discrepancies were in the calculations for the kWh savings for the ceiling mounted motion sensors and for the photocells, and for the kW savings for the photocells.

In addition, the workpapers prescribe savings based on certain conditions, which do not always apply to the installed conditions, and so do not accurately represent the actual situation evaluated.

As stated above, the wattage controlled and the hours reduced through the use of motion sensors and photocells are not representative of this installation.

Also, the invoices in the application paperwork noted that six lamp HO T5 fixtures were delivered / installed. The workpaper assumes four lamp HO T5 fixtures, and kWh and kW savings would be lower than forecast. Measure verification did uncover the presence of both four lamp and six lamp fixtures.

Based upon hourly use figures obtained from site personnel, hours are expected to be 4,862 hours/year, somewhat higher than the average stated in the workpapers for warehouse operations. Energy savings in this case would be higher than indicated by the workpapers.

The ex ante savings figures can be checked for reasonableness using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x (1 – diversity factor)

The check calculations for the installation of motion sensors and photocells on these fixtures are shown:

kW controlled = $kW_{pre\ sensor}$ = $kW_{post\ sensor}$ = 724 motion sensors x 234 watts/ fixture (four lamp HO T5) / 1000 watts/kW = 169.42 kW

Energized $hours_{pre}$ = 4862 hours/years

Energized $hours_{post}$ = 4862 Hours/year x 0.84 (using diversity factor as default) = 4,084.08 hours

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$ = 169.42 kW x 4,862 hours/yr - 169.42 kW x 4084.08 hours/yr = 131,792 kWh/yr (verses 1,034,541 kWh/yr identified as the ex ante savings for this sub-measure)

kW savings = $kW_{pre\ sensor}$ – $kW_{post\ sensor}$ + $kW_{post\ sensor}$ x (1 – diversity factor) = 0 + 169.42 kW * (1 – 0.84) = 27.1 kW (verses 220.8 kW identified as the ex ante savings for the sub-measure)

Other measures also show larger savings than may be realistic in this application. The ex ante savings reported appear to exceed the building kWh energy use and kW peak demand from utility records and expected use for a facility of this size and type.

In general, the ex ante savings figures in the Installation Report Review (IRR) would be expected to be identical to the utility tracking system savings figures. The total savings in the Installation Report Review are listed as 1,934,306.26 kWh/yr and 428.7 kW, and the utility tracking system lists the savings as 1,934,305 kWh/yr and 428 kW.

4. Measurement & Verification Plan

According to the application paperwork, the building is a single level, 250,000 sf warehouse. There is a mezzanine within the warehouse area that comprises approximately 5 % of the total floor area. Lighting retrofits were conducted in both areas. The area in the application may have been the square footage associated with the primary meter at the facility and did not reflect the balance of the warehouse area covered by two other meters at the facility. The facility representative and other documents indicated that square footage is approximately 650,000 to 700,000 sf.

According to the application paperwork, pre-retrofit conditions were as follows: 2,123 T12 lamps in 3 and 4 foot fixtures (to be converted to fixtures using T8 lamps); 117 four foot T12 lamps and 100 eight foot T12 lamps (to be removed); 465 metal halide fixtures using 400-watt lamps (to be replaced by 465 fixtures using T8 lamps); and three exit signs using 20 watt lamps.

After the retrofit, there were 437 three-foot T8 lamps and 1686 four-foot T8 lamps in fixtures with electronic ballasts, and 465 high bay four lamp or six lamp fixtures using T8 lamps. Occupancy wall box sensors were installed at 4 locations and 724 ceiling mounted occupancy sensors were installed. In addition, 175 photocells were installed. Three LED exit signs were installed to replace the pre-measure higher wattage fixtures. A total of 117 four foot T12 lamps and 100 eight foot T12 lamps were removed.

The project saves energy through the installation of lighting fixtures with a lower connected wattage and through the control of the lighting fixtures with occupancy sensors / photocells to reduce the hours of operation.

The contractor documentation in the package indicates that the majority of fixtures are located above the access aisles where parts are racked.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the lighting measures.

Formulae and Approach

Billing analysis using a modified version of IPMVP Option C will be utilized. The kW and kWh savings from these measures are expected to be over 20% of the pre retrofit building energy use; in this unconditioned dry good warehouse, lighting will be the predominant energy end use. There were no other reported changes which would have an impact on consumption.

The peak demand prior to the retrofit was approximately 187 kW for the primary meter and an additional 170 kW for the combined use of the other two meters, for a combined use of 357 kW. Annual energy use approximates 1,441,263 kWh per year according to utility consumption records.

Utility billing and interval data should support this approach if there are no other significant loads or other significant energy conservation activities which occurred in the months immediately following the retrofit. There is not expected to be significant seasonal variation and several months should be sufficient for comparison; however, a one to two year period would more fully capture actual variations and the persistence of savings.

Interval data on a 15 minute basis during the summer months of June to September might be needed to accurately determine summer peak period demand savings since motion sensors and photocell controls are expected to contribute significantly to estimated peak load reduction. At present, there is an interval meter on only the largest account.

Billing analysis based on IPMVP Option C is expected to be the most reliable way to capture the energy effects of multiple sub-measures and pre existing conditions at this facility.

Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = $kWh_{pre} - kWh_{post}$

Summer peak demand period savings = $kW_{pre} - kW_{post}$ averaged between 2 pm to 5 pm, Monday to Friday, in June, July, August, September

Since actual billing and interval data will be used, whole building data should be the most accurate way to quantify the savings considering the pre retrofit conditions are uncertain. The most significant variables to be qualified are that there were no changes to operation not related to the measure which affect the pre and post retrofit energy usage.

Uncertainty for the savings estimate for the warehouse fixture retrofit and for the motion sensors / photocells controlling these fixtures can be more fully understood by setting projected ranges on the primary variables – the kWh and the kW savings. The estimated savings as provided in the approved application were 1,934,306.26 kWh and 428.7 kW.

Uncertainty from utility billings

- kWh: 420,000 kWh expected savings based on 30% savings from bills, 415,800 kWh minimum , 424,200 kWh maximum (+/- 1% for utility metering).
- kW: 105 kW expected based on 30% savings from bills, 104 kW minimum, 106 kW maximum (+/- 1% for utility metering).

Uncertainty from 30 % savings estimate

- kWh: 420,000 kWh expected, 210,000 kWh minimum ; 630,000 kWh maximum (+ / - 50% for range of possible savings)
- kW: 105 kW expected , 55 kW minimum , 155 kW maximum (+ / - 50% for range of possible savings)

Uncertainty from changes in schedules and other energy use increases / decreases

- kWh: 420,000 kWh expected, 378,000 minimum , 462,000 maximum (+/- 10% for additional equipment or energy saving measures)
- kW: 105 kW expected , 80 kW minimum , 130 kW maximum (+/- 25% for additional equipment or energy saving measures and based on extrapolating to actual hottest day period and from the main meter)

Accuracy and Equipment

The primary utility meter captures 15 minute interval data and, for the purposes of the evaluation, the three meters are considered to be 100% accurate where reviewed data are deemed reasonable.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on June 6, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Lighting fixture quantities and hours of operation were verified.

According to the facility's maintenance coordinator, the building is a one story 700,000 sf warehouse used for parts receiving, warehousing and distribution. There is a mezzanine within the warehouse parts stocking area that comprises approximately 5 % of the total floor area and provides a comparable amount of floor/storage space. Lighting is provided to both levels. The building is reported to be approximately 18 years old. It has minimal windows (at the offices) and skylights (in the warehouse); the skylights provide sufficient daylight to justify the installation of photocells. Bay doors are opened and closed manually throughout the day providing more or less ambient light in the front receiving and shipping area of the building.

The building is occupied on a varying schedule, from approximately 4:30 am to 10:00 pm Monday through Friday and Saturday from 9:00 am to 3 pm. Partial occupancy occurs at the beginning and end of these periods and shifts overlap between 12 noon and 1 to 3 pm. The morning shifts are staggered with work starting from 4:30 am to 6:30 am and ending between 1 pm and 3 pm. In general, the afternoon shift is complete by 8:00 pm with the last few employees leaving the warehouse around 10:00 pm. Maximum occupancy is approximately 110 employees at the overlap period (12 noon to 3 pm) with an average of 40 to 50 employees at other times. Approximately 60% of the warehouse staff operates forklifts and 40% receive or package parts for storage or distribution. Shipping generally occurs in the morning and receiving is scheduled in the afternoons. This allows for more efficient work flows in the warehouse and at the exterior loading docks.

The shift supervisor and security personnel are responsible for turning lights off during the unoccupied 37.5 hour period between 3:00 p.m. on Saturday and 4:30 a.m. Monday.

The facility is closed 5 holidays annually. The maintenance coordinator indicated that 25% of the employees work in the front area of the building where receiving and shipping occurs, 25% of the staff are in the middle area of the building where large machinery is shipped, 25% of the staff work in the western portion of the building in auto parts distribution and warehousing, and 25% work throughout the pick/shelf areas and in the offices.

Interior security lighting is provided in three columns – at the east and west ends, and in the middle of the warehouse. The columns have approximately nine fixtures each. An additional bank of fifteen fixtures lies along the back wall. All fixtures over the side aisles and in the rack areas have sensors that turn off all lamps in that fixture. For the safety fixtures, at least two lamps are always energized. When these areas are occupied, the motion sensors turn on the other two lamps in these fixtures.

The 175 photocells control fixtures that do not illuminate main aisles. All photocell-controlled fixtures were noted to have three levels of control (low level 2-lamp lighting, high level 4-lamp lighting, or off), depending on the ambient light level.

The three utility meters are area-specific within the warehouse and not dedicated to lighting. Other non-lighting energy uses include three forklift charging areas with multiple stations and five (5) 0.5 hp motors on small conveyors. Forklift batteries are charged at night. The maintenance coordinator suggested a better schedule would allow the batteries to cool following charging before use. A change, if any occurs, may affect energy demand. Other energy loads include desk lamps and small fans and heaters.

Shipping and receiving operations are not expected to change in the near future. Lighting needs are met now and will not need modification in the foreseeable future. Work in this facility is at capacity for the available space.

The building and lights were 18 years old at the time of the measure implementation. The lights were functional but with significant maintenance problems, which required substantial maintenance time. Fixtures were not lined up with aisles. As a result, lamps were hard to change, requiring periodic rental of a special boom truck. In addition, wiring and ballasts were failing from age, with brittle insulation near fixtures. A number of ballasts were humming.

The new fixtures have made a noticeable improvement in light levels, maintenance has been greatly reduced and energy reductions are noticeable. Similar retrofits are planned for other facilities around the United States.

The program did not spur other specific on-site measures, but management is considering changing out twenty three high pressure sodium 1000 watt exterior fixtures and lamps and applying photocells.

An increase in energy awareness in the warehouse staff, other than the maintenance coordinator, has not been apparent. However, management is aware of the economics and details of the retrofit, has seen the savings, and is implementing similar retrofits at other warehouse facilities outside of the state.

Installation Verification

It was physically verified that six lamp fluorescent fixtures using T12 lamps were retrofit to allow use of T8 lamps and relocated to the Section B narrow aisles. Other new one, two, four and six lamp fixtures using T8 lamps were located in the other aisles and mezzanine areas of the east end of the facility, replacing all metal halide fixtures and fluorescent fixtures using T12 lamps. The facility representative verified that the metal halide fixtures were replaced on a one for one basis.

The number and type of fixtures and controls were observed and appear to be in agreement with the number and types that were in the ex ante calculations and for which incentives were paid. The itemization in an invoice from the lighting contractor support the quantities installed.

It is noted that, in the post installation inspection, the reviewer counted and verified the itemized measures and identified that eight (8) additional four lamp, four foot HO T5 fixtures were installed.

The retrofit was completed in July 2005.

A small area at the west end of the building did not have fluorescent fixtures or lamps changed, but overhead HID fixtures were removed. No motion sensors were applied to these lights and they are always energized.

These are the only measures in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 5 below.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measures in the SPC application covering the lighting efficiency retrofit, replacements, motion sensors, photocells, and exit signs.

For purposes of the ex post calculations, there were 465 400-watt metal halide fixtures and 2123 T-12 lamps in fluorescent fixtures before the retrofit. The documentation indicated an additional 217 lamps were removed permanently; 724 ceiling mounted and 4 wall box occupancy sensors were installed to control lighting times following inactivity in any area controlled by these sensors. In addition, three LED exit signs were installed in the mezzanine and 175 photocells were installed to restrict lighting when sufficient ambient light is available in the warehouse from the skylights.

Summary of Results

The ex post savings for this lighting retrofit project were determined using billing analysis incorporating utility consumption data. Average daily kWh use (Figure 1) was plotted from one year prior to the retrofit until one year after the retrofit to confirm that there was no major changes or instability in electricity use other than that caused by the lighting retrofit in July, 2005. The electricity end-uses at this facility are lighting, forklifts charging, conveyor motors, and office activities. The facility representative confirmed that there was no change in the electricity use patterns before and after the retrofit other than the change to the light fixtures. The graph indicates a significant change in energy use in July 2005. However, it is noted that fluctuations in monthly energy averages before the measure implementation appear to have wider variation than those fluctuations after the measures.

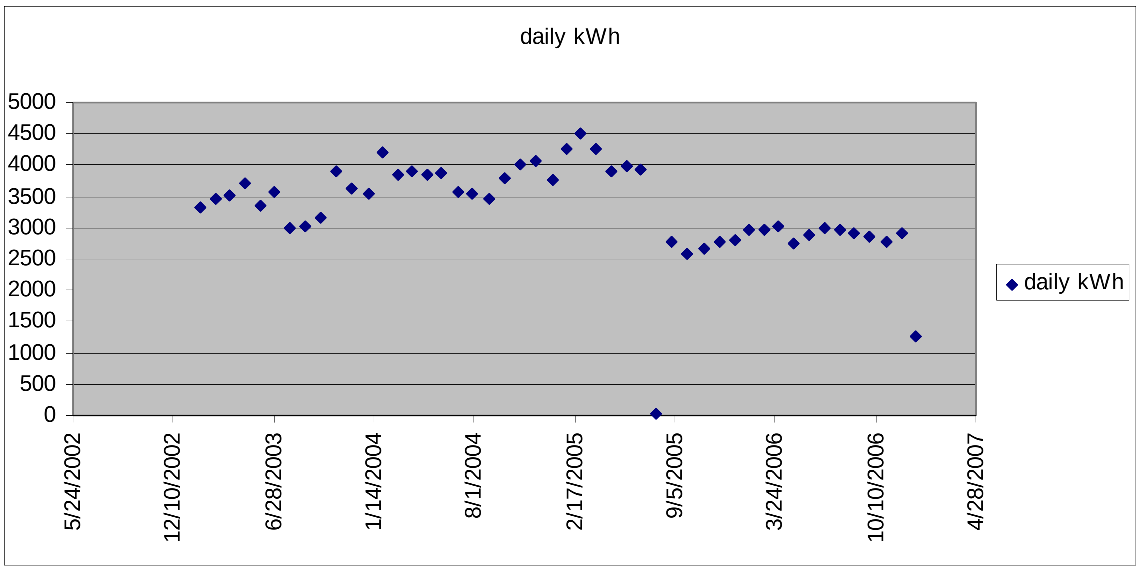
The kWh energy consumption in the twelve month periods immediately before and immediately after the retrofits were compared and the difference of 412,188 kWh is determined to be the ex post savings figure for annual energy savings.

There were no adjustment or regression performed as weather dependency is very small for this facility. It is not clear that shipments or throughputs would affect lighting use in a significant manner.

All lights are functional when the building is occupied. Very few burned out lights were observed during the site visit. Burned out lights now are easily accessible and regularly replaced as they show signs of dimming or failure. The prevalence of burned out lamps was not known prior to the retrofit. Therefore, there was no adjustment to the baseline lighting energy consumption due to burned out lamps.

All lights are expected to be available during the peak demand period defined as the hottest weekday periods between 2 pm to 5 pm, Monday to Friday, in the months of June, July, August and September.

Figure 1: Average Daily kWh Consumption



Graph of averaged daily use by monthly billing for January 2003 to December 2006

The ex post impacts were calculated from utility consumption data as follows:

- Pre retrofit kWh use is summed for the three meters and a 365 day period from 6/29/2004 to 6/29/2005 for annual pre-retrofit kWh of 1,441,263 kWh.
- Post retrofit kWh use is summed for the three meters and a 365 day period from 6/29/2005 to 6/29/2006 for annual post-retrofit kWh of 1, 029,075 kWh.
- Pre-retrofit wattage was averaged over the months of June to September during the period from 2 pm to 5 pm on non-holiday weekdays in 2004 (adjusted for the kW demand percentage from the one interval meter) and found to be 299.2 kW
- Post-retrofit wattage was averaged over the months of June to September during the period from 2 pm to 5 pm on non-holiday weekdays in 2004 (adjusted for the kW demand percentage from the one interval meter) and found to be 188.8 kW

- The resulting annual kWh savings is 1,441,263 kWh/yr – 1, 029,075 kWh/yr = 412,188 kWh/yr
- Summer peak demand reduction impacts were estimated by subtracting average post-retrofit from average pre-retrofit peak load.
  Peak kW savings is 299.2 kW – 188.8 kW = 110.4 kW

The customer provided June, July, August, and September utility billing data in hard copy for the site. These bills supplemented the existing utility data with actual kW readings justifying the use of the interval data from one meter to extrapolate kW demand savings for the entire facility.

Pre-retrofit annual consumption (for one year prior to retrofit) was 1,441,263 kWh. Peak demand was 366.0 kW. This coincides relatively closely with the pre-retrofit baseline usage of 1,440,431 kWh and 310.2 kW listed in the application.

Table 1 summarizes the total metered energy use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and the additional data obtained from the customer. The baseline end use energy is the calculated energy use for the pre and post implementation evaluations for the specific quantities of the equipment listed in the specific measures

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	366.0	1,441,263
Baseline End Use	329.4	1,297,137
Ex Ante Savings	428.7	1,934,306
Ex Post Savings	110.4	412,188

Table 2 summarizes the percentages of savings obtained for calculated post installation and ex post measure inspection values compared to total metered and baseline end use kW and kWh energy. Baseline end use was estimated at 90% of total kWh use and kW demand at this facility.

Table 2: Percent Savings and Demand Reduction (Ex Ante, Ex Post)

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	117.1%	134.2%	30.2%	28.6%
Baseline End Use %	130.1%	149.1%	33.5%	31.8%

The summary in Table 2 of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations, indicate the ex ante results showed a 117.1% decrease in total meter kW, a 130.1 % decrease in lighting end use kW, a 134.2% decrease in total meter kWh, and a 149.1% decrease in lighting end use kWh. These were clearly overstated. The ex post results showed a 30.2% decrease in total meter kW, a 33.5% decrease in lighting end use kW, a 28.6% decrease in total meter kWh, and a 31.8% decrease in lighting end use kWh.

6. Additional Evaluation Findings

The ex post energy and demand savings are significantly lower than the ex ante energy savings because the assumed controlled wattage of the motion sensors was higher than the actual controlled wattage. The photocells also were forecast to save a significant amount of energy and yield demand savings in excess of what was in the Express Efficiency workpapers; however, the basis for these savings and the sub-measure interactions was not explained in the application paperwork. Finally, the ex post kWh energy and kW demand reduction is lower than the ex ante estimate because the ex ante savings estimated the HID fixture replacement wattage at 0.234 kW per fixture when many of the fixtures installed were six lamp fixtures consuming approximately 0.351 kW.

In addition to saving energy, the benefits of the project are increased clarity of light, increased light levels, increased employee comfort and yielded better working conditions. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. Participation in the 2004/2005 SPC Program has encouraged management to consider other energy efficiency projects, such as the installation of timers or photocells for external parking lot lights.

The pre-retrofit lighting fixture type, quantities, and hours of operation were not able to be physically verified. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative and in the application paperwork. The level of billing analysis employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $350,747 and a $78,727.25 incentive, the project had a 1.39 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is substantially less than the ex ante, and the estimated simple payback is 6.55 years. A summary of the economic parameters for the project is shown in Table 3.

7. Impact Results

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	11/23/2004	$350,747	428.7	1,934,306	0	$251,460	$78,727	1.08	1.39
SPC Program Review (Ex Post)	7/12/2007	$350,747	110.4	412,188	0	$53,584	$78,727	5.08	6.55

The realization rate of the peak kW demand is 0.26 and the realization rate of the energy savings is 0.21 as summarized in Table 4. The Installation Verification Summary is shown in Table 5 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 6.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	428.0	1,934,305	-
SPC Installation Report (ex ante)	428.7	1,934,306	-
Impact Evaluation (ex post)	110.4	412,188	-
Engineering Realization Rate	0.26	0.21	NA

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING	L		Replace: 2123 T12 lamps with T8 lamps, 465 MH fixtures with T8 HO fixtures; install: 728 motion sensors, 175 photocells, 3 exit signs; remove 217 T12 lamps,		3,721	Four/six lamp T8 HO fixtures and three/four lamp T8 fixtures;motion sensors/photocells/exit signs	Physically verified lamp type and verified quantity from floor plan and documentation of previous inspectors.	1.00

Table 6: Multi Year Reporting Table

Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	967,153	206,094	428.700	110.400		
3	2006	1,934,305	412,188	428.700	110.400		
4	2007	1,934,305	412,188	428.700	110.400		
5	2008	1,934,305	412,188	428.700	110.400		
6	2009	1,934,305	412,188	428.700	110.400		
7	2010	1,934,305	412,188	428.700	110.400		
8	2011	1,934,305	412,188	428.700	110.400		
9	2012	1,934,305	412,188	428.700	110.400		
10	2013	1,934,305	412,188	428.700	110.400		
11	2014	1,934,305	412,188	428.700	110.400		
12	2015	1,934,305	412,188	428.700	110.400		
13	2016	1,934,305	412,188	428.700	110.400		
14	2017	1,934,305	412,188	428.700	110.400		
15	2018	1,934,305	412,188	428.700	110.400		
16	2019	1,934,305	412,188	428.700	110.400		
17	2020	1,934,305	412,188	428.700	110.400		
18	2021	967,153	206,094				
19	2022						
20	2023						
TOTAL	**2004-2023**	30,948,880	6,595,008				

Final Report

SITE A069 2K5SCEL184 Tech ------------------------- . IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 3 END USE: Lighting

Measure	High Bay T5 Lighting Retrofit / Occupancy Sensors
Site Description	Warehouse

1. Measure Description

Install 912 fixture mounted occupancy sensors to reduce lighting hours of operation on T5 fluorescent fixtures retrofit under the Summer Initiative Program. Provide incentive based on a portion of the lamp changeouts associated with the Summer Lighting initiative Program, described as follows:

> *Replace 560 high intensity discharge fixtures utilizing 400 watt metal halide lamps with 560 fluorescent fixtures utilizing three (3) T5 lamps. Replace 227 high intensity discharge fixtures utilizing 400 watt metal halide lamps with 227 fluorescent fixtures utilizing four (4) T5 lamps. Replace 156 high intensity discharge fixtures utilizing 250 watt metal halide lamps with 156 fluorescent fixtures utilizing three (3) T5 lamps.*

2. Summary of the Ex Ante Calculations

Savings for this measure were given as 306.452 kW and 1,480,283.28 kWh in the Approved Total section of the Installation Report Review. These include both occupancy sensor savings and the additional energy savings that exceeded the Summer Lighting Initiative Program (SLIP) approved savings values. These are identical to the savings figures in the tracking system figures, allowing for rounding functions.

The additional energy savings from the SLIP program are based upon the changeout of metal halide fixtures to a slightly reduced number of fluorescent fixtures using T5 lamps. Savings of 28.382 kW and 177,103.68 kWh/yr were calculated using the product of 6,240 hours of operation per year and wattages for the fixtures, and then subtracting the original approved SLIP savings.

The customer used the Itemized Measure Application Form to calculate kW and kWh savings for the occupancy sensors. The basis of the incentive payment was the itemized incentive list. Savings for this measure were given as 306.452 kW and 1,480,283.28 kWh.

The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. For ceiling mounted occupancy sensors, the savings are based on the control of eight (8) fluorescent T12 fixtures, consuming 72 watts each, in an office conference room. Savings are based on a reduction from 2,210 hours/year to 1,040 hours/year (1,170 hours/year reduction). The workpaper reports 789 kWh savings (674 kWh/year plus a 17% office sector demand interactive effects factor). The non-coincident peak reduction of 0.305 kW was derived from the 0.576 kW controlled wattage and a 53% reduction in hours. Coincident peak reduction in the workpaper was noted to be 0.381 kW, which included a 1.25 demand sector interactive effects factor.

3. Comments on the Ex Ante Calculations

The original application was submitted as a Standard 2005 itemized application. Total ex ante savings was estimated to be 491.1 kW and 2,225,900.6 kWh. These are listed as the Application Approved savings amounts.

The savings in the Installation Report Review are adjusted for 31 fixtures removed instead of replaced, and are given as 510.6 kW and 2,753,592.7 kWh. These amounts are based on the Installation Report Review, Summary of Approved Measures sheet. This sheet contains three measures: the SLIP approved savings for the fixtures and the additional savings for the fixtures as two separate measures in the calculated section and the occupancy sensors in the itemized section.

The savings were calculated for the lamp replacements. This measure was later transferred to the Summer Initiative program and the incentive for the lamps was recalculated using the application for that program. The savings for the lamps were given as 204 kW and 1,273,309 kWh and were to receive the incentives through the SLIP.

The fixture replacement was transferred to the Summer Lighting Incentive Program (SLIP). The savings from the fixtures that exceeded the original SLIP approved values were rebated through the SPC program as “Additional Energy Savings.” The “Additional Energy Savings” is mislabeled “Outdoor System Replacement” in the tracking system.

The measures evaluated will be the two measures listed in the tracking system: 1) Outdoor System Replacement and 2) Lighting Sensors.

The overall and additional energy savings associated with the SLIP lamp retrofits appear to be realistic. The savings associated with the motion sensors may be high based on the lower controlled wattage as compared to the workpapers. However, actual reduced hours of operation will have a large impact as well. The kw savings are likely higher than realistic, as kW savings are based on the higher expected controlled wattage in the workpapers.

The ex ante savings figures can be checked for reasonableness using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

$$\text{kWh savings} = kW_{pre} \times \text{energized hours}_{pre} - kW_{post} \times \text{energized hours}_{post}$$

$$\text{Coincident peak demand period savings} = kW_{pre} - kW_{post} + kW_{post} \times (1 - \text{diversity factor})$$

The check calculations for the main measures (involving conversion from HID fixtures and installation of motion sensors on these fixtures) were performed as follows:

- Pre-retrofit hours of operation: 6,240 hrs/yr
  Pre-retrofit wattage: 0.458 kW per fixture x 787 lamps + 0.295 kW per fixture x 156 lamps = 360.5 kW + 46 kW = 406.5 kW
  Annual kWh usage: 406.5 kW x 6,240 hrs/yr = 2,536,560 kWh/yr
- SLIP post-retrofit usage: Post retrofit hours of operation: 6,240 hrs/ yr
  Post-retrofit wattage: 0.234 kW per fixture x 196 lamps + 0.179 kW per fixture x 560 lamps + 0.179 kW per fixture x 156 lamps = 184.1 kW + 18.3 kW +18.3 kW = 174.0 kW
- Annual kWh usage: 174.0 kW x 6,240 hrs/yr = 1,085,760 kWh/yr
- SPC program savings: Post-retrofit hours of operation for fixtures with occupancy sensors (based on the Express Efficiency workpaper reported reduction of 53%): 6,240 hrs/yr x 47% = 2,933 hrs/year
- Post-retrofit wattage: 174.0 kw x (1-0.84) (84% diversity factor) = 27.8 kW
- Annual kWh usage: 174.0 kW x 2,933 hrs/yr = 510,342 kWh/yr
- The resulting annual kWh savings = 2,536,560 kWh/yr – 1,085,760 kWh/yr = 1,450,800 kWh/yr (SLIP – 12.2 % to SPC - 177,104 kWh/yr)
- + The resulting annual kWh savings = 1,085,760 kWh/yr – 510,342 kWh/yr = 575,418 kWh/yr (SPC motion sensors)
- 406.5 kW – 174.0 kW = 232.5 kW (SLIP – 12.2 % to SPC - 28.4 kW)
- 27.8 kW (SPC)

The SLIP savings check agrees with the ex ante savings in the Installation Report Review. The SPC savings check calculation show only 35% of the kWh savings and 10% of the kW savings as compared to the ex ante savings.

Total SPC reportable savings: 177,104 kWh/yr + 575,418 kWh/yr = 752,522 kWh/yr

Summer peak impacts were estimated by adding the SPC allocated SLIP savings (post-retrofit from pre-retrofit connected load) and adding the diversity adjusted motion sensor savings.

Summer peak demand reduction is calculated as follows:

- 28.4 kW + 27.8 kW = 56.2 kW

In general, the savings figures in the final Implementation Report Review (IRR) would be expected to be identical to the utility tracking system savings figures.

The savings from the SLIP measures are not included in the SPC tracking system.

4. Measurement & Verification Plan

The building is a single level 425,000 sf warehouse used for distribution of computer parts. It is reported to be approximately 8 years old. The building has minimal windows, but many skylights. The building is occupied around the clock from 10:00 pm Sunday to 2:00 am Saturday. Occupancy is approximately 23 to 30 employees at any given time. According to the application, before the retrofit there were eight hundred (787) metal halide fixtures using 400-watt lamps and one hundred fifty six (156) metal halide fixtures using 250-watt lamps. After the retrofit, there are one hundred ninety-six (196) four-lamp T-5 fluorescent fixtures and seven hundred sixteen (716) three-lamp T-5 fluorescent fixtures; all are controlled by individual, fixture mounted occupancy sensors. The project saves energy through the installation of lighting fixtures with a lower connected wattage and through the control of the lighting fixtures with occupancy sensors to reduce the hours of operation.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

IPMVP Option C approach should be considered. The savings reported in the utility tracking system is approximately 20% – 30% of the kW and kWh consumed based upon the pre-retrofit building use (peak demand was 419 kW and annual energy use was 3,705,479 kWh per year in 2004). Utility billing and interval data should support this approach if there are no other significant loads or other significant energy conservation activities which occurred in the months immediately following the retrofit. There is not expected to be significant seasonal variation and several months should be sufficient for comparison; however, a one to two year period would more fully capture actual variations and the persistence of savings. Interval data on a 15 minute basis during the summer months of June to September might be needed to accurately determine summer peak period demand savings since motion sensors are expected to contribute significantly to estimated peak load reduction.

If Option C cannot be used due to changes in the facility or its operation in the time periods immediately before or after the retrofit, then a modified version of IPMVP Option A can be utilized. Lighting loggers would be used to quantify hours of operation. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

$kWh\ savings = kWh_{pre} - kWh_{post}$

Summer peak demand period savings = the average $kW_{pre} - kW_{post}$ during the three contiguous hottest days expected between 2 pm to 5 pm, Monday to Friday, in June, July, August, September

To estimate peak demand kW reduction, the reduction in connected kW due to the increased lighting efficiency will be added to the post-retrofit connected load multiplied by the percent of energized time. The derivation or extrapolation of the average percent of time energized for the coincident peak demand periods will be described.

Documentation provided indicates that there are 912 fixtures with individual motion sensors which compromise the majority of the projected savings. These fixtures will be the primary target for evaluation efforts. The majority of the fixtures are located in the aisles of the warehouse.

The most significant variables to be quantified are the pre-retrofit and post-retrofit fixture hours of operation. Pre-retrofit hours will be confirmed with site personnel and interviews. The focus will be on verifying that, prior to the retrofit, the entire complement of fixtures was completely energized during the hours listed (6,240 hours/year) and that the listed hours/year were valid (for example, building or staff schedule logs for the pre-retrofit period could be examined if available). Appropriate modifications for the savings calculations would be made to the pre-retrofit usage figures if required, in order to establish a realistic baseline for energy use.

Monitoring with light loggers will be conducted on approximately 10% of the fixtures. The use of eleven sampling points is generally consistent with SPC program documentation from March 2001 (Appendix E, Sampling); this document suggests guidelines for determining sampling point requirements necessary to achieve an 80% confidence interval with 20% precision (using a coefficient of variation of 0.5.)

Usage patterns will be determined in the on-site interview and loggers will be randomly distributed throughout the facility with at least one logger in each usage area. The light loggers will be placed so as to be unaffected by fixtures not on motion sensors or by ambient outside light.

If the light loggers cannot be placed in suitable locations, it will be considered that, where the lighting circuits can be isolated and it can be determined that only lighting loads for the warehouse fixtures are controlled by that lighting circuit, a current or power meter could be used to track multiple fixtures. The total current / power would be determined by activating all fixtures and by confirming loads using the electrical drawings. Between three and six current/power meters are expected to be needed, to capture a representative sample of the lighting fixtures.

The lighting loggers or current sensors would be left in place for a period of 7 to 14 days. Attention will be given to the time period for monitoring, in order to avoid periods of irregular usage patterns (e.g., during holidays or breaks). While longer periods might be preferable, these periods are appropriate given the scope of the evaluation and reported usage characteristics.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture hours of operation. The lighting fixture quantities seem to be well established and were counted to within 5% to 10% in utility pre-installation inspection visits. The pre-retrofit and post-retrofit connected loads associated with various fixture types are also adequately quantified in the SPC lighting wattage tables.

Uncertainty for the savings estimate for the production facility fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables.

<u>For lower wattage fixtures (T5 conversion from HID fixtures) Only 12.2 % of these savings are attributed to SPC.</u>

- 912 fixtures expected, minimum 866, maximum 958 (+/- 5%)
- 6,240 hours pre retrofit expected/reported, minimum 5000 hours, maximum 7000 hours (based on + 10% / -20%, or approximately one hour at the start and end of each day)
- 232.4 kW expected, minimum 209 kW, maximum 256 kW (includes +/- 5% for number of fixtures and +/- 5% for fixture wattage difference)

<u>For motion sensors controlling the above fixtures</u>

- 912 fixtures expected, minimum 866, maximum 958 (+/- 5%)
- 0.84 diversity factor expected/reported for a warehouse, minimum 0.35 diversity factor, maximum 0.95 diversity factor (- 49% , +11% based on judgment of use for site type)
- 2,933 hours expected, minimum 2,000 hours; 4,000 maximum hours (+ / - 30% from annualizing estimates from short monitoring period)
- 27.8 kW reported savings includes number of fixtures, post-retrofit fixture wattage and diversity factor; minimum 20 kW, maximum 100 kW (- 30% , +400% based on judgment of use for site type)

Accuracy and Equipment

The light loggers to be used are Dent TOU-L Lighting Smart*logger* dataloggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Annualizing that data from a 7 to 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

Current or power meters may also be used. The current loggers to be used, if this M&V technique is selected, would be HOBO U-12 loggers, with matched current transformers. The accuracy range is 4.5 %. The sensor would be calibrated to an Amprobe ACD-41PQ, with an accuracy of +/- 2%. An advantage of using current or power meters to monitor load is that the percent of time energized for an increased number of fixtures may be able to be captured.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on June 6, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Lighting fixture quantities and hours of operation were verified.

The building is occupied around the clock starting 10 p.m. Sunday until 2 a.m. Saturday. The facility has 150 employees, but average occupancy at any given time is 20-30 employees. The facility is closed 6 holidays annually (Memorial Day, 4^{th} of July, Labor Day, Thanksgiving, Christmas and New Years).

Installation Verification

The facility representative verified that the metal halide fixtures were replaced on a one for one basis. It was physically verified that there were 716 three-lamp T-5 fluorescent fixtures and 196 four-lamp T-5 fixtures were installed in the facility with occupancy sensors. The retrofit was completed in August 2005.

The installation of T5s and motion sensors, are the only measures in this application. The verification realization rate for this project is 1.00 (912/912). A verification summary is shown in Table 5 below.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measures in the SPC application covering the lighting efficiency retrofit. These are the only measures in this application. The savings from the fixtures that was credited to the Summer Lighting Incentive Program will be excluded from the analysis.

Summary of Results

The facility representative stated that the building is occupied continuously on weekdays. The building is closed from 2 a.m. Saturday to 10 p.m. Sunday. All lights are on when the building is occupied. It is assumed the lights are off during the unoccupied periods.

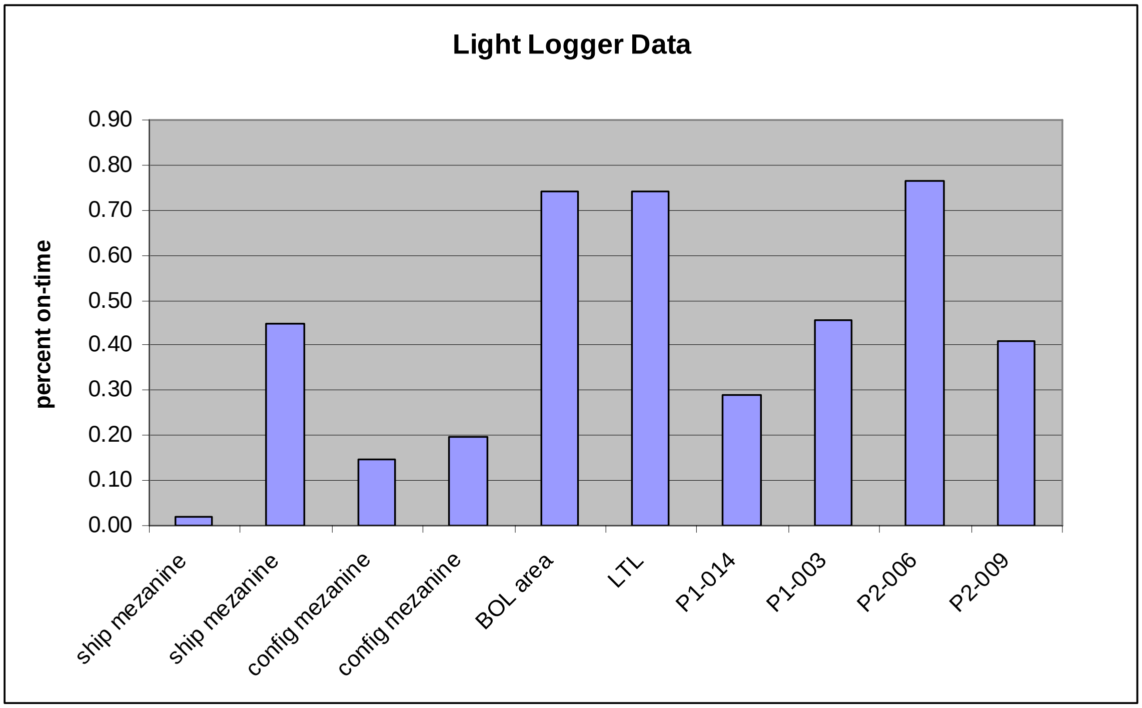
Very few burned out lights were observed during the site visit. Burned out lights are regularly replaced. Therefore, there was no adjustment to the lighting energy consumption due to burned out lamps.

Most lights are expected to be operating during the coincident peak demand period defined as the three contiguous hottest weekdays expected between 2 pm to 5 pm, Monday to Friday, in the week with the hottest weekday in June, July, August or September.

The electricity end-uses at this facility are lighting, forklift charging and conveyers and compressed air. The facility representative stated that there was a significant increase in conveyer use at the same time as the lighting retrofit so billing analysis will not be optimal for this site.

The light loggers were installed as follows: two in each mezzanine, four in the aisles, and two in the open areas. The on-time of the fixtures was recorded between 6:00 PM on 6/6/07 and 6:00 AM on 6/27/07. The percent on-time during this time period is shown for each of the fixtures in Figure 1 below. The average percent on-time was 100% for the open areas, 75% for the aisle areas, and 46% (area-weighted average) for the mezzanine areas in this 20.5 day period.

Figure 1: Light Logger Data at site A069



The ex ante calculations were revised after the evaluation site visit to reflect actual hours of operation and the actual number of fixtures installed, and the one or two lamp security mode which operates on perimeter lights in the open areas and three to four lights per aisle whenever the motion sensor is not activated. The three lamp fixtures operate with only one lamp energized and the four lamp fixtures operate with two lamps energized in security mode.

- Pre-retrofit hours of operation were 6,485 hrs/year, as measured by the lighting loggers in the open areas (LTL and BOL areas). This agrees with the facility's reported operating schedule and reported pre retrofit lighting operating hours. The loggers did not, however, capture any of the six annual holidays. If lights were de-energized, the operating hours would be reduced 144 hours, or about 2%.

Pre-retrofit wattage for the 400W metal halide fixtures was 0.458 kW per fixture x 787 lamps = 360.4 kW.

Pre-retrofit wattage for the 250W metal halide fixtures was 0.295 kW per fixture x 156 lamps = 46.0 kW.

Annual kWh usage was 360.4 kW x 6,485 hrs/yr + 46.0 kW x 6,485 hrs/yr = 2,635,504 kWh/yr.

- Post-retrofit hours of operation for the SLIP incented lighting changeout are 6,485 hrs/year for the open area T5 fixtures, 6,485 hrs/year for the aisle area T5 fixtures, and 6,485 hrs/year for the mezzanine areas.
  Post-retrofit wattage using power draw for actual ballasts installed is 0.182 kW per three-lamp fixture x 716 fixtures
  + 0.242 kW per four-lamp fixture x 196 fixtures = 177.7 kW.

- Annual kWh usage is the sum of the energy used by the fixtures in normal mode + the energy used by the security fixtures when in security mode = (47.4 kW x 6,485 hrs/yr for the open area + 101.92 kW x 6,485 hrs/yr for the aisles + 28.4 kW x 6,485 hrs/year for the mezzanine areas) normal mode + (2,275 hrs/yr x 0.121 kW/fixture x 76 fixtures in the open areas + 2,275 hrs/yr x 0.061 kW/fixture x 110 fixtures in the aisles + 2,275 hrs/yr x 0.061 kW/fixture x 54 fixtures in the mezzanine areas) security mode = 1,196,065 kWh/yr.
- The resulting annual kWh savings is 2,635,504 kWh/yr – 1,196,065 kWh/yr = 1,483,548 kWh/yr.

Summer peak impacts for the SLIP lighting changeout were estimated by subtracting post-retrofit load from pre-retrofit load. The load totals 228.8 kW.

Savings attributed to the SPC program were the additional savings over the original SLIP demand and energy savings.

- SPC savings from the SLIP program are 228.8 kW – 204.1 kW = 24.7 kW.
- SPC energy savings from the SLIP program are 1,483,548 kWh – 1,273,309 kWh = 210,239 kWh

Savings from the Occupancy Sensor installation are attributed 100 % to the SPC program.

- Pre-retrofit kW load (metal halide connected) minus post-retrofit kW load is 177.7 kW and 1,196,065 kWh/yr as described above.

Post retrofit lighting use is determined by the light logger data.

- Annual kWh usage is the sum of the energy used by the fixtures in normal mode + the energy used by the security fixtures when in security mode = (47.4 kW x 6,485 hrs/yr for the open area + 101.92 kW x 4,201 hrs/yr for the aisles + 28.4 kW x 1,848 hrs/year for the mezzanine areas) normal mode + (2,275 hrs/yr x 0.121 kW/fixture x 76 fixtures in the open areas + 4,201 hrs/yr x 0.061 kW/fixture x 110 fixtures in the aisles + 6,912 hrs/yr x 0.061 kW/fixture x 54 fixtures in the mezzanine areas) security mode = 862,511 kWh/yr.
- The resulting annual kWh savings is 1,196,065 kWh/yr – 862,511 kWh/yr = 333,534 kWh/yr.

Summer peak impacts were estimated by using the connected loads and the diversity factor adjusted savings for occupancy sensor use. Coincident peak is calculated in this case by analyzing the light logger data to determine the fraction of lights illuminated during the peak period of 2 pm to 5 pm on weekdays.

coincident peak diversity factor	
1.00	open area
0.48	aisles
0.46	mezzanine

Summer peak demand reduction is calculated as 68.3 kW follows:

- Pre-retrofit kW load (metal halide connected) minus post-retrofit kW load 101.9 x (100% - 48%) + 28.4 x (100% - 46%) = 68.3 kW

Total SPC ex post savings are the additional SLIP savings and the occupancy sensor savings.

- The resulting annual kWh savings is 210,239 kWh/yr + 333,534 kWh/yr = 543,792 kWh/yr.
- The resulting kW savings are 24.7 + 68.3 kW = 93.0 kW.

Utility billing data for the site was obtained. Pre-retrofit annual consumption (2004) was 3,705,479 kWh. Peak demand was 419.0 kW. No pre-retrofit baseline usage was listed in the application. Baseline use for lighting at this facility was estimated at 80% of the total load. Table 1 summarizes the total metered use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 73.2% decrease in total meter kW, a 91.4% decrease in lighting end use kW, a 39.9% decrease in total meter kWh, and a 49.9% decrease in lighting end use kWh. The higher ex ante savings were due to the overestimation of the motion sensor savings because the workpapers did not accurately represent the fixtures installed. The ex post results showed a 22.2% decrease in total meter kW, a 27.7% decrease in lighting end use kW, a 14.7% decrease in total meter kWh, and a 18.3% decrease in lighting end use kWh.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	419.0	3,705,479
Baseline End Use	335.2	2,964,383
Ex ante Savings	306.5	1,480,283
Ex Post Savings	93.0	543,792

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	73.2%	39.9%	22.2%	14.7%
Baseline End Use %	91.4%	49.9%	27.7%	18.3%

6. Additional Evaluation Findings

The ex post kW demand reduction is lower than the ex ante estimate because the motion sensor demand reduction was based on the workpapers which assume a (per unit) controlled wattage of 0.576, much higher than the wattage actually controlled (0.242 and 0.182), and the assume a usage factor of 47%, lower than the measured usage factor of 75% in the aisles.

The ex post energy savings are changed from the ex ante energy savings because the ex ante calculations did not take into account the post retrofit security lighting where approximately 230 fixtures are always illuminated at a one or two lamp level.

In addition to saving energy, the increased lumen output was believed to increase worker productivity in picking products off the shelves, and the fluorescent fixtures do not produce as much heat, keeping the building cooler in the summertime. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. Participation in the 2004/2005 SPC Program has encouraged the customer to install “High Speed Low Velocity” fans to provide air circulation. Sixteen (16) fans were installed in August 2006 without participation in any incentive program. The customer would like to install a more efficient conveyer system, but has not discovered the proper solution and this retrofit is pending.

7. Impact Results

The pre-retrofit lighting fixture type, quantities and hours of operation were unable to physically verified. However, these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With the motion sensor cost of $146,768 and $41,492 incentive, the project had a 0.55 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 1.49 years. A summary of the economic parameters for the project is shown in Table 3.

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	8/30/2005	$146,768	306.5	1,480,283	0	$192,437	$41,492	0.55	0.76
SPC Program Review (Ex Post)	6/11/2007	$146,768	93.0	543,792	0	$70,693	$41,492	1.49	2.08

The engineering realization rate for this application is 0.30 for demand kW reduction and 0.37 for energy savings kWh. According to the installation report and the tracking system, the ex ante savings are 1,480,283 kWh annually and demand reduction is 306.5 kW. A summary of the realization rate is shown in Table 4.

The Installation Verification Summary is shown in Table 5 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 6.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	306.5	1,480,283	-
SPC Installation Report (ex ante)	306.5	1,480,283	-
Impact Evaluation (ex post)	93.0	543,792	-
Engineering Realization Rate	0.30	0.37	NA

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Replace 560 400W metal halide fixtures with 560 3-lamp HO T5 fluorescent fixtures, replace 227 400W metal halide fixtures with 227 4-lamp HO T5 fluorescent fixtures, replace 156 250W metal halide fixtures with 3-lamp HO T5 fluorescent fixtures and add 912 fixture mounted occupancy sensors.		961	4 lamp and 3-lamp T-5 HO fixtures and occupancy sensors	Physically verified lamp type and quantity.	1.00

Table 6: Multi Year Reporting Table

Program ID Program Name		**SPC 2004 Application # A069 2004 – 2005 SPC Evaluation**					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004						
2	2005	492,934	181,264			0	0
3	2006	1,480,283	543,792	306.5	93.0	0	0
4	2007	1,480,283	543,792	306.5	93.0	0	0
5	2008	1,480,283	543,792	306.5	93.0	0	0
6	2009	1,480,283	543,792	306.5	93.0	0	0
7	2010	1,480,283	543,792	306.5	93.0	0	0
8	2011	1,480,283	543,792	306.5	93.0	0	0
9	2012	1,480,283	543,792	306.5	93.0	0	0
10	2013	1,480,283	543,792	306.5	93.0	0	0
11	2014	1,480,283	543,792	306.5	93.0	0	0
12	2015	1,480,283	543,792	306.5	93.0	0	0
13	2016	1,480,283	543,792	306.5	93.0	0	0
14	2017	1,480,283	543,792	306.5	93.0	0	0
15	2018	1,480,283	543,792	306.5	93.0	0	0
16	2019	1,480,283	543,792	306.5	93.0	0	0
17	2020	1,480,283	543,792	306.5	93.0	0	0
18	2021	986,855	362,528	306.5	93.0	0	0
19	2022					0	0
20	2023						
TOTA	**2004-2023**	23,684,035	8,700,676				

Final Report

SITE A070 (2K5SCEL199) Coop IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: Lighting

Measure	High Bay T5 Lighting Retrofit / Occupancy Sensors
Site Description	Warehouse

1. Measure Description

Install 443 fixture mounted occupancy sensors to control 443 fluorescent fixtures. The fluorescent fixtures were retrofit from metal halide fixtures under the Summer Initiative program. This summer initiative peak lighting measure included replacement of 429 high intensity discharge fixtures utilizing 400 watt metal halide lamps with 429 fluorescent fixtures utilizing four (4) T5 lamps. It also included replacement of 14 high intensity discharge fixtures utilizing 400 watt metal halide lamps with 14 fluorescent fixtures utilizing six (6) T5 lamps.

2. Summary of the Ex Ante Calculations

The customer used the Itemized Measure Form to calculate kW and kWh savings. The basis of the incentive payment was the itemized incentive list. The original application was submitted as a Standard 2005 itemized application. The lamps were later transferred to the Summer Initiative program and the incentive for the lamps was recalculated using the application for that program. Total savings was estimated to be 234.4 kW and 919,072.4 kWh. These are listed as the Application Approved savings amounts.

The savings in the Installation Report Review are given as 234.5 kW and 964,798.3 kWh. These amounts are based on the Installation Report Review (IRR), Summary of Approved Measures sheet. This sheet contains two measures, one in the calculated section and one in the itemized section. The savings for the calculated measure is revised based on findings at the post-installation inspection, increased hours of operation, and slight changes in the number of fixtures, as noted in the comments section of the Installation Report Review. The savings for itemized measure #1 is stipulated based on the workpapers, and is revised with the new number of fixtures (revised from 447 to 443).

The tracking system contains only the savings from the occupancy sensors (633,013 kWh and 135.12 kW). The savings from the fixtures was transferred to the Summer Initiative Lighting Program. The tracking system values are used as the ex ante savings, and only the motion sensor savings are evaluated in this report. The occupancy sensor measure lists savings in the Installation Report Review as 633,013.78 kWh and 135.115 kW, which is in agreement with the utility tracking system (excepting for rounding functions).

The incentive in the tracking system also agrees with the gross incentive approved for the occupancy sensors listed separately in the IRR; the incentive of $18,163 was calculated as 50% of the capital cost of $36,326.

The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. The hours of operation for a warehouse are fixed in the workpapers at 3,550 hours/year. The workpapers note a diversity factor of 84% for a warehouse.

For ceiling mounted occupancy sensors, the savings are based on the control of eight (8) fluorescent T12 fixtures, consuming 72 watts each, in an office conference room. Savings are based on a reduction from 2,210 hours/year to 1,040 hours/year (1,170 hours/year reduction). The workpaper reports 789 kWh savings (674 kWh/year plus a 17% office sector demand interactive effects factor). The non-coincident peak reduction of 0.305 kW was derived from the 0.576 kW controlled wattage and a 53% reduction in hours. Coincident peak reduction in the workpaper was noted to be 0.381, which included a 1.25 demand sector interactive effects factor.

3. Comments on the Ex Ante Calculations

The ex ante calculations appear to be the calculations embedded in the Itemized Measure Form on the Summary of Approved Measures page of the Project Application Review. The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers as described above. The calculations performed with figures from those workpapers do not accurately represent the actual situation evaluated. The workpapers assume fixture wattage of 0.576 kW whereas the actual connected wattage is 0.234 for the majority of the fixtures, which is only 40% of the assumed fixture wattage.

The ex ante savings figures can be checked for reasonableness using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

$$\text{kWh savings} = kW_{pre} \times \text{energized hours}_{pre} - kW_{post} \times \text{energized hours}_{post}$$

$$\text{Coincident peak demand period savings} = kW_{pre} - kW_{post} + kW_{post} \times (1 - \text{diversity factor})$$

The check calculations for the only measure (installation of motion sensors on the new HID fixtures) were performed as follows:

- Pre-retrofit hours of operation: 3,337 hrs/yr

- Post-retrofit hours of operation for fixtures with occupancy sensors (based on an 47% on-time factor):   3,337 hours x (1-0.53) = 1,568 hrs/year
- Post-retrofit wattage: (0.234 kW per four-lamp fixture x 429 fixtures + 0.351 kW per six-lamp fixture x 14 fixtures) x 0.84 = (100.4 kW + 4.9 kW) x 0.84 = 88.5 kW
  Annual kWh usage: 105.3 kW x (3,337hrs/yr – 1,568 hrs/yr) = 186,235 kWh/yr

Summer peak impacts were estimated by multiplying the post-retrofit connected load by the percent reduction in on-time due to the occupancy sensors.

Summer peak demand reduction is calculated as follows:

- Post retrofit connected kW load times 0.16 (84% on-time post retrofit): 105.29 kW x 16% = 16.8 kW

These savings are much lower than the ex-ante savings because the assumptions used to calculate the itemized measure are very different from the actual situation. The connected wattage of the actual controlled fixtures is much lower than the assumption in the workpaper, and the expected diversity factor of 84% for a warehouse is also different than the assumptions for coincident peak load reduction in the workpapers.

In general, the savings figures in the final Implementation Report (IR) would be expected to be identical to the utility tracking system savings figures. The total savings in the Installation Report Review were given as 633,013 kWh and 135 kW. The tracking system is in agreement. The tracking system values are used as the ex ante savings.

4. Measurement & Verification Plan

The building is a single level 208,000 sf warehouse for light fixtures. According to the application, before the retrofit there were four hundred and forty seven (443) metal halide fixtures using 400-watt lamps. After the retrofit, there are four hundred twenty nine (429) four-lamp T-5 fluorescent fixtures, and fourteen (14) six-lamp T-5 fluorescent fixtures. All four hundred and forty three (443) fixtures are controlled by individual, fixture mounted occupancy sensors. The project saves energy through the installation of lighting fixtures with a lower connected wattage and through the control of the lighting fixtures with occupancy sensors to reduce the hours of operation.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

IPMVP Option C approach should be considered. The savings based on utility billing information are over 30% of the pre-retrofit kW and kWh consumed (peak demand is approximately 325 kW and annual energy use approximates 800,000 kWh per year according to the utility billing data). Utility billing and interval data should support this approach if there are no other significant loads or other significant energy conservation activities which occurred in the months immediately following the retrofit. There is not expected to be significant seasonal variation and several months should be sufficient for comparison; however, a one to two year period would more fully capture actual variations and the persistence of savings. Interval data on a 15 minute basis during the summer months of June to September might be needed to accurately determine summer peak period demand savings since motion sensors are expected to contribute significantly to estimated peak load reduction.

If Option C cannot be used due to changes in the facility or its operation in the time periods immediately before or after the retrofit, then a modified version of IPMVP Option A can be utilized. Lighting loggers would be used to quantify hours of operation. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = $kWh_{pre} - kWh_{post}$

Coincident summer peak demand period savings = $kW_{pre} - kW_{post}$, averaged during the hottest expected periods between 2 pm to 5 pm, Monday to Friday, in June, July, August, September.

To estimate the average expected peak demand kW reduction, since this measure is not weather dependent, the average of all reductions during that periods as stated above could be used. Alternately, the hottest days, from the climate data, as stated above, could be used.

Actual billing and interval data may be the most accurate way to quantify the savings considering the pre retrofit conditions are uncertain. The most significant variables to be qualified is that there were no changes to operation not related to the measure which affect the pre and post retrofit energy usage.

Uncertainty for the savings estimate for the production facility fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables.

<u>Uncertainty with utility billings</u>

- kWh: 186,235 kWh expected, 184,000 kWh minimum , 188,000 kWh maximum (+- 1% for utility metering)
- kW: 16.8 kW expected , 16 kW minimum , 17 kW maximum hours (+- 1% for utility metering)

<u>Uncertainty from changes in schedules and other energy use increases / decreases</u>

- kWh: 186,235 kWh expected, 176,000 kWh minimum , 196,000 kWh maximum (+/- 5% for additional equipment or energy saving measures)

- kW: 16.8 kW expected , 15 kW minimum , 18 kW maximum hours (+/- 10% for additional equipment or energy saving measures and based on extrapolating to actual hottest day period)

Accuracy and Equipment

The utility meters capture 15 minute interval data and for the purposes of the evaluation are considered to be 99% accurate where reviewed data is deemed reasonable.

The light loggers to be used are Dent TOU-L Lighting Smart*logger* dataloggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Annualizing that data from a 7 to 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

Current or power meters may also be used. The current loggers to be used, if this M&V technique is selected, would be HOBO U-12 loggers, with matched current transformers. The accuracy range is 4.5 %. The sensor would be calibrated to an Amprobe ACD-41PQ, with an accuracy of +/- 2%. An advantage of using current or power meters to monitor load is that the percent of time energized for an increased number of fixtures may be able to be captured.

A Dent Elite Pro may also be used for long them current measurements. The accuracy of current measurements is +/- 2% to +/- 2.5%, depending on the current transducer used. Voltage measurements have an accuracy of +/- 1%.

Annualizing the kW data to the hottest summer period is projected to result in a possible error in the final results of +/- 5 %.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

This comprehensive retrofit of warehouse lighting included replacement of high intensity discharge fixtures utilizing 400 watt metal halide lamps with fluorescent fixtures utilizing four (4) or six (6) T5 lamps. It also included installation of fixture mounted occupancy sensors to reduce lighting hours of operation. The on-site survey was conducted on June

26, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Lighting fixture quantities and hours of operation were verified.

Installation Verification

It was physically verified that thirteen (13) six-lamp T-5 fluorescent fixtures and four hundred twenty-nine (429) four-lamp T-5 fixtures were installed in the facility, and they each had a motion sensor. The Installation Report noted fourteen (14) six-lamp T-5 fluorescent fixtures instead of thirteen (13). The facility representative was questioned about this and he stated that some six-lamp T-5 fixtures were removed from aisle 9-10 because it was found to be too bright. The retrofit was completed in July 2005.

The motion sensor retrofit is the only measure in this application. The verification realization rate for this project is 0.99 (442/443). A verification summary is shown in Exhibit 5.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measure in the SPC application covering the lighting efficiency retrofit. This is the only measure in this application.

Summary of Results

Thirteen (13) Pacific Science and Technology light loggers were installed at the facility for 43 days (from June 26, 2007 to August 9, 2007) in aisles 2 to 20 and the front open area, 122 fixtures in total. A Dent Elite Pro power meter was installed for the same time period on the electrical circuit serving aisles 21 to 58, 320 fixtures in total. The average on-time of all the light loggers is 33%, and the average on-time measured by the Dent Elite Pro is 30%.

All lights are expected to be operating during the peak demand period defined as the hottest weekday periods between 2 pm to 5 pm, Monday to Friday, in June, July, August or September.

The facility representative stated that the building is occupied 8.5 hours Monday-Friday (between 7:00 am and 3:30 p.m.) and is closed on weekends. The facility has 33 employees who are all present on weekdays when the facility is open. The facility is closed 10 holidays annually. The facility representative stated that the facility hours of operation did not change before or after the lighting retrofit.

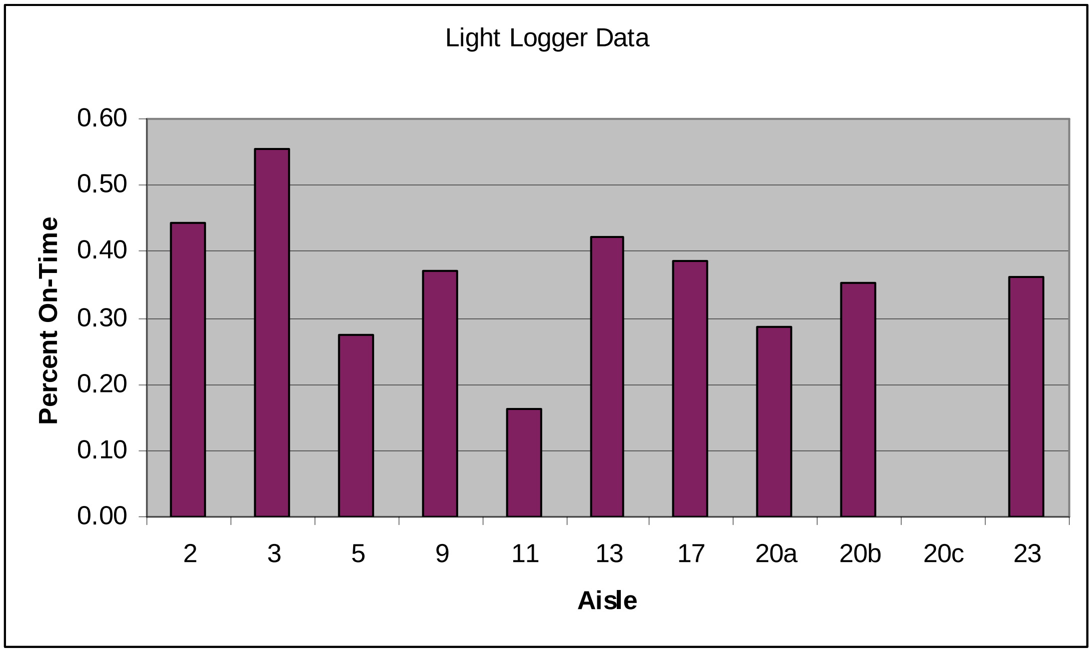
The electricity end-uses at this facility are lighting, forklifts charging, electric garage doors and office air conditioning. The office is a very small portion of the total floor area. The facility representative confirmed that there was no change in the electricity use patterns before and after the retrofit other than the change to the light fixtures themselves.

The baseline for pre-retrofit hours of operation is difficult to determine at this site because the on-site interview information does not match up with light logger data. Light loggers show longer hours of building operation than indicated in interview. The interview indicated that lights only operate from 7:00 am to 3:30 pm, but the light logger in aisle 11 shows illumination between 6 am and 6 pm on weekdays, and illumination on Saturdays between approximately 5:30 am and 9:30 am. The logger in aisle 3 shows illumination from 6 a.m. to 8 p.m. 6 days a week, and illumination from 11 a.m. to 8 p.m. on Sunday. The light logger in aisle 2 shows a similar weekday pattern, and 8 am to 4 pm on weekends. Light loggers also show some illumination in the building late at night and early morning, possibly due to birds triggering the motion sensors.

The facility representative was contacted again by phone to confirm the hours of operation after discovering the discrepancies between light logger data and the initial facility representative interview. He confirmed that there are people that arrive at the building at 6 am and some who stay as late as 7:30 pm. Before the retrofit, the lights would have been all on during this time period, and the supervisor was responsible for turning off the lights when he left. The cleaning crew comes in on Saturdays and the lights would be switched on while they are in the building. There are very rarely employees in the building on the weekend. He did not confirm or deny that there could be birds or other animals in the building turning the lights on during times when the building is otherwise unoccupied. After this conversation, the pre-retrofit operating hours were revised to 12 hours per weekday and 4 hours on Saturday.

Very few burned out lights were observed during the site visit. The facility representative mentioned that there had been quite a few burnt out 400W metal halide lamps before the retrofit. This is consistent with the interval billing data, which shows only a 72 kW peak period demand reduction instead of the expected 104 kW reduction. There was an adjustment to the pre-retrofit energy calculations to account for 15% burnt out bulbs. There was no adjustment to the lighting energy consumption post retrofit due to burned out lamps because all lamps appeared operational at the time of the site visit.

Figure 1: Light Logger Data at Site A070



Because of the difficulty determining the baseline energy use, light logger analysis was supplemented by billing analysis; the savings determined by both methods are presented below. The fixture energy savings are for comparison to billing data only, these savings were transferred to the Summer Lighting Program, and are therefore not part of this evaluation.

Light Logger Analysis:

- Pre-retrofit hours of operation: 3,219 hrs/yr (52.18 weeks x 64 hours/week – annual holidays of 120 hours = 3,219 hours, or 36.7%)
  Pre-retrofit wattage: 0.458 kW per fixture x 442 lamps x 85% of lights operational = 172 kW
  Annual kWh usage: 172 kW x 3,219 hrs/yr = 555,886 kWh/yr
- Post-retrofit hours measured with light loggers ranges from 1,219 to 4,853 hours/year depending on the aisle. The weighted average is 2,716 hours/year (31%) for the (429) 0.234 kW fixtures, 2,659 hours/year for the (13) 0.351 kW fixtures.

  Post retrofit fixture energy use: A detailed calculation of the hours recorded by each light logger multiplied by the number and wattage of fixtures in each aisle results in energy use of 282,506 kWh/year.

  Motion sensor energy savings: (pre-retrofit usage factor – post retrofit usage factor) x post retrofit connected load x 8760 hours = (0.367-0.31) x 105 kW x 8760 = **55,655 kWh**.

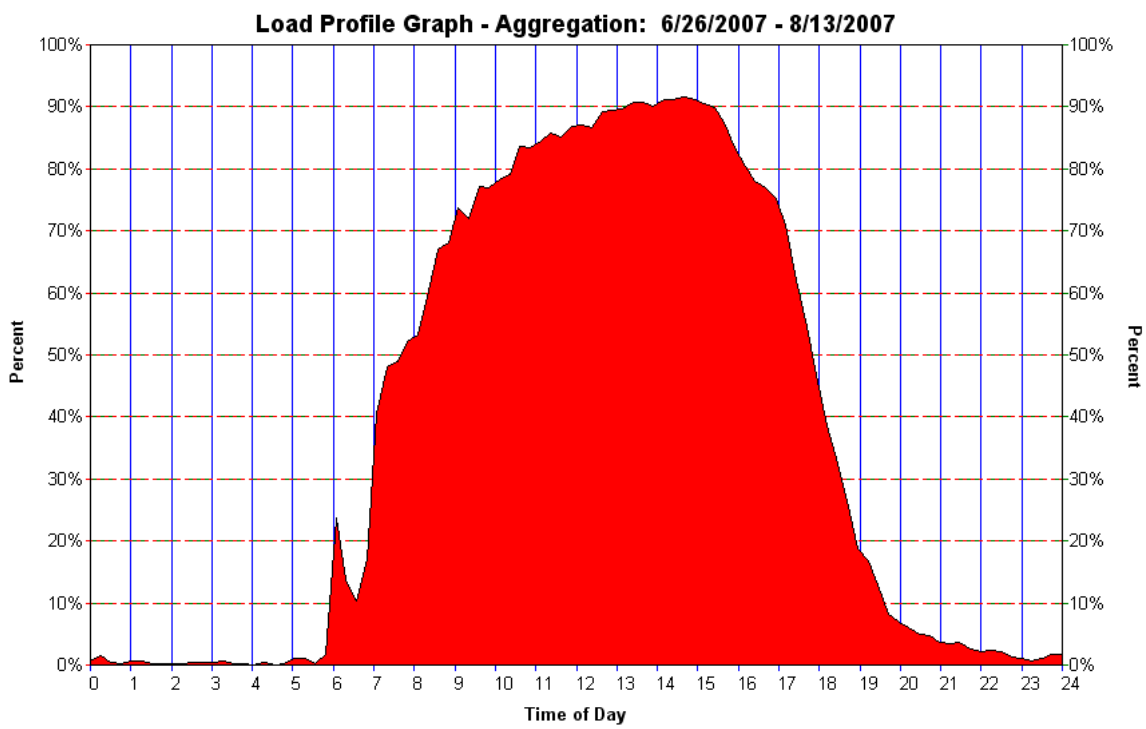
- The resulting annual kWh savings from the fixtures = 555,886 kWh/yr – 282,506 = 273,380 kWh/yr. (The fixture savings are for comparison to billing data only)

The largest uncertainty at this site is the number of hours that the lights were energized pre-retrofit. A parametric analysis was performed changing only the number of hours in the calculation to determine an upper and lower bound on the energy savings due to the uncertainty of the pre-retrofit hours. The expected value for the hours of operation is 12 hours a day, as reported by the facility representative in the second conversation. The upper bound is 13 hours a day, as supported by the light logger data. The lower bound is 9 hour a day, as reported in the initial interview. Table 1 shows the energy and demand savings for the expected number of house, and the lower and upper bounds. The results are shown in Table 1.

Table 1: Uncertainty in Energized Hours

Uncertainty	high	expected	minimum
hours	3480	3219	2437
kWh	83,035.4	55,654.9	-26486.4
percent change	8%		-24%

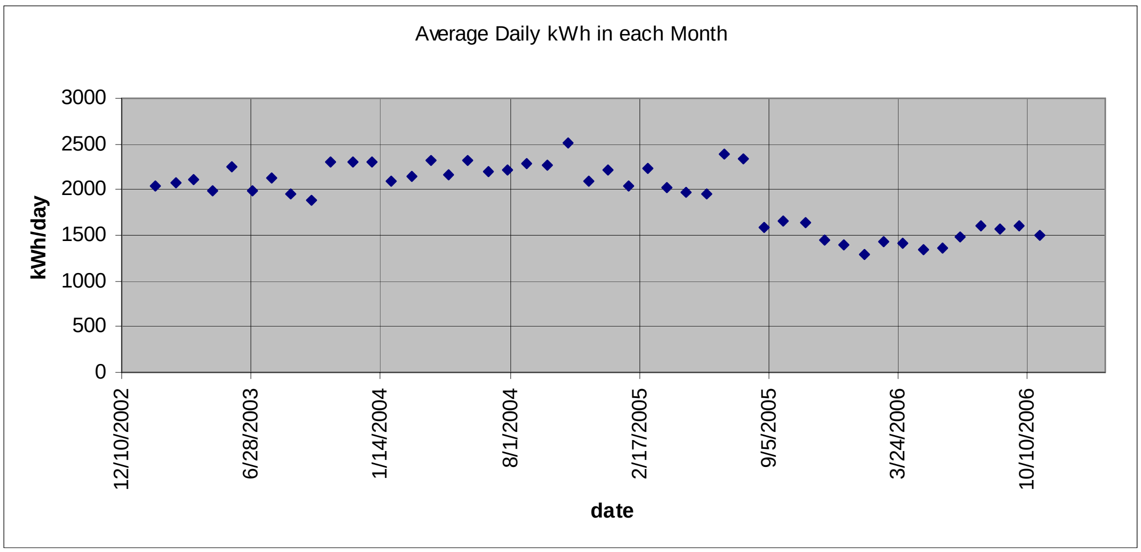
Figure 2: Weekday Load Profile of Aggregated Light Logger Data at Site A070



Summer peak impacts of the motion sensors were estimated by subtracting post-retrofit from pre-retrofit diversity factor and multiplying by connected load. The light loggers showed that between the hours of 2 and 5 pm on weekdays, approximately 85% of the lights are on (see Figure 2). This correlates closely with the diversity factor for a warehouse noted in the workpaper. Before the retrofit, the lights were always on during the summer peak period. Summer peak demand savings = (1-0.85) x 105 kW = **15.7 kW**. Summer peak demand savings due to the fixture replacement = pre-retrofit connected load – post-retrofit connected load = 170.8 kW – 105 kW = 65.8 kW. Total summer peak reduction (for comparison to billing data) = 65.8 kW + 15.7 kW = 81.5 kW

The ex post savings for the HID retrofits with the motion sensor control were compared to actual billing data. Average daily kWh use was plotted from one year prior to the retrofit until one year after the retrofit to confirm that there was no major change in electricity use other than the lighting retrofit in July, 2005. The month of July was removed from the analysis as the retrofit was partially complete during this month.

Exhibit 1: Daily kWh Consumption



The ex post impacts were calculated from billing data as follows:

- Pre retrofit kWh use is summed for the 365 day period from 6/30/2004 to 6/29/2005 and adjusted to 365.25 days for annual pre-retrofit kWh of 797,842 kWh.
- Post retrofit kWh use is summed for the 367 day period from 7/30/2005 to 7/31/2006 and adjusted to 365.25 days for annual post-retrofit kWh of 537,724 kWh.
- Pre-retrofit wattage was averaged over the summer peak period (July, August and September 2004 and June 2005) as the pre-retrofit kWh use and found to be 212 kW

- Post-retrofit wattage was averaged over the summer peak period (August and September 2005 and June and July 2006) as the post-retrofit kWh use and found to be 140 kW
- The resulting annual kWh savings is 797,842 kWh/yr – 537,724 kWh/yr = 260,118 kWh/yr
- Summer peak demand reduction impacts were estimated by subtracting average post-retrofit from average pre-retrofit peak load. (Interval data was not used for the 2 pm to 5 pm weekday time periods in the summer months due to the expectation that the maximum kW demand of the facility will occur during this interval.)

  Peak kW savings is 212 kW – 140 kW = 72 kW

The savings calculated using the billing data and those calculated with light loggers for the entire retrofit are in relatively good agreement. The billing data shows 13,261 kW/year lower energy savings than those calculated using the light loggers, indicating that before the retrofit the lights may have been illuminated more than 3,219 hrs/yr. The demand savings are 11 kW lower in the billing analysis than in the light logger analysis, indicating that there were perhaps more than 15% burnt out bulbs. The light logger energy and peak demand savings will be used for the ex post savings.

Exhibit 2 summarizes the total metered use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers. The baseline use is calculated based on the number of pre-retrofit fixtures, their wattage, and hours of use. It is obvious that the ex-ante peak demand and energy savings are overestimated when they are compared with the baseline end use. The ex-ante demand savings for motion sensors alone are 2/3 of the total baseline connected wattage and the energy savings for these motion sensors is higher than the fixture energy consumption.

Exhibit 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results show savings ranging from 40% to 115%. The ex post results for the occupancy sensor measure show much smaller savings ranging from 5% to 10%. This is believed to be realistic due to the limited number of hours of use and reduction possible. The savings from the metal halide changeout are more certain and account for most of the savings shown in the billing analysis.

Exhibit 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	325	800,000
Baseline End Use	172.7	555,886
Ex ante Savings	135.1	633,013
Ex Post Savings	15.7	55,655

Exhibit 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	41.6%	79.1%	4.8%	7.0%
Baseline End Use %	78.2%	113.9%	9.1%	10.0%

6. Additional Evaluation Findings

The ex post kW demand reduction is lower than the ex ante estimate because the ex ante savings was grossly overestimated by the itemized calculation. The workpapers assume a connected wattage approximately three times higher than the actual connected wattage, and they assume a 24% reduction in usage factor, whereas in actuality the reduction in usage factor in this case was about 6%. They also assume an interactive effects factor of 17%, but since this warehouse space is not air conditioned there is no interactive energy benefit. However, the coincident peak demand is accurate. The workpapers assume a 16% reduction in peak load due to the motion sensors, while our light logger measurements showed only 15% reduction.

There are no perceived non-energy benefits at the facility other than the ability to showcase their energy efficient lighting to customers. (This is a warehouse belonging to a company connected with energy utilization.) The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. Participation in the 2004/2005 SPC Program has not encouraged them to perform other energy efficiency projects.

7. Impact Results

The pre-retrofit lighting fixture type, quantities and hours of operation were unable to physically verified. However, these parameters appear to have been accurately assessed and quantified based on discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $112,916 and a $18,163 incentive, the project had a 1.37 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 15.61 years. A summary of the economic parameters for the project is shown in Exhibit 4.

Exhibit 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	6/1/2005	$112,916	135.1	633,013	0	$82,292	$18,163	1.15	1.37
SPC Program Review (Ex Post)	6/11/2007	$112,916	15.7	55,655	0	$7,235	$18,163	13.10	15.61

The engineering realization rate for this application is 0.12 for demand kW reduction and 0.09 for energy savings kWh. According to the installation report, the ex ante savings are 633,013 kWh annually and demand reduction is 135.1 kW. A summary of the realization rate is shown in Exhibit 5.

The Installation Verification Summary is shown in Exhibit 6 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Exhibit 7.

Exhibit 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	135.1	633,013	-
SPC Installation Report (ex ante)	135.1	633,013	-
Impact Evaluation (ex post)	15.7	55,655	-
Engineering Realization Rate	0.12	0.09	NA

Exhibit 6: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Installation of 443 fixture mounted occupancy sensors		442	Occupancy sensors	Physically verified lamp type and quantity.	1.00

Exhibit 7: Multi Year Reporting Table

Program ID Program Name	SPC 2004 Application # A070 2004 – 2005 SPC Evaluation						
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004						
2	2005	211,004	18,552				
3	2006	633,013	55,655	135.10	15.74		
4	2007	633,013	55,655	135.10	15.74		
5	2008	633,013	55,655	135.10	15.74		
6	2009	633,013	55,655	135.10	15.74		
7	2010	633,013	55,655	135.10	15.74		
8	2011	633,013	55,655	135.10	15.74		
9	2012	633,013	55,655	135.10	15.74		
10	2013	633,013	55,655	135.10	15.74		
11	2014	633,013	55,655	135.10	15.74		
12	2015	633,013	55,655	135.10	15.74		
13	2016	633,013	55,655	135.10	15.74		
14	2017	633,013	55,655	135.10	15.74		
15	2018	633,013	55,655	135.10	15.74		
16	2019	633,013	55,655	135.10	15.74		
17	2020	633,013	55,655	135.10	15.74		
18	2021	422,009	37,103	135.10	15.74		
19	2022						
20	2023						
TOTA	**2004-2023**	10,128,208	890,479				

Final Site Report

SITE A071 (2004-596) Fair IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 5 END USE: Other

Measure	Cool Roof Installation
Site Description	Offices and Residential Facility

1. Measure Description

Install 52,000 square feet of cool roof coating on four buildings.

2. Summary of the Ex Ante Calculations

The customer used the SPC Itemized Measure Application Form and submitted for a cool roof incentive (H-F1) based on a net 52,000 square feet (sf) of total roof area; the kW and kWh savings were submitted with the application and approved based on the figures generated from the Measure Savings Worksheet (15.6 kW and 26,000 kWh). These values correspond to values from the Express Efficiency workpapers presented on a per square foot basis. The basis of the incentive payment was the itemized incentive list; the customer applied for a net roof area of 52,000 sf distributed among the roofs at four buildings at the facility. Rooftop "penthouse" mechanical rooms did not receive the reflective roofing, in conformance with SPC program rules.

Total ex ante savings are recorded as 15.6 kW/year and 26,000 kWh/year in the Installation Report Review and in the tracking system.

The ex ante calculations for itemized measures are typically based on the Express Efficiency workpapers. For cool roofs, the SCE workpapers state that the savings estimated for this measure is 0.5 kWh per square foot per year based on the savings value of 0.31 kWh per year for new construction in most climate zones in California. The 0.5 kWh per square foot per year is based on the LBNL study for new construction which cited the 0.31 kWh per year figure multiplied by a factor of 1.6 to account for the additional savings expected in retrofit situations. The kW savings figure of 0.0003 per square foot has been taken from the LBNL work and this figure was also multiplied by 1.6 to account for retrofit construction.

3. Comments on the Ex Ante Calculations

Total ex ante savings are recorded as 15.6 kW/year and 26,000 kWh/year in the Installation Report Review; these figures agree with the utility tracking system.

Installation inspection notes confirmed a cool roof reflective white coating was applied to 52,000 square feet of roof surface. There was no mention of the building occupancy or uses within the four buildings except for a photograph of a site plan that indicates Child Care and Volunteer Services. The hours of operation for the buildings and use of air conditioning systems should be considered in the evaluation.

Other than a discrepancy in the total cost of the cool roof project, which did not affect the incentive or ex ante calculations, all other conditions of the SPC program guidelines appeared to be fulfilled. These include the following.

- The roof must be flat
- The roof must be located in one of climate zones 2-15
- The building must have electrically-driven vapor compression air conditioning systems
- The building must *not* have a radiant barrier between the interior ceiling and the roof surface

Summer peak kW impacts are expected to be low, based on the relatively low heat load reductions and the intermittent cycling nature of the packaged air conditioning equipment in place at the facility.

The Express Efficiency workpapers that are the basis of the ex ante calculations appear to be based solely on the LBNL study for new construction and an estimated increase of 1.6 when applying to retrofit situations. No supporting documentation was provided and the savings figures may be based on empirical results. The savings estimates appear to be reasonable and not grossly understated or overstated based upon experience with similar projects.

4. Measurement & Verification Plan

The four buildings in total comprise 52,000 sf of roof area. Information in the application indicates the buildings are at least 40 years old (or that 40 years have elapsed since the last major renovation). Photos indicate the roofs are flat and there are no skylights. The inspection report indicates each building has an air handling unit in roof penthouses served by a central chiller plant. The customer installed a cool roof (Sarnafil G410 Energy Smart White Roof Coating). The measure included removal of old coal tar roof material and installation of the new Sarnafil roof.

The measure saves energy by increasing roof reflectivity, and limits heat buildup in the roof and heat transmission through the roofing materials to interior spaces.

The measure was itemized under the 2004 SPC program and the savings were based on the workpapers.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction from the cool roof over the expected useful life of the measure.

Formulae and Approach

A modified version of IPMVP Option A can be utilized, incorporating the SPC calculator. Some parameters, such as pre-retrofit roof surface characteristics and HVAC equipment efficiency, will be stipulated according to manufacturers' data.

The condition of the roof will be inspected to allow for wear. The square footage will be determined accurately from the drawings and skylight areas and rooftop equipment areas/penthouses will be deducted. Any shading from adjacent structures or landscaping will be noted. Additionally, the conditioned area will be determined.

The 2005 SPC calculator will be used to calculate the savings with the measured and stipulated variables. The inputs to the model used in the SPC calculator are the location of the building, solar reflectance (SR), infrared emittance (IE), roof insulation value (R), air conditioner efficiency, and roof area. The solar reflectance of the new roof may be measured with an albedometer. The parameters that have the most effect on the savings are the roof R value, the solar reflectance, and the roof area. The focus will be on determining these variables accurately for the pre and post retrofit situations.

The SPC calculator cool roof calculation code was examined to ascertain the approach used. The calculations all involve polynomial equations of the second or third order which appear to be fitted to empirical data. There are no notes as to the source of the empirical data; a possible source is the Demonstration of Energy Savings of Cool Roofs project by the Heat Islands Group at Lawrence Berkeley National Lab. (http://eetd.lbl.gov/HeatIsland/PROJECTS/DEMO/)

Thickness of building components for the insulation R value calculation will be measured to the extent possible, and the type of insulation material determined. Building plans will be consulted for roof construction and slope.

The complexity of the building systems and heat transfer variables, along with the magnitude of the savings for this measure, preclude the use of a calibrated building model. A calibrated building model constructed for this purpose should take into account many variables, such as reflectivity, emissivity, building configuration, insulation value, and actual cooling equipment efficiencies, and it should be calibrated to actual energy use of the building. An uncalibrated building model is much easier to build since there are many existing building model tools such as DOE2. Such a model may be appropriate here since the magnitude of the total building energy use is less important than the change in energy use due to a specific change in the building.

If a large uncoated area is not available for measurement, the uncertainty associated with the older roof reflectivity introduces a large source of error, also limiting the building model approach. Direct measurements using a pyranometer and other tools to measure the post retrofit reflectivity are possible. However, reflectivity values specified by the manufacturer of the cool roof could also be used. It should be noted that these are typically values for the reflectivity of a new cool roof; weathered values have a lower reflectivity and should be used if available.

Uncertainty for the savings estimate for the retrofit can be more fully understood by setting projected ranges on the primary variables.

For the SPC calculator inputs

- Location (+/- 5% for changes in weather due to distance of 20 miles)
- U = 1/R; R = 5.9 for standard roof assembly, default value in E-Quest (+/- 5%)
- Solar Reflectance: pre 0.15, post 0.86 (+/- 40% pre, +/- 10% post due to degredation)

- Infrared Emittance: pre 0.91, post 0.91 (+/-15% pre, and +/- 5% post due to degredation)
- Area = 52,000 sf; + 5%, -30% (based on application paperwork)
- kW/Ton = 0.8; +/- 20%

Accuracy and Equipment

If necessary, measuring wheels will be used to record roof area.

Standard measurement devices for area and insulation thickness calculation will be made to the nearest 0.5 inch and converted to two decimal places for area calculations. Error is expected to be less than 2%.

Roof Surface Albedometer if used: spectral range: 305 - 2800 nm, resolution: 1 W/m2, accuracy , +/- 5% estimated accuracy.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on June 27, 2007. Information on the installed roofing and operating conditions was collected by inspection of the building roofs, interior spaces and by interviewing the facility representative. Temperature measurements of the roofing surface and interior spaces were collected. Building uses and hours of operation were identified and recorded.

The entire facility encompasses over 50 buildings with use by hundreds of people daily. The buildings analyzed in this evaluation were built in the 1950’s. The old roofs at the buildings had surpassed their useful lives. Roofing installations at the facility usually are delayed until funds for improvements are applied for and become available. The facility included the cool roof measure as part of the re-roofing design.

The facility representative indicated the roofs of the buildings were more than 20 years old at the time the measure was implemented and very likely were the original roofs. There had been some leaks; associated maintenance was required occasionally. The roofs had reached the point where a new roof was required. The old roof performance was considered “fair” at the time of re-roofing; however, the old roof would have lasted with ongoing maintenance until a new roof was funded.

The facility prioritizes maintenance and replacement on an as needed / as funded basis rather than on a preventive maintenance schedule. No maintenance issues related to the new roof are considered necessary for now. Maintenance is performed as needed. The facility staff is pleased with reduced maintenance issues associated with the new roof and no need for maintenance is anticipated for many years. The new roof is warranted for 15 years.

Two of the four buildings covered by this evaluation include residential space, meeting and conference rooms, offices, common areas, training spaces, a library and dining facilities. The other two buildings are used for offices and child care services. Occupancy and use depend on specific needs of clients or specific tasks of employees.

The four buildings covered under this measure are occupied 24 hours per day 7 days per week with varying use schedules. The percent use of the buildings is listed in the following:

Exhibit 1: Building Usage

Building Use	% Partial Occupancy 8 am to 6 pm (Day)	% Partial Occupancy 6pm to 8 am (Night)
Offices and volunteer services	25%	0% to 5%
Offices, chapel, meeting areas and library	30% to 40%	0% to 5%
Offices and child remedial training & child care	35% to 40%	1% to 2 %
Offices & child remedial training	40% to 45%	15%

The cool roof covers these areas of the buildings. The construction is reinforced concrete. The plans suggest the concrete is 3 inches thick. According to the contract plan notes, the old roof surface coating and flashing were to be removed, then a 1.5 inch thick new polyisocyanurate rigid insulation (R-10) was adhered to the cleaned concrete deck and the Sarnafil G-410 new thermoplastic fiberglass reinforced PVC, white color, 60 mil thick, membrane - Type II, Grade 1 “Energy-Star” mat was adhered to the rigid insulation using Sarnacol 2121 adhesive.

The facility representative indicated that the buildings within this evaluation are heated with steam heat and cooled with 46° F to 47° F chilled water at a central heating/cooling plant. For air conditioning, the chilled water is stored in a large reservoir or holding tank and distributed to the buildings as required by demand. Building temperatures are controlled by wall mounted thermostats. Chilled water is sent to the cooling coils within the rooftop mounted fan driven air handling system. The chillers are Carrier 550 ton units. Because of the age and condition of the chiller, an efficiency of 0.8 kW/Ton was assumed. At the time of inspection, two units were operating; the third chiller was under repair. There is redundancy at the facility, so that heating and cooling demands can be met.

Installation Verification

The roofs of the four buildings were inspected on June 27, 2007. The condition of the roof surfaces was noted. Photographs were obtained. In addition, one air handling unit of four in the penthouse structure above the roof level was inspected. The facility representative indicated the air handling units were identical. These are dual deck heating / cooling units with heat exchangers fans and mixing chambers providing mixed and conditioned air to the interior spaces. Conditioned air is delivered through ducts in a drop ceiling plenum area. A portion of return air is delivered to the rooftop air handler units also via ducts. Heating and cooling of these buildings is controlled by wall mounted thermostats, but the actual heat and cooling water are produced at a central plant at the facility.

The material of the cool roof was in serviceable condition with minimal wear indicated. The color of the white surface of the roofing material was weathered or occluded by surface grime presumably deposited from airborne particulates and from trees adjacent to the buildings. Grime or particulates had accumulated in low areas of the relatively flat roof and obscured the effective reflectance of the former white surface. The accumulation and deposition of the dark particulates was interpreted to have come from the particulates being washed to and settling in the low areas of the roof following rain storms and the ensuing period of drying. The comparison of reflectance was interpreted in terms of surface temperature measurements between relatively "white" surface areas of the roof and gray to black areas. Temperature measurements were taken between 10:13 am and 10:45 am. The nearly white areas had surface temperatures ranging from 101° F to 108° F while the darker gray and black areas had temperatures ranging from 135° F to 150° F. This is a temperature range difference between 34° F and 42° F. A somewhat larger temperature range difference might be expected between peak demand hours in the afternoon. The temperature measurements show qualitatively that the clean white roof surface is more effective at reducing the roof temperature than the areas obscured by surface deposits.

The roofs of the other two buildings were observed and noted to be the same in construction, appearance, and condition. The roof area was measured from plans provided by the utility representative. The area of the mechanical rooms was subtracted from the total roof area, but no deduction was made for exhaust fan outlets because they covered a negligible roof area.

The retrofit was completed in July 2005.

This is the only measure in this application. The verification realization rate for this project is 0.91 (47,385 / 52,000). A verification summary is shown in Exhibit 6 below.

Scope of the Impact Assessment

The impact assessment scope is for the cooling end use measure in the SPC application covering the cool roof installation. This is the only measure in this application.

Summary of Results

Approximately two years have elapsed since the new reflective roof material was installed. The condition of the roofs appear in good condition and serviceable. The reflectance of the roof was not measured. A film of gray/brown particulate matter appeared to have adhered to the roof surface with approximately 30% of the roof having substantially dark areas created by accumulated particulates in low areas. The particles are presumed to have accumulated from airborne deposition.

In 2004, all cool roof measures were itemized, and savings were calculated based on the workpapers. The 2005 SPC calculator is the modeling tool that is used to calculate the ex post savings for this site. As a check on the SPC calculator tool, savings for a different site in the SPC evaluation effort were also calculated, using e-Quest/DOE 2.2, and the result was compared to the result from the SPC Calculator. The e-Quest/DOE 2.2 program has the limitation, however, that it does not model changes in infrared emittance. For many applications, this is acceptable because a black asphalt roof and cool roof products have high infrared emittance, usually about 90%. The savings calculated with e-Quest/DOE 2.2 agreed very well with the SPC calculator, so it was not deemed necessary to use the e-Quest model at all cool roof evaluation sites.

The radiative properties of the cool roof were determined by values listed in the Cool Roof Rating Council (CRRC) products directory. The CRRC administers a Rating Program under which companies can label roof surface products with radiative property values rated under a strict program administered by the CRRC. All radiative property testing is conducted by accredited testing laboratories. Solar reflectance can be measured in accordance with ASTM test methods C1549, E1918, E903 and CRRC-1 Method #1: Test Method for Certain Variegated Products. Thermal emittance is measured in accordance with ASTM C1371. For aged ratings, product samples are exposed for three years at the CRRC Approved Test Farm. Product ratings are verified periodically through the CRRC's Random Testing Program. The product used in this application, “G410, Energy Smart White Roof Coating” manufactured by Sarnafil, is listed with a solar reflectance of 0.86 and an infrared emittance of 0.91 in the CRRC directory.

The radiative properties of the pre retrofit tar and gravel roof surface were determined by values listed in an Energy Efficiency Fact Sheet on Reflective Roof Coatings published by the Washington State University Energy Program. They cite modified bitumen and tar and gravel roofs as having albedos from 0.10 to 0.20. The solar reflectance used, 0.15, is an average value within the range given. The infrared emittance of 0.90 is common to many materials, including black asphalt. For comparison, solar reflectivity and infrared emmittance are 0.16 and 0.91 respectively for a grey asphalt shingle roof.

Table 1: Physical Characteristics of Roofing Materials

	Tar and Gravel	Cool Roof
Solar Reflectivity	0.15	0.86
Infrared Emittance	0.90	0.91

The roof area was determined from roof dimensions measured on plans provided by the facility representative, subtracting the area for the mechanical penthouses noted on the plans and observed on the roof. The calculated roof area, 47,385 square feet, is somewhat smaller than the original ex ante roof area of 52,000 square feet given in the SPC application. The uncertainty in the roof measurement is +/- 10%.

The facility representative stated that the buildings are occupied continuously at any time but with varying percentages of occupancies and resultant cooling demands. The building is never closed, although there are reduced occupancies from 6 pm to 8 am daily and on weekends. Cooling demand varies according to occupancy and weather conditions.

The buildings are heated and cooled from a central plant. The model number of the 550 ton Carrier chiller was not recorded at the site visit. Because of the age and condition of the chiller, an efficiency of 0.8 kW/ton was assumed.

From the central chiller plant chilled water is sent to the building roof top cooling coils where fans and valved mixing chambers condition the air for introduction into the interior spaces. Cooling is accomplished by forced air convection through the ducts and introduced through ceiling registers. Return air is captured through ceiling registers and ducts in the drop ceiling utility raceway. Temperatures were obtained in both ceiling type areas of a sample of the interiors. All interior spaces were conditioned. Temperatures ranged from 66° F to 68° F on the painted concrete surfaces. The thermostat setting was at 70° F. Thermostat settings were set and locked out by facility managers. At the painted sound proof ceilings, the temperature reading was 67° F. Painted surfaces without sound proof tiles had temperatures 69° F to 70° F range. Measurements collected at one plenum opening indicated concrete surface temperatures ranging from 72° F to 75° F at the lower, vertical concrete structure and at the underside of the roof deck, respectively.

The ceilings of the interior spaces are of two types. Some common areas such as meeting rooms or the library have the structural concrete roofing exposed. Most other interior areas (approximately 65%) have a drop ceiling which contains piping and air supply and return ducts. The drop ceilings appear to be 2 by 4 inch wood framing with plaster surfaces. Some areas have acoustic ceiling tiles applied to the ceiling. These are prevalent in hallways and rooms where people congregate. The building plans showed “GAFTEMP” Isotherm Roof Insulation with thickness of 1.5 inches and rated R-value of 10 specified to be applied underneath the cool roof coating.

The input and output values used in and generated by the SPC Calculator for this cool roof are shown in Table 2.

Table 2: Ex Post Results of SPC Calculator

SPC Calculator - Ex Post		
	Baseline	Cool Roof
Solar Reflectance	0.15	0.86
Infrared Emmittance	0.9	0.91
kW/ton	0.8	0.8
R-value	10	10
Net Roof Area	47,385	47,385
CA Climate Zone	6	6
Space Cooling (kWh)	22,303	4,380
Savings (kWh)	17,923	

The ex ante savings for this site are based on the workpapers. The ex post savings calculated with the 2005 SPC Calculator (17,923 kWh/year) are 31% lower than the reported ex ante savings (26,000 kWh/year). The savings may still be overstated because the solar reflectance and infrared emittance values used in the calculation refer to a newly installed cool roof, whereas the roof at this location showed some degradation.

It has been noted that the installation of the cool roof application was in mid 2005. By the inspection in September 2007, significant "graying" of the white roof surface had occurred during the intervening two years of weathering. Air born sediments had accumulated on the white surfaces of the roof turning the brilliant white to a light gray color at the higher areas and to darker shades of gray in the lower areas where puddles form on the roof after a rain. This effect diminishes the reflective properties of the installation and increases the surface temperature of the roof.

Exhibit 2 summarizes the total metered use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers. The Total Meter Annual kWh refers to the energy used by the whole facility in 2003. The baseline use is calculated as 30% of the total electricity use for the facility; the percent dedicated to "other uses" assumes 40% for lighting and 30% for air conditioning equipment. There are no results for peak period kW demand savings because the SPC calculator does not calculate these savings due to the cycling nature of the AC equipment.

Exhibit 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results show energy savings ranging from 0.2% to 0.6%. The predicted savings were a very small portion of the total energy use and the baseline end use for this site. The ex post results for the cool roof show smaller savings ranging from 0.1% to 0.4%.

Exhibit 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	2,419	13,636,661
Baseline End Use	726	4,090,998
Ex ante Savings	15.6	26,000
Ex Post Savings	-	17,923

Exhibit 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	0.6%	0.2%	N/A	0.1%
Baseline End Use %	2.1%	0.6%	N/A	0.4%

6. Additional Evaluation Findings

The electricity end-uses at these buildings include fan cooling ventilation, air conditioning compression, fan heating ventilation, steam and chilled water circulating and return pumps, air mixing valves, temperature controls, lighting, office equipment, training equipment, cleaning equipment, food refrigeration. The facility representative confirmed that there was no change in the electricity use patterns before and after the retrofit other than the roofing, however activities are always in flux to meet the needs of the clients. No drastic changes are anticipated for the near future, but major changes in the use and functions of these four buildings are anticipated within one to four years. It is not clear whether substantial renovation that might affect or remove the cool roof matting will occur; none was anticipated.

It does not appear that participation in the SPC program stimulated involvement in other energy efficiency efforts or programs.

The cost submitted represents the entire roofing installation and was high for just the additional costs for the cool roof.

7. Impact Results

The pre-retrofit roof type was not able to be physically verified. However, the facility representative was knowledgeable about the pre-existing roof, and was able to characterize its characteristics sufficiently for the needed analysis. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $349,800 and a $5,200 incentive, the project had almost a 102 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is smaller than the ex ante, and the estimated simple payback is just under 148 years. A summary of the economic parameters for the project is shown in Exhibit 4.

Exhibit 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	8/4/2005	$349,800	-	26,000	0	$3,380	$5,200	101.95	103.49
SPC Program Review (Ex Post)	6/29/2007	$349,800	-	17,923	0	$2,330	$5,200	147.90	150.13

The engineering realization rate for this application is 0.69 for energy savings. According to the installation report, the ex ante savings are 26,000 kWh annually and demand reduction is 15.6 kW. Because of the cycling nature of air conditioning equipment demand savings have been omitted from the 2005 SPC calculator and omitted from the ex post savings. A summary of the realization rate is shown in Exhibit 5.

Exhibit 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	15.6	26,000	-
SPC Installation Report (ex ante)	15.6	26,000	-
Impact Evaluation (ex post)	-	17,923	-
Engineering Realization Rate	-	0.69	NA

The Installation Verification Summary is shown in Exhibit 6.

The savings over the full life of the measure are shown in the Multi Year Reporting Table in Exhibit 7.

Exhibit 6: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Installation of a Cool Roof	O- Other			Installation of a Cool Roof	47385 ft^2	Cool Roof	Physically verified cool roof type and verified area from plans.	0.91

Exhibit 7: Multi Year Reporting Table

Program ID Program Name		SPC 2004 Application # A071 2004 – 2005 SPC Evaluation					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004						
2	2005	10,833	7,468	15.6	0.0		
3	2006	26,000	17,923	15.6	0.0		
4	2007	26,000	17,923	15.6	0.0		
5	2008	26,000	17,923	15.6	0.0		
6	2009	26,000	17,923	15.6	0.0		
7	2010	26,000	17,923	15.6	0.0		
8	2011	26,000	17,923	15.6	0.0		
9	2012	26,000	17,923	15.6	0.0		
10	2013	26,000	17,923	15.6	0.0		
11	2014	26,000	17,923	15.6	0.0		
12	2015	26,000	17,923	15.6	0.0		
13	2016	26,000	17,923	15.6	0.0		
14	2017	26,000	17,923	15.6	0.0		
15	2018	26,000	17,923	15.6	0.0		
16	2019	26,000	17,923	15.6	0.0		
17	2020	15,167	10,455				
18	2021						
19	2022						
20	2023						
TOTA	**2004-2023**	390,000	268,845				

Final Report

SITE A072 Haa IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 2 END USE: Lighting

Measure	High Bay T5 Lighting Retrofit / Occupancy Sensors
Site Description	Warehouse / Manufacturing

1. Measure Description

Replace 1,147 high intensity discharge fixtures using 400 watt metal halide lamps with 1,147 fluorescent fixtures using four (4) high output (HO) T5 lamps. Install 1,143 fixture mounted infrared occupancy sensors to reduce lighting hours of operation. Four fixtures will not be outfitted with occupancy sensors as these fixtures remain energized continuously for safety lighting.

2. Summary of the Ex Ante Calculations

The Installation Report Review lists the kW and kWh savings for the two itemized measures, one for lighting fixture replacement and one for occupancy sensors. The kW and kWh savings in the Installation Report Review are given as 256.93 kW / 1,027,712.00 kWh for the reduced wattage fixtures and 348.62 kW / 1,633,261.3 kWh for the occupancy sensor controls. The sums of these total approved savings are 605.5 kW and 2,660,973.3 kWh. The savings for the measures are identical in the utility tracking system, with the exception of rounding functions.

The savings for the itemized measures are reported to be based on the Express Efficiency workpapers. The savings calculations are described in these workpapers and savings are prescribed on a per unit basis.

The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers.

These workpapers note that a conversion from metal halide fixtures to high output (HO) T5 fixtures results in a wattage reduction from 0.458 kW to 0.234 kW, for a non-coincident peak reduction of 0.224 kW. For the “Assembly Industrial” market sector, coincident peak reduction is noted as 0.215 kW and kWh savings is noted as 1,025 kWh/year. The hours of operation for an assembly industrial facility are fixed in the workpapers at 4,900 hours/year. The workpapers note a diversity factor of 0.80 for the assembly industrial market sector.

For ceiling or wall mounted occupancy sensors, the workpaper documents savings based on the control of eight (8) 4 foot 2 lamp fluorescent fixtures with 34 watt T-12 lamps, consuming 72 watts each including the ballast, in an office conference room. Savings are based on a reduction of usage from 2,210 hours/year to 1,040 hours/year (1,170 hours/year reduction). The workpaper reports a total of 789 kWh savings for all sectors (674 kWh/year plus a 17% office sector energy interactive effects factor). The non-coincident peak reduction of 0.305 kW was derived from the 0.576 kW controlled wattage and a 53% reduction in hours. Coincident peak reduction was reported at 0.381 kW, which includes a 1.25 average office sector “Demand Interactive Effects” factor.

3. Comments on the Ex Ante Calculations

The ex ante calculations in the Installation Report Review are reportedly based on the itemized workpapers. However, specific calculation details are not provided. The workpapers do not describe this specific application.

The hours of operation were estimated in the pre-installation inspection report. The estimated hours are in aggregate similar to the 4,900 hours per year estimate used in the workpaper.

The workpapers presume the occupancy sensor use for a warehouse will reduce lighting to 47 % of normal operating hours. Further, an office sector interactive effects factor of 1.25 kW is used to calculate coincident kW savings

The project sponsor conducted a pilot study in the manufacturing environment at the facility to evaluate the reduced lighting hours from occupancy sensor controls. The estimated reduction in annual hours of lighting use is given as 15% of normal operating hours. The workpapers would appear to overstate the percentage of time controlled. The number of hours controlled also appear to be overstated. This is particularly true when the dual control feature applied at this facility is considered.

Regarding controlled wattage, the workpapers also presume each sensor controls four (4) standard fluorescent fixtures (576 watts), while each sensor actually controls one high output fixture (234 watts). The actual wattage controlled is 41 % of that forecast in the workpapers.

Note that the facility installed 1,143 new fluorescent fixtures with occupancy sensors and four additional fluorescent fixtures without sensors to replace the metal halide lights. Without sensors, these four fixtures will remain on all the time within the manufacturing plant for safety considerations.

The ex ante savings figures for the high output T5 retrofit substantially agree with figures calculated from the savings estimates in the workpapers. However, for occupancy sensors, the ex ante savings are significantly underestimated (for kW) and overestimated (for kWh), when compared to the workpapers.

The ex ante savings figures can be checked for reasonableness using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x (1 – diversity factor)

The check calculations for the main measures (involving conversion from HID fixtures and installation of motion sensors on these fixtures) were performed as follows:

- Pre-retrofit hours of operation (distributed per fixture): 4,952 hrs/yr (from pre-installation report hours)
  Pre-retrofit wattage: 0.458 kW per fixture x 1,147 lamps = 525.3 kW
  Annual kWh usage: 525.3 kW x 4,952 hrs/yr = 2,601,286 kWh/yr
- Post-retrofit hours of operation for fixtures with occupancy sensors (based on an average 20% reduction in hours): 4,952 hours x (1- 0.2) = 3,962 hrs/year
- For the post retrofit connected kilowatt load: 0.234 kW per fixture X 1,147 fixtures = 268.4 kW, where post-retrofit wattage for fixtures with and without sensors is: 0.234 kW per four-lamp fixture x 4 fixtures without motion sensors + 0.234 kW per four-lamp fixture x 1,143 fixtures with motion sensors = 0.9 kW + 267.5 kW = 268.4 kW.
- Post-retrofit kWh usage: 0.936 kW x 8,760 hrs/yr + 267.5 kW x 3,962 hrs/yr = 1,067,719 kWh/yr
- The resulting annual kWh savings = 2,601,286 kWh/yr – 1,067,719 kWh/yr = 1,533,567 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit connected load from pre-retrofit connected load. Note there were no peak savings attributed to the occupancy sensors.

Summer peak demand reduction is calculated as follows:

- Reduction in connected kW load plus reduction in load due to motion sensor use: (0.458 kW – 0.234 kW) x 1,147 + 0.234 kW x (1-0.80) x 1,143 = 256.9 kW + 53.5 kW = 310.4 kW

Based upon hourly use figures obtained from site personnel, hours are expected to be similar to the average stated in the workpapers for assembly industrial operations. However, the kWh and kW savings from occupancy sensors appears to be overstated. This seems to be the main source of inaccurate savings estimates.

4. Measurement & Verification Plan

The building is a single level manufacturing facility and warehouse for fabrication, assembly, and worldwide shipping of machinery. It is reported to be approximately 10 years old. The building has some skylights, but minimal windows in the three manufacturing buildings. Notes from the Pre-Installation Inspection indicate varied hours of operation, but in general the facility is used 21 hours each weekday and 8 hours on Saturday. It appears to be closed on Sunday. According to the application, before the retrofit there were 1,147 metal halide fixtures using 400-watt lamps. After the retrofit, there are 1,147 four-lamp T-5 fluorescent fixtures, of which 1,143 are controlled by individual, fixture mounted occupancy sensors. The project saves energy through the installation of lighting fixtures with a lower connected wattage and through the control of the lighting fixtures with occupancy sensors to reduce the hours of operation.

Notes in the Post Installation Inspection Report indicate that each fixture with an occupancy sensor contains one ballast for the two inner lamps and one ballast for the two outer lamps. The sensor logic is to turn off two lamps after 8 minutes of inactivity and the remaining two lamps after 60 minutes of inactivity. To maximize lamp life of all four lamps, the switching of lamps alternates after each inactive period.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

IPMVP (International Performance Measurement & Verification Protocol) Option A approach should be considered. The available billing data show a consistent increase in energy use from both pre and post measure bills. The energy use in some months is less than the previous month; however, the overall trend is an increase in use. The growth of the company operations and the many electrical energy end uses at the plant makes extraction of billing data for analysis for the installed lighting and sensor measure indiscernible from other energy uses.

Savings will be estimated based on partial field measurements of the lighting fixtures and intermittent operation of the lights controlled by occupancy sensors. Lighting loggers will quantify hours of operation.

The post installation paperwork indicates that the occupancy sensors operate the fixture ballasts on an alternating scheme to balance and extend ballast and lamp life. The alternation of lamps and the timing by the sensor controls should be considered to determine the operating hours. This may be accomplished by locating two loggers at each fixture - one to capture the operation of the inner two lamps and one to capture the operation of the outer two lamps. It is estimated that a minimum of 16 loggers will be needed to evaluate the lighting operation hours at the facility.

Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae and estimates of logged hours based on facility use:

kWh savings = $kWh_{pre} - kWh_{post}$

Summer peak demand period savings = $kW_{pre} - kW_{post}$ expected during the hottest days between 2 pm to 5 pm, Monday to Friday, in June, July, August, September.

To estimate the average expected peak demand kW reduction, since this measure is not weather dependent, the average of all reductions during those periods as stated above could be used. Alternately, the hottest days, from the climate data, as stated above, could be used.

Pre retrofit conditions are uncertain to the extent that maintenance and fixture condition are unknown. However, pre-retrofit energy use can be approximated by verifying the pre retrofit connected load and obtaining accurate pre retrofit hours of lighting.

To estimate peak demand kW reduction, the reduction in connected kW due to the increased lighting efficiency will be added to the post-retrofit connected load multiplied by the percent of energized time according to the following formulae.

Coincident peak demand period savings:

kW savings = $kW_{pre} - kW_{post} + kW_{post}$ x (average percent of energized lamps during 2 pm to 5 pm weekdays)

The derivation or extrapolation of the average percent of time energized used in the above formulae, for both the average peak demand period and the coincident peak demand periods, will be described.

kWh savings = kW_{pre} x energized $hours_{pre} - kW_{post}$ x energized $hours_{post}$

Documentation provided indicates that there are 1,143 fixtures with individual motion sensors and four new fixtures without sensors which compromise 100% of the projected savings. The majority of the fixtures are located in the aisles and over work areas of the warehouse/manufacturing space.

The most significant variables to be quantified are the pre-retrofit and post-retrofit fixture hours of operation. Pre-retrofit hours will be confirmed in interviews with site personnel. The focus will be on verifying that, prior to the retrofit, the entire complement of fixtures was completely energized during estimated operating hours (4,952 hours/year) and that the listed hours/year were valid (for example, building or staff schedule logs for the pre-retrofit period could be examined if available). Appropriate modifications for the savings calculations would be made to the pre-retrofit usage figures if required, in order to establish a realistic baseline for energy use.

The use of at least fifteen sampling points is generally consistent with SPC program documentation from March 2001 (Appendix E, Sampling); this document suggests guidelines for determining sampling point requirements necessary to achieve an 80% confidence interval with 20% precision (using a coefficient of variation of 0.5

Usage patterns will be determined in the on-site interview and loggers will be randomly distributed throughout the facility with at least one logger in each usage area. The light loggers will be placed so as to be unaffected by fixtures not on motion sensors or by ambient outside light.

If the light loggers cannot be placed in suitable locations, it will be considered that, where the lighting circuits can be isolated and it can be determined that only lighting loads for the warehouse fixtures are controlled by that lighting circuit, a current or power meter may be used to track multiple fixtures. The total current / power would be determined by activating all fixtures and by confirming loads using the electrical drawings. Between three and six current/power meters are expected to be needed, to capture a representative sample of the lighting fixtures.

The lighting loggers or current sensors would be left in place for a period of 7 to 14 days. Attention will be given to the time period for monitoring, in order to avoid periods of irregular usage patterns (e.g., during holidays or breaks). While longer periods might be preferable, these periods are appropriate given the scope of the evaluation and reported usage characteristics.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit lighting fixture hours of operation. The lighting fixture quantities seem to be well established and were counted to within 5% in utility post-installation inspection visits. The pre-retrofit and post-retrofit connected loads associated with various fixture types are also adequately quantified in the SPC lighting wattage tables.

Uncertainty for the savings estimate for the production, manufacturing facility fixture retrofit and for the occupancy sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables.

For lower wattage fixtures (T5 conversion from HID fixtures)

- 1,147 fixtures expected, minimum 1,089, maximum 1,204 (+/- 5%)
- 4,952 hours pre retrofit expected/reported; minimum 4,300 hours; maximum 5,600 hours (based on +/- 13%, or one hour at the start and end of each day)
- 268.4 kW expected, minimum 242 kW, maximum 295 kW (includes +/- 5% for number of fixtures and +/- 5% for fixture wattage difference)

For motion sensors controlling the above fixtures

- 1,143 fixtures expected, minimum 1,086, maximum 1,200 (+/- 5%)

- 3,962 post retrofit hours expected, minimum 3,200 hours; maximum 4,800 hours; includes + / - 20% from annualizing estimates from short monitoring period)
- 50 kW: kW reported savings includes number of fixtures, post-retrofit fixture wattage and diversity factor; +/- 50% expected, minimum 25 kW, maximum 75 kW
- Annualizing the kW data to the hottest summer period is projected to result in a possible error in the final results of +/- 5 %.

Accuracy and Equipment

The lighting loggers are light-sensitive data accumulators that capture periods when a lighting fixture is either on or off. Logged data are time and date stamped. Where reviewed data are deemed reasonable, for the purposes of the evaluation these loggers have a resolution of 1 second and are generally considered to be 100% accurate. Uncertainty occurs in the manual, sensitivity setting of the logger. This must be set accurately, but the logger also may be influenced by ambient or adjacent lighting not intended to be monitored or the logger sensitivity may be altered by significant vibration or interference from external influences. In this application, additional uncertainty can occur from the proximity of two loggers in a fixture where the outer or inner two lamps may trip the logger positioned for monitoring the opposite pair of lamps within the fixture. The accuracy in this application is estimated to be +/- 10%.

The proposed lighting data loggers are Dent TOU-L SMARTLoggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

Annualizing those data from a 7 to 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

Current or power meters may also be used. The current loggers to be used, if this M&V technique is selected, would be HOBO U-12 loggers, with matched current transformers. The accuracy range is 4.5 %. The sensor would be calibrated to an Amprobe ACD-41PQ, with an accuracy of +/- 2%. An advantage of using current or power meters to monitor load is that the percent of time energized for an increased number of fixtures may be able to be captured.

All data collected will be reviewed to ensure they conform to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis, if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

Lighting retrofits were completed by June 26, 2004. The on-site survey was conducted on June 28, 2007. The facility representative provided information on the pre-installation lighting conditions and on the installed lighting and operating conditions. The evaluator verified lighting fixture quantities and measured hours of operation using the Dent SMARTlogger lighting loggers.

There are three buildings totaling 756,900 square feet (this included two exterior roofed areas). The buildings have varying occupancies throughout the day. The original, main building has the largest square footage and the most activity with reduced sizes and levels of activity in Buildings 2 and 3. Building 1 has corporate offices and other conditioned space on the north side at the front of the building. The offices were not part of the retrofit measures. Building 1 also has two additional engineering design office spaces and break areas for the employees located at the centers of the open plan manufacturing floor in machine shop and assembly areas.

The lighting changeout and occupancy sensor measures were installed in the open manufacturing space of the three buildings as well as in the two open bay work areas under awning roofs on the east and south sides of Building 1.

The buildings encompass the following areas:

Building 1 Areas:	Machine Shop 1	152,000 sq. ft.	Built 1997
	Assembly	210,000 sq. ft.	
	East Exterior Awning	12,500 sq. ft.	
	South Exterior Awning	11,400 sq. ft.	
Building 2 Areas:	Machine Shop 2	123,000 sq. ft.	Built 2001-2002
	Electrical Assembly	68,000 sq. ft.	
Building 3 area:	Initial assembly And warehouse	180,000 sq. ft.	Built 2003- 2004
Total facility square footage for measures:		756,900 sq. ft.	

The installed fixtures and lamps are Precision Fluorescent T5 Hi-Bay Luminaires, Model PTEE-SQ4-4-2X4-4L54-UL-O-NW-DS-NVT /PTEE 4L T5, as confirmed in the field inspection and from a packing list for the fixtures and lamps. These fixtures have peak wattage of 0.234 kW each.

Light loggers were placed in pairs on lights deemed to be both representative of the normal activities, and located away from interfering skylights. After selecting a representative fixture, the evaluator placed a light logger on one of the outer pair of lamps and one on the inner pair of lamps to capture the dual level of 4-lamp and 2-lamp operation. The sensor logic is set to turn on all four lamps when the occupancy sensor is activated. After eight minutes of lighting, if occupancy is no longer sensed, either the inner or outer pair of lamps turns off; after approximately 60 minutes of additional time, if occupancy is not sensed, the sensors turn off the two remaining activated lamps. To capture the alternation of sensor/ballast controls and the resultant energy use, two light loggers were placed on each monitored fixture; one logger to capture the operation of the inner pair of lamps and one to capture the outer pair. The logger sensitivity was set and each logger was attached to a lamp with the light sensor facing the lamp.

The facility representative indicated general areas where operations occur and provided these on the floor plan. After evaluating adjacent lighting that might interfere with the loggers, the reviewer placed and recorded the locations of the monitored fixtures in each of the three buildings.

The areas of the buildings contained the following quantity of four-lamp fixtures:

		Fixtures	
Building 1 Areas:	Machine Shop 1	206	
	Assembly	283	
	East Exterior Awning	28	
.	South Exterior Awning	21	
Building 2 Areas:	Machine Shop 2	276	
	Electrical Assembly	68	
Building 3 area:	Initial assembly And warehouse	+ 265	
Total fixtures at the facility:		1,147	Fixtures

Installation Verification

During the ex-post evaluation interview, the facility representative provided a floor plan of the three buildings for reference during the verification inspection. During the inspection, the conditions of the lamps and sensors were noted. The nameplate data from fixtures and lamps were verified using a file copy of the packing list for the delivery of the fixtures. The verification rate for this project is 1.00.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measure in the SPC application covering the lighting efficiency retrofits. The retrofits include the lower wattage fixtures and the occupancy sensors. This is the only measure in this application.

Summary of Results

The facility representative stated that the buildings are occupied continuously on weekdays from 5:30 a.m. to 7:00 p.m., partially occupied from 7:00 p.m. to midnight and not occupied from 12:00 a.m. to 5:30 a.m. There are approximately 500 employees on Saturday and approximately 20 employees on Sunday. With the exception of the exterior awning areas, all lights are energized when the building is occupied. The lights are deenergized during the unoccupied periods except for 4 fixtures that were installed without occupancy sensors. Operation of the sensors was not detailed by the facility; however, the representative indicated nearly all lights are off on Sunday afternoons.

Very few burned out lights were observed during the site visit. Burned out lights are regularly replaced. Therefore, there was no adjustment to the lighting energy consumption due to burned out lamps. The representative indicated it was easy to determine when lamps or ballasts need to be replaced. Ballasts have lasted well following an initial period of post installation failure.

A total of 13 pairs of lighting loggers were placed on 13 fixtures at locations encompassing a range of manufacturing activities. The data from 10 of the 13 fixtures were used to evaluate operations at the facility and to characterize operation of the lighting sensors. The other six loggers indicated the lights were on all the time at three of the fixtures. This would indicate either the occupancy sensors were broken and all four lamps of the fixtures burn continuously, or the sensitivity of the logger was set too high, or adjacent lighting somehow interfered with the logging.

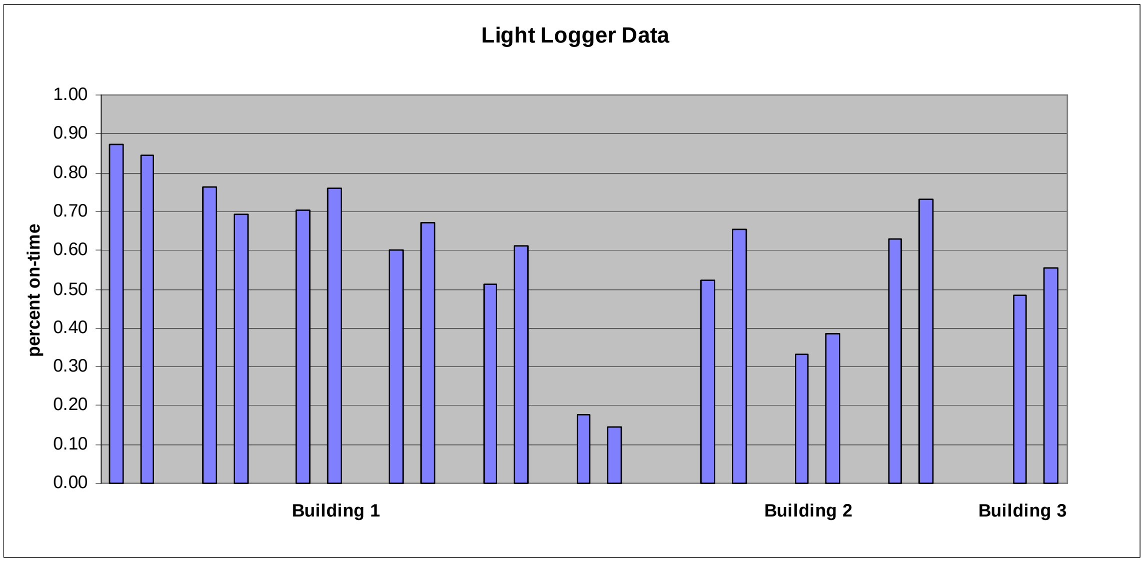
The continuous operation is unexplainable during the times when occupancy would not be expected, such as on Sunday afternoons. This would suggest the occupancy sensors are malfunctioning in the “on” condition or their sensitivity is set outside a properly functioning range (too sensitive to an object present in the field of sensing view).

Eliminating the six fixtures from the evaluation may bias lower the estimate of actual operating hours, whereas the evaluation may be biased high if the data from the six fixtures are included in the estimate and ex post savings would be decreased.

Thus, the six loggers on these three fixtures were eliminated from the analysis.

Using the 10 fixtures with reliable results, the loggers were evaluated for on/off times with log times annualized. The resultant average “on” time was 56%, or 4,906 hours per year. By including the three fixtures that were on continuously during the logging the resultant average on time was 65% or 5,680 hours per year.

Figure 1: Light Logger Data at site A072



The check calculations were revised after the evaluation site visit to reflect actual hours of operation, verified number of fixtures installed, and the motion sensors that were installed on most of the lighting fixtures.

- Pre-retrofit

Annualized hours of operation: 4,952 hrs/yr (from previous documentation)
Pre-retrofit wattage: 0.458 kW per fixture x 1,147 lamps = 525.3 kW
Annual kWh usage: 525 kW x 4,952 hrs/yr = 2,601,286 kWh/yr

- Post-retrofit

Hours of operation:4,906 hrs/yr (from loggers and new fixture documentation):

Post-Retrofit wattage of fixtures with motion sensors: 0.234 kW per four-lamp fixture x 1143 fixtures = 267.5 kW.

Annual kWh usage: 267.5 kW x 4,906 hrs/yr = 1,312,355 kWh/yr

Fixtures without sensors for kw determination: 0.234 kW per four-lamp fixture x 4 fixtures without motion sensors = 0.9 kW

- The resulting annual kWh savings for the lighting measures = 2,601,286 kWh/yr – 1,312,355 kWh/yr = 1,288,931 kWh/yr

The ex post savings for this project were determined from the reduction in connected load and the reduced hours of operation measured by the light loggers.

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load for 1143 fixtures changed out and adding the savings from denergization of fixtures during the peak demand periods due to occupancy sensor use. From inspection of post retrofit data, a diversity factor of 80% appears reasonable and is used in the ex post calculations.

Summer peak demand reduction is calculated as follows:

- Reduction in connected kW load plus reduction in load due to motion sensor use: (525.3 kW – 267.5 kW – 0.9 kW) + (267.5 kW x (1-0.80) = 256.9 kW + 53.5 kW = 310.4 kW.

The pre-retrofit annual consumption of 11,541,588 kWh was estimated from the utility billing data for the site for the period immediately preceding the retrofit. Peak demand was estimated at 1,317.5 kW before the retrofit, based on 8760 hours of usage (this figure is lower than the actual peak, which could not be determined from billing data).The baseline end use data is from the SPC Application Table 1 summarizes the total metered use, the baseline end use energy from the application paperwork, the original ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers. The ex-ante kW and kWh savings numbers provided in the application indicate greater savings would occur than the baseline usage for the measure.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1,317.5	11,541,588
Baseline End Use	523.3	2,109,812
Ex ante Savings	605.5	2,660,973
Ex Post Savings	310.4	1,288,931

The baseline end use was based on numbers from the check calculations for pre installation use of these lighting fixtures

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 46% decrease in total meter kW, a 116% decrease in lighting end use kW, a 23% decrease in total meter kWh, and a 126% decrease in lighting end use kWh. These very high savings were due to the overestimation of the motion sensor savings, and in part because the workpapers do not accurately represent the fixtures installed. The ex post results showed a 24 % decrease in total meter kW, a 59 % decrease in lighting end use kW, an 11 % decrease in total meter kWh, and a 61 % decrease in lighting end use kWh. Note that baseline end use relates to the calculated connected load of the pre-measure lighting.

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	46.0%	23.1%	23.6%	11.2%
Baseline End Use %	115.7%	126.1%	59.3%	61.1%

6. Additional Evaluation Findings

The primary differences between the ex ante and the ex post calculation is that the workpapers, forming the basis for the ex ante calculations, do not adequately represent the situation at this facility.

The fixture wattages used in the ex ante and ex post calculations were the same. The calculated ex post kW demand and kWh reductions are significantly less than the ex ante savings.

The measured hours of operations in various areas of the facility ranged from a low of 1,283 hours to a high of 7,313 hours for an installed fixture weighted average of 4,906 operation hours. From the lighting measurement, the lights were on an average of 53% of the time.

Ex post energy savings are less than the ex ante energy savings. Although hours of operations (4,906) used to calculate ex post savings are greater than operation hours determined from the application information, the substantially higher ex ante savings, in the application paperwork, derive from the savings attributed to the sensors.

Improved ex-post estimates can be derived by using loggers with lighting sensitivity as well as lighting periods of energization.

The cost estimates appear to be realistic. Incentives were based on fixture counts as the two measures were itemized measures.

In addition to saving energy, the benefits of the project are increased clarity of light, increased light levels, increased employee comfort and better working conditions. Other perceived benefits include reduced lighting maintenance hours and maintenance costs.

With the opening of a new, fourth warehouse size building in the near future, the customer anticipates some changes to operations that will affect energy consumption in the original three buildings. These effects are unknown at present.

Participation in the 2004/2005 SPC Program has encouraged the facility management to perform another energy efficiency project: the installation of variable frequency drives on compressor motors. Also, the facility representative likely will contact the utility or the project contractor for advice on energy savings measures that can be implemented on the new building. These measures will likely be pursued under utility sponsored programs.

7. Impact Results

The pre-retrofit lighting fixture type, quantities and hours of operation could not be physically verified; however, the application paperwork calculations from the contractor indicated that standard nominal 400 watt metal halide fixtures were removed. An estimate of the hours of operation listed in the application paperwork had been quantified by the facility representative according to functional area. The operation hours were refined in the Installation Report Review comments and confirmed in the evaluation interview with the facility representative. These parameters have been accurately assessed and adequately quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With an installed cost of $322,869.03 and a $136,317 incentive, the project had a 0.54 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 1.05 years. A summary of the economic parameters for the project is shown in Table 3.

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand savings, kWh	Estimated Demand savings, kWh	Estimated Gas Savings kWh therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive	Simple payback with incentive, yrs	Simple payback without incentive, yrs
Installation Approved Amount (Ex Ante)	10/12/2004	$322,869	605.5	2,660,973	0	$345,927	$136,317.00	0.54	0.93
SPC Program Review(Ex Post)	9/5/2007	$322,869	310.4	1,288,931	0	$167,561	$136,317.00	1.05	1.86

The utility tracking data are the approved estimates of ex ante savings. The utility tracking savings were 605.54 kW and 2,660,973.3 kWh. The ex post savings are 310.4 kW and 1,288,931 kWh. The engineering realization rate is the ratio of the ex post results to the utility tracking data. The engineering realization rate for this lighting application is 0.51 for demand kW reduction and 0.48 for energy savings kWh. A summary of the realization rate is shown in Table 4.

Table 4: Realization Rate Summary

	kW	KWh	Therm
SPC Tracking System	605.5	2,660,973	-
SPC Installation Report (ex ante)	605.5	2,660,973	-
Impact Evaluation (ex post)	310.4	1,288,931	-
Engineering Realization Rate	0.51	0.48	NA

The Installation Verification Summary is shown in Table 5 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 6.

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Lighting & Occupancy Sensors	L	-	Replace 1147 metal halide fixtures and lamps with 1,147 4-lamp HO T5 fluorescent fixtures and Install occupancy sensors on 1143 of these fixtures	-	1,147	4-Lamp HO T5 fluorescent fixtures	Verified lamp and fixture type from delivery documentation and verified quantity from previous inspector's documentation	1.00

Table 6: Multi Year Reporting Table

Program ID:	001 Application # A072						
Program Name:	SPC 04-05 Evaluation						
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	1,330,487	644,466	605.5	310.4		
2	2005	2,660,973	1,288,931	605.5	310.4		
3	2006	2,660,973	1,288,931	605.5	310.4		
4	2007	2,660,973	1,288,931	605.5	310.4		
5	2008	2,660,973	1,288,931	605.5	310.4		
6	2009	2,660,973	1,288,931	605.5	310.4		
7	2010	2,660,973	1,288,931	605.5	310.4		
8	2011	2,660,973	1,288,931	605.5	310.4		
9	2012	2,660,973	1,288,931	605.5	310.4		
10	2013	2,660,973	1,288,931	605.5	310.4		
11	2014	2,660,973	1,288,931	605.5	310.4		
12	2015	2,660,973	1,288,931	605.5	310.4		
13	2016	2,660,973	1,288,931	605.5	310.4		
14	2017	2,660,973	1,288,931	605.5	310.4		
15	2018	2,660,973	1,288,931	605.5	310.4		
16	2019	2,660,973	1,288,931	605.5	310.4		
17	2020	1,330,487	644,466				
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	42,575,568	20,622,896				

Based on a 16 year life.

Final Report

SITE A073 (04-0081) Toyo IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 2 END USE: Lighting

Measure	High Bay T5 Lighting Retrofit / Occupancy Sensors/Energy Management System Control
Site Description	Warehouse

1. Measure Description

Replace 1473 four hundred watt (400W) high pressure sodium fixtures with 1473 four-lamp high output (HO) T5 fluorescent fixtures, install 194 fixture mounted occupancy sensors to reduce lighting hours of operation, and install an energy management system (EMS) to manage and control the lighting system and ventilation fans in the facility.

2. Summary of the Ex Ante Calculations

The original application was submitted as a Standard 2004 SPC application. The customer used the Itemized Measure Form to calculate kW and kWh savings for the T5 fixtures and the occupancy sensors. The basis of the incentive payment for these measures was the itemized incentive list.

The EMS was listed as a calculated measure and the SPC Installation Report format was used for the calculation of the savings and incentive for this measure. Total savings for the EMS were estimated to be 537.0 kW and 1,214,711 kWh. These are listed as the Application Approved savings amounts in the Installation Report Review.

An additional measure of 50 photocells was submitted as an itemized measure with the original application, but it was removed in the Application Review after discussions with the project sponsor. The itemized rebate for a photocell is only applicable for exterior lighting. Since this measure was proposed for an indoor application, custom engineering calculations would be needed to calculate the savings and the incentive. The measure was included in the MDSS (the utility tracking system or Management Decision System Software), but the savings and incentive payment were both entered as zero.

The total savings in the Installation Report Review are listed as 926.1 kW and 2,811,730.5 kWh. In general, the savings figures in the final Installation Report Review (IRR) would be expected to be identical to the utility tracking system savings figures, and they are identical in this case (excluding rounding functions)..

The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. These workpapers note that a conversion from metal halide fixtures to high output (HO) T5 fixtures results in a wattage reduction from 0.458 kW to 0.234 kW, for a non-coincident peak reduction of 0.224 kW. Coincident peak reduction is noted as 0.205 kW and kWh savings is noted as 843 kWh/year. The hours of operation for a warehouse are fixed in the workpapers at 3,550 hours/year. The workpapers note a diversity factor of 84% for a warehouse.

For ceiling mounted occupancy sensors, the savings are based on the control of eight (8) fluorescent T12 fixtures, consuming 72 watts each, in an office conference room. Savings are based on a reduction from 2,210 hours/year to 1,040 hours/year (1,170 hours/year reduction). The workpaper reports 789 kWh savings (674 kWh/year plus a 17% office sector demand interactive effects factor). The non-coincident peak reduction of 0.305 kW was derived from the 0.576 kW controlled wattage and a 53% reduction in hours. Coincident peak reduction in the workpaper was noted to be 0.381, which included a 1.25 demand sector interactive effects factor.

3. Comments on the Ex Ante Calculations

The ex ante calculations in the Installation Report Review are based on the workpapers for the itemized measures and based on SPC Estimation Software for the calculated measure. Details of the calculation are shown in the Installation Report Review.

The ex ante savings figures can be checked for reasonableness using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation using the following formulae:

$$\text{kWh savings} = \text{kW}_{pre} \times \text{energized hours}_{pre} - \text{kW}_{post} \times \text{energized hours}_{post}$$

$$\text{Coincident peak demand period savings} = \text{kW}_{pre} - \text{kW}_{post} + \text{kW}_{post} \times (1 - \text{diversity factor})$$

Three measures are considered: conversion from T5 to HPS fixtures, installation of motion sensors on the aisle fixtures (approximately 66% of all T5 fixtures) and installation of EMS. The check calculations for the main measures were performed as follows:

- Pre-retrofit hours of operation: 5,100 hrs/yr (reported by customer) Pre-retrofit wattage: 0.458 kW per fixture x 1473 lamps = 674.6 kW Annual kWh usage: 674.6 kW x 5,100 hrs/yr = 3,440,633 kWh/yr
- Post-retrofit hours of operation for fixtures: 5,100 hrs/yr Post-retrofit wattage: 0.234 kW per fixture x 1473 lamps = 344.7 kW Annual kWh usage: 344.7 kW x 5,100 hrs/yr = 1,757,878 kWh/yr
- Fixture savings = 329.9 kW and 1,682,755 kWh/yr (vs.329.9 kW and 1,319,808 kWh/yr in the IRR).
- Occupancy sensor savings (based on a 55 % reduced usage factor) Reduced hours of operation: 5,100 hours x (1 -0.45) = 2,805 hrs/year Annual kWh saved: 344.7 kW x 2,805 hrs/yr = 966,833 kWh/yr (vs. 277,211 kWh/yr in the IRR).

- Annual kW saved based on a 84% diversity factor: 344.7 kW x (1-0.84) = 55.1 kw (vs. 59.17 kW in the IRR). Note that the entire complement of new lighting fixtures may not be controlled. The reduced usage factor may also be greater, due to control of fixtures in aisle areas.

- EMS savings:
  Controlled wattage: 1,473 T5 fixtures = 344.7 kW, 3,771 T8 fixtures = 192.3 kW
  Reduced hours: T5 fixtures = 1020 hrs, T8 fixtures = 4488 hrs
  Energy savings: T5 = 351,594 kWh/yr, T8 = 863,042 kWh/yr
  EMS Lighting Energy savings = 1,214,636 kWh/yr (lower than listed in the IRR due to rounding functions).

- The resulting annual kWh savings = 1,682,755 kWh/yr + 966,833 kWh/yr +1,214,636 kWh/yr = 3,864,224 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load.

Summer peak demand reduction is calculated as follows:

- Reduction in connected load plus reduction in load due to motion sensor use:
  Reduction in connected load: (0.458 kW – 0.234 kW) x 1473 = 329.9 kW
  Reduced load due to motion sensors: 344.7 kW x (1-0.84) = 55.1 kW
  Reduced load due to EMS: 344.7 kW + 192.3 = 537.0 kW
  329.9 + 55.1 + 537.0 = 922.0 kW

It should be noted that the kw savings for the reduced load from the MS assumes that all fixtures will be off at the coincident peak load for the utility, not the coincident peak load for the building. This may not be the case for this facility.

These calculations are based upon hourly use figures obtained from the Measure #3 Summary Information Sheet in the SPC Installation Report. These hours are higher than the average stated in the workpapers for warehouse operations, and kWh savings are thus expected to be higher than ex ante savings for the T5 fixture replacement measure. The controlled wattage in the workpapers is different than the actual controlled wattage for the motion sensor measure, and the diversity factor is lower than that expected for aisles in a warehouse; therefore, the actual savings are expected to be different than reported in the IRR for the motion sensor measure. The EMS savings appear to be accurate in the IRR because the calculation was based on actual hours and controlled wattage, provided that the EMS turns off the entire controlled wattage during the coincident peak demand periods.

The savings in the Installation Report Review are given as 926.1 kW and 2,811,730.5 kWh. In general, the savings figures in the final Installation Report Review (IRR) would be expected to be identical to the utility tracking system savings figures, and they are identical for this site (excluding rounding functions for kWh).

4. Measurement & Verification Plan

The building is a single level warehouse with an area of approximately 770,000 sf and is used for car parts distribution. The building has minimal windows, but many skylights. The building is occupied five days a week from 5 am to 11 pm, and Saturdays from 6 am to 11 am. Occupancy is approximately 480 employees. According to the application, before the retrofit there were fourteen hundred seventy-three (1,473) high pressure sodium fixtures using 400-watt lamps. After the retrofit, there are fourteen hundred seventy-three (1,473) four-lamp T-5 fluorescent fixtures, approximately 2/3 of which are controlled by ceiling mounted occupancy sensors; each sensor controls one aisle of T5 fixtures. The existing EMS was replaced by a newer EMS system. The exact functioning of the pre retrofit EMS was unclear. The project saves energy through the installation of lighting fixtures with a lower connected wattage and through the control of the lighting fixtures with occupancy sensors and the EMS to reduce the hours of operation.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

IPMVP Option C approach should be considered. The savings reported in the utility tracking system is approximately 20% – 30% of the kW and kWh consumed based upon the pre-retrofit building use (peak demand is approximately 1,300 kW and annual energy use approximates 8,300,000 kWh per year according to the utility bills. A billing summary was not included in the application). Utility billing and interval data should support this approach if there are no other significant loads or other significant energy conservation activities which occurred in the months immediately following the retrofit. There is not expected to be significant seasonal variation and several months should be sufficient for comparison; however, a one to two year period would more fully capture actual variations and the persistence of savings. Interval data on a 15 minute basis during the summer months of June to September might be needed to accurately determine summer peak period demand savings since motion sensors are expected to contribute significantly to estimated peak load reduction.

If Option C cannot be used due to changes in the facility or its operation in the time periods immediately before or after the retrofit, then a modified version of IPMVP Option A can be utilized. Lighting loggers would be used to quantify hours of operation. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

$$\text{kWh savings} = \text{kWh}_{pre} - \text{kWh}_{post}$$

$$\text{kW savings} = \text{kW}_{pre} - \text{kW}_{post}$$

Summer peak demand period savings will be reported as the expected average kW savings during the hottest periods between 2 pm to 5 pm, Monday to Friday, in June, July, August, September

To estimate the average expected peak demand kW reduction, since this measure is not weather dependent, the average of all reductions during that periods as stated above could be used. Alternately, the hottest days, as determined from climate records could be used.

If actual billing and interval data are used, whole building data may be the most accurate way to quantify the savings considering the uncertainty associated with the pre retrofit conditions. The most significant variable to be qualified is that there were no changes to operation not related to the measure which affect the pre and post retrofit energy usage.

Uncertainty for the savings estimate for the production facility fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables.

<u>Uncertainty with utility billings</u>

- kWh: 3,864,224 kWh expected; 3,824,000 kWh minimum; 3,904,000 kWh maximum (+ / - 1% for utility metering)
- kW: 922 kW expected, 912 kW minimum, 932 kW maximum hours (+/-1% for utility metering)

<u>Uncertainty from changes in schedules and other energy use increases / decreases</u>

- kWh: 3,864,224 kWh expected; 2,500,000 kWh minimum; 4,200,000 kWh maximum (+ 5%, - 30% for motion sensor / EMS operation; +/- 5% for additional equipment or energy saving measures)
- kW: 903.7 kW expected, 450 kW minimum, 972 kW maximum hours (+ 10%, - 50% for motion sensor / EMS operation, for additional equipment, and for energy saving measures and based on extrapolating to actual hottest day period)

Accuracy and Equipment

The utility meters capture 15 minute interval data and for the purposes of the evaluation are considered to be 99% - 100% accurate where reviewed data is deemed reasonable.

Annualizing the kW data to the hottest summer period is projected to result in a possible error in the final results of +/- 5 %.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on June 27, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Lighting fixture quantities and hours of operation were verified.

The building is occupied 18 hours Monday-Friday (between 5:00 a.m. and 11:00 p.m.) and on every other Saturday from 6:00 a.m. to 11:00 a.m. The facility has 400 employees, of which 20% are office staff and 80% are warehouse floor workers. The facility is closed 10 holidays annually.

Installation Verification

The facility representative verified that 1473 high pressure sodium fixtures were replaced with 1473 four-lamp T-5 fluorescent fixtures. It was physically verified that four-lamp T-5 fluorescent fixtures were installed in the facility. The retrofit was completed in October 2004. For purposes of the ex post calculations, it is assumed that there were 1473 four hundred watt high pressure sodium fixtures prior to the retrofit. There were no motion sensors or daylight harvesting installed before the retrofit and all lights were on when the facility was open.

This is the only measure in this application. The verification realization rate for this project is 1.00 (1473/1473 for fixture retrofit, 194/194 for motion sensors, and 1/1 for the energy management system). A verification summary is shown in Exhibit 5.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measure in the SPC application covering the lighting efficiency retrofit. This is the only end-use in this application.

Summary of Results

Billing data was analyzed at this site to determine pre-retrofit and post-retrofit energy usage. The maintenance personnel onsite calculated energy savings from billing data to provide the company with information on the payback time of the retrofit. The maintenance personnel provided those calculations in electronic format; those calculations are part of the basis of the energy savings analysis at this site.

The billing data used in the analysis was checked against billing data from the utility and was found to be accurate. The billing data is graphed in Exhibit 1, showing average daily energy consumption from December 1999 to August 2006. The 45% decrease in electrical energy consumption in October 2004 is immediately obvious.

The onsite interview with the facility representative revealed that there were significant, seasonally varying electric loads other than lighting at the facility. In the summer months, six (6) evaporative coolers and two (2) high speed low velocity (HVLS) fans are operated to cool the warehouse area. There are also conveyers in the main shipping area, and there are approximately 50 forklift chargers. The facility representative stated that there were equipment additions to the facility that affected the electric load, installed at approximately the same time as the lighting retrofit (primarily outdoor tower lighting and ventilation fans). The kW and kWh savings are less than 10% of the total usage.

The existing high pressure sodium lights were 10 years old, and were beginning to have ballast and bulb failures. The facility was planning a major change out of bulbs prior to the lighting retrofit.

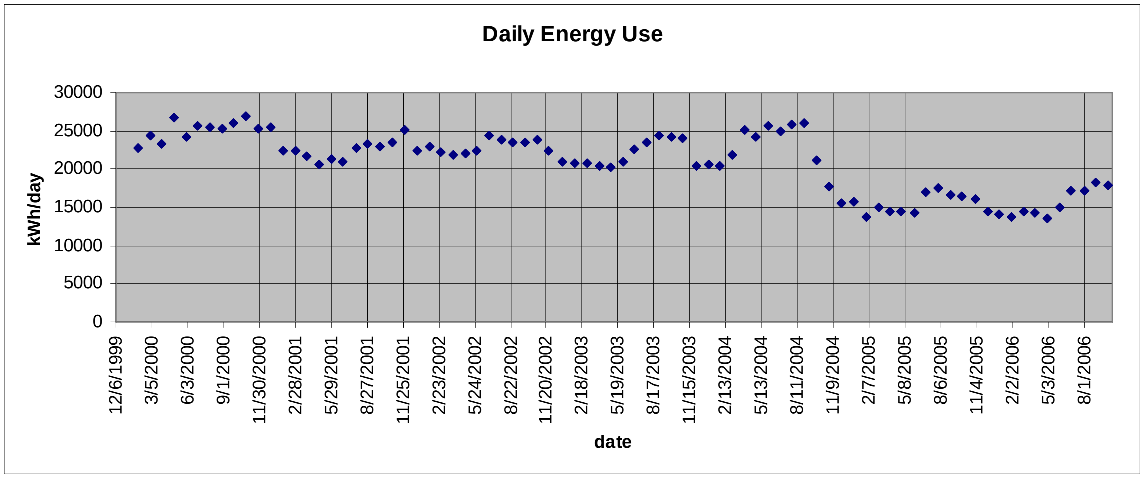
All lights are expected to be operating during the peak demand period defined as the hottest weekday periods between 2 pm to 5 pm, Monday to Friday, in June, July, August or September.

The ex post impacts were calculated from billing data as follows:

- Pre retrofit kWh use is summed for the 369 day period from 11/28/2002 to 12/01/2003 and adjusted to 365 days at 8,092,612 kWh. This is then adjusted for the yearly energy use of ventilation fans (336,662 kWh) and tower lights (58,909 kWh), which had not yet been installed at the facility, and adjusted for 10% non-operational bulbs (328,710 kWh),yielding pre-retrofit energy use of 8,729,172 kWh. (The energy consumption adjustment numbers come directly from the facility internal analysis)
- Post retrofit kWh use is summed for the 365 day period from 12/02/2004 to 12/01/2005 giving post-retrofit energy use of 5,645,388 kWh.
- Pre-retrofit wattage was averaged over the same period as the pre-retrofit kWh use and found to be 1327 kW.
- Post-retrofit wattage was averaged over the same period as the post-retrofit kWh use and found to be 1124 kW.
- The resulting annual kWh savings is 8,729,172 kWh/yr – 5,645,388 kWh/yr = 3,083,784 kWh/yr.
- Summer peak demand reduction impacts were estimated by subtracting average post-retrofit from average pre-retrofit peak load and adjusting for the peak demand load of the failed HID bulbs, the tower lighting and the ventilation fans (107 kW adjustment). Interval data was used for the 2 pm to 5 pm weekday time periods in the summer months of 2003 and 2005. The average during 2004 is very similar to the average in 2003.

Peak kW savings is 1166 kW – 1064 kW +107 kW= 209 kW

Exhibit 1: Daily kWh Consumption



The energy savings determined from the bills - 3,083,784 kWh/yr - are somewhat lower than the expected energy savings calculations in section 3 (3,864,224 kWh/yr). However, the demand savings determined from the bills is extremely different at 102 kW instead of the 903.7 kW predicted in the ex ante calculations. The EMS system may not be achieving the predicted savings of 537 kW, during the peak demand period of 2 pm to 5 pm. .

The engineering realization rate for this application is 0.23 for demand kW reduction and 1.10 for energy savings kWh. A summary of the realization rate is shown in Exhibit 5.

Exhibit 2 summarizes the total metered use in 2003 and the average kW demand for the same period, the baseline end use (pre-retrofit energy used by the warehouse and mezzanine lighting), the revised ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visits.

Exhibit 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations.

Exhibit 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1323.0	8,018,412
Baseline End Use	867.0	5,088,440
Ex ante Savings	926.1	2,811,730
Ex Post Savings	209.0	3,083,784

Exhibit 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	70.0%	34.4%	15.8%	37.7%
Baseline End Use %	106.8%	55.3%	24.1%	60.6%

6. Additional Evaluation Findings

The ex post kW demand reduction is lower than the ex ante estimate partly because the ex ante savings for the motion sensors and EMS appear to be overstated. The EMS savings were calculated, and the kW peak reduction was assumed to be the same as the controlled wattage, implying that the controlled fixtures would be off during the peak period. However, the onsite interview revealed that 12 pm – 3 pm is one of the busier parts of the day, with many employees leaving at 3:15 pm.

The ex ante and ex post energy savings are in very close agreement.

In addition to saving energy, the benefits of the project are increased production, and better mood because of the better color of light. The customer anticipates some possible changes to operation that would affect energy consumption in the foreseeable future, namely, they may reduce the on-time of aisle lighting when it is activated by the motion sensors from 15 minutes to 10 minutes, they may shut off the open area lighting at lunchtime, and they may put motion sensors in the conference rooms. Participation in the 2004/2005 SPC Program has encouraged them to perform other energy efficiency projects. The facility installed motion sensor on office lighting, and in restrooms and locker rooms. These retrofits were performed independently, without a rebate.

7. Impact Results

The pre-retrofit lighting fixture type, quantities and hours of operation were unable to physically verified. However, it is believed that these parameters have been accurately assessed and quantified based on discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $910,011 and an $179,746 incentive, the project had a 2.00 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback based on the ex ante savings is 1.82 years. A summary of the economic parameters for the project is shown in Exhibit 4.

Exhibit 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	1/11/2005	$910,011	926.1	2,811,730	0	$365,525	$179,746	2.00	2.49
SPC Program Review (Ex Post)	7/23/2007	$910,011	209.0	3,083,784	0	$400,892	$179,746	1.82	2.27

The realization rate of the peak kW demand is 0.23 and the realization rate of the energy savings is 1.10 as summarized in Exhibit 5. The Installation Verification Summary is shown in Exhibit 6 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Exhibit 7.

Exhibit 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	926.1	2,811,730	-
SPC Installation Report (ex ante)	926.1	2,811,730	-
Impact Evaluation (ex post)	209.0	3,083,784	-
Engineering Realization Rate	0.23	1.10	NA

Exhibit 6: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Replace EMS system.		1	EMS	Physically verified existence of EMS.	1.00
LIGHTING - OTHER	L		Replace 1473 400W high pressure sodium fixtures with 1473 4-lamp HO T5 fluorescent fixtures.		1,473	occupancy sensors	Physically verified existence of T5 lamps.	1.00
LIGHTING - OTHER	L		Install 194 fixture mounted occupancy sensors.		194	4 lamp T-5 HO fixtures	Physically verified existence of motion sensors.	1.00

Exhibit 7: Multi Year Reporting Table

Program ID Program Name		**SPC 2004 Application # A073 2004 – 2005 SPC Evaluation**					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004					0	0
2	2005			926.1	209	0	0
3	2006			926.1	209	0	0
4	2007			926.1	209	0	0
5	2008			926.1	209	0	0
6	2009			926.1	209	0	0
7	2010			926.1	209	0	0
8	2011			926.1	209	0	0
9	2012			926.1	209	0	0
10	2013			926.1	209	0	0
11	2014			926.1	209	0	0
12	2015			926.1	209	0	0
13	2016			926.1	209	0	0
14	2017			926.1	209	0	0
15	2018			926.1	209	0	0
16	2019			926.1	209	0	0
17	2020			926.1	209	0	0
18	2021					0	0
19	2022						
20	2023						
TOT	**2004-2023**						

FINAL SITE REPORT

SITE A074 (2004-xxxx) Stat IMPACT EVALUATION
SAMPLE CELL: TIER: 3 END USE: Refrigeration

Measure	Installation of RIFF (glass door freezer) cases
Site Description	Grocery store

1. Measure Description

Replace four open multi-deck and two coffin style display cases with four reach-in frozen food (RIFF) glass door freezer cases in each of four stores (#12 R1, #43 R2, #109 R3 and #113 P1). Install controls that will cycle refrigeration compressors on and off based on case temperature. As a result of the retrofit, two compressors at each store will be shut down.

2. Summary of the Ex Ante Calculations

The ex ante calculations only include savings related to the compressors, which are indicated to consist of Copeland 9RS-0765 and 4RL-1500 models. All four stores were assumed to have the same number and type of cases and compressors so that the savings estimate is the same for each store.

The customer assumed the following base case equipment and energy usage for each store (kW demand multiplied by 8,760 hrs/year = kWh/year):

Compressor	SST	Watt-h/Btu	kW	kWh/yr
9RS-0765	-30 °F	0.219	4.8	42,400
9RS-0765	-30 °F	0.219	5.6	48,681
4RL-1550	-30 °F	0.204	12.8	111,838
4RL-1550	-30 °F	0.204	12.8	111,838
9RS-0765	-20 °F	0.198	8.3	72,515
9RS-0765	-20 °F	0.198	8.3	72,515
Base case total			**52.5**	**459,787**

The customer assumed that two compressors will no longer be utilized. The following post-case equipment and specifications were assumed as the post-retrofit case for each store:

Compressor	SST	Watt-h/Btu	kW	kWh/yr
4RL-1550	-23 °F	0.208	6.7	59,088
4RL-1550	-23 °F	0.208	6.7	59,088
9RS-0765	-23 °F	0.203	6.3	55,222
9RS-0765	-23 °F	0.203	6.3	55,222
Post-retrofit total			**26.1**	**228,620**

Savings for each store:
[Base case total – Post-retrofit total] = 231,167 kWh and 26.4 kW

Savings total for application (per the Installation Report Review – IRR):
231,167 kWh/store x 4 stores = 924,668 kWh
26.1 kW/store x 4 stores = 105.6 kW

The utility tracking system notes savings for six stores, typically 154,111 kWh/yr/store and 17.4 kW per store (18.6 kW for one store). These savings total to 924,666 kWh / yr and 105.6 kW.

3. Comments on the Ex Ante Calculations

The ex ante calculations assume an identical configuration of type and size of compressors for all four sites. The actual type and size of compressors associated with the display case replacement are likely to vary from site to site. Furthermore, the compressor model numbers recorded, appear to be inconsistent through the project application documentation (i.e. model numbers stated on savings calculations sheet do not match the model numbers listed on pre-inspection sheet, which do not match the numbers in the application data and write-up).

An assumption of 8,760 hours/year run-time was used for the base case and post-retrofit calculations, even though the project application data includes estimated base case runtimes of 20 hours/day for the multi-deck freezer systems and 23 hours/day for the coffin freezer systems. The application data estimates 12 hours/day of runtime for the post retrofit case. The savings calculations should have calculated pre retrofit run-time hours based on operating hours/day instead of assuming a 24 hours/day.

The project application only includes energy savings related to reduced load on the compressors. Further energy savings calculations should explicitly include the impact of case door heaters, savings from reduced condenser operation and savings from more efficient lighting and evaporator fans in the cases. The general manager states that lighting in the cases used to be T12, but are now T8 fixtures. The project application assumed that the savings and penalties associated with these additional equipment impacts largely offset one another.

The general manager indicates that the stores use no gas, and that all space heating and domestic hot water heating is provided by heat recovery from the compressor system. The ex ante calculations did not take into account increased need for HVAC cooling during the summer, due to reduced loss of cold air from refrigerated cases to the conditioned space.

4. Measurement & Verification Plan

The goal of the measurement and verification (M&V) plan is to verify the energy savings through evaluating post retrofit run-time hours, power draw of the compressors and anti-sweat heaters, and light fixture consumption inside the new cases. This will provide documentation for the ex-post peak kW and the first year ex-post annual kWh reduction for the project.

There are 4 sites involved in this project with similar (basically identical) scope at each site. The four sites are grocery stores, typically open from around 6 a.m. to 11 p.m. daily. According to the application, before the retrofit there were six “open” style freezer cases (four multi-deck and two coffin freezers). After the retrofit, there were four glass door reach-in freezer cases with a total of 96 doors. We propose to use “pre” – “post” whole-building metered energy use (IPMVP Option C) to estimate the project impacts. The approach is detailed in the following section.

Formulae and Approach

A whole-building billing analysis methodology is proposed. The application file includes some whole store usage data that clearly shows a step change in energy use following case changes in other stores. Therefore, we feel that this approach will yield relevant results.

The kWh consumption for 24 billing periods prior to the project installation and 24 periods after installation will be compared. The billing periods compared will not include the period during which the installation was completed or the month immediately after to allow for adjustments and programming. The kWh will be normalized to 730 days by a direct proportion. We do not anticipate significant pre vs post period weather bias, however to confirm this we will extract and compare NOAA dry-bulb temperature data for the “pre” and “post” comparison periods. If the dry bulb cooling degree days (65°F base) for the pre and post periods vary by more than 5 percent, we will normalize the pre-and post kWh and the impacts for the degree day difference using a temperature regression analysis for the representative weather station for the store location. Each store will be considered separately and the results for each of the 4 sites will then be summed to calculate the total project impact.

The annual savings for each of the project stores will be calculated by

$$\text{Annual kWh Savings}_{\text{Store}} = \sum_{1}^{24} \frac{\text{kWh}_{\text{pre-retrofit}}}{\text{Billing Days}_{\text{pre-retrofit}}} - \frac{\text{kWh}_{\text{post-retrofit}}}{\text{Billing Days}_{\text{post-retrofit}}}$$

For 24 similar pre- and post-retrofit billing periods.

The total project savings will be calculated as:

$$\text{Total Annual kWh Savings} = \sum_{1}^{4} \text{Annual kWh Savings}_{\text{store}}$$

The technical representatives for the customer and the sponsor will be interviewed regarding the performance of the various control measures and to explain any major discrepancies between the projections and the evaluation findings. If possible, access to the control screens for all of the stores from a central location will be arranged to verify post-installation operating schedules, settings, etc.

Two sites (half of the four total sites) will be visited to verify installation of the measures and to observe post-installation operation and settings. One store location has already been visited for verification.. Because the impact methodology proposed is a “billing analysis” approach, the verification visits will serve to explain any discrepancies in the impacts rather than serve as a data source. A questionnaire and site survey form will be developed prior to the visit to serve as a guide for the site observations.

Accuracy and Equipment

SCE revenue meter data will be used. If necessary, NOAA weather data for stations closest to each store will be used. These sources are expected to be >98% accurate. A spot meter amp reading of the sweat-heaters will be used to measure current when sweat-heater is on. A spot meter amp reading of the compressors will also be use to assess energy demand both when loaded and unloaded. No on-site measurement equipment is expected to be used. Site verifications will also utilize control system observation data and interviews.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment.

The on-site survey was conducted on September 18, 2007. Installation of new glass door freezer cases (RIFF) and retirement of two compressors were confirmed by on-site visits to three stores (#12 R1, #43 R2 and #113 P1). Whole store billing data was analyzed to calculate ex post savings.

Installation Verification

The facility representative verified that there had previously been open multi-deck and coffin style display cases in each of the four stores. He also confirmed that previously, the cases were defrosted four times/day for 1 hour each time. We physically verified that there are four new reach in frozen food (RIFF) glass door freezer cases, with a total of 96 doors. Cases were verified as having anti-sweat heaters controlled by humidistats.

All lighting in the cases was confirmed to be T8 lamps, with the facility representative confirming that the lamps were previously T12s. Two compressors on the refrigeration rack were labeled for frozen foods, but were also labeled "Out of Service" and were observed to be off. This is consistent with the project application. Stores were verified to have no gas utility service, and that space heating and domestic water heating loads are provided by heat recovery from the compressor system in each store.

These are the only measures in this application. The verification realization rate for this project is 1.0.

Scope of the Impact Assessment

The impact assessment scope is for the AC/R end use measures, covering the refrigeration retrofits. A whole-building billing analysis is used since the installation of glass door freezer cases affects consumption related to case lighting and store HVAC cooling needs.

Summary of Results

Twenty-four months of billing data before and after the retrofits was not available for the Stater Brothers stores. Therefore, 12 billing periods prior to installation and 12 months after installation of the new cases was compared. For all four stores, the following periods were selected:

- Pre-installation period: January 2003 through December 2003
- Post-installation period: May 2004 through April 2005

The closest NOAA weather station for all four stores is a municipal airport. The dry bulb cooling degree days (CDD) for the pre- and post- periods did vary by more than 5 percent (see Table 1).

Table 1: Comparison of Weather Data from "Pre" and "Post" Periods

	CDD
January 2003 through December 2003	1,766
May 2004 through April 2005	1,370
Difference	-22%

Yet the billing data (kWh consumption) at each store was not found to be correlated to weather (see Table 12). Therefore, the pre- and post- kWh consumption is not normalized to weather, as proposed in the M&V plan.

The annual savings for each store is calculated by:

$$\text{Annual kWh Savings}_{\text{Store}} = \sum_{n=1}^{12} \frac{\text{kWh}_{\text{pre-retrofit}}}{\text{month}_{\text{pre-retrofit}}} - \sum_{n=1}^{12} \frac{\text{kWh}_{\text{post-retrofit}}}{\text{month}_{\text{post-retrofit}}}$$

For two stores, #43 and #113, there were an identical number of billing days in each period. For two stores, #12 and #109, there was one additional billing day in the post-retrofit period (see Table 2 below).

Table 2: Comparison of Billing Days in Pre-Retrofit Period and Post Retrofit

Site	Number of days in pre-retrofit period	Number of days in post-retrofit period
#12 Rialto	366	367
#43 Rialto	365	365
#109 Ridgecrest	364	365
#113 Perris	365	365

This is resolved by subtracting an average days worth of kWh consumption (average kWh/day) from the annual kWh consumption, through the following equation:

$$\text{Annual kWh Savings}_{\text{Store\_Ajusted}} = \text{Annual kWh Savings}_{\text{Store}} - \frac{\sum_{n=1}^{12} \text{kWh}_{\text{post-retrofit}}}{\sum_{n-1}^{12} \text{Billing Days}}$$

Typically, the average kWh consumption per day for stores #12 and #109 in the post-retrofit year was 4,030 kWh and 4,058 kWh, respectively.

Since the energy use at the stores is not weather dependent, and refrigeration equipment is in operation throughout the night as well as in the daytime, the peak kW demand savings is calculated using the difference in weighted average demand from the pre-retrofit period and post-retrofit period.

$$\text{Demand Savings} = \frac{\sum_{n=1}^{12} kWh_{pre-retrofit}}{\left(\sum_{n-1}^{12} \text{Billing Days}_{pre-retrofit}\right) x(24hrs/dy)} - \frac{\sum_{n=1}^{12} kWh_{post-retrofit}}{\left(\sum_{n-1}^{12} \text{Billing Days}_{post-retrofit}\right) x(24hrs/dy)}$$

Table 3 summarizes the ex post electric savings for the four stores. Table 4 shows what the total metered use (summation across all four stores) was prior to the retrofit, as well as the ex ante savings and ex post savings. The total metered consumption may be compared to savings (as well as the baseline end use energy), since savings on the refrigeration units have interactive effects with the building's HVAC needs and energy used related to case lighting, fans and anti-sweat heaters.

Demand reduction was calculated by taking the average kW using the total billing kWh in the pre retrofit and post retrofit periods.

Table 3: Ex Ante and Ex Post Results for Each Store

Site	Ex ante savings		Ex post savings	
	kW	kWh/yr	kW	kWh/yr
#12 Rialto	26.14	231,167	56.3	494,475
#43 Rialto	26.14	231,167	32.5	284,564
#109 Ridgecrest	26.14	231,167	52.8	461,481
#113 Perris	26.14	231,167	45.5	398,547
TOTAL	105.6	924,668	187.1	1,639,066

Table 4: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	865.4	7,580,833
Baseline End Use	432.7	3,790,417
Ex ante Savings	105.6	924,668
Ex Post Savings	187.1	1,639,066

Refrigeration baseline end use estimated at 50% of total use.

The engineering realization rate for this application is 1.77 for both demand kW reduction and for annual energy savings kWh/yr. Table 5 is a summary of the percent of energy savings for the total metered use (across all four stores), and for both the ex ante and ex post savings calculations.

Table 5: Percent Savings and Demand Reductions (Ex Ante and Ex Post)

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	12.2%	12.2%	21.6%	21.6%
Baseline End Use %	24.4%	24.4%	43.2%	43.2%

Supporting Calculations

To corroborate the results of the billing analysis, spot measurements were taken at the stores and EMS data was collected to analyze run-times and set-points. Savings are estimated for the compressors (reduction in run-time hours), compressors (two no longer in operation), lighting changes in the cases (T12 to T8 lamps) and the installation of anti-sweat door heaters.

The following equation is used to calculate the annual kWh savings related to the compressors.

$$\text{Annual kWh}_{\text{compressor}} = \left[(\text{Amps}) \times (\text{Volts}) \times (\text{PF}) \times (\sqrt{3}) \times (1 \text{ kW/1,000 watts})\right] \times \text{Operating Hours}$$

The amp readings were taken using a RCC 305 digital clamp meter. Nameplate voltage information is used. A power factor (PF) of 0.8 was assumed. Operating hours were taken from recorded EMS data, where compressors appear to run for about 24 to 30 minutes during each hour, with 40 minutes each day for defrost. Prior to the retrofit, the facility representative indicated that the compressors ran 20 hours a day, with four hours of defrost. The kWh savings are calculated by taking the difference between $\text{Annual\_kWh}_{\text{compressor\_pre-retrofit}}$ and $\text{Annual\_kWh}_{\text{compressor\_post-retrofit}}$. Total savings are summed for all four compressors.

Table 6: Annual kWh Savings on Each Compressor Still in Operation (Store #12)

Compressor	Amps	Volts	Op hours (pre-retrofit)	Op hours (post-retrofit)	Annual kWh (pre-retrofit)	Annual kWh (post-retrofit)	Savings kWh/yr
#7	25.6	460	7,300	3,358	77,380	24,776	52,604
#8	27.5	460	7,300	3,358	77,380	26,615	50,765
#9	27.8	460	7,300	3,358	77,380	26,905	50,475
#10	28.2	460	7,300	3,358	77,380	27,293	50,087
				TOTAL	309,520	105,589	203,931

As shown in Table 6, for Store #12, the average kWh/yr consumed in the pre-retrofit period by the each of the four compressors is estimated to be 77,380. Based on the on-site observations, the two retired compressors are assumed to be similar to those currently in use. Therefore, estimated energy savings related to shutting down two compressors is equal to 154,760 kWh/yr (77,380 x 2).

The new glass door freezer cases in each store visited had 102 T8 lamps in total. According to the facility representative, the old open cases had T12 lamps. For the purposes of this analysis, the pre-retrofit equipment is assumed to use the same number of lamps. According to the SPC Handbook (Appendix B, 2006 Table of Standard Fixture Wattages), the following wattages are assumed for high output fluorescent fixtures:

- 1-lamp T12 fixture = 85 Watt (SPC Fixture Code F41 SHS)
- 1-lamp T8 fixture = 36 Watt (SPC Fixture Code F41 ILL-H)

Total savings are estimated as (85 – 36 Watts/fixture) x 102 fixtures x 8,760 hrs/year x (1 kW/1000 W) = 43,782 kWh/year saved.

The following equation is used to calculate what the increased load is due to the anti-sweat door heaters. The anti-sweat door heaters are programmed to be all on (100%) at relative humidity of 65% and all off (0%) at 25% relative humidity. Between 25% and 65% the heaters cycle on and off several times a minute in proportion to the level of humidity in the store. For example, at 45% relative humidity, the heaters cycle on half the time, since this is half way between 25% and 65%. Hourly humidity data for the typical meteorological year (TMY) for Climate Zone 10 was used to approximate the humidity levels in the stores. This resulted in expected annual operating hours for the anti-sweat door heaters of 4,333 hrs/year in each store.

$$\text{Annual kWh}_{\text{Anti-sweats}} = \left[(\text{Amps}) \times (\text{Volts}) \times (1\text{kW}/1{,}000\ \text{Watts})\right] \times \text{Operating Hours}$$

The current (amps) on each of the 17 channels in Store #12 was measured and summed to 97.9 amps total. The seventeen channels were confirmed to align with the glass doors on the new freezer cases. A voltage of 120 V is used. The results of this calculation yield an increase in use of 50,908 kWh/year due to the anti-sweat door heaters.

Table 7 summarizes the back up calculations estimate of annual kWh savings in each store. The results are roughly consistent with the billing analysis.

Table 7: Summary Of Bottom-Up Calculations For Savings (Store #12)

Measure	**Annual kWh savings**
Reduced operating hours on compressors	203,931
Shut down two compressors	154,760
T12 to T8 change in cases	43,782
Anti-sweat heaters in new cases	-50,908
TOTAL for one store	351,565

The back-up calculations result in estimated savings totaling 1,406,260 kWh/year for the four stores, which is within 15% of the billing analysis savings of 1,639,066 kWh/year. Therefore, the billing analysis results will be used as the ex post savings values.

6. Additional Evaluation Findings

The ex post kW demand and annual kWh savings is greater than the ex ante estimates, mostly because the ex ante estimate did not include the reduction in post-retrofit compressor operating hours from 20 hours a day to approximately 12 hours a day. Furthermore, the pre-retrofit kW consumption by the compressors may have been under-estimated in the ex ante calculation.

Table 8: Summary Of Key Uncertainties In Ex Post Calculations

Uncertainties	Possible solutions
Sampling only 3 out of 4 stores	Visit all four stores and take measurements
Pre-retrofit conditions (e.g. kW of base case compressors, and exact T12 fixture type)	Better documentation from pre-installation reports, including spot readings of base case equipment

The facility representative stated that the cost estimate provided in the application is from the price quotes provided by Hussman and estimated cost of labor, including electrician and other contractors. The estimate is perceived to be accurate; but may in fact be high. In addition to saving energy, the benefits of the project are improved sales related to frozen foods. The facility representative indicated the improved comfort level for store customers has led to this increase in sales. The customer does not anticipate any changes in operation that will affect energy consumption in the foreseeable future.

The customer's participation in the 2004/2005 SPC Program has encouraged them to perform other energy efficiency projects. They are now planning installations of VFDs for air handler units, additional T12 to T8 lighting retrofits, and energy efficient motors. They will be participating in Express Efficiency, SPC and Savings by Design programs for some measures, and other measures they plan to do without utility incentives.

With a cost of $1,600,000 for new freezer cases for all four stores, and an incentive of $129,453.52, the project had a 12.2 year simple payback based on ex ante calculations. Using the ex post savings results for the project, the estimated payback is 6.9 years, including the incentive. The source of the project cost was from the facility representative, and includes both in-house and contractor labor.

7. Impact Results

Table 9: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, Therms	Estimated Annual Cost Savings	SPC Incentive, $	Simple Payback w/ Incentive	Simple Payback w/o Incentive
Installation Approved Amount (Ex Ante)	2/2/2004	$1,600,000	105.6	924,668	0	$120,207	$129,453.52	12.2	13.3
SPC Program Review (Ex Post)	10/10/2007	$1,600,000	187.1	1,639,066	0	$213,079	$129,453.52	6.9	7.5

Table 10: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	105.6	924,668	0
SPC Installation Report (ex ante)	105.6	924,668	0
Impact Evaluation (ex post)	187.1	1,639,066	0
Engineering Realization Rate	1.77	1.77	n/a

Table 11: Installation Verification Summary

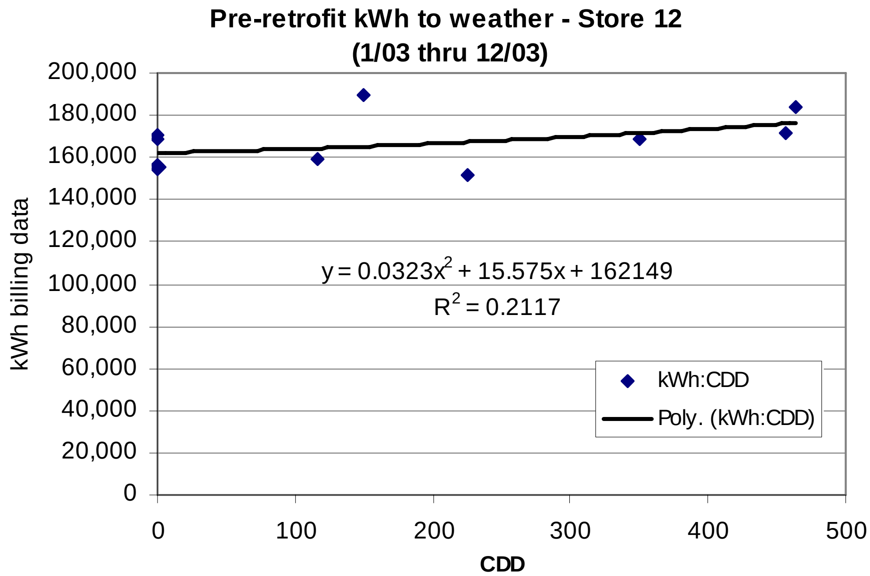
Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified	Verification Realization Rate
RIFF glass door installation	AC&R	Replace open multi-deck and coffin style cases with glass door freezer cases (4 stores)			96 doors at each store	Hussman freezer cases (30 inch doors) RL-4, RL-2, RLN-5, RLN-4 and RLNI-5	Physically verified installation at three stores and spot metered electricity use	1.00

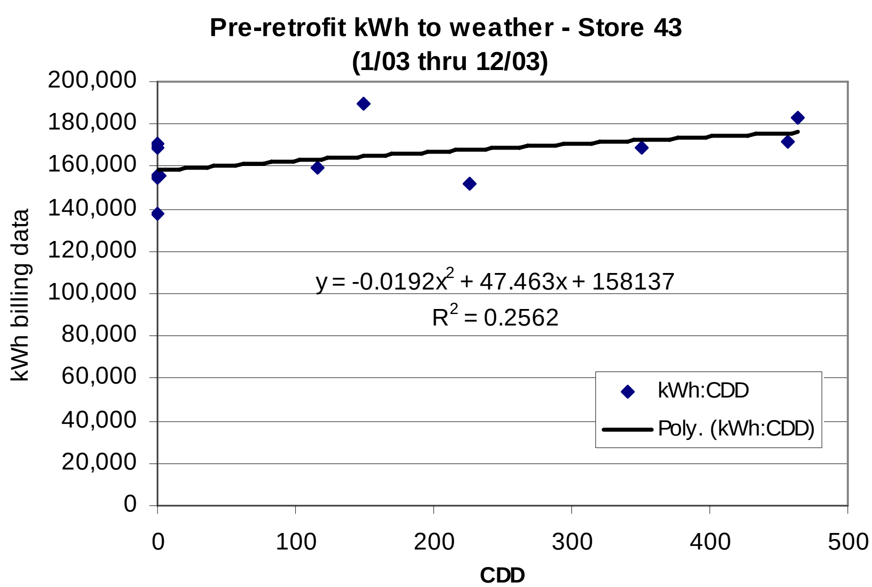
Table 12: Multi Year Savings Table

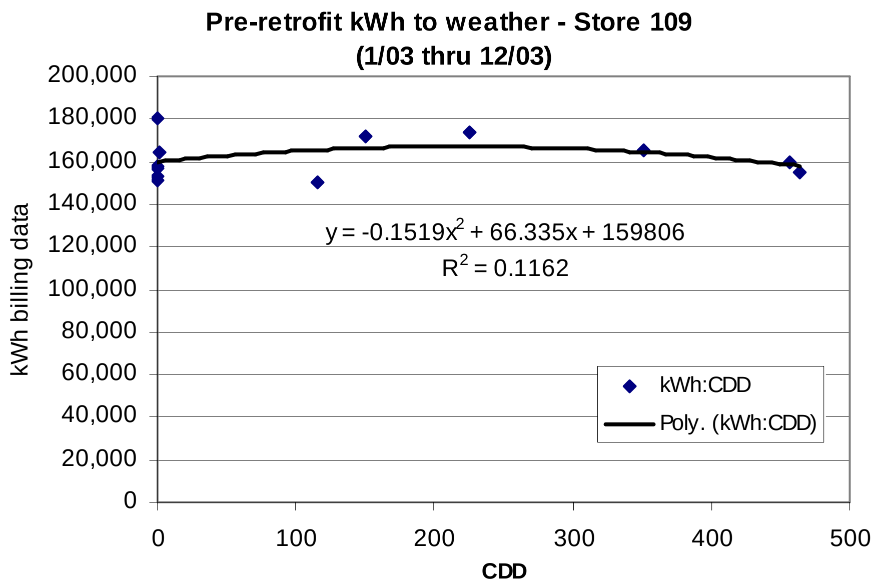
Program Name:		SPC 04-05 Evaluation Site A074					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	616,445	1,092,711	105.6	187.1		
2	2005	924,668	1,639,066	105.6	187.1		
3	2006	924,668	1,639,066	105.6	187.1		
4	2007	924,668	1,639,066	105.6	187.1		
5	2008	924,668	1,639,066	105.6	187.1		
6	2009	924,668	1,639,066	105.6	187.1		
7	2010	924,668	1,639,066	105.6	187.1		
8	2011	924,668	1,639,066	105.6	187.1		
9	2012	924,668	1,639,066	105.6	187.1		
10	2013	924,668	1,639,066	105.6	187.1		
11	2014	924,668	1,639,066	105.6	187.1		
12	2015	924,668	1,639,066	105.6	187.1		
13	2016	924,668	1,639,066	105.6	187.1		
14	2017	924,668	1,639,066	105.6	187.1		
15	2018	924,668	1,639,066	105.6	187.1		
16	2019	924,668	1,639,066	105.6	187.1		
17	2020	308,223	546,355				
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	14,794,688	26,225,056				

APPENDIX A

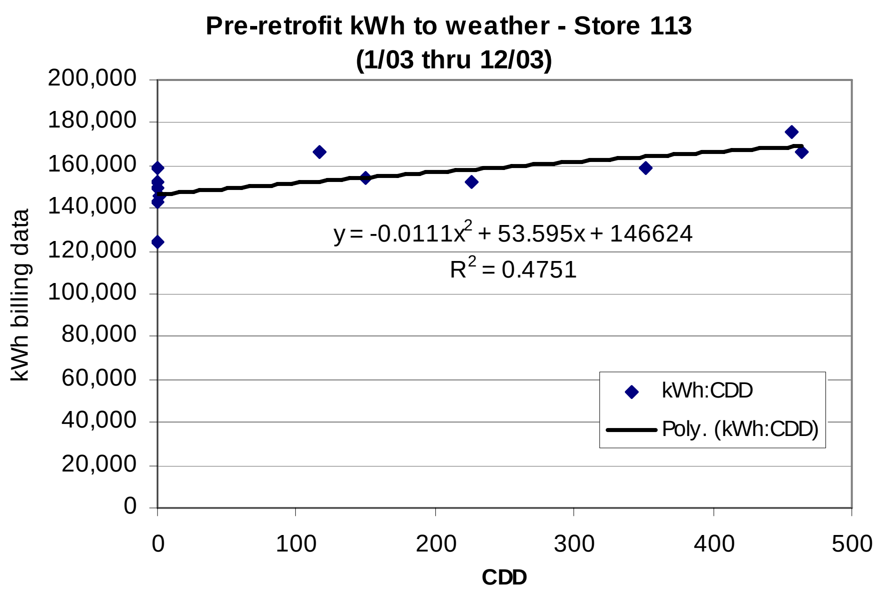
The following graphs show billing data and dry bulb cooling degree days. A polynomial trend line fit was applied to each data set for four stores. None of the stores demonstrated a relationship between kWh consumption and CDD, as all R-squared values were far less than 0.90.







Pre-retrofit kWh to weather - Store 109
(1/03 thru 12/03)
kWh billing data
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
y = -0.1519x2 + 66.335x + 159806
R2 = 0.1162
kWh:CDD
Poly. (kWh:CDD)
0
100
200
300
400
500
CDD



Pre-retrofit kWh to weather - Store 113
(1/03 thru 12/03)
kWh billing data
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
y = -0.0111x2 + 53.595x + 146624
R2 = 0.4751
kWh:CDD
Poly. (kWh:CDD)
0
100
200
300
400
500
CDD

Final Report

A075 SITE (2K4SCE158) Hart IMPACT EVALUATION
SAMPLE CELL: ORIGINAL   TIER: 5   END USE: Other

Measure	Cool Roof
Site Description	Warehouse / Printing and Distribution Center

1. Measure Description

Install 73,780 square feet of cool roof reflective white coating.

2. Summary of the Ex Ante Calculations

The kWh savings were determined using the SPC Itemized Measure Application Form. The incentive was set at $0.10 per square foot of eligible roof coated with eligible roofing product.

The total ex ante savings are recorded as 36,890 kWh/year and 22.1 kW in the Installation Report Review.

The ex ante calculations for itemized measures are typically based on the Express Efficiency workpapers. For cool roofs, the SCE workpapers state that the savings estimated for this measure is 0.5 kWh per square foot per year based on the savings value of 0.31 kWh per year for climate zones 2-15 (the LBNL study for new construction cited the 0.31 kWh per year figure multiplied by a factor of 1.6 to account for the additional savings expected in retrofit situations). The kW savings figure of 0.0003 per square foot has been taken from the LBNL work and this figure was also multiplied by 1.6 to account for retrofit construction.

3. Comments on the Ex Ante Calculations

The total savings in the Installation Report Review were recorded as 36,890 kWh/year and 22.1 kW; these figures agree with the utility tracking system, allowing for rounding functions.

The area was changed from 55,185 sf in the original application to 73,780 sf, in the Installation Report Review because the installation reviewer determined that a 22,000 sf area that had previously been excluded because it was thought to be over unconditioned space should be included since the space under it was not separated from adjacent conditioned areas, and was indirectly cooled by the air conditioners for those areas.

Summer peak kW impacts are expected to be low, based on the relatively low heat load reductions and the intermittent cycling nature of the packaged air conditioning equipment in place at the facility.

The Express Efficiency workpapers that are the basis of the ex ante calculations appear to be based solely on the LBNL study for new construction and an estimated increase of 1.6 when applying to retrofit situations. No documentation was provided and the savings figures may be based on empirical results.

The kWh and kW figures do not appear to be grossly understated or overstated based upon experience with similar projects.

4. Measurement & Verification Plan

The facility has one building, and the entire roof is coated with the cool roofing material.

The measure saves energy by increasing roof reflectivity, and limits heat buildup in the roof and heat transmission through the roofing materials to interior spaces.

The measure was itemized under the 2004 SPC program and the savings were based on the workpapers.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful life of the measure.

Formulae and Approach

A modified version of IPMVP Option A can be utilized, incorporating the SPC calculator. Some parameters, such as pre-retrofit roof surface characteristics and HVAC equipment efficiency, will be stipulated according to manufacturers' data.

The condition of the roof will be inspected to allow for wear. The square footage will be determined accurately from the drawings and skylight areas and rooftop equipment areas/penthouses will be deducted. Any shading from adjacent structures or landscaping will be noted. Additionally, the conditioned area will be determined.

The 2005 SPC calculator will be used to calculate the savings with the measured and stipulated variables. The inputs to the model used in the SPC calculator are the location of the building, solar reflectance (SR), infrared emittance (IE), roof insulation value (R), air conditioner efficiency, and roof area. The solar reflectance of the new roof may be measured with an albedometer. The parameters that have the most effect on the savings are the roof R value, the solar reflectance, and the roof area. The focus will be on determining these variables accurately for the pre and post retrofit situations.

The SPC calculator cool roof calculation code was examined to ascertain the approach used. The calculations all involve polynomial equations of the second or third order which appear to be fitted to empirical data. There are no notes as to the source of the empirical data; a possible sources is the Demonstration of Energy Savings of Cool Roofs project by the Heat Islands Group at Lawrence Berkeley National Lab. (http://eetd.lbl.gov/HeatIsland/PROJECTS/DEMO/)

Thickness of building components for the insulation R value calculation will be measured to the extent possible, and the type of insulation material determined. Building plans will be consulted for roof construction and slope.

The complexity of the building systems and heat transfer variables, along with the magnitude of the savings for this measure preclude the use of a calibrated building model. A calibrated building model constructed for this purpose should take into account many variables, such as reflectivity, emissivity, building configuration, insulation value, and actual cooling equipment efficiencies, and it should be calibrated to actual energy use of the building. An uncalibrated building model is much easier to build since there are many existing building model tools such as DOE2. Such a model may be appropriate here since the magnitude of the total building energy use is less important than the change in energy use due to a specific change in the building.

If a large uncoated area is not available for measurement, the uncertainty associated with the older roof reflectivity introduces a large source of error, also limiting the building model approach. Direct measurements using a pyranometer and other tools to measure the post retrofit reflectivity are possible. However, reflectivity values specified by the manufacturer of the cool roof can also be used. It should be noted that these are typically values for the reflectivity of a new cool roof; weathered values have a lower reflectivity and should be used if available.

Uncertainty for the savings estimate for the retrofit can be more fully understood by setting projected ranges on the primary variables.

<u>For the SPC calculator inputs</u>

- Location = Brea, Orange County, CA (California Climate Zone 8) (+/- 5% for changes in weather due to distance of 20 miles)
- U = 1/R; R = 5.9 for standard roof assembly, default value in E-Quest (+/- 5%)
- Solar Reflectance: pre 0.31, post 0.90 (+/- 40% pre, +/- 10% post due to degredation)
- Infrared Emittance: pre 0.65, post 0.87 (+/-15% pre, and +/- 5% post due to degredation)
- Area = 73,780 sf; + 5%, -30% (based on application paperwork)
- SEER = 10; +/- 20%

Accuracy and Equipment

If necessary, measuring wheels will be used to record roof area.

Standard measurement devices for area and insulation thickness calculation will be made to the nearest 0.5 inch and converted to two decimal places for area calculations. Error is expected to be less than 2%.

Roof Surface Albedometer if used: spectral range: 305 - 2800 nm, resolution: 1 W/m2, accuracy +/- 5% estimated.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The entire roof surface of this production/warehouse facility was coated with Sunwhite Elastomeric Roof Coating, classified as a cool roof product because of its high reflectivity (>90%, Cool Roof Rating Council, CRRC) and high emissivity (0.87). This product will decrease the heat gain to the area under the roof. The on-site survey was conducted on August 8, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the roof and as built building plans and by interviewing the facility representative.

Installation Verification

It was physically verified that 73,876 square feet of roof coating was applied at the facility. The area was verified by consulting building plans and the roof coating was verified by inspection. The exterior roof is built-up asphalt roofing that has been covered with the cool roof coating. The retrofit was completed in July 2004.

The cool roof retrofit is the only measure in this application. The verification realization rate for this project is 1.00 (73,876 / 73,780). A verification summary is shown in Table 9.

Scope of the Impact Assessment

The impact assessment scope is for the cool roof end use measures in the SPC application covering the application of the acrylic cool roof coating. This is the only measure in this application.

Summary of Results

In 2004, when this project was submitted to SPC, all cool roof measures were itemized, and savings were calculated based on the workpapers. In 2005, a cool roof measure was included in the SPC calculator. The 2005 SPC calculator is the modeling tool that is used to calculate the ex post savings for this site. As a check on the SPC calculator tool, savings are also calculated using e-Quest/DOE 2.2, and the result is compared to the result from the SPC Calculator. e-Quest/DOE 2.2 has the limitation, however, that it does not model changes in infrared emittance. For many applications, this is acceptable because a black asphalt roof and cool roof products have high infrared emittance, usually about 90%. However, at this site, the pre-existing roof was not black asphalt and the model selected should allow for changes in emittance.

The interview with the facility representative revealed that the roof existing before the application of the cool roof was a built up asphalt roof installed in 1980 with an aluminum spray coating that had been applied in 1992. Since the time that the spray was applied, the roof had been patched in many places with Henry's Wet Patch, a black roof patching product. The solar reflectivity and infrared emittance values for the aluminum coating and the black patching material were determined from the default values given in the SPC calculator. They are given in Table 1. It was estimated that 25% of the roof surface was covered with black patching material just before the application of the cool roof, based on customer inputs. A weighted average of the solar reflectivity and infrared emittance was used for the baseline input values. The manufacturer's data sheet for the cool roof product, "Ultra White Elastomeric Roof Coating," provided a reflectivity value of 90% (tested according to ASTM C-523) and an emissivity of 87%. The absorptivity (of the incident solar radiation) is an input needed for the E-Quest/DOE 2.2 model. It is calculated as one minus the solar reflectivity (since all the incident radiation is either reflected or absorbed, and no solar radiation is transmitted).

Table 1: Physical Characteristics of Roofing Materials

	Aluminum coating, average SR	Black asphalt	Weighted average (0.25 black, 0.75 aluminum)	Cool roof
Solar Reflectivity	0.39	0.05	0.305	0.90
Infrared Emittance	0.56	0.90	0.645	0.87
Absorptivity	0.61	0.95	0.695	0.10

The roof area was determined by taking building dimensions from the "as built" plans to calculate gross floor area, and then subtracting the area for the skylights and HVAC equipment that were counted on the roof. The calculated roof area, 73,876 square feet, is very close to the ex ante roof area of 73,780 square feet.

The model numbers of the HVAC equipment were recorded at the site visit, and were queried in the ARI Unitary Directory. Many could not be found, but the two that were had a SEER of 10 and 13. A SEER value of 10 is used in the calculation because this is the most commonly used default value. This will yield higher savings than if newer equipment with higher SEER is assumed.

The roof was observed to have no insulation, but it did have a radiant barrier. This should have disqualified the project from the program, according to the 2004 SPC Program Guidelines. The existence of the radiant barrier decreases the savings from the cool roof, however there is very little literature available to quantify the savings reduction. Hashem Akbari of the Lawrence Berkeley National Laboratory Heat Islands Group stated (personal communication 10/5/07) that he had used Micropass to analyze the effect of radiant barriers in residential applications on cool roof performance, and had found that they could degrade the savings by up to 50%. The SPC calculator does not take account of any radiant barrier effects on savings since these buildings are normally excluded from the program. The ex post savings calculations exclude the effect of the radiant barrier.

The roof R-value used in the ex post savings calculation (5.9 BTU/ft^2 °F) is the default value for a built up roof in the e-Quest/DOE-2 model to allow comparison of that model with the SPC calculator. A similar value (5 BTU/ft^2 °F) is suggested in the SPC calculator for un-insulated roofs. The input and output values used in and generated by the SPC Calculator for this cool roof are shown in Table 2.

Table 2: Results of SPC Calculator, Baseline Aluminum Coating with 25% Black Patching

SPC Calculator - aluminum coating with 25% black patching		
	Baseline	Cool Roof
Solar Reflectance	0.31	0.9
Solar Absorptance	0.69	0.1
Infrared Emmittance	0.65	0.87
SEER	10	10
R-value	5.9	5.9
Net Roof Area	73,876	73,876
CA Climate Zone	8	8
Roof Component Space Cooling (kWh)	88,267	15,813
Savings (kWh)	72,454	

The savings calculated with the 2005 SPC Calculator (72,545 kWh/year) are 96% larger than those determined by the itemized method in 2004 (36,890 kWh/year).

The uncertainty at this site lies predominantly in the determination of the pre-retrofit solar reflectivity and infrared emittance values, as well as in the effect of the radiant barrier. The range of values given in the SPC Calculator for an aluminum roof varies from 0.26 to 0.50 for solar reflectivity and from 0.52 to 0.68 for infrared emittance. There is also uncertainty around the percent of roof that was covered with black patching material, which has very different solar properties. The percent of patching could have been as low as 10% or as high as 30%. Parametric analysis was used to calculate the uncertainty in the kWh savings from the uncertainty in baseline SR, IE and % roof patching; the post retrofit cool roof values were held constant in this analysis. Table 1 shows the energy savings for the expected values, and the lower and upper bounds. The results are shown in Table 3.

Table 3: Uncertainty in Baseline Input Variables

	high	expected	minimum
SR	0.46	0.31	0.2
IE	0.75	0.65	0.56
kWh	52,773	72,454	87,335
percent change	-27%		21%

The savings determined with the SPC calculator were compared to e-Quest/DOE-2.2 to see how well the two models compare. Since it is not possible to change the infrared emittance in the e-Quest/DOE-2.2 model, this variable was held constant at 0.87 in the SPC calculator, reducing the savings to 63,525 kWh. The e-Quest/DOE-2.2 model inputs and results are shown in Table 4; the savings are 3% lower than those calculated using the SPC calculator. The savings calculated with e-Quest support the SPC calculator model and hence, do not support the savings stipulated in the workpapers (36,890 kWh), which are 49% lower than those determined using the SPC Calculator.

Table 4: Results of E-Quest/DOE 2.2 model

E-Quest/DOE 2.2 Model		
	Baseline	Cool Roof
Solar Reflectance	0.31	0.9
Solar Absorptance	0.69	0.1
SEER	10	10
R-value	5.9	5.9
Net Roof Area	73,789	73,789
CA Climate Zone	8	8
Space Cooling (MBTU)	397	173
Space Cooling (kWh)	116,320	50,659
Savings (kWh)	65,661	
With Radiant Barrier		
Space Cooling (MBTU)	374	243
Space Cooling (kWh)	109,581	71,198
Savings (kWh)	38,383	

In e-Quest it was possible to model the roof with and without an interior radiant barrier, the results are shown in Table 4. The interior radiant barrier yielded some savings in the baseline case, but in the case of the cool roof, energy use is higher when there is an interior radiant barrier in addition to the cool roof. When the internally generated cooling load is higher than the externally generated load (as can be the case in California, particularly when a cool roof reduces the external load) additional insulation (or a radiant barrier) will increase the load on the air conditioner because the internally generated heat is not allowed to escape. Based on available information, cool roof savings seem to be significantly reduced when there is a radiant barrier in place.

Table 5 summarizes the total metered use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers. The baseline use is calculated as 30% of the total electricity use for the facility; the percent dedicated to other uses assumes 40% for lighting and 30% for air conditioning. There are no results for peak period kW demand savings because the SPC calculator does not calculate these savings due to the cycling nature of the AC equipment.

Table 6 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results show energy savings ranging from 0.9% to 2.9%. The ex post results for the cool roof show larger savings ranging from 1.7% to 5.7%. The very small overall savings are believed to be realistic due to small savings expected from a cool roof.

Table 5: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	930	4,238,926
Baseline End Use	279.0	1,271,678
Ex ante Savings	22.13	36,890
Ex Post Savings	0.0	72,454

Table 6: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	2.4%	0.9%	0.0%	1.7%
Baseline End Use %	7.9%	2.9%	0.0%	5.7%

6. Additional Evaluation Findings

The occupants find that the building is noticeably cooler after the installation of the cool roof. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. Participation in the 2004/2005 SPC Program has possibly encouraged them to perform other energy efficiency projects. They are considering the possibility of a lighting retrofit through the SPC or other incentive programs.

Installation costs appear to be realistic.

7. Impact Results

The pre-retrofit roof type was unable to physically verified. However, the facility representative was very knowledgeable about the pre-existing roof, and was able to characterize its characteristics sufficiently for the needed analysis. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $41,962 and a $7,396 incentive, the project had a 7.21 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante (assuming that there was no radiant barrier), and the estimated simple payback is 3.67 years. A summary of the economic parameters for the project is shown in Table 7.

Table 7: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	11/19/2004	$41,962	22.1	36,890	0	$4,796	$7,378	7.21	8.75
SPC Program Review (Ex Post)	8/8/2007	$41,962	-	72,454	0	$9,419	$7,378	3.67	4.46

The engineering realization rate for this application is 1.96 for energy savings kWh, again assuming there is no radiant barrier on the interior roof surface. The presence of the radiant barrier should have been identified and noticed in the inspection this site: the measure likely would have been disqualified from the SPC program pursuant to program guidelines.

According to the installation report, the ex ante savings are 36,890 kWh annually and demand reduction is 22.1 kW. Demand reduction is not calculated in the ex post savings because of the cycling nature of air conditioning equipment. A summary of the realization rate is shown in Table 8.

The Installation Verification Summary is shown in Table 9 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 10.

Table 8: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	22.1	36,890	-
SPC Installation Report (ex ante)	22.1	36,890	-
Impact Evaluation (ex post)	-	72,454	-
Engineering Realization Rate	0.00	1.96	NA

Table 9: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
H-F1 COOL ROOF	2-H	Installation of a Cool Roof under the H-F1 intemized measure			73,876 ft^2	Cool Roof	Physically verified cool roof type and area.	1.00

Table 10: Multi Year Reporting Table

Program ID Program Name		SPC 2004 Application # A075 2004 – 2005 SPC Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	12,297	30,189	22.1			
3	2006	36,890	72,454	22.1			
4	2007	36,890	72,454	22.1			
5	2008	36,890	72,454	22.1			
6	2009	36,890	72,454	22.1			
7	2010	36,890	72,454	22.1			
8	2011	36,890	72,454	22.1			
9	2012	36,890	72,454	22.1			
10	2013	36,890	72,454	22.1			
11	2014	36,890	72,454	22.1			
12	2015	36,890	72,454	22.1			
13	2016	36,890	72,454	22.1			
14	2017	36,890	72,454	22.1			
15	2018	36,890	72,454	22.1			
16	2019	36,890	72,454	22.1			
17	2020	24,593	48,303				
18	2021						
19	2022						
20	2023						
TOT	**2004-2023**	553,350	1,092,848				

15 year measure lifetime

Final Report

SITE A076 (24SCE605) Ros IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 1 END USE: Lighting

Measure	High Bay T5 Lighting Retrofit / Occupancy Sensors
Site Description	Warehouse

1. Measure Description

Replace 1800 high pressure sodium fixtures using 400 watt lamps with 1800 four lamp high output (HO) T5 fluorescent fixtures, install 428 fixture mounted occupancy sensors to reduce lighting hours of operation, replace 515 metal halide fixtures using 1,000 watts with 400 watt pulse start metal halide fixtures, and replace 36 metal halide fixtures using 1,000 watt lamps with 36 eight lamp T5 HO fluorescent fixtures.

2. Summary of the Ex Ante Calculations

The original application was submitted as a Standard Performance Contract 2004 application. The customer used the Itemized Measure Form to calculate the kWh savings for the four lamp fluorescent fixtures using T5 HO lamps and for the occupancy sensors. The basis of the incentive payment for these measures was the itemized incentive list. The replacement of 551 metal halide fixtures using 1000 watt lamps was listed as a calculated measure with details of the calculations listed in the SPC application paperwork. Total savings were estimated to be 898.2 kW and 4,778,844.9 kWh.

These savings are also listed in the Installation Report Review, Summary of Approved Measures. This sheet contains four measures, two in the calculated section and two in the itemized section. In general, the savings figures in the final Installation Report (IR) would be expected to be identical to the utility tracking system savings figures. The only difference between the IRR and the utility tracking system are the number of significant digits and the combination of the two calculated measures into one measure in the tracking system, producing only three measures listed in the tracking system

The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. These workpapers note that a conversion from metal halide fixtures to high output (HO) T5 fixtures results in a wattage reduction from 0.458 kW to 0.234 kW, for a non-coincident peak reduction of 0.224 kW. Coincident peak reduction is noted as 0.205 kW and kWh savings are noted as 843 kWh/year. The hours of operation for a warehouse are fixed in the workpapers at 3,550 hours/year. The workpapers note a diversity factor of 84% for a warehouse.

For ceiling mounted occupancy sensors, the savings are based on the control of eight (8) fluorescent T12 fixtures, consuming 72 watts each, in an office conference room. Savings are based on a reduction from 2,210 hours/year to 1,040 hours/year (1,170 hours/year reduction). The workpaper reports 789 kWh savings (674 kWh/year plus a 17% office sector demand interactive effects factor). The non-coincident peak reduction of 0.305 kW was derived from the 0.576 kW controlled wattage and a 53% reduction in hours. Coincident peak reduction in the workpaper was noted to be 0.381, which included a 1.25 demand sector interactive effects factor.

3. Comments on the Ex Ante Calculations

The ex ante calculations in the Installation Report Review area based on the workpapers for the itemized measures. Details of the calculated measures are shown in the application paperwork.

The ex ante savings figures can be checked for reasonableness using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x (1 – diversity factor)

Four measures are considered: conversion to four lamp T5 fluorescent fixtures from 400 watt metal halide fixtures, installation of motion sensors on the aisle fixtures, conversion from 1000 watt metal halide fixtures to eight lamp T5 fluorescent fixtures and conversion from 1000 watt metal halide fixtures to 400 watt pulse start metal halide fixtures. The check calculations for the main measures were performed as follows:

- Pre-retrofit hours of operation: 7,008 hrs/yr
  Pre-retrofit wattage: 0.458 kW per fixture x 1800 lamps = 824.4 kW
  Pre-retrofit wattage: 1.08 kW per fixture x 551 lamps = 595 kW
  Annual kWh usage: (824.4 + 595) kW x 7,008 hrs/yr = 9,947,716 kWh/yr
- Post-retrofit hours of operation for fixtures: 7,008 hrs/yr
  Post-retrofit wattage: 0.234 kW per fixture x 1800 lamps = 421.2 kW
  Post-retrofit wattage: 0.468 kW per fixture x 36 lamps = 17 kW
  Post-retrofit wattage: 0.415 kW per fixture x 515 lamps = 214 kW
  Annual kWh usage: (421.2+17+214) kW x 7,008 hrs/yr = 4,567,625 kWh/yr
- Fixture savings = 5,380,091 kWh/yr, 13% higher than the 4,778,845 kWh/yr listed in the Installation Report Review (IRR).
- Occupancy sensor savings (based on a 47% usage factor):
  Reduced hours of operation: 8,760 hrs/yr x (1 -0.47) = 4,643 hrs/yr
  Annual kWh saved: 100.2 kW x 4,643 hrs/yr = 464,986 kWh/yr, slightly lower than the 611,580 kWh/yr in the IRR.
- The resulting annual kWh savings = 5,845,076 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load.

Summer peak demand reduction is calculated as follows:

- Reduction in connected load plus reduction in load due to motion sensor use:
  Reduction in connected load: (0.458 kW – 0.234 kW) x 1800 = 403.2 kW (exactly the same as the IRR)
  Reduction in connected load: (1.08 kW – 0.468 kW) x 36 = 22 kW (exactly the same as the IRR)
  Reduction in connected load: (1.08 kW – 0.415 kW) x 515 = 342 kW (exactly the same as the IRR)
  Reduced load due to motion sensors: 0.234 kW x 428 fixtures x (1-.84) = 16 kW (lower than the 130.5 kW listed in the IRR, due to the lower post retrofit controlled wattage)

These calculations are based upon hourly use figures obtained from the Application Review Comments in the SPC Project Application Review. These hours are higher than the average stated in the workpapers for warehouse operations, and kWh savings are thus expected to be higher for the T5 fixtures replacement measures. The controlled wattage in the workpapers is higher than the actual controlled wattage for the motion sensor measure therefore the actual demand and energy savings are expected to be lower than reported in the IRR for the motion sensor measure.

4. Measurement & Verification Plan

The building is a single level 1,400,000 square foot warehouse used for clothing distribution and was reportedly two years old in 2004. The building has minimal windows, but many skylights. The building is occupied 21.5 hours a day, five days per week, and also 21.5 hours on Saturdays as required. The maintenance crew of 5-6 people occupies the building from 5am to 2:30am Saturday and Sunday for scheduled building maintenance. According to the application, before the retrofit there were eighteen hundred (1800) metal halide fixtures using 400-watt lamps. After the retrofit, there are eighteen hundred (1800) four-lamp T-5 fluorescent fixtures, approximately one quarter of which is controlled by fixture mounted occupancy sensors in the rack aisles. The post retrofit fixtures in the staging area and the open areas are controlled by an existing EMS that uses daylight harvesting to reduce light levels when natural light is available (as were the pre retrofit fixtures). The project saves energy through the installation of lighting fixtures with a lower connected wattage and through the control of the lighting fixtures with occupancy sensors.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

IPMVP Option C approach should be considered. The savings reported in the utility tracking system is approximately 20% – 30% of the kW and kWh consumed based upon the pre-retrofit building use (peak demand is approximately 3500 kW and annual energy use approximates 19,200,000 kWh per year according to the utility billing records). Utility billing and interval data should support this approach if there are no other significant loads or other significant energy conservation activities which occurred in the months immediately following the retrofit. There is not expected to be significant seasonal variation and several months should be sufficient for comparison; however, a one to two year period would more fully capture actual variations and the persistence of savings. Interval data on a 15 minute basis during the summer months of June to September might be needed to accurately determine summer peak period demand savings since motion sensors are expected to contribute significantly to estimated peak load reduction.

It is noted that there were significant billing fluctuations on a yearly basis that must be investigated. Note that the kW savings also fluctuates during the peak period and therefore coincident demand savings may not be able to be determined through billing analysis. If Option C cannot be used due to changes in the facility or its operation in the time periods immediately before or after the retrofit, then a modified version of IPMVP Option A can be utilized. Lighting loggers would be used to quantify hours of operation, and will be supplemented by records from the EMS. To the extent possible, verification of control strategies, wattages of pre existing fixtures through interviews and inspection of building plans, and the presence of metal halide dimming devices or high low control will be obtained. Wattage and current measurements of new fixtures, both on a spot and trending basis, should be taken to confirm the existing fixture use patterns, if lighting circuits can be isolated.

Lighting loggers would be placed over the rack areas with the new occupancy sensors and over the main warehouse areas over areas which were retrofit with the pulse start metal halide fixtures, as well as in the areas which were retrofit with the fluorescent T5 HO fixtures. These last two areas are the main contributors to the overall kW and kWh savings. A minimum of five sensors in each of these areas should be considered to provide adequate coverage for fixtures affected by day lighting control via the EMS. Alternately, power or current loggers and measurements over a lighting circuit with known quantities and wattages would be used in each area.

Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = $kWh_{pre} - kWh_{post}$

Summer peak demand period savings = average kW demand savings ($kW_{pre} - kW_{post}$) during the hottest periods between 2 pm to 5 pm, Monday to Friday, in June, July, August, September

To estimate the average expected peak demand kW reduction, since this measure is not weather dependent, the average of all reductions during that periods as stated above will be used.

The most significant variables to be qualified is that there were no changes to operation not related to the measure which affect the pre and post retrofit energy usage if Option C is used.

Monthly electric consumption records reveal savings consistent with expected annual decreases. However, significant variations may need to be addressed through regression against appropriate variables (weather, hours, building area, other changes, etc.)

The demand savings were unable to be determined consistently from interval data. Given the use of dimming control via the EMS before and after the retrofit, it its likely that the coincident demand savings is overstated in the application paperwork. During the hours of 2 pm to 5 pm, significant daylighting reductions in both pre and post retrofit power draw are possible. The number of lamps affected by the day lighting control must be identified. Schedules should be verified to the maximum extent possible by the EMS, with trends set up if possible. These figures will be used to adjust pre and post retrofit hours.

No invoices were provided in the application paperwork. The number of fixtures should be verified to eliminate this possible cause for lower peak demand savings.

Priority should be given to pre retrofit wattages, determining that all 1000 watt lamps were replaced, verses a mix of 400 watt lamps and 1000 watt lamps. It should also be determined that all new fluorescent fixtures using T5 HO lamps (which replaced 400 watt metal halide fixtures) use four verses six or eight lamps, and that the replaced lamps used 400 watt verses 250 watt lamps. Interviews, as well as inspection of building plans, as-built drawings, and retrofit documentation, should be used as appropriate.

Uncertainty for the savings estimate for the production facility fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables.

Uncertainty with measurements and calculations

- Number of fixtures: 2,351 expected, +/- 10 %
- Number of hours: 7,008 expected, +15% , - 30% (based on an arbitrary use reduction in the application paperwork)
- kW of fixtures: 1,420 kW pre +/- 30% , 652 kW post +/- 20%
- kW saved: 898 kW expected , +/- 5 % (based on extrapolating to actual hottest day period)
- kW for coincident peak: 798 expected, + 5%, - 70% depending on EMS control

Uncertainty with utility billings (from regression techniques, changes in schedules and other energy use increases / decreases, if Option C is used)

- kWh: 4,778,845 kWh expected, 4,539,903 kWh minimum, 5,017,787 kWh maximum (+/- 5% for additional equipment or energy saving measures)
- kW: 898 kW expected , 853 kW minimum, 943 kW maximum hours (+/- 5% for additional equipment or energy saving measures and based on extrapolating to actual hottest day period)

Accuracy and Equipment

The utility meters capture 15 minute interval data and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Lighting loggers, if employed, would be Dent time of use loggers with a resolution of 1 second. These are deemed to be 100% accurate.

The multi-meter used will be an Amprobe ACD-41PQ with voltage accuracy of +/- 0.5% and resolution to one tenth of a volt, with current accuracy of +/- 1.0% and resolution to one tenth of an ampere.

Annualizing the kW data to the hottest summer period is projected to result in a possible error in the final results of +/- 5 %.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

This comprehensive retrofit of warehouse lighting included one for one fixture replacement throughout the warehouse. The warehouse can be divided into 2 different areas, the ‘hotel’ area used for storing product until it is ready to be distributed, and the distribution area. The hotel area contains approximately 100 aisles. The aisle area is divided by four wider aisles called breezeways, also used for storing product, and a center aisle that runs perpendicular to the aisles and the breezeways. The aisles are lighted by 428 four lamp high output (HO) T5 fluorescent fixtures with individual motion control on each fixture. The breezeways, center aisle and perimeter of the hotel area are lighted by 300 four lamp high output (HO) T5 fluorescent fixtures on daylight harvesting controlled by the EMS. These 728 fixtures were each 400 watt high pressure sodium fixtures before the retrofit. Also within the ‘hotel’ area are a staging area and a shipping area. These areas combined are lighted by 36 eight lamp high output (HO) T5 fluorescent fixtures that are not on daylight harvesting or motion control. These fixtures were 1000 watt metal halide fixtures before the retrofit.

The distribution area consists of the upper mezzanine, lower mezzanine, and an open area. The open area is lighted by 'stadium' fixtures mounted on the wall or on the support poles for the roof. In the upper and lower mezzanine areas 1072 high pressure sodium fixtures using 400 watt lamps were replaced with the same number of four lamp high output (HO) T5 fluorescent fixtures. The 550 fixtures in the upper mezzanine are on daylight harvesting control by the EMS. The 522 fixtures in the lower mezzanine are not on daylight harvesting control because there is no daylight to harvest. The mezzanine was lighted by 400 watt high pressure sodium fixtures before the retrofit. The 515 pole-mounted and wall-mounted metal halide fixtures using 1,000 watts posed a challenge to find a suitable replacement fixture because of their location. After in situ testing of several fixtures, it was decided to replace them with 400 watt pulse start metal halide fixtures. The facility representative noted that there was a reduction in light levels in this area after the retrofit, but he said that the light levels were higher than necessary before the retrofit.

The on-site survey was conducted on August 10, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Lighting fixture quantities and hours of operation were verified.

Installation Verification

It was physically verified that 800 four lamp high output (HO) T5 fluorescent fixtures, 428 fixture mounted occupancy sensors and 515 pulse start metal halide fixtures using 400 watts and 36 eight lamp T5 HO fluorescent fixtures were installed in the facility. The retrofit was completed in the end of July 2005.

There are four measures in this application: replacement of 1000 watt metal halide fixtures with 400 watt pulse start metal halides, replacement of 1000 watt metal halide fixtures with eight lamp high output T5 fixtures, replacement of 400 watt high pressure sodium fixtures with four lamp high output T5 fixtures, and motion sensor installation on a portion of the fixtures. The tracking system combines the first two measures into one line item. The verification realization rate for this project is 1.00 (2351/2351). A verification summary is shown in Table 6.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measure in the SPC application covering the lighting efficiency retrofit. These are the only measures in this application.

Summary of Results

One HOBO data logger and a Dent Elite Pro logger were installed at the facility for 41 days (from August 10, 2007 to September 20, 2007.) The HOBO was installed to record amps on circuit 21 in electrical box H6K using a current transducer on an external channel. This monitored the current draw for twelve four lamp T5 fixtures with occupancy sensors in twelve different aisles of an area used for storage of products. A Dent Elite Pro power meter was installed for the same time period on two electrical circuits in electrical box H7K serving 51 pole mounted pulse start metal halide fixtures. These fixtures are controlled by an EMS with daylight harvesting photocells, although the control system and the photocells are not part of the SPC rebate application. The average on-time of the motion sensor controlled T5's is 14.3%, and the average on-time measured by the Dent Elite Pro is 74%.

Data collected at the facility show that this facility has a lower lighting load during the peak demand period defined as the hottest weekday periods between 2 pm to 5 pm, Monday to Friday, in June, July, August or September. The motion sensor controlled lights have a diversity factor of 12.8% during the peak period and the daylight harvesting lights have a diversity factor of 40.8%. The coincident peak savings reported will be only those savings from the fixture changeouts and from the motion sensors since the EMS was not part of the SPC rebate.

The facility representative stated that the building is occupied 21.5 hours Monday-Friday and occasionally Saturday (between 5:00 am and 2:30 am). The maintenance crew works the same hours (21.5 hours a day) on Saturday and Sunday as well as during the week. The facility operates two shifts of employees, whose numbers vary depending on the need. The facility is closed 6 holidays annually. They also shut the plant when the economy slows and they have fewer products to distribute. The facility was closed one weekday during the monitoring period, and was closed on the day the equipment was removed (a Thursday); however, the lights were on their normal schedule, even though the facility was closed. The facility representative stated that the facility hours of operation did not change before or after the lighting retrofit.

The monitoring of pole-mounted and wall-mounted 'stadium' lights showed that all these lights are on weekdays and Saturdays between 3:30am and 5:00am when the facility is closed. Sunday operation shows reduced light levels during the day. The interview with the facility representative revealed that the maintenance crew works on weekends, turning the lights on in work zones if needed. Pre-retrofit hours are estimated at 24 hours on weekdays and 8.5 hours each weekend day.

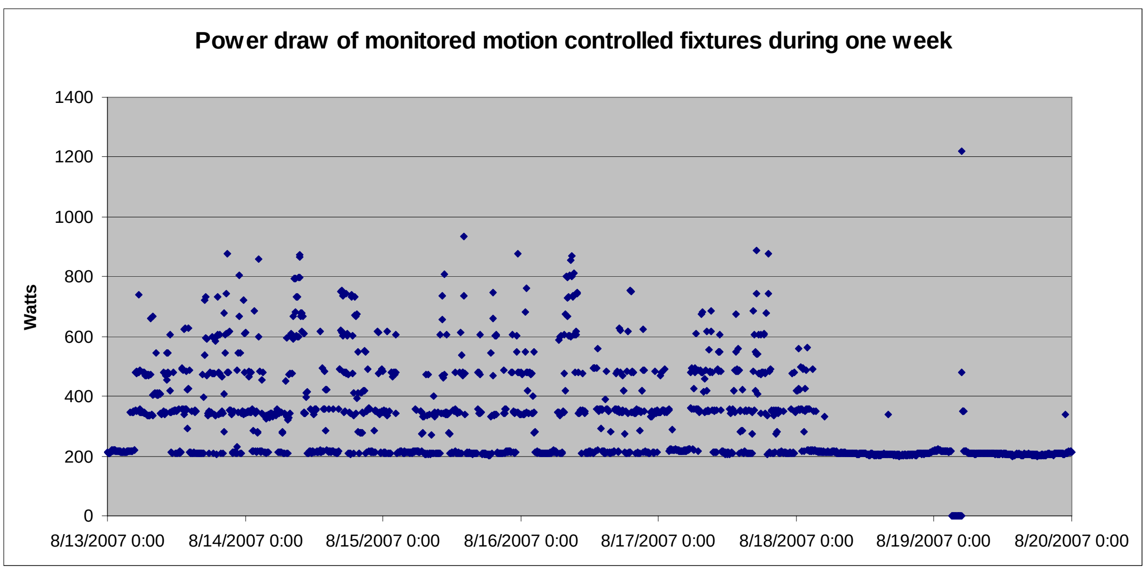
The electricity end-uses at this facility are lighting, forklifts charging, air conditioning, and electric motors for the conveyers. The facility representative confirmed that there was no change in the electricity use patterns before and after the retrofit other than the change to the light fixtures themselves.

Invoices were obtained from the facility representative totaling $1,104,267.14 for the project cost, slightly different from the $1,109,747.00 cost in the Installation Report and tracking system. Invoices were absent from the original application.

Burned out lamps were impossible to spot at the site visit because of the cycling nature of most of the lights. Only two areas contained lights that operated continuously, and very few burnt out lamps were observed in these areas. Four lights were found disconnected on one of the pulse start metal halide circuits that was monitored. The facility representative mentioned that there had been a few burnt out 1000W metal halide lamps before the retrofit since some of those lamps were on during the two year construction period. The lighting retrofit occurred when the building had been in operation only two years. There was no adjustment to the lighting energy consumption pre or post retrofit due to burned out lamps.

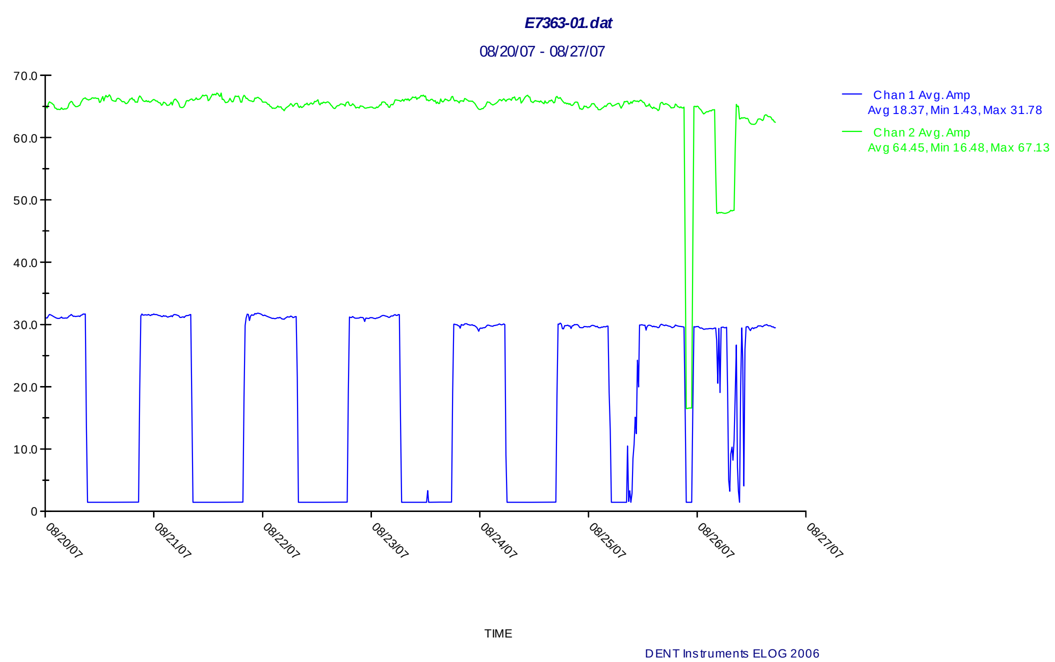
The monitoring of the current for one of the circuits in the 'hotel' area showed some interesting things about the 4L T5 fixtures on motion sensors. Twelve (12) fixtures were on the monitored circuit, each specified to use 203 watts. Each fixture is located in a separate aisle, so they are expected to be activated individually, not in groups, as would be the case if several were located in the same aisle. The graph below shows slightly more than 200 watts drawn continuously indicating that one fixture is always illuminated, perhaps because of a malfunctioning or disabled motion sensor. There is another distinct line at about 350 watts, most likely indicating illumination of a second fixture with one lamp burnt out. There are a few measurements at 300 watts indicating illumination of a second fixture with two lamps burnt out. There are also a few measurements at 406 watts, most likely indicating illumination of two fixtures with all lamps operational. Another horizontal line at 500 watts most likely indicates three fixtures illuminated with two lamps burnt out in the 12 that should be energized. The maximum number of lamps that are energized over this week-long period is 24 lamps out of the total of 48 lamps on this circuit. It may be that there are more than a few burnt out lamps in the hotel area.

Figure 1: Power Calculated from HOBO Logger Data and Spot Voltage Measurements at Site A076



The measurements of the stadium lights are also interesting. Current was monitored on two of the legs of circuit panel H7K serving only the stadium lights. The wire monitored on channel 1 served 20 fixtures. (It had been intended to serve 24 fixtures, but 4 were disconnected at the circuit breaker, presumable for temporary repairs.) The wire monitored on channel 2 served 31 fixtures, 10 of which are designated as security lighting to be always illuminated. The graph in Figure 2 shows one week of data, starting on Monday at 12:00 am and ending the following Monday at 12:00 am. The data from channel 1 shows that the lights come on as a group every evening at 9:30 pm and stay on until 10:00 am the next day. During the day these lights cycle when the photocells indicate to the EMS that more or less light is needed. During this particular week the lights cycled on briefly on Thursday, at the end of the day on Saturday and throughout the day on Sunday. All the monitored lights (except the 10 security lights) cycle off between 3:30 am and 5:00 am Sunday morning. The lights monitored on channel 2 are always on except during the aforementioned period on Sunday and from 10:15 am to 2:45 pm Sunday when 9 fixtures turn off. This pattern is repeated every week.

Figure 2: Amperes Measured with DENT Data Logger on Electrical Box H7K at Site A076



The ex post savings calculations are as follows:

Cut sheets provided by the facility representative provided the basis for the power requirements for each fixture. The wattage of two types of fixtures (the 203 watt fixtures in the hotel area and the 413 watt pulse start metal halide stadium fixtures) was verified with measurements, and both were found to be accurate.

- Pre-retrofit hours of operation: 7,004 hrs/yr (52.18 weeks x 137 hours/week – annual holidays of 144 hours = 7,004 hours)
  Pre-retrofit wattage: 0.458 kW per fixture x 1800 lamps + 1.08 kW per fixture

x 551 lamps = 1419.5 kW
Annual kWh usage: 1419.5 kW x 7,004 hrs/yr = 9,942,697 kWh/yr

- Post-retrofit average on-time of fixtures on motion sensors measured with HOBO logger equates to 1249.2 hours / year (14.3%). The coincident peak diversity factor is 12.8%. Post retrofit on-time for the non-motion sensor fixtures is the same as pre-retrofit on-time since EMS control was not part of the implemented measures under this application.

  Post-retrofit fixture energy use:
  Post-retrofit wattage: 0.234 kW per fixture x 1372 fixtures + 0.203 kW per fixture x 428 fixtures + 0.336 kW per fixture x 36 fixtures + 0.413 kW per fixture x 515 fixtures = 632.7 kW
  Annual kWh usage: 632.7 kW x 7,004 hrs/yr = 4,431,886 kWh/year.

  Motion sensor energy savings: (pre-retrofit usage factor – post retrofit usage factor) x post retrofit connected load x 8760 hours = (0.80-0.143) x 86.9 kW x 8760 = 500,042 kWh.

- The resulting annual kWh savings from the fixtures = 9,942,697 kWh/yr – 4,431,886 kWh/yr + 500,042 kWh/yr = 6,010,853 kWh/yr.

The largest uncertainty at this site is the number of hours that the lights were energized pre-retrofit. A parametric analysis was performed changing only the number of hours in the calculation to determine an upper and lower bound on the energy savings due to the uncertainty of the pre-retrofit hours. The expected value for the hours of operation is 24 hours a day, five days a week and 8.5 hours a day on weekends. The upper bound is 24 hours a day, seven days a week. The lower bound is 21.5 hour a day, six days a week. Table 1 shows the energy and demand savings for the expected number of house, and the lower and upper bounds. The results are shown in Table 1.

Table 1: Uncertainty in Energized Hours

Uncertainty	high	expected	low
hours	8,622	7,004	6,587
kWh	7,423,998	6,010,853	5,646,171
percent change	24%		-6%

Summer peak impacts for the fixture retrofit were estimated by subtracting post-retrofit connected load from pre-retrofit connected load. 1419.5 kW- 632.7 kW = **786.8** kW. Summer peak impacts of the motion sensors were estimated by subtracting post-retrofit from pre-retrofit diversity factor and multiplying by connected load. The HOBO logger showed that between the hours of 2 and 5 pm on weekdays, approximately 12.8% of the lights are on (see Figure 1). Before the retrofit, the lights were always on during the summer peak period. Summer peak demand savings = (1.0 - 0.128) x 86.9 kW = **75.8 kW**.

The ex post savings for the HID retrofits with the motion sensor control were not calculated using actual billing data because the large air conditioning load would require a weather dependent analysis which may yield less accurate results. The average daily energy use is plotted for each month for a qualitative assessment of the energy savings. The retrofit was performed in March through July of 2005. The peak summer load occurs in July or August, and the plot in Figure 3 shows that the peak was reduced by approximately 10,000 kWh per day after the retrofit.

Figure 3: Daily kWh Consumption

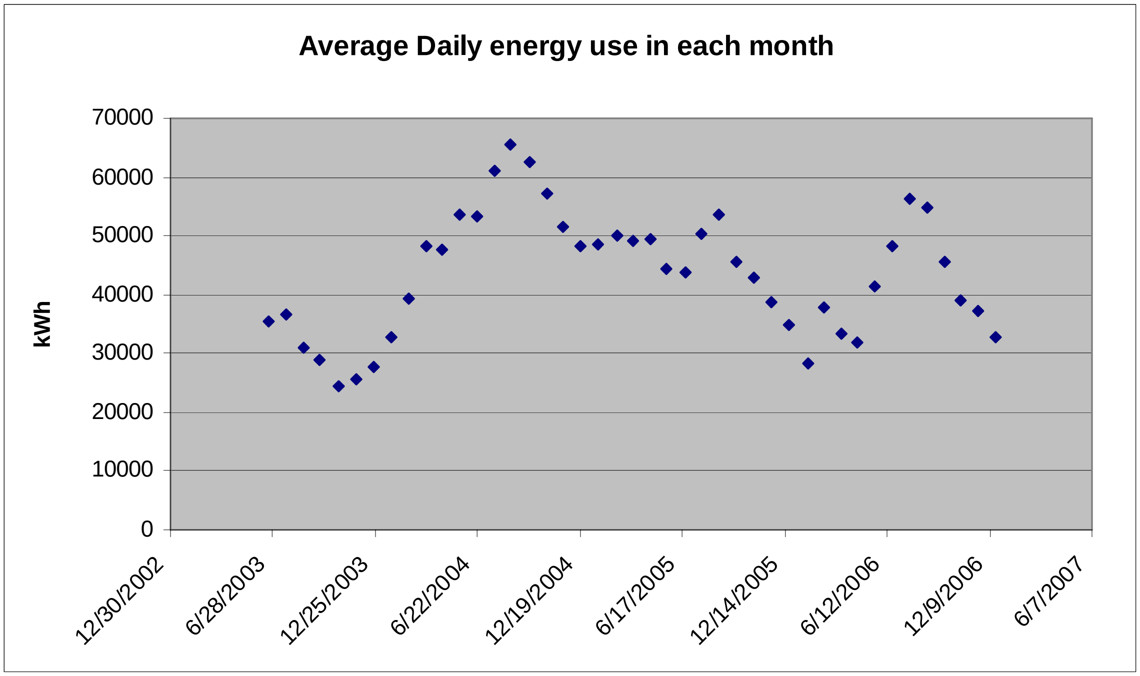


Table 2 summarizes the total metered use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers. The baseline use is calculated based on 40% of the total electric meter.

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results show kW / kWh savings ranging from 23.7% to 24.9% of the total meter and 59.2% to 62.3% for the baseline use. The ex post results show 3% smaller baseline end use kW savings, and 16% larger energy savings. This is believed to be realistic because the controlled wattage of the motion sensors may be overestimated in the ex ante calculations, but the use reduction savings due to the motion sensors may be underestimated (as compared to the workpaper estimates). The ex post savings may seem high in comparison to the baseline energy use.

Table 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	3792.0	19,191,060
Baseline End Use	1516.8	7,676,424
Ex ante Savings	898.2	4,778,845
Ex Post Savings	862.5	6,010,853

Table 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	23.7%	24.9%	22.7%	31.3%
Baseline End Use %	59.2%	62.3%	56.9%	78.3%

6. Additional Evaluation Findings

The ex post kW demand reduction is lower than the ex ante estimate because the ex ante motion sensor savings were overestimated by the itemized calculation. The workpapers assume a connected wattage approximately three times higher than the actual connected wattage, and they assume a 24% reduction in usage factor, whereas in actuality the reduction in usage factor in this case was 80%. The overestimation of connected load and underestimation of use reduction counteract each other, resulting in only a slightly reduced kW demand in the ex post calculation. The coincident peak demand reduction is also inaccurate. The workpapers assume a 16% reduction in peak load due to the motion sensors, while datalogger measurements showed an 87% reduction.

The only perceived non-energy benefits at the facility is that the facility is cooler. This makes it more comfortable for the employees. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. Participation in the 2004/2005 SPC Program lead corporate management to mandate energy efficient fixtures at a new facility located in the same locale..

7. Impact Results

The pre-retrofit lighting fixture type, quantities and hours of operation were unable to be physically verified. However, these parameters appear to have been accurately assessed and quantified based on discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $1,109,747 and a $281,155 incentive, the project had a 1.33 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is more than the ex ante while the costs are less at $1,104,267, and the estimated simple payback is 1.05 years. A summary of the economic parameters for the project is shown in Table 4.

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	8/232005	$1,109,747	898.2	4,778,845	0	$621,250	$281,555	1.33	1.79
SPC Program Review (Ex Post)	8/10/2007	$1,104,267	862.5	6,010,853	0	$781,411	$281,555	1.05	1.41

The engineering realization rate for this application is 0.96 for demand kW reduction and 1.26 for energy savings kWh. According to the installation report, the ex ante savings are 4,778,844.9 kWh annually and demand reduction is 898.2 kW. A summary of the realization rate is shown in Table 5.

The Installation Verification Summary is shown in Table 6 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 7.

Table 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	898.2	4,778,845	-
SPC Installation Report (ex ante)	898.2	4,778,845	-
Impact Evaluation (ex post)	862.5	6,010,853	-
Engineering Realization Rate	0.96	1.26	NA

1. Tracking System values used for realization rate calculations.

Table 6: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Replace 1800 400W high pressure sodium fixtures with 1800 4-lamp HO T5 fluorescent fixtures, install 428 fixture mounted occupancy sensors, replace 515 1000W metal halide fixtures with 515 400W pulse start metal halide fixtures.		2,351	4 lamp T-5 HO fixtures, occupancy sensors	Physically verified existence of T5 lamps, pulse start metal halide and motion sensors from as built plans spot-checked against existing lamps.	1.00

Table 7: Multi Year Reporting Table

Program ID Program Name		SPC 2004 Application # A076 2004 – 2005 SPC Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program KWh Savings	Ex-Post Gross Evaluation Confirmed Program KWh Savings	Ex-Ante Gross Program-Projected Peak Program KW Savings	Ex-Post Gross Evaluation Projected Peak KW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004					0	0
2	2005	1,991,185	2,504,522			0	0
3	2006	4,778,845	6,010,853	898.200	862.542	0	0
4	2007	4,778,845	6,010,853	898.200	862.542	0	0
5	2008	4,778,845	6,010,853	898.200	862.542	0	0
6	2009	4,778,845	6,010,853	898.200	862.542	0	0
7	2010	4,778,845	6,010,853	898.200	862.542	0	0
8	2011	4,778,845	6,010,853	898.200	862.542	0	0
9	2012	4,778,845	6,010,853	898.200	862.542	0	0
10	2013	4,778,845	6,010,853	898.200	862.542	0	0
11	2014	4,778,845	6,010,853	898.200	862.542	0	0
12	2015	4,778,845	6,010,853	898.200	862.542	0	0
13	2016	4,778,845	6,010,853	898.200	862.542	0	0
14	2017	4,778,845	6,010,853	898.200	862.542	0	0
15	2018	4,778,845	6,010,853	898.200	862.542	0	0
16	2019	4,778,845	6,010,853	898.200	862.542	0	0
17	2020	4,778,845	6,010,853	898.200	862.542	0	0
18	2021	4,778,845	6,010,853	898.200	862.542	0	0
19	2022	2,787,660	3,506,331	898.200	862.542		
20	2023						
TOTA	**2004-2023**	81,240,365	102,184,501				

Final Report

SITE A077 (04-587) Kraf IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: Lighting

Measure	High Bay T5 Lighting Retrofit / Occupancy Sensors
Site Description	Refrigerated Warehouse

1. Measure Description

Replace T12 lamps (in fixtures using four foot and eight foot lamps) with 36 T8 lamps; replace 248 metal halide fixtures using 400 watt lamps with four-lamp high output (HO) T5 fixtures; install 248 ceiling mounted occupancy sensors to control the new T5 fixtures; replace 21 standard metal halide pulse fixtures using 400 watt lamps with pulse start metal halide lighting systems using 320 watts.

2. Summary of the Ex Ante Calculations

The customer used the Itemized Measure Form to calculate kW and kWh savings. The basis of the incentive payment was the itemized incentive list. The original application was submitted as a Standard 2004 itemized application. No calculations of demand or energy savings were provided.

The total ex ante kW demand and kWh savings submitted were 133.9 kW and 587,710.08 kWh in the Installation Report Review (IRR). All four (4) of the measures were itemized, and the savings were stipulated based on the workpapers.

The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. The hours of operation for a warehouse are fixed in the workpapers at 3,550 hours/year. However, the “Lighting Equipment Survey Table” in the paperwork shows pre retrofit lighting hours of operation for all areas were 6,000 hours per year. The workpapers note a diversity factor of 84% for a warehouse.

Section H – L292 of the workpapers covers savings from replacement of metal halide (MH) HID fixtures to high bay, high output (HO) T5 or T8 fluorescent fixtures and lamps. The workpapers assume metal halide fixture wattage (with ballast) at 0.458 kW, four lamp HO T5 system wattage at 0.234 kW, and a total wattage drop from 0.458 kW to 0.234 kW per fixture for a non-coincident peak reduction of 0.224 kW per fixture. Coincident peak reduction is noted as 0.205 kW and kWh savings is noted as 843 kWh/year based on a warehouse market sector with the assumed operating hours.

For ceiling mounted occupancy sensors, the savings are based on the control of eight (8) fluorescent T12 fixtures, consuming 72 watts each, in an office conference room. Savings are based on a reduction from 2,210 hours/year to 1,040 hours/year (1,170 hours/year reduction). The workpaper reports 789 kWh savings (674 kWh/year plus a 17% office sector demand interactive effects factor). The non-coincident peak reduction of 0.305 kW was derived from the 0.576 kW controlled wattage and a 53% reduction in hours. Coincident peak reduction in the workpaper was noted to be 0.381, which included a 1.25 demand sector interactive effects factor.

The replacement of MH fixtures to T5 fixtures and the use of motion sensors are the two main measures and are responsible for 98% of the estimated savings. For this reason, the other two workpapers are not reviewed for this site application.

The tracking system savings match the IRR with minor differences; savings are listed as 133.91 kW and 587,710 kWh. The tracking system values are used as the ex ante savings. The incentive in the tracking system also agrees with the total incentive approved for the measures in the IRR; the incentive of $27,758 includes a $2,852 downward adjustment so that the occupancy sensor rebate did not exceed 50% of the measure cost.

3. Comments on the Ex Ante Calculations

The ex ante calculations appear to be based upon prescriptive savings contained in the Itemized Measure Forms. The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers as described above. The calculations performed with figures from those workpapers do not accurately represent the actual situation evaluated. For instance, the workpapers assume fixture wattage of 0.576 kW for occupancy sensors, whereas the actual connected wattage is 0.234 for those fixtures, which is only 40% of the assumed fixture wattage.

The ex ante savings figures can be checked for reasonableness using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

$$\text{kWh savings} = kW_{pre} \times \text{energized hours}_{pre} - kW_{post} \times \text{energized hours}_{post}$$

$$\text{Coincident peak demand period savings} = kW_{pre} - kW_{post} + kW_{post} \times (1 - \text{diversity factor})$$

The check calculations for the two primary measures (installation of motion sensors and retrofit of HID fixtures) were performed as follows:

- Pre-retrofit hours of operation: 6,000 hrs/yr
- Pre-retrofit wattage: 0.458 kW per metal halide lamp x 248 lamps = 113.6 kW
- Post-retrofit hours of operation for fixtures with occupancy sensors (based on an 47% on-time factor): 6,000 hours x (1-0.53) = 2,820 hrs/year
- Post-retrofit wattage: (0.234 kW per four-lamp fixture x 248 fixtures = 58.0 kW
- Diversity savings = 0.234 kW per four-lamp fixture x 248 fixtures x 0.16 (diversity factor of 0.84) = 9.3 kW

Annual kWh usage: (113.6 kW x 6,000 hrs/yr) – (58.0 kW x 2,820 hrs/yr) =

681,600 kWh/yr – 163,560 kWh/yr = 518,040 kWh/yr

Summer peak impacts were estimated by adding the reduced load and multiplying the post-retrofit connected load by the percent reduction in on-time due to the occupancy sensors during peak periods (1.00 – the diversity factor).

Summer peak demand reduction is calculated as follows:

- Load reduction + Post retrofit connected kW load times 0.16 for motion sensor fixtures (84% on-time post retrofit): 113.6 kW – 58.0 kW + 9.3 kW = 64.9 kW

The energy savings are similar to those reported in the IRR for these measures (576,581 kWh). Coincident peak savings are much lower than the ex-ante savings because the assumptions used to calculate the itemized measure are very different from the actual situation. The connected wattage of the actual controlled fixtures is much lower than the assumptions in the workpaper. The expected diversity factor of 84% for a warehouse also appears different than the assumptions for coincident peak load reduction used for the itemized measure calculations.

In general, the savings figures in the final Implementation Report Review (IRR) would be expected to be identical to the utility tracking system savings figures. The total savings in the Installation Report Review were given as 587,710 kWh and 133.9 kW. The tracking system is in agreement, allowing for minor reporting differences. The tracking system values are used as the ex ante savings.

4. Measurement & Verification Plan

The building is a single level 197,000 sf refrigerated warehouse. It is reportedly about 18 years old. According to the application, before the retrofit there were two hundred sixty nine (269) metal halide fixtures using 400-watt lamps and thirty six (36) four foot T12 lamps in two lamp fixtures. After the retrofit, there are two hundred forty eight (248) four-lamp T-5 fluorescent fixtures, twenty one (21) 320 watt pulse-start metal halide fixtures and thirty six (36) T8 lamps in 2 and 4 lamp fluorescent fixtures. All two hundred forty eight (248) T5 fixtures are controlled by individual, fixture-mounted occupancy sensors. The project saves energy through the installation of lighting fixtures with a lower connected wattage and through the control of the lighting fixtures with occupancy sensors to reduce the hours of operation.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

A modified version of IPMVP Option A can be utilized. Lighting loggers would be used to quantify hours of operation.

There is one central warehouse area with motion sensor and HO T5 retrofits. A minimum of six loggers and / or one to two data loggers should be used to quantify hours of operation in the post retrofit case and to capture current fluctuations. The current may be monitored and power measured at the same time to establish an accurate relationship.

Monitoring should occur over the period of one week or longer.

The pre retrofit usage listed as 6,000 hours per year should be verified.

Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = average hourly peak reduction = kW_{pre} – kW_{post} + kW_{post} x ((energized $hours_{pre}$ - energized $hours_{post}$)) / energized $hours_{pre}$) during the three contiguous hottest days expected between 2 pm to 5 pm, Monday to Friday, in June, July, August, September

Thus, to estimate peak demand kW reduction, the reduction in connected kW due to the increased lighting efficiency will be added to the post-retrofit connected load multiplied by the percent of energized time according to the above formulae. The derivation or extrapolation of the average percent of time energized used in the above formulae will be described.

The most significant variables to be quantified are the pre-retrofit and post-retrofit fixture hours of operation. Pre-retrofit hours will be confirmed with site personnel and interviews. The focus will be on verifying that, prior to the retrofit, the entire complement of fixtures was completely energized during the hours listed (6,000 hours/year) and that the listed hours/year were valid (for example, building or staff schedule logs for the pre-retrofit period could be examined if available). If dual-level lighting high pressure sodium fixtures were in use, the operating schedules for each lighting level should be confirmed as accurately as possible. Appropriate modifications for the savings calculations would be made to the pre-retrofit usage figures if required, in order to establish a realistic baseline for energy use.

Monitoring with light loggers will be conducted on approximately 5% of the aisles and a center aisle where feasible. A minimum of two sensors for two aisles and one sensor per central aisle could be used in each of the three warehouses, requiring fifteen (15) sensors. However, additional sensors may be required, based on usage and traffic patterns. The use of fifteen sampling points is generally consistent with SPC program documentation from March 2001 (Appendix E, Sampling); this document suggests guidelines for determining sampling point requirements necessary to achieve an 80% confidence interval with 20% precision (using a coefficient of variation of 0.5).

A random sampling approach would involve setting up a grid for the warehouse, labeling fixtures sequentially according to their location, and randomly selecting from the total number of fixtures using a random number generator. This approach will avoid overweighting or assigning a weighting factor for the central aisles. The majority of the lighting is expected to be over side aisles with racked storage. The warehouse is considered to be one usage group for the purposed of assigning fixtures to be sampled. Fixture numbering would be from one corner of the buildings to the adjacent corners. The fixtures selected using this technique would be as follows:

Primary Sample Fixture #: 30, 48, 58, 85, 94, 140, 146, 151, 214, 249, 321, 363, 412, 429, and 443.

Secondary Sample Fixture #: 31, 56, 70, 81, 90, 91, 114, 123, 128, 129, 242, 291, 340, 341, 350, 395, 468, 474, 508, and 512.

The secondary backup sample of fixtures would be monitored in sequence only if the selected fixtures from the primary sample could not be monitored or isolated.

The light loggers would be placed so as to be unaffected by fixtures not on motion sensors or by ambient outside light.

If the light loggers cannot be placed in suitable locations, it was considered that, where the lighting circuits can be isolated and it can be determined that only lighting loads for the warehouse fixtures are controlled by that lighting circuit, a current or power meter could be used to track multiple fixtures. The total current / power would be determined by activating all fixtures and by confirming loads using the electrical drawings. Between three and six current/power meters are expected to be needed, to capture a representative sample of the lighting fixtures.

The lighting loggers or current sensors would be left in place for a minimum period of 7 days. Attention will be given to the time period for monitoring, in order to avoid periods of irregular usage patterns (e.g., during holidays or breaks). While longer periods might be preferable, these periods are appropriate given the scope of the evaluation and reported usage characteristics.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture hours of operation. The lighting fixture quantities seem to be well established and were counted to within 5% to 10% in utility post-installation inspection visits. The pre-retrofit and post-retrofit connected loads associated with various fixture types are also adequately quantified in the SPC lighting wattage tables.

Uncertainty for the savings estimate for the warehouse fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables.

<u>For lower wattage fixtures (T5 and pulse start MH conversion from 269 HID fixtures, and T8 conversion from 35 T12 fixtures)</u>

- 305 fixtures expected, minimum 290, maximum 320 (+/- 5%)
- 6,000 hours pre retrofit expected/reported, minimum 3000 hours, maximum 7000 hours (+17%, - 50% based on pre-retrofit utility bill analysis from application)
- 124.5 kW expected, minimum 123.6 kW, maximum 137.0 kW (includes +/- 5% for number of fixtures and +/- 5% for fixture wattage difference)

<u>For motion sensors controlling the T5 fixtures</u>

- 248 fixtures expected, minimum 236, maximum 260 (+/- 5 %)
- 2,820 hours post retrofit expected/reported, minimum 1,410 hours, maximum 5,640 hours (- 50% , +100% based on judgment of use for site type; includes + / - 5% from annualizing estimates from short monitoring period)
- 9.3 kW calculated diversity savings includes number of fixtures, post-retrofit fixture wattage and diversity factor; minimum 4.7 kW, maximum 13.9 kW (reflects + / - 50% expected range)

There may be a small potential source of error introduced since measurement will not be performed on the two smallest measures. This error is estimated at a maximum of + /- 2% and is not included in the analysis of uncertainty due to its size.

Accuracy and Equipment

The light loggers to be used are Dent TOU-L Lighting Smart*logger* dataloggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Annualizing that data from a 7 to 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

Current or power meters may also be used. The current loggers to be used, if this M&V technique is selected, would be HOBO U-12 loggers, with matched current transformers. The accuracy range is 4.5 %. The sensor would be calibrated to an Amprobe ACD-41PQ, with an accuracy of +/- 2%. An advantage of using current or power meters to monitor load is that the percent of time energized for an increased number of fixtures may be able to be captured.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

This comprehensive retrofit of warehouse lighting included replacement of high intensity discharge fixtures utilizing 400 watt metal halide lamps with 320 watt pulse start metal halide fixtures in the freezer room, and fluorescent fixtures utilizing four (4) T5 lamps in the refrigerated and dry goods storage section. It also included installation of fixture mounted occupancy sensors to reduce lighting hours of operation and replacement of T12 lamps with T8 lamps in the compressor room. The on-site survey was conducted on August 9, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Lighting fixture quantities and hours of operation were verified.

Installation Verification

It was physically verified that twenty (20) 320 watt metal halide fixtures, thirty-six (36) T8 lamps and two hundred sixty four (264) four-lamp T-5 fixtures were installed in the facility. Each T5 fixture had a motion sensor. The Installation

Report noted twenty-one (21) 320 watt metal halide fixtures instead of twenty (20), and two hundred forty-eight (248) four lamp T-5 fixtures instead of two hundred sixty four (264). The retrofit was completed in December 2004.

The four lighting measures (pulse start metal halides, T8's, T5's and motion sensors) are the only measures in this application. The overall verification realization rate for this project is 1.06. A verification summary for each of the measures is shown in Table 5.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measure in the SPC application covering the lighting efficiency retrofit. These are the only measures in this application.

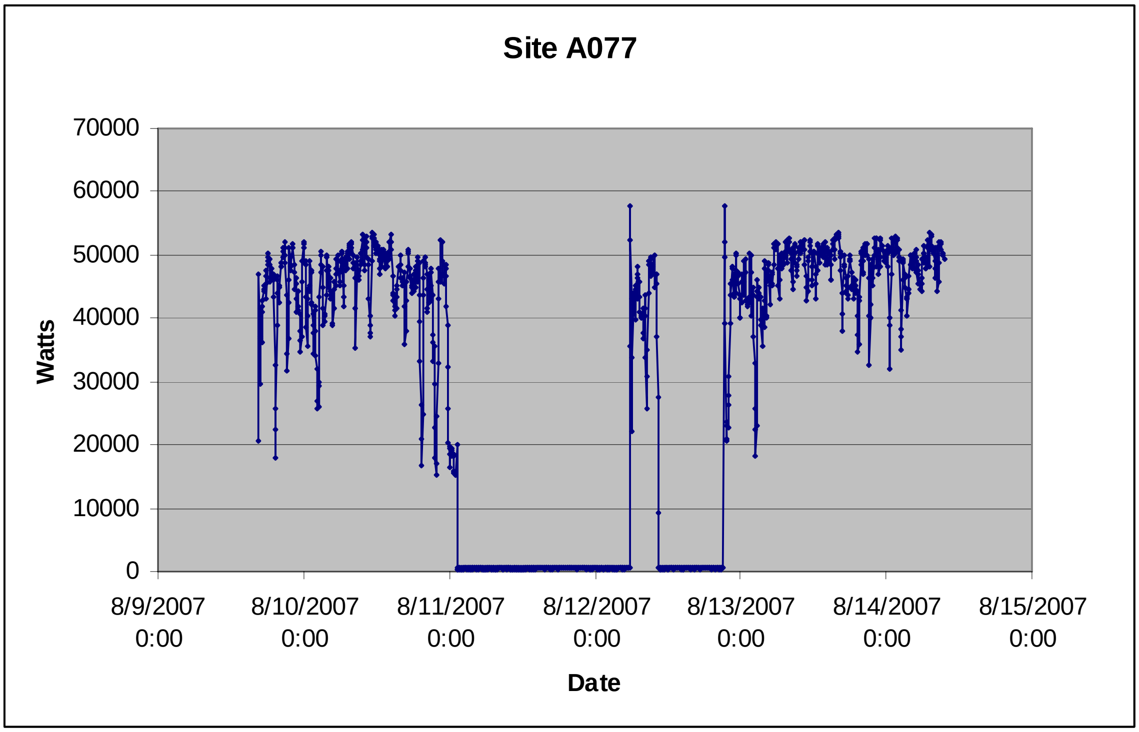
Summary of Results

Two (2) Hobo loggers with Onset current transducers were installed at the main electrical panel of the facility for 41 days (from August 9, 2007 to September 20, 2007). The current transducers were installed on two of the three main legs serving the electrical panel, and they sampled the current every five minutes during the monitoring period. The maintenance manager verified that all of the warehouse lights were served out of this panel, including the dry goods area, refrigerated areas, freezer areas, compressor room, battery charger area and maintenance areas. Spot measurements were taken on the third leg to determine the percent of load distributed on the three legs. The load distribution was assumed to be constant; it was, however, found to vary somewhat throughout the day depending on which individual light fixtures are energized at any given time.

Spot measurements were also taken on the circuits serving the pulse start metal halide fixtures in the freezer room. The power draw of 4,763 watts was measured for 13 lamps, yielding 365 watts per fixture for the energy savings calculations.

The power draw of the monitored fixtures was calculated for every sample point, and a simple ratio was used to determine the power draw of all the fixtures. A portion of the calculated wattage is shown in Figure 1. The calculated power for the T8 and pulse start metal halide fixtures was subtracted from the total power, and the remainder was compared to the calculated power for the motion sensor controlled fixtures. At the maximum measured power draw, 93% of the fixtures were illuminated. The average illumination over the monitoring period was 46%, and the illumination during coincident peak demand period, between 2 pm to 5 pm, Monday to Friday, was 60%.

Figure 1: Power Calculated from Amp and Volts Measurements on L1 and L2 of the Main Electrical Panel at Site A077



The facility representative stated that the building is occupied 24 hours Monday-Friday, and between 7:00 am and 3:30 pm on Saturdays and some Sundays. The facility has 79 employees who work in three shifts. The facility is closed 7 holidays annually. The facility representative stated that the facility hours of operation changed only slightly after the retrofit, with Sunday shifts occurring more frequently. The logger data concurs with the hours stated by the facility representative. There is no seasonal variation in the occupancy of the building. The electricity end-uses at this facility are refrigeration, lighting, and forklifts charging.

Very few burned out lights were observed during the site visit. The facility representative mentioned that it was necessary to replace some of the T5 lamps since the retrofit because of dimming over time. Burnt out bulbs waiting to be shipped to the recycling facility were observed in the mechanical room. The following model numbers were recorded: GE Ecolux F32T8 SP41 ECO, Sylvania T12 Cool White F40, and Starcoat GE T5 F54W/840 HO. The T12 lamps are probably those changed recently in the office area, which was not part of the retrofit, but they are likely the same type of T12 bulb that was existing in the compressor room, as bulbs are often ordered in large batches.

Energy Savings Calculations:

- Pre-retrofit hours of operation: 6,537 hrs/yr (52.18 weeks x 128.5 hours/week – annual holidays of 168 hours)

Pre-retrofit wattage: 0.458 kW per fixture x 284 lamps + 0.036 kW per T12 lamp x 36 lamps = 131.3 kW
Annual kWh usage: 131.3 kW x 6,537 hrs/yr = 858,746 kWh/yr

- Post-retrofit hours are the same as pre-retrofit.
- Post-retrofit wattage: 0.364 kW per metal halide fixture x 20 lamps +0.234 kW per T5 fixture x 264 lamps + 0.029 kW per T8 lamp x 36 lamps = 70.1 kW
  Annual kWh usage: 70.1 kW x 6,537 hrs/yr = 458,240 kWh/yr

  Motion sensor energy savings: (pre-retrofit usage factor – post retrofit usage factor) x post retrofit connected load on motion sensors (61.8 kW) x 8760 hours = (1-0.46) x 61.8 kW x 8760 = 292,662 kWh/yr.
- Annual kWh savings from the fixtures = 858,746 kWh/yr – 458,240 = 400,506 kWh/yr.
- Total Annual kWh savings = 292,662 + 400,506 = 693,167 kWh/yr.

Summer peak impacts of the motion sensors were determined from the measured data by averaging the percent of fixtures illuminated only during the 2 pm to 5 pm weekday period. The coincident peak diversity factor is 0.60 for the motion sensors installed at this facility. This is somewhat lower than the diversity factor for a warehouse noted in the workpaper. Before the retrofit, the lights were always on during the summer peak period.

Summer peak demand savings = (1-0.60) x 61.8 kW = 24.8 kW.

Summer peak demand savings due to the fixture replacement = pre-retrofit connected load – post-retrofit connected load = 131.4 kW – 70.1 kW = 61.3 kW.

Total summer peak reduction = 61.3 kW + 24.8 kW = 86.1 kW

Table 1 summarizes the total metered use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers. The baseline use is calculated based on the number of pre-retrofit fixtures, their wattage, and hours of use. The total meter peak demand was determined from interval data and the annual electrical energy use was determined from billing data from July 2004 and to June 2005. Earlier billing data was not available. The baseline end use was taken as 40% of the total meter, the portion allocated for this facility to lighting loads.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results show kW and kWh savings ranging from 21% of the total meter to 53% of the baseline end use. The ex post results show smaller peak demand savings ranging from 14% of the total meter to 35% of the lighting end use demand, but show larger energy savings, ranging from 25% of the total meter to 63% of the baseline lighting end use energy.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	630.0	2,770,000
Baseline End Use	252.0	1,108,000
Ex ante Savings	133.9	587,710
Ex Post Savings	86.1	693,167

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	21.3%	21.2%	13.7%	25.0%
Baseline End Use %	53.1%	53.0%	34.2%	62.6%

6. Additional Evaluation Findings

The ex post kW demand reduction is lower than the ex ante estimate because the ex ante savings was overestimated by the itemized calculation. The workpapers assume a connected wattage approximately three times higher than the actual connected wattage. They also assume a coincident peak diversity factor of 84%; actual measurements showed coincident diversity at 60%. These two differences between the actual situation and the workpapers act in opposing directions, the first causing overestimated savings, and the second underestimated savings, but the net is that the coincident peak savings are overestimated.

Energy savings, however, are underestimated in this case by the workpapers because the actual hours of operation (6537 hours per year) are much longer than those assumed in the workpapers (3,550 hours per year for a warehouse). The actual fixture savings (400,506 kWh/year) are approximately double the workpaper assumed savings (233,337 kWh/year). The usage factor of the motion sensors assumed in the workpapers (43%) is very close to accurate; our measurements showed a usage factor of 46%. However, the actual energy savings from the motion sensors (292,662 kWh/year) is 17% lower than annual energy savings calculated from workpaper assumptions (354,373 kWh/year).

The only perceived non-energy benefit at the facility is increased comfort due to brighter lighting. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. Participation in the 2004/2005 SPC Program has caused upper management to consider energy use to a greater extent.

7. Impact Results

The pre-retrofit lighting fixture type, quantities and hours of operation were unable to physically verified. However, these parameters appear to have been accurately assessed and quantified based on discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $92,155 and a $27,758 incentive, the project had a 0.84 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is more than the ex ante, and the estimated simple payback is 0.71 years. A summary of the economic parameters for the project is shown in Table 3.

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	2/4/2005	$92,155	133.9	587,710	0	$76,402	$27,758	0.84	1.21
SPC Program Review (Ex Post)	8/9/2007	$92,155	86.1	693,167	0	$90,112	$27,758	0.71	1.02

The engineering realization rate for this application is 0.64 for demand kW reduction and 1.18 for energy savings kWh. According to the installation report, the ex ante savings are 587,710 kWh annually and demand reduction is 133.9 kW. A summary of the realization rate is shown in Table 4.

The Installation Verification Summary is shown in Table 5 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 6.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	133.91	587,710	-
SPC Installation Report (ex ante)	133.9	587,710.08	-
Impact Evaluation (ex post)	86.1	693,167	-
Engineering Realization Rate	0.64	1.18	NA

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING	L		Replace 36 T12 lamps with 36 T8 lamps		584	36 Four lamp T8 fixtures	Physically verified lamp type and quantity.	1.06
LIGHTING	L		Replace 248 metal halide fixtures using 400 watt lamps with four-lamp high output (HO) T5 fixtures		264	Four lamp high output T5 fixtures	Physically verified lamp type and quantity.	1.06
LIGHTING	L		Install 248 ceiling mounted occupancy sensors;		264	occupancy sensor	Physically verified lamp type and quantity.	1.06
LIGHTING	L		Replace 21 standard metal halide pulse fixtures using 400 watt lamps with pulse start metal halide lighting systems using 320 watts.		20	320 W pulse start metal halide	Physically verified lamp type and quantity.	0.95

The overall realization rate is 1.06 based on the total number of fixture/sensors.

Table 6: Multi Year Reporting Table

Program ID Program Name		**SPC 2004 Application # A077 2004 – 2005 SPC Evaluation**					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004						
2	2005			133.9	86.1		
3	2006			133.9	86.1		
4	2007			133.9	86.1		
5	2008			133.9	86.1		
6	2009			133.9	86.1		
7	2010			133.9	86.1		
8	2011			133.9	86.1		
9	2012			133.9	86.1		
10	2013			133.9	86.1		
11	2014			133.9	86.1		
12	2015			133.9	86.1		
13	2016			133.9	86.1		
14	2017			133.9	86.1		
15	2018			133.9	86.1		
16	2019			133.9	86.1		
17	2020			133.9	86.1		
18	2021						
19	2022						
20	2023						
TOT	**2004-2023**						

Final Report

SITE A078 (05-018) Nest IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 3 END USE: Lighting

Measure	High Bay T5 Lighting Retrofit / Occupancy Sensors
Site Description	Warehouse

1. Measure Description

Install two hundred twenty one (221) T5 fixtures, install one hundred five (105) T5 fixtures with motion sensors, install seven hundred ten (710) T8 lamps with ballasts, de-lamp two hundred thirty eight (238) T12 lamps, install 25 ceiling mounted occupancy sensors, install 8 wall box occupancy sensors, and install 33 exit signs.

2. Summary of the Ex Ante Calculations

The customer used the Itemized Measure Form to calculate kW and kWh savings for the T8 to T12 retrofit, the de-lamping, and the occupancy sensors. The basis of the incentive payment was the itemized incentive list. Custom calculations were provided to determine the savings from the T5 lamps and exit signs. The original application was submitted as a Standard 2005 itemized application. Total savings was estimated to be 184.1 kW and 1,764,804.08 kWh. These are listed as the Application Approved savings amounts.

The overall scope of work verified during the Post-installation inspection remained the same as the Application approved scope of work. A final invoice provided by the project sponsor showed that the final project cost is lower than the project cost approved in the Application; however, the invoice measure costs did not affect the incentive.

The savings reported in the tracking system are the same as those in the Post-Installation Report except for the number of significant figures reported (1,764,804 kWh and 184.17 kW). The incentive in the tracking system ($87,787.85) also agrees with the gross incentive approved for the measures listed in the IRR.

The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. The hours of operation for a warehouse are fixed in the workpapers at 3,550 hours/year. The workpapers note a diversity factor of 84%, and a demand interactive effects factor of 1.09 for a warehouse. The four itemized measures are the T12 to T8 conversion, de-lamping of T12 fixtures, and two types of occupancy sensors.

The T-12 to T8 conversion is described in lighting measure *L290 (High Performance 4 foot T-8 System from T-12)* in the workpapers. This measure assumes that a high performance 4-foot T-8 lamp and ballast combination is replacing a standard T-12 system. To be considered a high performance system, the new ballast must have a ballast factor of less than or equal to 0.77 and use premium lamps that initially produce at least 3100 lumens. The existing system is assumed to be a two-lamp T-12 system using 72 watts (34 watt lamps and energy-saver magnetic ballast).

De-lamping of the T12 fixtures is described in lighting measure *L19 (Removing a 4-foot Lamp)* in the workpapers. The calculations are for conversion from a 3-lamp to a 2-lamp fixture. The original fixture wattage is based on T-12, 34-watt lamps with energy-saving ballast. One lamp and its associated ballast are removed. Total installed wattage drops from 0.115 kW to 0.072 kW.

For ceiling mounted occupancy sensors, the savings are based on the control of eight (8) fluorescent T12 fixtures, consuming 72 watts each, in an office conference room. Savings are based on a reduction from 2,210 hours/year to 1,040 hours/year (1,170 hours/year reduction). The workpaper reports 789 kWh savings (674 kWh/year plus a 17% office sector demand interactive effects factor). The non-coincident peak reduction of 0.305 kW was derived from the 0.576 kW controlled wattage and a 53% reduction in hours. Coincident peak reduction in the workpaper was noted to be 0.381, which included a 1.25 demand sector interactive effects factor.

3. Comments on the Ex Ante Calculations

The ex ante calculations for the itemized measures appear to be the calculations embedded in the Itemized Measure Form on the Summary of Approved Measures page of the Project Application Review. The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers as described above. The calculations performed with figures from those workpapers do not accurately represent the actual situation evaluated. The major discrepancies are: 1) the hours of operation for the T8 fixtures are 8736 hours a year instead of the 3550 hours used in the workpapers; 2) the hours of operation of the de-lamped fixtures are 8736 instead of 4000 hours in the workpapers; 3) the de-lamped connected wattage is 0.036 kW per lamp instead of an almost 20% higher wattage lamp of 0.43 kW; and 4) the workpapers assume connected fixture wattage of 0.576 kW for ceiling mounted occupancy control sensors whereas the actual connected wattage is 0.360 for the majority of the fixtures, which is less than 65% of the assumed fixture wattage.

The ex ante savings figures can be checked for reasonableness using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

$$\text{kWh savings} = kW_{pre} \times \text{energized hours}_{pre} - kW_{post} \times \text{energized hours}_{post}$$

Coincident peak demand period savings = $kW_{pre} - kW_{post} + kW_{post}$ x (1 – diversity factor)

The check calculations were performed as follows:

Table 1: Savings Summary of Approved Measures

Summary of Approved Measures - savings					
Calculated	**hrs**	**kW**	**# fixtures**	**kW**	**kWh**
1000W MH to 12LT5	8736	0.378	163	61.6	538,259.90
1000W MH to 6LT5	8736	0.729	57	41.6	363,007.01
1000W MH to 2LT5	8736	0.963	1	1.0	8,412.77
1000W MH to 12LT5 w/sensor	8736	0.378	66	24.9	420,323.90
1000W MH to 6LT5 w/sensor	8736	0.729	39	28.4	308,166.77
exit signs	8736	0.014	33	0.5	4,036.03
Itemized					
119 fixtures delamped by two lamps	8736	0.036	238	8.6	74,850.05
T12 to T8	8736	0.011	710	7.8	68,228.16
ceiling occ. Sensor (hrs off)	4368	0.36	25	1.4	39,312.00
wall box occ. Sensor	4368	0.312	8	0.4	10,902.53
				176.19	**1,835,499.12**

The use reduction factor assumed for all the motion sensor fixtures is 50%. The diversity factor is assumed to be 0.84, as stated in the workpapers for a warehouse. Summer peak impacts are shown in the kW column of Table 1.

The energy savings are slightly higher than the ex-ante savings due to the longer hours of operation than those assumed in the workpapers for the itemized measures. The peak demand savings are slightly lower than the ex-ante calculations because the diversity factor for a warehouse (0.84) is slightly higher than that in an office (0.81), which is used in the workpaper calculations, and no interactive effects were used in the check-calculations.

In general, the savings figures in the final Implementation Report (IR) would be expected to be identical to the utility tracking system savings figures. The total savings in the Installation Report Review were given as 1,764,804 kWh and 184.1 kW. The tracking system is in agreement (except for rounding functions).

4. Measurement & Verification Plan

The building is a single level 400,000 s.f. bottling facility and warehouse for bottled water. According to the application, before the retrofit there were three hundred and twenty six (326) metal halide fixtures using 1000-watt lamps in the warehouse and production areas. There were also seven hundred ten (710) T12 lamps located in fixtures on the mezzanine, in offices and other areas. After the retrofit, there are ninety six (96) six-lamp T-5 fluorescent fixtures, and two hundred twenty nine (229) twelve-lamp T-5 fluorescent fixtures and one (1) two-lamp T-5 fixture. One hundred five (105) T-5 fixtures are controlled by individual, fixture mounted occupancy sensors. Thirty three wall or ceiling mounted occupancy sensors control some of the T8 lamps. The project saves energy through the installation of lighting fixtures with a lower connected wattage and through the control of the lighting fixtures with occupancy sensors to reduce the hours of operation.

According to the application, for the primary measures, before the retrofit there were 326 metal halide fixtures using 1000 watt lamps. After the retrofit, there are:

2 lamp T5 HO fixtures: 1 without motion sensors
6 lamp T5 HO fixtures: 57 without motion sensors, 39 with motion sensors
12 lamp T5 HO fixtures: 163 without motion sensors, 66 with motion sensors

These retrofits and the other lighting measures will be verified.

The project saves energy through the installation of lighting fixtures with a lower connected wattage and through the control of the lighting fixtures with occupancy sensors to reduce the hours of operation.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

A modified version of IPMVP Option A can be utilized. Lighting loggers would be used to quantify hours of operation. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Average peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x ((energized $hours_{pre}$ - energized $hours_{post}$)) / energized $hours_{pre}$) during the hours from 12 pm to 7 pm, Monday to Friday, in June, July, August, and September

Coincident peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x ((energized $hours_{pre}$ - energized $hours_{post}$)) / energized $hours_{pre}$) during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in June, July, August, September

Thus, to estimate peak demand kW reduction, the reduction in connected kW due to the increased lighting efficiency will be added to the post-retrofit connected load multiplied by the percent of energized time according to the above formulae. The derivation or extrapolation of the average percent of time energized used in the above formulae, for both the average peak demand period and the coincident peak demand periods, will be described.

Documentation provided indicates that there are 105 fixtures with individual motion sensors which comprise over 40% of the projected savings. These fixtures would be a primary target for evaluation efforts. The majority of the fixtures are located in the aisles of the warehouse. The savings from the other primary lighting measure (HID to T5) are about 50% of the total savings according to application data. Evaluation efforts will, for this reason, focus on the warehouse lighting.

The most significant variables to be quantified are the pre-retrofit and post-retrofit fixture hours of operation. Pre-retrofit hours will be confirmed with site personnel and interviews. The focus will be on verifying that, prior to the retrofit, the entire complement of fixtures was completely energized during the hours listed (8,736 hours/year) and that the listed hours/year were valid (for example, building or staff schedule logs for the pre-retrofit period could be examined if available). Appropriate modifications for the savings calculations would be made to the pre-retrofit usage figures if required, in order to establish a realistic baseline for energy use. Lighting loggers could be used if there are significantly less than 8736 hours per fixture for the 221 fixture without motion sensors.

The wattages can be determined pre retrofit through inspection of lighting plans and interview and tests / wattage readings on fixtures not retrofit.

The wattages can also be determined post retrofit through inspection of lighting plans and tests / wattage readings on fixtures / lighting circuits not retrofit.

Monitoring with light loggers will be conducted on approximately 5% of the aisles and a center aisle where feasible. A minimum of two sensors for two aisles and one sensor per central aisle could be used in each of the three warehouses, requiring fifteen (15) sensors. However, additional sensors may be required, based on usage and traffic patterns. The use of fifteen sampling points is generally consistent with SPC program documentation from March 2001 (Appendix E, Sampling); this document suggests guidelines for determining sampling point requirements necessary to achieve an 80% confidence interval with 20% precision (using a coefficient of variation of 0.5).

A random sampling approach would involve setting up a grid for the warehouse, labeling fixtures sequentially according to their location, and randomly selecting from the total number of fixtures using a random number generator. This approach will avoid overweighting or assigning a weighting factor for the central aisles. The warehouse is considered to be one usage group for the purposed of assigning fixtures to be sampled. Fixture numbering would be from one corner of the buildings to the adjacent corners.

The light loggers would be placed so as to be unaffected by fixtures not on motion sensors or by ambient outside light.

If the light loggers cannot be placed in suitable locations, it was considered that, where the lighting circuits can be isolated and it can be determined that only lighting loads for the warehouse fixtures are controlled by that lighting circuit, a current or power meter could be used to track multiple fixtures. The total current / power would be determined by activating all fixtures and by confirming loads using the electrical drawings. Between three and six current/power meters are expected to be needed, to capture a representative sample of the lighting fixtures.

The lighting loggers or current sensors would be left in place for a period of 7 to 14 days. Attention will be given to the time period for monitoring, in order to avoid periods of irregular usage patterns (e.g., during holidays or breaks). While longer periods might be preferable, these periods are appropriate given the scope of the evaluation and reported usage characteristics.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture hours of operation. The lighting fixture quantities seem to be well established and were counted to within 5% to 10% in utility post-installation inspection visits. The pre-retrofit and post-retrofit connected loads associated with various fixture types are also adequately quantified in the SPC lighting wattage tables.

Uncertainty for the savings estimate for the warehouse fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables.

<u>For lower wattage fixtures (T5 conversion from HID fixtures)</u>

- 326 fixtures expected (+/- 5%)
- 8,736 hours pre retrofit expected/reported, minimum 5000 hours, maximum 8760 hours (based on pre-retrofit lighting spreadsheet from application)
- 386.2 kW expected (includes +/- 5% for number of fixtures and +/- 5% for fixture wattage difference)

<u>For motion sensors controlling 105 of the above fixtures</u>

- 105 fixtures expected, (+/- 5 %)
- 4368 hours post retrofit expected/reported (- 50% , +100% based on judgment of use for site type; includes + / - 5% from annualizing estimates from short monitoring period)
- 4.2 kW and 155,432 kWh expected savings includes number of fixtures, post-retrofit fixture wattage and diversity factor (+ / - 50% expected range)

There may be a small potential source of error introduced since measurement will not be performed on the smallest measures. This error is estimated at a maximum of + /- 2% and is not included in the analysis of uncertainty due to its size.

Accuracy and Equipment

The light loggers to be used are Dent TOU-L Lighting Smart*logger* dataloggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Annualizing that data from a 7 to 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

Current or power meters may also be used. The current loggers to be used, if this M&V technique is selected, would be HOBO U-12 loggers, with matched current transformers. The accuracy range is 4.5 %. The sensor would be calibrated to an Amprobe ACD-41PQ, with an accuracy of +/- 2%. An advantage of using current or power meters to monitor load is that the percent of time energized for an increased number of fixtures may be able to be captured.

A Dent Elite Pro may also be used for long term current measurements. The accuracy of current measurements is +/- 2% to +/- 2.5%, depending on the current transducer used. Voltage measurements have an accuracy of +/- 1%.

Annualizing the kW data to the hottest summer period is projected to result in a possible error in the final results of +/- 5 %.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

This comprehensive retrofit of production area and warehouse lighting included replacement of high intensity discharge fixtures utilizing 1000 watt metal halide lamps with fluorescent fixtures utilizing two (2), six (6) or twelve (12) T5 lamps. It also included installation of 105 fixture mounted occupancy sensors to reduce lighting hours of operation. In addition, the retrofit included installation of seven hundred ten (710) T8 lamps and ballasts, two hundred thirty eight (238) T12 lamps removed, installation of twenty five (25) ceiling mounted occupancy sensors, installation of eight (8) wall box occupancy sensors, and installation of thirty three (33) exit signs.

The on-site survey was conducted on August 9, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Lighting fixture quantities were verified by spot checking and hours of operation were verified through the facility representative interview.

Installation Verification

It was physically verified that seventy six (76) six-lamp T-5 fluorescent fixtures (thirty five of them with motion sensors) and one hundred sixty one (161) twelve-lamp T-5 fixtures (sixty five with motion sensors) were installed in the facility. It was also physically verified that there were two hundred forty (240) T8 lamps and 24 ceiling mounted motion sensors in the mezzanine area. The retrofit was completed in November 2005.

This application includes seven measures: T5 fixtures with motion sensors, T5 fixtures without motion sensors, exit signs, T8 lamps, T12 de-lamping, ceiling mounted motion sensors and wall box motion sensors. Fixtures were counted in eight areas to spot check the fixture count for verification purposes. The eight areas had realization rates as follows: bottling lines 3-5, 0.88, packaging and open storage area, 1.01 (12-lamp) and 0.52 (6-lamp), blow mold area, 1.0, tank area 1.64 (but they were 6-lamp fixtures instead of 12-lamp), lines 1-2, 0.5, warehouse, 1.03, mezzanine 1.04. The weighted realization rate for these areas was applied to the project as a whole. The verification realization rate for this project is 0.953 (1150/1207). A verification summary is shown in Table 6.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measure in the SPC application covering the lighting efficiency retrofit. This is the only measure in this application.

Summary of Results

At this site, 93% of the energy savings and 86% of the peak demand reduction was from the replacement of 1000W metal halide fixtures with high bay T5 fixtures. The focus of the evaluation measurements is only on these fixtures. The ex ante calculations will be carried through to the ex post results for the remainder of the measures.

Five (5) Pacific Science and Technology light loggers were installed at the facility for 36 days (from August 9, 2007 to September 14, 2007): three in the warehouse area and two in the production area. Time limitations of on site staff limited the number of loggers that could be installed. Data was not able to be retrieved from one of the loggers in the production area. The other logger in the production area showed that the measured fixture was energized all the time. The average on-time of the three light loggers in the warehouse area is 94%.

All lights are expected to be operating during the peak demand period defined as the hottest weekday periods between 2 pm to 5 pm, Monday to Friday, in June, July, August or September.

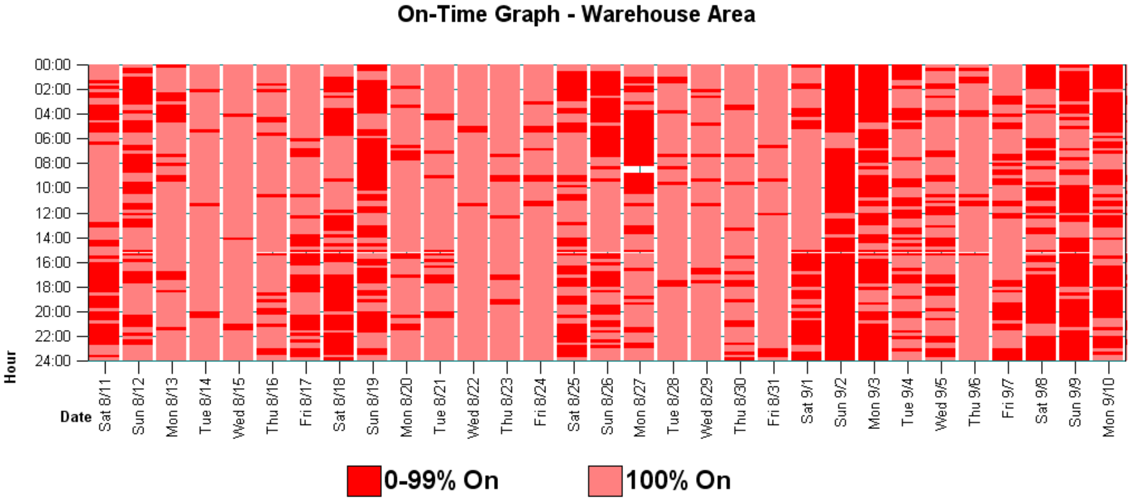
The facility representative stated that the building is occupied 24 hours, seven days a week. The facility has between 270 and 300 employees depending on the season; employees are split into three shifts, with half of the employees on the first shift, one quarter of the employees on the second shift, and the remaining quarter on the third shift. The facility is not closed on any annual holidays. The facility representative stated that the facility hours of operation did not change before or after the lighting retrofit. He also stated that summers are busier with higher production rate. The facility has been expanding production capacity by replacing old equipment with higher speed, higher output bottling equipment.

The electricity end-uses at this facility are lighting, forklifts charging, injection and blow molders, bottling lines, conveyers and office and filler room air conditioning. The office is a small portion of the total floor area. The facility representative confirmed that there was no change in the electricity use patterns before and after the retrofit other than the change to the light fixtures themselves.

The baseline for pre-retrofit hours of operation is documented in the “LT-survey” spreadsheet provided in the application materials. This spreadsheet showed that all the lights were in operation 8,736 hours per year (except four T8 fixtures under the mezzanine, operational only 1,000 hours a year). The on-time graph in Figure 1 shows that the lights in the warehouse area are indeed operational every day of the week, including weekends and holidays. There is generally less activity in the warehouse area on Saturday, Sunday and Monday. The percent on-time recorded by the loggers in the warehouse area is 0.94. This on-time percentage will be applied to all the T5 fixtures with motion sensors, located primarily in the warehouse area, but also in the packaging, husky, perform, garage, and utility areas.

The light logger in the production area showed that the fixture was energized all the time that the logger was installed, confirming that the lights are on 24 hours a day 7 days a week in the production area. This will be applied to all T5 fixtures without motion sensors. Very few burned out lights were observed during the site visit so there will be no adjustment for burnt out bulbs.

Figure 1: Light Logger Data at site A078



The power draw on one circuit was measured to determine the actual wattage of the T5 fixtures. Eight 12-lamp T5 fixtures in the tank area were powered by the circuit measured. The fixtures are wired on a 480 V Delta configuration. The current measurements on the three legs were 4.86A, 2.85A and 4.2A with 467V between each of the legs the total power to the three fixtures is 5.562 kW or 0.695 kW/fixture. This is just slightly lower than the 0.702 kW specified in the literature for these fixtures. The measured wattage will be used in the ex post calculations.

Light Logger Analysis of T5 fixtures:

- Pre-retrofit hours of operation: 8,736 hrs/yr (52.18 weeks x 168 hours/week – annual holidays of 24 hours = 8,736 hours, or 99.7%)
  Pre-retrofit wattage: 1.08 kW per fixture x 326 lamps = 352.08 kW
  Annual kWh usage: 352.08 kW x 8,736 hrs/yr = 3,075,771 kWh/yr
- Post-retrofit hours measured with light loggers are 7,972 hrs/yr for 105 fixtures with motion sensors. The remaining 221 fixtures remain at pre-retrofit hours of operation.

  Post retrofit wattage: 0.695 for 12-lamp fixtures (163 without motion sensors and 66 with motion sensors), 0.348 kW for 6-lamp fixtures (57 without sensors and 39 with sensors) and 0.116 for the single two-lamp fixture = 192.68 kW.

  Annual kWh usage: 192.63 kW x 8,736 hrs/yr = 1,683,252 kWh/year.
- Motion sensor energy savings: (pre-retrofit usage factor – post retrofit usage factor) x post retrofit connected load x 8760 hours = (0.997-0.940) x 59.44 kW x 8760 hours/year = 29,681 kWh.
- The annual kWh savings from the fixtures = 3,075,771 kWh/yr – 1,683,252 kWh/yr + 29,681 kWh/yr = 1,362,838 kWh/yr.

- Adding 303,737 kWh/yr savings from the other measures, total kWh savings are 1,666,575 kWh/yr.

Summer peak impacts of the motion sensors were estimated by subtracting post-retrofit from pre-retrofit diversity factor and multiplying by connected load. The light loggers showed that between the hours of 2 and 5 pm on weekdays, approximately 98% of the lights are on (see Figure 2). Before the retrofit, the lights were always on during the summer peak period.

- Summer peak demand savings = (1-0.98) x 59.42 kW = 1.16 kW.
- Summer peak demand savings due to the fixture replacement = pre-retrofit connected load – post-retrofit connected load = 352.1 kW – 192.6 kW = 159.5 kW.
- The total savings is 160.7 kW.
- Including 50.5 kW from other measures, the total savings is 211.2 kW.

Figure 2: Weekday Load Profile of Aggregated Light Logger Data in Warehouse Aisles at site A078

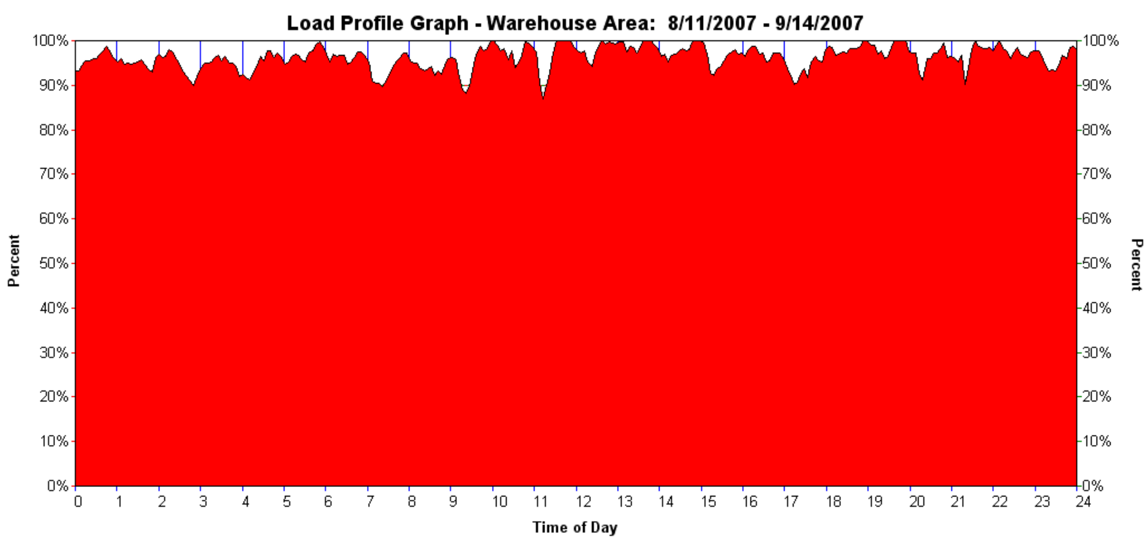
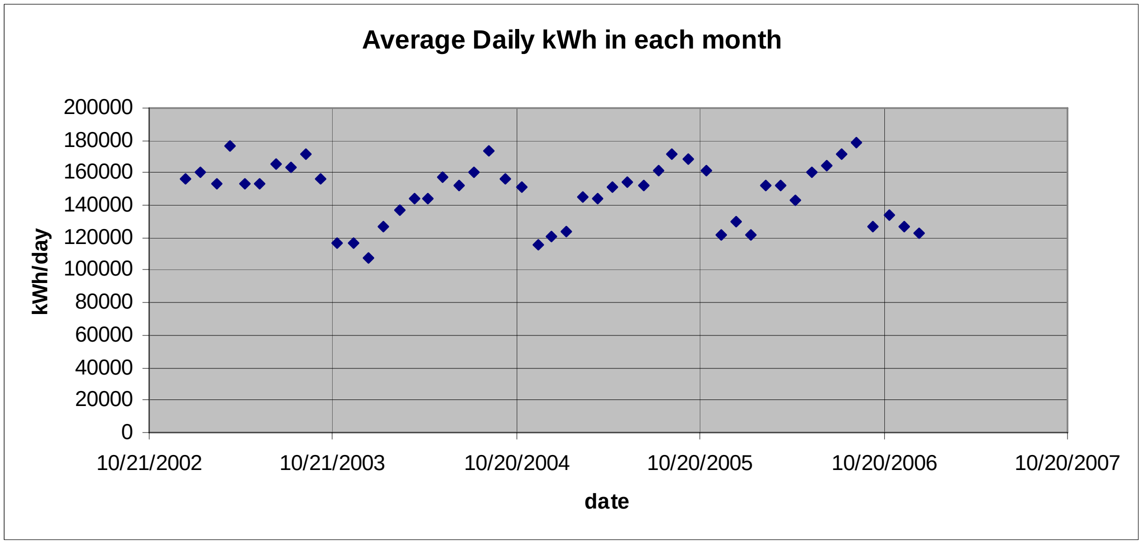


Figure 3: Daily kWh Consumption



Billing data was examined to see if savings are apparent. Figure 3 illustrates that the savings are not apparent because the expected savings (approximately 4,500 kWh/day) is small compared to the normal yearly fluctuation in energy use (70,000 kWh/day.) The facility representative mentioned that production is higher in the summer than the winter because the demand for water is higher. The facility representative also mentioned they have been replacing 1990's vintage equipment with newer faster bottling lines which have increased their production while decreasing their energy use. From the billing data it looks like energy use has remained constant over the past 4 years although production has increased.

Table 2 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers. The total meter energy use and peak demand are from the utility billing data in the year 2004, before the retrofit. The baseline use is calculated based on the number of pre-retrofit fixtures, their wattage, and hours of use. The ex ante and ex post results are similar showing that the ex ante calculations is a good estimate of actual savings in this case.

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante and ex post results show baseline end use savings ranging from 47% to 55%. This is reasonable for a lighting retrofit. The savings are only a small percent of the total energy used at this facility due to the large energy needed for industrial process at this site.

Table 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	8512.0	49,487,080
Baseline End Use	386.9	3,330,303
Ex ante Savings	184.1	1,764,804
Ex Post Savings	211.2	1,666,575

Table 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	2.2%	3.6%	2.5%	3.4%
Baseline End Use %	47.6%	53.0%	54.6%	50.0%

6. Additional Evaluation Findings

The ex post kW demand reduction is higher than the ex ante estimate primarily because the measured fixture power draw was slightly lower than the power draw specified in the literature. The ex post energy savings are somewhat lower than the ex ante energy savings because the motion sensor savings are overestimated. The ex ante calculations used an on-time factor of about 50% whereas the measured on time factor is about 95%.

There are no perceived non-energy benefits at the facility. The light levels are the same as they were before the retrofit. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. Participation in the 2004/2005 SPC Program has encouraged them to perform other energy efficiency projects, specifically installation of an EMS for the compressors and new ammonia chillers. Both projects were done through the SPC program.

7. Impact Results

The pre-retrofit lighting fixture type, quantities and hours of operation were unable to be physically verified. However, these parameters appear to have been accurately assessed and quantified based on discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $261,664.93 and an $87,787.85 incentive, the project had a 0.56 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 0.60 years. A summary of the economic parameters for the project is shown in Table 4.

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	11/15/2005	$217,285	184.1	1,764,804	0	$229,425	$87,788	0.56	0.95
SPC Program Review (Ex Post)	8/9/2007	$217,285	211.2	1,666,575	0	$216,655	$87,788	0.60	1.00

The engineering realization rate for this application is 1.15 for demand kW reduction and 0.94 for energy savings kWh. A summary of the realization rate is shown in Table 5.

The Installation Verification Summary is shown in Table 6 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 7.

Table 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	184.1	1,764,804	-
SPC Installation Report (ex ante)	184.1	1,764,804	-
Impact Evaluation (ex post)	211.2	1,666,575	-
Engineering Realization Rate	1.15	0.94	NA

Table 6: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Installation of 221 T5 fixtures, installation of 105 T5 fixtures with motion sensors, installation of 710 T8 lamps with ballasts, 238 T12 lamps removed, installation of 25 ceiling mounted occupancy sensors, installation of 8 wall box occupancy sensors, installation of 33 exit signs.		1,150	T5 fixtures, T8 fixtures, occupancy sensors, exit signs	Physically verified lamp type and spot checked quantity	0.95

Table 7: Multi Year Reporting Table

Program ID Program Name		SPC 2004 Application # A078 2004 – 2005 SPC Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004					0	0
2	2005					0	0
3	2006			184.1	211.2	0	0
4	2007			184.1	211.2	0	0
5	2008			184.1	211.2	0	0
6	2009			184.1	211.2	0	0
7	2010			184.1	211.2	0	0
8	2011			184.1	211.2	0	0
9	2012			184.1	211.2	0	0
10	2013			184.1	211.2	0	0
11	2014			184.1	211.2	0	0
12	2015			184.1	211.2	0	0
13	2016			184.1	211.2	0	0
14	2017			184.1	211.2	0	0
15	2018			184.1	211.2	0	0
16	2019			184.1	211.2	0	0
17	2020			184.1	211.2	0	0
18	2021			184.1	211.2	0	0
19	2022						
20	2023						
TOT	2004-2023						

Final Report

SITE A079 (2004-014) IrviColl IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 2 END USE: Lighting

Measures	Comprehensive Lighting Retrofit and Occupancy Sensors
Site Description	Educational Campus

1. Measure Description

Replace 9,006 four-foot T12 lamps with T8 lamps and electronic ballasts; replace 334 incandescent fixtures with compact fluorescent lamps (CFLs) of varying sizes; replace 34 incandescent fixtures with pulse start metal halide fixtures; replace 8 mercury vapor fixtures with pulse start metal halide fixtures; remove 715 four-foot fluorescent T12 lamps; install 216 ceiling mounted occupancy sensors; and install 115 LED exit signs.

2. Summary of the Ex Ante Calculations

The total estimated ex ante savings of 270.0 kW and 2,067,659.63 kWh and the incentive of $ 194,052.62 were reported for all measures in the Installation Report Review.

This impact evaluation covers lighting retrofits and does not cover the three HVAC measures, one of which was itemized and two of which were calculated measures. The ex ante savings for the balance of the measures, the lighting retrofits, were 226.3 kW and 1,079,831 kWh and the associated incentive was $57,841. Except for rounding functions, these figures agree with the utility tracking system.

The largest ex ante savings listed on the Installation Report Review (in the Summary of Itemized Measures) are derived from three measures - the replacement of 9,006 T12 lamps with T8 lamps and electronic ballasts, the removal of 715 lamps in fixtures converted from T12 to T8 lamps, and the installation of 216 ceiling mounted occupancy sensors. These measures comprise 84 % of the lighting savings and contribute 193 kW and 904,159 kWh of the estimated ex ante lighting savings of 226.3 and 1,079,831. The evaluation will focus on these measures. The balance of estimated savings was for the other fixtures mentioned in Section 1.

The ex ante calculations for the itemized measures are typically based on the 2004-2005 California Utility Express Efficiency Workpapers. The workpapers discuss general descriptions of measures that are the basis for evaluation. The workpaper assumptions for the lighting measures implemented at college market sector sites include 3,900 annual operating hours and a coincident diversity factor of 0.68 where applicable.

The following sections of the workpapers provided source information for evaluating the energy savings measures implemented at this facility. Sections E-L23 discusses fixture conversions and lamp retrofit from 4 foot T12 to T8 fixtures. Section E – L19 discusses savings from delamping 4 foot T12 lamps with T8 lamp and ballast replacements. In section J – L83 for ceiling or wall mounted occupancy sensors, the workpaper savings are based on the control of fluorescent fixtures. The workpapers for the measures implemented at this facility are discussed individually in the following paragraphs.

The section E-L23 measure covers conversion from 4 foot T12 fixtures with energy saving magnetic ballasts to 4 foot T8 fixtures with three 32 watt T8 lamps and electronic ballasts. The total installed wattage drops from 0.115 kW to 0.084 kW for a noncoincident demand savings of 0.031 kW per fixture or 0.010 kW per lamp. For a college market sector, coincident demand savings is 0.007 kW and annual kWh savings is 40 kWh per lamp.

Section E-L19 measure covers the conversion from a 3-lamp to a 2-lamp fixture. The original fixture wattage is based on T-12, 34-watt lamps with energy-saving ballast. One lamp and its associated ballast are removed. Total installed wattage drops from 0.115 kW to 0.072 kW for a non-coincident demand savings of 0.043 kW per lamp removed. For a college market sector coincident demand savings is 0.036 kW and annual kWh savings is 193 kWh per lamp.

In section J–L83 for ceiling or wall mounted occupancy sensors, the workpaper savings are based on the control of eight (8) 4 foot 2 lamp fluorescent fixtures with 34 watt T-12 lamps, consuming 72 watts per fixture including the ballast, in an office conference room. Savings are based on a reduction of lighting hours from 2,210 hours/year to 1,040 hours/year (1,170 hours/year reduction). The workpaper reports a total 789 kWh/yr savings (674 kWh/year plus a 17% office sector demand interactive effects factor). The non-coincident peak reduction of 0.305 kW was derived from the 0.576 kW controlled wattage and a 53% reduction in hours. Coincident peak reduction was reported at 0.381 kW, which includes a 1.25 demand sector interactive effects factor.

3. Comments on the Ex Ante Calculations

The ex ante calculations are calculated automatically using the Itemized Measure Form. The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers as described in the previous section. The calculations performed with the values from those workpapers do not always accurately represent the actual situation evaluated.

The ex ante savings figures can be checked for accuracy using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x (1 – diversity factor)

The check calculations for the evaluated measures (involving conversion of T12 to T8 fluorescent lamps and electronic ballasts, removal of T12 lamps with conversion to T8 lamps, and installation of motion sensors) were performed as follows:

Pre retrofit 4 foot fixture conversions

- Pre-retrofit hours of operation 3,900 hrs/yr (workpapers)

  Pre-retrofit wattages fluorescent lighting:

  0.036 kW per lamp for 4 foot T12 lamps x 9,006 lamps = 324.2 kW

  Annual pre measure kWh use: 324.2 kW x 3,900 hrs/yr = 1,264,380 kWh/yr

Post retrofit 4 foot fixture conversions

- Post-retrofit hours of operation 3,900 hrs/yr

  Post-retrofit wattages fluorescent lighting:

  0.024 kW per lamp for 4 foot T8 lamp x 9,006 lamps = 216.1 kW

  Annual post measure kWh use: 216.1 kW x 3,900 hrs/yr = 842,790 kWh/yr

  Fixture conversion savings: 1,264,380 kWh/yr – 842,790 kWh/yr = 421,590 kWh/yr

  324.2 kW – 216.1 kW = 108.1 kW

Pre-Retrofit de-lamp connected load

- Pre-retrofit hours of operation 3,900 hrs/yr

  Pre-retrofit wattages fluorescent lighting:

  0.036 kW per lamp x 715 lamps = 25.74 kW

  Annual pre measure kWh use: 25.74 kW x 3,900 hrs/yr =

  100,386 kWh/yr

Post-Retrofit de-lamp connected load

- Post-retrofit hours of operation 0 hrs/yr

  Post-retrofit wattages fluorescent lighting:

  0.0 kW per lamp x 715 lamps = 0 kW

  Annual pre measure kWh use: 100,386 kWh/yr

De-lamp Savings: 100,386 kWh/yr – 0 kWh/yr = 100,386 kWh/yr

25.74 kW – 0 kW = 25.74 kW

Occupancy sensors

- Pre-installation hours of operation: 3,900 hrs/yr; coincident diversity factor for college market sector: 0.68

  0.576 kW per sensor (workpapers controlled wattage) x 216 sensors = 124.42 kW (may be a low estimate)

  Annual pre measure kWh use: 124.42 kW x 3,900 hrs/yr = 485,238 kWh/yr

- Post-installation hours of operation: 1,040 hrs/yr (from workpapers - may be a low value for estimate post retrofit operating hours based on the market sector)

  0.576 kW per sensor x 216 sensors = 124.42 kW

  Annual post measure kWh use: 124.42 kW x 1,040 hrs/yr = 129,396 kWh/yr

  Occupancy sensor savings: 485,238 kWh/yr – 129,396 kWh/yr = 355,842 kWh/yr

  Non-coincident demand savings: 0.576 x (1-0.68) x 216 sensors = 39.81 kW

  Total savings for the three measures: 421,590 kWh/yr + 100,386 kWh/yr + 355,842 kWh/yr = 877,818 kWh/yr

  Total demand savings: 108.1 kW + 25.74 kW + 39.81 kW = 173.65 kW

The expected kW savings 173.65 are within 10% of the estimated ex ante savings of 193 kW; the expected 877,818 kWh/yr savings are 97% of the ex ante savings of 904,159 kWh/yr listed in the IRR for these sub measures. The greatest uncertainty appears to be with the actual hours of operation at the college and the impacts by the occupancy sensors on those hours.

Based upon hourly use figures obtained from the estimates in the original application documents for this facility, hours may be lower than the average stated in the workpapers for college operations, and kWh savings then would be expected to be lower. However, there may not be significant changes to the kW estimates.

4. Measurement & Verification Plan

The facility encompasses over 25 buildings and 262,887 square feet (sf) and is reported to be 30 years old. The buildings are part of an educational campus with varying uses and occupancy patterns.

The major portion of the savings come from the three measures listed – the conversion of 9006 T12 lamps to T8 lamps with ballast changes, the removal of 715 lamps, and the installation of 216 occupancy sensors.

Spot power measurements may be used to obtain the wattages of the post retrofit 4 foot T8 fixtures.

Dataloggers also may be used at central lighting panels to verify usage patterns. Either power or current may be recorded to capture these trends. Recording periods should be one week or more.

To determine hours of operation, lighting loggers will be installed in various areas (if possible, in areas with and without occupancy sensor controls).

Given the large number of buildings, three of the largest buildings with the greatest usage will be monitored with lighting loggers.

A representative sample of usage areas will be selected. This would include open offices, private offices, classrooms, lecture halls, common areas in the student center and in libraries, and 24 hour areas such as halls.

These, then, could be weighted by relative proportions of their total areas. Preliminary weighting would be 65% classrooms, 10% offices, 10% lecture halls, 10% open areas, and 5% common areas. The facility representative will be questioned to refine these percentages based on the actual areas receiving lighting retrofits.

The wattages of the new 4 foot T8 fixtures (both lamp and ballasts) will be confirmed through collection of ballast and lamp information. To the extent possible, information about the pre-retrofit fixtures will be obtained to make accurate calculations. The collection of ballast and lamp information on these older fixtures also will be attempted (primarily from existing, non-retrofit fixtures or retained equipment).

The facility also removed fluorescent lamps. Information regarding the previous fixture locations will be obtained, through as built drawings of the lighting retrofit and the existing fixtures to perform accurate evaluation.

The controlled wattages of motion sensors will be determined to the extent possible.

The other lighting retrofits at the facility, including the installation of the CFLs, the interior HID fixtures, and LED exit lights, will be verified to the extent possible.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the lighting measures.

Formulae and Approach

A modified version of IPMVP Option A can be used. Lighting loggers would be used to quantify hours of operation. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = $kWh_{pre} - kWh_{post}$

Summer peak demand period savings are $kW_{pre} - kW_{post}$ during the three expected contiguous hottest days between 2 pm to 5 pm, Monday to Friday, of the week with the hottest day in June, July, August, and September.

To estimate the average expected peak demand kW reduction, since this measure is not weather dependent, the average of all reductions during that period, as stated above, could be used. Alternately, the hottest days, from the climate data could be used.

Uncertainty for the savings estimate for the office building fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables.

For lower wattage fixtures (T8 conversion from T12 lamps)

- 9,006 lamps expected, minimum 8,100, maximum 9,906 (+/- 10 %)
- 3,000 average hours pre retrofit expected/reported, minimum 1,000 hours, maximum 5,000 hours (+/- 67 %)
- 226 kW expected, minimum 205 kW, maximum 250 kW (includes +/- 10 % for number of fixtures and +/- 5 % for fixture wattage difference)

For motion sensors controlling the above fixtures

- Number of controlled fixtures 2,000 fixtures expected, minimum 1000, maximum 3,000 (+/- 50 %)
- 1,000 average hours post retrofit expected/reported for fixtures with occupancy sensors, minimum 500 hours, maximum 2,500 hours (- 50 % , +150 % based on judgment of use for site type; includes + / - 5% from annualizing estimates from short monitoring period.

There will be a small potential error estimated at +/- 1% to 2%, since M&V will not be performed on the smallest measures which contribute a smaller amount of savings. This is not included in the analysis of uncertainty due to its size.

Accuracy and Equipment

The utility meters capture 15 minute interval data and for the purposes of the evaluation are considered to be 99% accurate where reviewed data are deemed reasonable.

The lighting loggers capture on/off cycles of the lighting equipment 15 minute interval data and have a resolution of 1 second. For the purposes of the evaluation the loggers are considered to be 100% accurate where reviewed data are deemed reasonable.

The light loggers to be used are Dent TOU-L Lighting SMART*logger* dataloggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

Annualizing the logged data from a 7 to 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

Current or power meters also may be used. The current loggers to be used, if this M&V technique is selected, would be HOBO U-12 loggers, with matched current transducers. The accuracy range is 4.5 %. The sensor would be calibrated to an Amprobe ACD-41PQ, with an accuracy of +/- 2%. An advantage of using current or power meters to monitor lighting load at an electrical panel is that the percent of time energized for an increased number of fixtures may be able to be captured.

A Dent Elite Pro may also be used for long term current measurements. The accuracy of current measurements is +/- 2% to +/- 2.5%, depending on the current transducer used. Voltage measurements have an accuracy of +/- 1%.

Annualizing the kW data to the hottest summer period is projected to result in a possible error in the final results of +/- 5 %.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 7, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Twenty-one lighting loggers were installed in several buildings with different usage types at the facility.

Installation Verification

Quantities and types of fixtures and lamps had been verified during the post-installation inspection. One, two, and three lamp four-foot fluorescent fixtures (3,795) and two lamp eight-foot fixtures (196), all with T12 lamps were replaced with one, two, three, and four lamp fluorescent fixtures with high performance T8 lamps and electronic ballasts. The facility maintained the normal operating schedule before and after the retrofit. Additionally, compact fluorescent, pulse start HID, and LED exit sign fixtures were installed according to the retrofit plan. Wall or ceiling occupancy sensors (216) were installed in offices, restrooms, class rooms and conference rooms. Seven hundred fifteen (715) fixtures had lamps and associated ballasts removed.

The date of completion for the installation was estimated to be May 2004 based on dated correspondence in file.

All items for the lighting retrofits could not be counted. However, the sampled areas appeared to have the listed quantities for lighting retrofits installed.

The verification realization rate for this project is 1.0. A verification summary is shown in Table 5 below.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measures in the SPC application covering both lighting efficiency and lighting control retrofits. Lighting was one of two end use measures in this application. The measure end use for this review is lighting only.

Summary of Results

Twenty-one Dent TOU-L lighting Smart Loggers were installed in several buildings for 58 days (from August 7, 2007- October 5, 2007) to measure the operating hours of a representative sample of the retrofit lighting fixtures. Eight (8) fixtures monitored were not controlled by occupancy sensors, and 13 of 21 fixtures monitored had fluctuating light levels and were presumed to have occupancy sensor controls. The facility representative stated that the monitored period had been representative of normal facility operation. It was found that 19 % of the fixtures in the sample were not energized the entire period, 19 % of the fixtures in the sample were energized the entire 58 day period, and the balance of fixtures sampled (62 %), on average were energized 27.6 % of the time (compared to the 12 % assumed in the workpapers). On weekdays, lights with fluctuating light levels presumed to have sensors were energized an average of 36.4 % of the time, while on weekends, lights were on nearly 6 % of the time. This equates to 27.7 % of the total week, or 2,426 hours/year (assuming that the weeks monitored were typical).

Weekday lighting data was aggregated. The average measured hourly lighting profiles are shown in Figure 1. As expected, weekend lighting profiles are different than weekday profiles. Overall, the post retrofit lights are on about 36 % of the time and off 64 % of the time.

At the coincident peak demand period, between 2 pm and 5 pm weekdays, the graph indicates the lights were on an average 64 % of the time with the highest use in the late mornings and with decreasing lighting use in the afternoon and evening.

The lighting profiles for all loggers were aggregated and the average loading profile is displayed in Figure 1. Although some buildings and classrooms are used on weekends they are a small percent of the lighting use. The loading profile presented in Figure 2 is for weekdays. Building and classroom use is between the hours of 6:30 a.m. and 10:30 p.m., with greatest lighting energy demand between 7:30 a.m. and 3:30 p.m.

Figure 1: Aggregate Daily Lighting 7-Day Use Profile by Hour

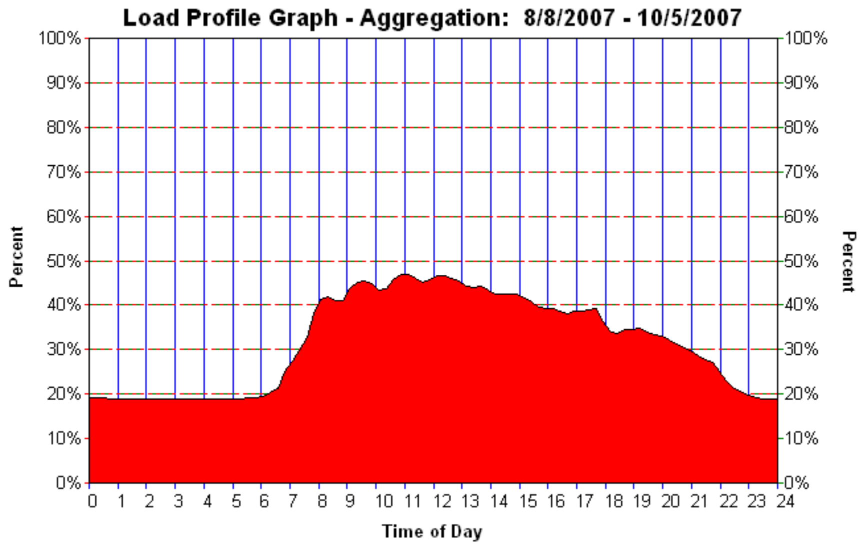
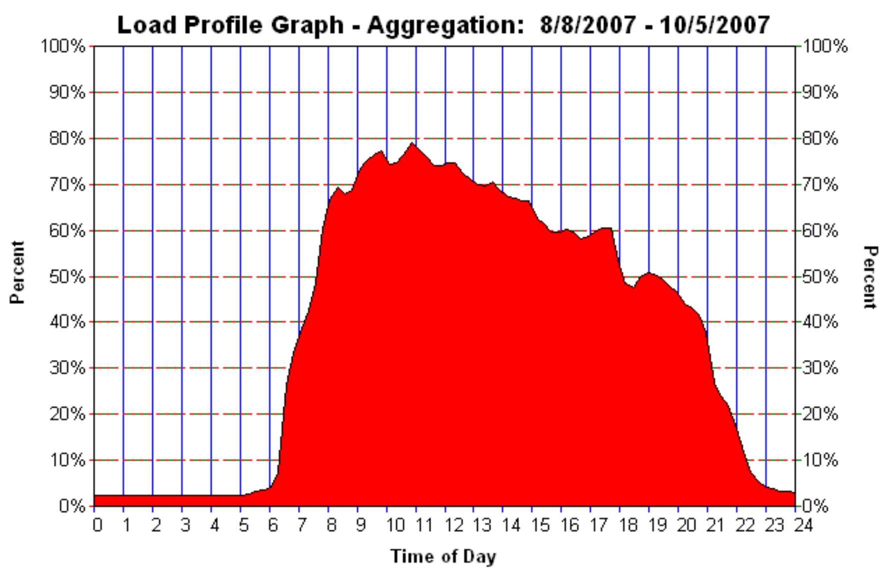


Figure 2: Aggregate Daily Lighting Weekday Use Profile by Hour



The ex ante calculations were performed using the workpaper operating schedules and lighting fixture wattages from the SPC tables. One table in the original application provided hours of use for the various activity types on the campus. The listed room use hours averaged over all lights calculated to be 3,001 hours. For the controlled fixtures average hours were 2,609 hrs without control and 1,717 average hours adjusted for percent time estimated for the application. These hours will be used as the pre retrofit and post retrofit hours in the ex post calculations.

The largest contributions to savings were the replacement of 9,006 four-foot T12 lamps with T8 lamps and electronic ballasts, the installation of 216 occupancy sensors, and the removal of 715 lamps from T12 type fixtures with retrofit for T8 lamps and ballasts. The ex post impacts are calculated for these lamps, sensors and fixtures as follows:

Pre-retrofit hours of operation are presumed at 3,000 hrs/year. (This was the weighted average as defined by the project sponsor in the application paperwork – this figure was used as it was not possible to use lighting logger results. The lighting loggers would record reduced hours due to motion sensor installation. It was not possible to deactivate these sensors to get operating hours without sensors).

Pre retrofit 4 foot fixture conversions kW and kWh

- Pre-retrofit hours of operation 3,000 hrs/yr (weighted average)

  Pre-retrofit wattages fluorescent lighting:

  0.036 kW per lamp for 4 foot lamp x 9,006 lamps = 324.2 kW

  Annual pre measure kWh use: 324.2 kW x 3,000 hrs/yr =

  972,600 kWh/yr

Post retrofit 4 foot fixture conversions kW and kWh

- Post-retrofit hours of operation 3,000 hrs/yr

  Post-retrofit wattages fluorescent lighting:

  0.024 kW per lamp for 4 foot fixture x 9,006 lamps = 216.1 kW

  Annual post measure kWh use: 216.1 kW x 3,000 hrs/yr =

  648,300 kWh/yr

The difference in connected load producing savings: 972,600 kWh - 648,300 kWh = 324,300 kWh

- Total pre-retrofit kW demand calculated for all fixtures defined in the application paperwork is 324.2 kW

- Total post-retrofit kWh demand calculated for all fixtures is 216.1 kW

- The difference is the kW demand savings: 324.2 kW – 216.1 kW =108.1 kW

Pre-Retrofit de-lamp connected load

- Pre-retrofit hours of operation 3,000 hrs/yr

  Pre-retrofit wattages fluorescent lighting:

  0.036 kW per fixture x 715 lamps (715 fixtures) = 25.74 kW

  Annual pre measure kWh use: 25.74 kW x 3,000 hrs/yr =

  77,220 kWh/yr

Post-Retrofit de-lamp connected load

- Post-retrofit hours of operation 3,000 hrs/yr

  Post-retrofit wattages fluorescent lighting:

  0 kW per lamp x 715 lamps = 0 kW

  Annual pre measure kWh use: 0 kW x 3,000 hrs/yr =

  0 kWh/yr

  De-lamp Savings: 77,220 kWh/yr - 0 kWh/yr = 77,220 kWh/yr

  25.74 kW – 0kW = 25.74 kW

Occupancy sensors

- Pre-installation hours of operation: 3,000 hrs/yr. These are estimated hours provided in the sponsor's paperwork.
- 0.576 kW per sensor x 216 sensors = 124.42 kW (note that this fixture wattage approximately equates to an average of ten two lamp T8 fixtures). This was considered reasonable; it was not possible to count all fixtures controlled by motion sensors and the lighting table was not clear which fixtures were controlled.

  Annual pre measure kWh use: 124.42 kW x 3,000 hrs/yr = 373,260 kWh/yr

- Post-installation hours of operation: 27% measured x 8760 hrs /yr = 2,365.2 hrs/yr

  0.576 kW per sensor x 216 sensors = 124.42 kW

  Annual post measure kWh use: 124.42 kW x 2,365.2 hrs/yr = 294,278 kWh/yr

  Occupancy sensor savings: 373,260 kWh/yr – 294,278 kWh/yr = 78,982 kWh/yr

Non-coincident demand savings: 0.576 x (1-0.64 average measured diversity factor / on-time) x 216 sensors = 44.79 kW

Total savings for the three largest saving measures are: 324,300 kWh/yr + 77,220 kWh/yr + 78,982 kWh/yr = 480,502 kWh/yr

The kW savings from the three largest measures are: 108.1 kW + 25.74 kW + 44.79 kW = 178.63 kW

With the other lighting measures listed on the IRR summary included in the savings calculation (175,671.0), the total savings are 656,173 kWh/yr.

The kW savings from the three largest measures are: 178.63 kW. Adding the savings from other measures listed in the IRR summary (33.75 kW), the kW savings are 212.4 kW.

Utility billing data for the site was reviewed. In the 12 month period from May 15, 2003 – April 15, 2004 (pre-retrofit), the facility consumed 1,753,128 kWh. Peak demand was 529.92 kW in September 2003. [Outside of the specified period the college had peak demand as high as 908 kW.] In the following year the energy use was 1,739,971 kWh, which is only a reduction of 13,157 kWh. Table 1 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak	Annual
	Demand kW	kWh
Total Meter	529.92	1,753,128
Baseline End Use	508.3	1,524,900
Ex ante Savings	226.3	1,079,831
Ex Post Savings	212.4	656,173

Baseline usage was for fixtures affected only. Billing data may not include all meters for the facility.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 42.7 % decrease in total meter kW, a 44.5 % decrease in lighting end use kW, a 61.6 % decrease in total meter kWh, and a 70.8 % decrease in lighting end use kWh. The ex post results showed a 40.1% decrease in total meter kW, a 41.8% decrease in lighting end use kW, a 37.4 % decrease in total meter kWh, and a 43.0% decrease in lighting end use kWh.

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	42.7%	61.6%	40.1%	37.4%
Baseline End Use %	44.5%	70.8%	41.8%	43.0%

6. Additional Evaluation Findings

The ex post kW demand reduction is less than the ex ante estimate. The differences were in all three primary sub-measures evaluated - the T12 to T8 conversion, the lamp removals, and the occupancy sensors. The per lamp kW value used for the fluorescent lamps conversion in the Installation Report Review (IRR) appears to be greater than the actual value of the lamps used at the facility for the delamping measure. The ex post kW savings for occupancy sensors are dependant on the hours of reduction, which were estimated from the logging data to be lower than provided by the workpapers and those used in the IRR. As compared with the IRR savings, lower ex post kWh savings were estimated for T12 to T8 fixture replacements, and significantly less savings was estimated for the ex post delamping and occupancy sensors. This follows for the same reasons; the ex post kW demand was calculated at a lower kW per lamp rate and the savings for the occupancy sensors and delamping have less savings with fewer hours of use than considered by the workpapers on which the IRR savings are based for itemized measures.

The cost estimate provided in the application is from the input data for the IRR. No invoice for the work performed for the lighting project was found in the paperwork. Cost data are presented in Table 3.

In addition to saving energy, the benefits of the project are better quality of lighting and increased light levels in some areas. The customer did not indicate any changes to operation that will affect energy consumption in the foreseeable future. It is not known that the customer's participation in the 2004/2005 SPC Program has encouraged them to perform any other energy efficiency projects for which they did not participate in an incentive program.

It was not possible to verify the pre-retrofit lighting fixture type, quantities and hours of operation. However, these parameters have been accurately assessed and quantified based on discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

7. Impact Results

With a total capital cost of $639,179.00 for the lighting measures and a $57,842 incentive, the project had a 4.14 year simple payback based on the ex ante calculations.

The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 6.81 years. A summary of the economic parameters for the project is shown in Table 3.

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	1/31/2005	$639,173	226.3	1,079,831	0	$140,378	$57,842	4.10	4.55
SPC Program Review (Ex Post)	10/24/2007	$639,173	212.4	656,173	0	$85,302	$57,842	6.75	7.49

The engineering realization rate for this application is 0.94 for demand kW reduction and 0.61 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 4.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	226.3	1,079,831	-
SPC Installation Report (ex ante)	226.3	1,079,831	-
Impact Evaluation (ex post)	212.4	656,173	-
Engineering Realization Rate	0.94	0.61	NA

The pre-retrofit lighting fixture type, quantities and hours of operation could not be verified physically. However these parameters have been accurately assessed and quantified based on documentation in the Installation Report. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures. Installation verification is summarized in Table 5. The savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 6.

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Replace 9006 T12 fluorescent lamp fixtures with T8 lamps and electronic ballasts; Install 216 Occupancy sensors; remove 715 T12 lamps		3991 T8 fixtures with 9006 T8 four-foot lamps; 215 ceiling mounted occupancy sensors; 715 two-foot and four-foot luminaires reduced by one or two lamps each and reflectors added.	Two-foot and four-foot straight and U-tube fixtures - all with T8 lamps	Physically verified lamp type and verified quantity from floor plan and documentation of previous inspectors.	1.00

Table 6: Multi Year Savings

Program ID:		04-0014 Application # A079					
Program Name:		SPC 04-05 Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	449,930	273,405				
2	2005	1,079,831	656,173	226.3	212.4		
3	2006	1,079,831	656,173	226.3	212.4		
4	2007	1,079,831	656,173	226.3	212.4		
5	2008	1,079,831	656,173	226.3	212.4		
6	2009	1,079,831	656,173	226.3	212.4		
7	2010	1,079,831	656,173	226.3	212.4		
8	2011	1,079,831	656,173	226.3	212.4		
9	2012	1,079,831	656,173	226.3	212.4		
10	2013	1,079,831	656,173	226.3	212.4		
11	2014	1,079,831	656,173	226.3	212.4		
12	2015	1,079,831	656,173	226.3	212.4		
13	2016	1,079,831	656,173	226.3	212.4		
14	2017	1,079,831	656,173	226.3	212.4		
15	2018	1,079,831	656,173	226.3	212.4		
16	2019	1,079,831	656,173	226.3	212.4		
17	2020	629,901	382768	226.3	212.4		
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	17,277,296	10,498,768				

16 year measure lifetime

Final Report

SITE A080 (2004-XXX) Equi IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 3 END USE: Lighting

Measures	Comprehensive Lighting Retrofit, including Occupancy Sensors, Time clocks, and LED Exit Signs
Site Description	Offices

1. Measure Description

Replace 108 two-foot, 407 three-foot, and 12,157 four-foot T12 lamps with T8 lamps and associated ballasts, replace 300 T12 fixtures with U-tube HO T8 fixtures, install 283 wall mounted and 181 ceiling mounted occupancy sensors, install 52 time clocks, and install 245 LED exit signs.

2. Summary of the Ex Ante Calculations

The total estimated ex ante savings of 256.2 kW and 1,218,062 kWh and the incentive of $ 74,260.86 were reported in Revision 2 of the Installation Report Review (IRR). Except for rounding functions for kW, these figures agree with the utility tracking system. However, the incentive of $ 76,205.90 identified by totaling the sub measures in the Installation Report Review is the correct figure,. It is unclear why the utility tracking system incentive and the IRR indicate the incentive to be $ 74,261.

The retrofit of 300 U-tube T12 fixtures, replaced with U tube T8 lamps and ballasts, was a calculated measure contributing 6.0 kW and 26,208 kWh to the total estimated ex ante savings. The balance of the eight measures as listed above was composed of itemized measures.

Four itemized measures provide the greatest contribution to the total estimated ex ante savings, according to the IRR. The main itemized measures include installation of 12,157 four foot T8 lamps and ballasts, 181 ceiling mounted occupancy sensors for larger work and conference areas, 283 wall box occupancy sensors for offices and small areas, and 52 time clocks controlling low use rooms and areas. These measures contribute 233.9 kW and 1,078,642 kWh savings of the total estimated savings 256.2 kW and 1,218,062 kWh.

The ex ante calculations for the itemized measures are typically based on the 2004-2005 Express Efficiency Workpapers. The workpapers discuss general descriptions of measures that are the basis for evaluation. For this facility, the ex ante calculations are based upon the office market sector. The workpaper assumptions for the lighting measures implemented at this site include 4,000 annual operating hours and a coincident diversity factor of 0.81 where applicable.

Individual sections of the workpapers provided source information for evaluating the energy savings measures implemented at this facility.

Conversion from 4 foot T12 fixtures with energy saving magnetic ballasts to 4 foot T8 fixtures with three 32 watt T8 lamps and ballasts.
The total installed wattage drops from 0.115 kW to 0.084 kW for a non-coincident demand savings of 0.031 kW per fixture (0.010 kW per lamp). For an office market sector, coincident demand savings is 0.009 kW and annual kWh savings is 42 kWh per lamp under the assumed operating hours and coincident diversity factor.

Wallbox-mounted occupancy sensors.
The workpaper savings are based on the control of three 4-foot 2-lamp fluorescent fixtures with 34 watt, T-12 lamps and energy saving magnetic ballasts consuming 72 watts per fixture (including ballast); the fixtures are located in a private office space. Savings are based on the reduction of hours of use from a total of 2,550 hours/year (60 hours/week for 50 weeks/year and manually switched off 15% of the time). It is assumed that the office occupant spends six hours per day in the office for 50 weeks/yr (1,500 hours/year), so that the occupancy sensor turns off lights for 1,050 hours/year (a 41% reduction over manual switching). The workpaper reports a total savings of 266 kWh/yr (227 kWh/year plus a 17% office sector demand interactive effects factor). The non-coincident peak reduction of 0.089 kW was derived from the 0.216 kW controlled wattage and a 41% reduction in hours. Coincident peak reduction was reported at 0.111 kW, which includes a 1.25 demand sector interactive effects factor (0.089 x 1.25).

Ceiling or wall mounted occupancy sensors.
The workpaper savings are based on the control of eight (8) 4 foot 2 lamp fluorescent fixtures with 34 watt T-12 lamps, consuming 72 watts each (including the ballast); the fixtures are located in an office conference room. Savings are based on a reduction of use hours from 2,210 hours/year to 1,040 hours/year (1,170 hours/year reduction). The workpaper reports a total 789 kWh savings (674 kWh/year plus a 17% office sector demand interactive effects factor). The non-coincident peak reduction of 0.305 kW was derived from the 0.576 kW controlled wattage and a 53% reduction in hours. Coincident peak reduction was reported at 0.381 kW, which includes a 1.25 demand sector interactive effects factor.

Time clocks.
In this scenario, exterior lights operate 4,380 hours per year. Without the time clock, the exterior lights would operate for an additional 1,248 hours per year (approximately 3 months at 3 additional hours per day). For the savings calculation, the time clock is assumed to control four 70-watt (95 watts each including ballast) high pressure sodium lamps. The non-coincident demand savings are 0.380 kW when controls shut off equipment. Savings for all market sectors are 474 kWh per year. There are no coincident demand savings.

3. Comments on the Ex Ante Calculations

The ex ante calculations appear to be embedded in the Itemized Measure Form. The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers as described above. The calculations performed with the values from those workpapers do not accurately represent the actual situation evaluated.

The ex ante savings figures can be checked for accuracy using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x (1 – diversity factor)

The check calculations for the main measures (involving conversion of the fluorescent lamps, installation of motion sensors, and installed time clocks) which contributed the largest savings were performed as follows:

4 foot fluorescent fixture conversions

- Pre-retrofit hours of operation: 4,000 hrs/yr

  Pre-retrofit wattages fluorescent lighting:

  0.036 kW per lamp for 4 foot fixture x 12,157 lamps = 437.652 kW

  Annual pre measure kWh use: 437.562 kW x 4,000 hrs/yr =

  1,750,608 kWh/yr
- Post-retrofit hours of operation: 2,000 hrs/yr

  Post-retrofit wattages:

  0.029 kW per lamp for 4 foot lamp x 12,157 lamps = 352.553 kW

  Total post measure kWh savings : 352.553 kW x 2,000 hr/yr = 705,106 kWh/yr

  The resulting annual kWh savings = 1,750,608 kWh/yr – 705,106 kWh/yr = 1,045,502 kWh/yr

- The total estimated kW demand reduction is: 437.562 kW – 352.553 kW = 85.0 kW

Based on the above calculations, the kW savings expected may be much lower than the forecast ex ante kW savings. The kWh savings expected appear to be in line with the ex ante savings, however.

4. Measurement & Verification Plan

The ex ante energy savings have not been fully supported with detailed documentation. There is a significant difference in the energy savings reported and the energy savings expected, especially for the demand savings.

Analysis of billing data indicates an increase in energy use from pre to post installation periods. Billing analysis does not appear to be applicable to this site.

It is essential to get an accurate number for wattage reduction and operating hours in order to determine the energy savings accurately.

The building is a 22-story office tower encompassing 409,412 square feet and is approximately 20 years old.

The major portion of the energy savings come from two measures, the replacement of four foot T12 fixtures with four foot T8 fixtures and installation of occupancy sensors in various areas on various fixture types.

Spot power measurements may be used to obtain the wattages of the post retrofit 4 foot T8 fixtures.

Dataloggers also may be used at central lighting panels to verify usage patterns. Either power or current may be recorded to capture these trends. Recording periods should be one week or more.

To determine hours of operation, lighting loggers will be installed in various areas, and, if possible, in areas with and without occupancy sensor control.

Lighting loggers will be installed on a minimum of three floors to determine the operating hours. A lighting logger may be placed on each floor if a large central open space exists; this placement would help capture most of the savings due to use reduction.

The timing schedule for the time clocks installed will be verified.

Information regarding the wattages of the lamps and the number of lamps being controlled by the time clocks may be obtained from as built drawings or lighting retrofit plans.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

A modified version of IPMVP Option A will be used. Lighting loggers would be used to quantify hours of operation. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = $kWh_{pre} - kWh_{post}$

Summer peak demand period savings = $kW_{pre} - kW_{post}$ + kW reduction during occupied periods, during the three expected contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in June, July, August, September

To estimate the average expected peak demand kW reduction, since this measure is not weather dependent, the average of all reductions during that period as stated above could be used. Alternately, the reduction on the hottest days, as determined from the climate data, could be used.

Uncertainty for the savings estimate for the office building fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables.

Uncertainty for the savings estimate for the office fixture retrofit and for the motion sensors and timers controlling these fixtures can be more fully understood by setting projected ranges on the primary variables:

<u>For lower wattage fixtures (T8 conversion from T12 lamps), U-tube lamps and LED lamps</u>

- 13,127 lamps expected, minimum 12,471, maximum 13,783 (+/- 5 %)
- 4,000 hours pre retrofit expected/reported; minimum 3,600 hours; maximum 4,400 hours (+ / - 10 %)

<u>For motion sensors controlling the above fixtures</u>

- Number of controlled fixtures 2,258 fixtures expected; minimum 2,145; maximum 2,371 (+/- 5 %)
- post retrofit expected/reported 2,200 hours; minimum 2,000 hours; maximum 4,400 hours (- 10 % , +100 % based on judgment of use for site type)

There will be a small potential error, estimated at +/- 1% to 2%, since M&V will not be performed on the smallest measures which contribute a small amount of savings. This is not included in the analysis of uncertainty due to its size.

Accuracy and Equipment

The light loggers to be used are Dent TOU-L Lighting SMART*logger* dataloggers, expected to be accurate to +/- 1%. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Annualizing that data from a 7 to 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

Current or power meters may also be used. The current loggers to be used, if this M&V technique is selected, would be HOBO U-12 loggers, with matched current transformers. The accuracy range is +/- 4.5 %. The sensor would be calibrated to an Amprobe ACD-41PQ, with an accuracy of +/- 2%. An advantage of using current or power meters to monitor load is that the percent of time energized for an increased number of fixtures may be able to be captured.

A Dent Elite Pro may also be used for long term current measurements. The accuracy of current measurements is +/- 2% to +/- 2.5%, depending on the current transducer used. Voltage measurements have an accuracy of +/- 1%.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 6, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. Lighting fixture quantities and hours of operation were verified.

The building is open 24 hours. It is, however, normally occupied from 8 am to 6 pm seven days a week. On weekdays, the building houses approximately 450 occupants with a maximum of approximately 500 occupants, 95% of which are office staff and 5% of which are building services personnel. The occupancy is believed to be approximately 95 to 98 percent at any given time during the day and substantially less at night and weekends. The building is open on holidays with no seasonal variation in occupancy.

Installation Verification

It appeared the fixtures were replaced on a one for one basis and the final count was in accord with the final fixture spread sheet submitted by the project sponsor based upon the sampled floors, invoices, and the post installation inspection. It was physically verified that two, three, and four-foot fluorescent fixtures with T-8 lamps and U-tube T-8 fixtures were installed. The retrofit was completed in June 2004. Given the size of the building, the quantities of lamps and motion sensors appear reasonable. For purposes of the ex post calculations, it is assumed that there were 108 two foot T-8 lamps, 407 three-foot T-8 lamps, and 12,157 four-foot T-8 lamps installed to replace T-12 fluorescent lighting. Additionally, 245 LED exit signs were installed to replace incandescent fixtures, 52 digital timers were installed in low use areas, 464 occupancy sensors were installed in offices, conference areas, and in large and small work areas, and 300 U-Tube fixtures were installed.

The measures in this application all pertain to lighting upgrades. The verification realization rate for this project is 1.00. A verification summary is shown in Table 5.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measures in the SPC application covering the lighting efficiency retrofits. Lighting efficiency retrofits comprise the only end use in this application.

Summary of Results

Ex-post savings were determined by extrapolating from the light logger data collected from a representative sample of floors to the entire building. Lighting logger data were collected from all loggers and the average was 49.6% (0.496). Eight (8) of the sixteen (16) lights logged were either energized continuously or not energized at all. The lights that showed any hours of operation were energized an average of 61 %. The load profile for the logged data is provided in the following graph (Figure 1).

Figure 1: Average Daily Load Profile

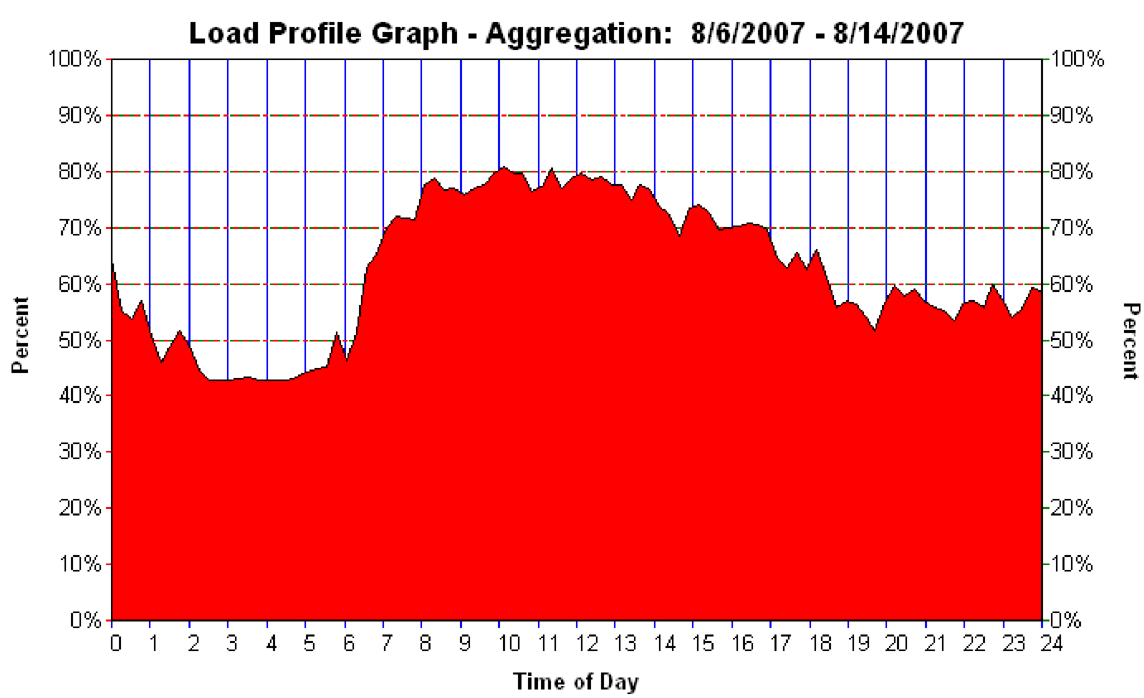
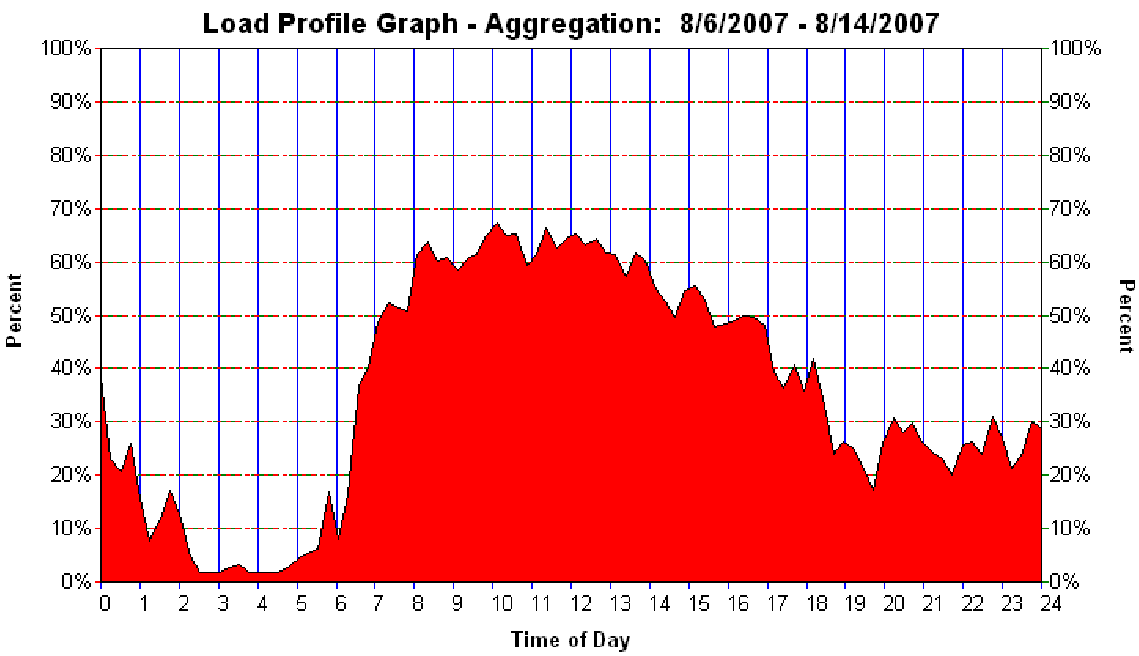


Figure 2 shows the average load profile over 24 hours of fixtures with intermittent operation. The graph plots the percent of lights energized by the hour per day. The two graphs are very similar. In Figure 2, the monitored lights which were energized 100% of the time have been removed from the dataset. The average is 37%.

Figure 2: Average Daily Load Profile - Controlled Fixtures



The ex ante calculations were revised to reflect the average hours of operation, actual number of fixtures installed, and the motion sensors that were installed. The ex-post calculations included an accounting of the new fixture wattages and the logged and verified hours to determine savings. Savings are determined from the pre-retrofit energy use minus the post retrofit energy use. Additional savings are realized from the reduced hours of energization of the post-retrofit connected load times the percent of time the post retrofit fixtures are off as a result of timer switch or occupancy sensor controls. Energy use and savings were calculated as follows:

- Total pre-retrofit kW demand - calculated from the lighting tables for all T12 itemized fixtures defined in the itemized measures is 451.03 kW.
- Total post-retrofit kW demand calculated for the replacement T8 itemized fixtures is 286.64 kW
- The difference is the kW demand savings for these three line items: 451.03 kW – 286.64 kW = 164.39 kW
- Pre-retrofit hours of operation are 4,472 hrs/yr. These hours are the weighted average of operation hours as defined by the project sponsor in the application

paperwork and the lighting fixture tables. This figure was used since it was not possible to deactivate the occupancy sensors and monitor lighting to obtain an estimate of pre-retrofit hours. For the pre-retrofit hours, use of lighting logger results would record reduced hours due to motion sensor installation and would not provide correct pre-retrofit operating hours. These hours are slightly higher than prescribed for this sector in the program workpapers.

- Power demand in kW for the major contributing loads came from the lighting tables as listed in the above bulleted items. Total pre-retrofit kWh use for the two, three and four lamp fixtures defined in the application paperwork as itemized measures are given by the kW times the operation hours.

  451.03 kW x 4,472 hrs/yr = 2,017,006 kWh/yr

- Total post-retrofit kWh use for all fixtures calculated with the 4,472 hours of operation

  286.64 kW x 4,472 hrs/yr = 1,281,854 kWh/yr

  The difference in connected load producing savings: 2,017,006 kWh - 1,281,854 kWh = 735,152 kWh

This compares to ex ante savings of 609,430 kWh and 133.7 kW for the four foot T8 lamps and ballasts installed and to ex ante savings of 636,558 kWh and 139.7 kW for the combined two, three and four foot T8 lamps and ballasts installed.

The additional savings from use of occupancy sensors is the energy use reduction through reduced hours of operation resulting from these switches. The lighting loggers indicated the controlled lights were energized 36.8% of the time on average. Lighting logger data were collected from all loggers and the average was 49.6% (0.496). Eight (8) of the sixteen (16) lights logged were either energized continuously or not energized at all.

The lower lighting energization figure of 36.8% is used. This equates to 36.8 x 4472 hours = 3,224 hours energized. The affected lights were summed based upon the lighting tables provided in the application paperwork. It was determined that 2,258 fixtures or 6,255 lamps were controlled. These include fifteen U-tube fixtures controlled. The total kW for controlled fixtures was calculated as 238.7 kW.

238.7 kW kW x 4,472 hrs/yr = 1,067,466 kWh/yr
238.7 kW kW x 3,224hrs/yr = 769,569 kWh/yr

1,067,466 kWh/yr – 769,569 kWh = 297,897 kWh

- Total ex post savings for the lamp retrofits and sensors are calculated as the sum: 735,152 kWh + 297,897 kWh = 1,033,049 kWh
- Ex ante savings from other measures: 26,208kWh + 86,083 kWh =112,291 kWh

- Total ex post savings for all measures are 1,4033,049 kWh + 112,291kWh = 1,145,340 kWh

Note that the coincident diversity factor (CDF) used in the workpapers is sometimes used in sensor savings calculations; the assumptions account for the fact that not all of the savings will occur during the peak period. The lighting use kW percentage reduction is 19% (1 – diversity factor of 0.81). The value 0.81 is the office market sector CDF.

From Figure 2, for intermittently controlled lights, the average diversity factor in the 2 pm – 5 pm periods is 55%. For the ex post occupancy sensor demand savings, a factor of 45% is used:

238.7 kW x 19% =107.4 kW

- Total kW savings for the lamp retrofits and sensors are calculated as the sum: 164.4 kW + 107.4 kW = 271.8 kW
- Ex ante savings from other measures: 6.0 kW + 10.4 kW = 16.4 kW
- Total ex post savings for all measures are 271.8 kWh + 16.4 = 288.2 kWh

Very few burned out lights were observed during the site visit. Burned out lights are replaced on an as needed basis under a maintenance schedule. There was no adjustment to the lighting energy consumption due to burned out lamps.

Utility billing data for the site was obtained from the utility. Pre-retrofit annual consumption (for one year prior to retrofit) was 6,593,738 kWh and represents the total energy use. Peak demand was 957.6 kW. The pre-retrofit baseline usage, for the lighting end use is 2,178,371 kWh and 489.0 kW, as listed in the application.

Table 1 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	957.6	6,593,738
Baseline End Use	489.0	2,178,371
Ex ante Savings	256.2	1,218,062
Ex Post Savings	288.20	1,145,340

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 26.8 % decrease in total meter kW, a 52.4 % decrease in lighting end use kW, an 18.5 % decrease in total meter kWh, and a 55.9 % decrease in lighting end use kWh. The ex post results showed a 18.0 % decrease in total meter kW, a 35.2 % decrease in lighting end use kW, a 13.7 % decrease in total meter kWh, and a 41.5 % decrease in lighting end use kWh. The percentage of savings to total metered use and baseline use are presented in Table 2.

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	26.8%	18.5%	30.1%	17.4%
Baseline End Use %	52.4%	55.9%	58.9%	52.6%

6. Additional Evaluation Findings

The ex post kW demand reduction is higher and the kWh savings is lower than the ex ante estimates because the ex ante savings estimated the fixture wattages and hours using Express Efficiency workpaper assumptions. More realistic wattages of the four foot lamps replaced caused some of this change, while the motion sensors monitored fewer hours of reduction (as opposed to the reduced number of hours estimated in the Express Efficiency workpapers).

In addition to saving energy, the benefits of the project are better illumination of areas, faster turn-on times with the newer fixtures, increased occupant comfort and better working conditions. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. Participation in the 2004/2005 SPC Program has encouraged management/owners of the building to perform other energy efficiency projects at this facility, as well as at 35 other buildings owned by the company. They have participated in the SPC programs and in incentive programs independent of the SPC program.

The costs seem reasonable for this type of retrofit.

7. Impact Results

With a cost of $259,748 and a $74,261 incentive, the project had a 1.17 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and as a result the estimated simple payback period is slightly longer at 1.25 years. Without the incentives, the payback would be approximately 1.5 years. A summary of the economic parameters for the project is shown in Table 3.

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	10/25/2004	$259,748	256.2	1,218,062	0	$158,348	$74,261	1.17	1.64
SPC Program Review (Ex Post)	7/18/2007	$259,748	288.2	1,145,340	0	$148,894	$74,261	1.25	1.74

The engineering realization rate for this application is 1.12 for demand kW reduction and 0.94 for energy savings kWh. According to the installation report, the ex ante savings are 1,218,061 kWh annually and demand reduction is 256.2 kW. These values match the utility's program tracking data with the exception of rounding differences. A summary of the realization rate is shown in Table 4.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	256.23	1,218,061	-
SPC Installation Report (ex ante)	256.2	1,218,062	-
Impact Evaluation (ex post)	288.2	1,145,340	-
Engineering Realization Rate	1.12	0.94	NA
1. Tracking System values used for realization rate calculations.			

The pre-retrofit lighting fixture type, quantities and hours of operation could not be verified physically. However these parameters have been accurately assessed and quantified based on documentation in the Installation Report. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures. Installation verification is summarized in Table 5. The savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 6.

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Reduced hours of operation - Lighting kW and kWh reductions through lowered connected load, time clocks, and occupancy sensors		13,733	300 U tube T8 fixtures, 245 LED Exit signs, 12,672 2-, 3-, & 4-foot T8 lamps and ballasts, 52 digital timers and 464 occupancy sensors	Physically verified lamp type and verified quantity from documentation of previous inspectors.	1.00

The figure of 13,733 is the total of all lighting measures.

Table 6: Multi Year Reporting Table

Program ID:			Application # A080				
Program Name:			**SPC 04-05 Evaluation**				
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program KWh Savings**	**Ex-Post Gross Evaluation Confirmed Program KWh Savings**	**Ex-Ante Gross Program-Projected Peak Program KW Savings**	**Ex-Post Gross Evaluation Projected Peak KW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004	609,031	572,670	256.2	288.2		
2	2005	1,218,062	1,145,340	256.2	288.2		
3	2006	1,218,062	1,145,340	256.2	288.2		
4	2007	1,218,062	1,145,340	256.2	288.2		
5	2008	1,218,062	1,145,340	256.2	288.2		
6	2009	1,218,062	1,145,340	256.2	288.2		
7	2010	1,218,062	1,145,340	256.2	288.2		
8	2011	1,218,062	1,145,340	256.2	288.2		
9	2012	1,218,062	1,145,340	256.2	288.2		
10	2013	1,218,062	1,145,340	256.2	288.2		
11	2014	1,218,062	1,145,340	256.2	288.2		
12	2015	1,218,062	1,145,340	256.2	288.2		
13	2016	1,218,062	1,145,340	256.2	288.2		
14	2017	1,218,062	1,145,340	256.2	288.2		
15	2018	1,218,062	1,145,340	256.2	288.2		
16	2019	1,218,062	1,145,340	256.2	288.2		
17	2020	609,031	572,670				
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	19,488,989	18,325,440				

Final Report

SITE A081 (04-118) Hya **IMPACT EVALUATION**
SAMPLE CELL: ORIGINAL **TIER: 2** **END USE: Lighting**

Measures	Lighting Retrofit
Site Description	Hotel

1. Measure Description

Replace 800 four foot 2-lamp T12 fixtures with T8 fixtures; replace 4,566 incandescent fixtures with CFL lamps greater than 27 watts; install 126 LED exit signs.

Strip curtains and door gaskets were installed. These measures are in a separate end use category and are excluded from the scope of this evaluation.

2. Summary of the Ex Ante Calculations

The original kW demand and kWh savings submitted were 207.71 kW and 1,034,462 kWh. The savings were provided on the Energy/On-Peak Demand Savings and Incentive Summary Form. Notes in the Project Application Review indicate the savings were approved as revised during the review process. The total approved savings in the Installation Report Review are given as 465.9 kW and 2,246,480 kWh. For the lighting measures evaluated, the ex ante savings are 443.3 kW and 2,095,196 kWh/yr. Theses figures agree with the utility tracking system.

The ex ante calculations for the itemized measures are typically based on the 2004-2005 California Utility Express Efficiency Workpapers. The workpapers discuss general descriptions of measures. For this facility, the ex ante calculations utilize a hotel market sector. The workpaper assumptions for the lighting measures implemented at this site include 5,500 annual operating hours and a coincident diversity factor of 0.67 where applicable.

The workpapers cover conversion from 2 lamp 4 foot T12 fixtures with energy saving magnetic ballasts to 4 foot T8 fixtures with two 32 watt T8 lamps and ballasts. The total installed wattage drops from 0.72 kW to 0.058 kW for a noncoincident demand savings of 0.014 kW per fixture or 0.007 kW per lamp. For a hotel market sector, coincident demand savings is 0.007 kW and annual kWh savings is 56 kWh per lamp under the assumed operating hours and coincident diversity factor.

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The workpapers show replacement of a fixture consisting of a 100 watt incandescent lamp fixture with a fixture consisting of 32 watt fluorescent lamps driven by electronic ballast. The total installed wattage drops from 0.100 kW to 0.031 kW for a non-coincident demand savings of 0.069 kW per fixture, a coincident kw reduction of 0.053 and an annual kWh savings of 433 kWh per fixture.

The workpapers also detail the savings from installation of high efficiency LED exit signs to replace older signs containing two 20-watt incandescent lamps. Total installed wattage drops from 0.040 kW to 0.004 kW. The noncoincident demand savings are 0.036 kW per LED fixture and with a 0.18 Demand Interactive Effects factor, the noncoincident demand savings are 0.042 kW. Fire code requires exit signs to operate all year, or 8760 hrs/yr. The savings are 0.036 kW x 8760 x 1.114 = 351 kWh per year. The calculation includes the 11.4% average Energy interactive effects. Coincident demand savings are 0.042 kW x 1.0 = 0.042 kW.

3. Comments on the Ex Ante Calculations

The measures are itemized measures and the customer used the Itemized Measure Form to calculate the incentives. The basis of the incentive payment was the itemized incentive list.

The Project Application (PA) paperwork indicated that 2000 incandescent fixtures were replaced with CFL fixtures were to be installed in the facility. In addition, 800 T12 lamps were to be replaced with T8 lamps and 126 LED exit signs were to be installed.

The post installation inspection and the Installation Report Review (IRR) reported that 4,566 CFLs replaced incandescent fixtures.

The ex ante calculations appear to be embedded in the Itemized Measure Form of the IRR. The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers as described above. The calculations performed with figures from those workpapers do not always accurately represent the actual situation evaluated.

The ex ante savings figures can be checked for accuracy using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post}

The check calculations were performed as follows:

4 foot fixture conversions

- Pre-retrofit hours of operation 5,500 hrs/yr

  Pre-retrofit wattages fluorescent lighting:

  0.036 kW per lamp for 4 foot fixture x 800 lamps = 28.80 kW

  Annual pre measure kWh use: 28.80 kW x 5,500 hrs/yr =

  158,400 kWh/yr

Screw in CFL, >= 27 watts

- Pre-retrofit hours of operation 5,500 hrs/yr

  Pre-retrofit wattages incandescent lighting:

  0.100 kW per fixture x 4,566 lamps = 456.6 kW

  Annual pre measure kWh use: 456.6 kW x 5,800 hrs/yr =

  2,511,300 kWh/yr

LED exit signs

- Pre-installation hours of operation: 8,760 hrs/yr

  Pre-measure exit lighting 0.040 kW per exit sign x 126 fixtures = 5.04 kW

  Annual pre measure kWh use: 5.04 kW x 8,760 hrs/yr = 44,150 kWh/yr

Total pre measure energy use for lighting loads: 158,400 kWh/yr + 2,511,300 kWh/yr + 44,150 kWh/yr = 2,713,850 kWh/yr

4 foot fixture conversions

- Post-retrofit hours of operation: 5,500 hrs/yr

  Post-retrofit wattages:

  0.029 kW per lamp for 4 foot fixture x 800 lamps = 23.2 kW

  Total post measure kWh savings for fluorescent lighting: 23.2 kW x 5,500 hr/yr = 127,600 kWh/yr

Screw in CFL,>= 27 watts

- Post-retrofit hours of operation 5,500 hrs/yr

  Post-retrofit wattages incandescent lighting:

  0.031 kW per lamp x 4,566 lamps = 141.5 kW

  Annual pre measure kWh use: 132.41 kW x 5,500 hrs/yr = 778,250 kWh/yr

LED exit signs

- Post-installation (LED’s) hours of operation: 8,760 hrs/yr

Post-measure LED exit lighting 0.004 kW per fixture x 126 fixtures = 0.5 kW
Annual post measure kWh use: 0.5 kW x 8,760 hrs/yr = 4380 kWh/yr

- Total post measure energy use for lighting loads: 127,600 kWh/yr + 778,250 kWh/yr + 4,380 kWh/yr = 910,230 kWh/yr

- The resulting annual kWh savings = 2,713,850 kWh/yr – 910,230 kWh/yr = 1,803,620 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load.

Summer peak demand reduction is calculated as follows:

- Reduction in connected kW load plus reduction in load use: (28.8 + 456.6 + 5.04) kW – (23.2 + 141.5 + 0.5) kW = 325.24 kW

4. Measurement & Verification Plan

According to the application paperwork, the building consists of 16 floors with a total floor area of 382,684 sq.ft. The building is reported to be approximately 19 years old.

It is essential to get an accurate number of lamps replaced, operating hours, and wattage reduction in order to determine the energy savings accurately.

The major portion of the energy savings come from replacing incandescent fixtures with CFL fixtures. The following information regarding this measure will be obtained:

- Number of pre-retrofit incandescent fixtures (location and wattage).
- Wattages and number of CFL lamps or fixtures installed as replacement.
- Number of operating hours for the CFL fixtures.
- Any change in operating hours since the replacement.

To determine operating hours, time of use loggers will be placed on the wiring to the table lamps using CFLs. Lighting loggers may be placed on wall mounted fixtures if possible.

The original application indicated 2000 CFL’s replaced incandescent fixtures but the post installation inspection reported 4566 CFL’s replaced incandescent fixtures. Verification of the reasons for this change in the number of lamps installed will be attempted. It will also be attempted to collect the hours for other areas, if these lamps were place in areas besides guest rooms.

Note that it is possible that each lamp was replaced with a dual lamp CFL fixture. This is common for ceiling mounted fixtures and may be applicable for wall fixtures in certain cases. However, this is not common for lamp fixtures.

Invoices should be obtained for the lighting retrofits. Older lamps in stock will be verified, and it will be determined , if possible, if these lamps were identical to the pre retrofit lamps.

Another measure is the replacement of 800 T12 fixtures with T8 fixtures. The following will be verified:

- The number and location of the fluorescent fixtures using T8 lamps.
- The number of hours for the fluorescent fixtures, obtained through building management personnel estimates, housekeeping staff observations, and the use of lighting loggers if possible.
- Wattages of the pre and post retrofit fixtures through checking lighting drawings, old ballasts and lamps in stock, and new ballasts/lamps.

Spot readings can be conducted on typical CFLs to determine wattage draw with ballasts.

Lighting panels for floors could be monitored over a period of two weeks, if space exists in panels for monitoring equipment.

LED exit lighting will be verified for several floors and information will be obtained regarding the previous exit lighting.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

IPMVP Option A approach should be considered. Lighting loggers would be used if possible to quantify hours of operation. The loggers will be placed in the rooms and hallways to determine the operating hours. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = $\text{kWh}_{pre} - \text{kWh}_{post}$

Summer peak demand period savings = $\text{kW}_{pre} - \text{kW}_{post}$ during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, of the week with the hottest day in June, July, August, September
.
Uncertainty for the savings estimate for the warehouse fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables.

<u>Uncertainty with installation of screw in CFL > = 27watts</u>

- 4,566 lamps expected to be installed, minimum 2,200, maximum 6,800 (+ /- 50% expected range)

- 5,500 operating hours reported/expected, minimum 4,400 hours, maximum 6,600 hours (+ / - 20% expected range)
- 429.2 kW savings expected, 350 kW minimum, 510 kW maximum (+/- 20% expected range).
- kWh savings: 1,800,000 kWh expected; 1,500,000 kWh minimum; 2,100,000 kWh maximum (+ / - 30% for range of possible savings)

Accuracy and Equipment

The lighting loggers capture on/off cycles of the lighting equipment 15 minute interval data and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Annualizing the kW data to the hottest summer period is projected to result in a possible error in the final results of +/- 5 %.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 6, 2007. Information on the retrofit and the operating hours were collected by inspection of the lighting fixtures and by interviewing the facility representatives.

Installation Verification

The facility representative verified that there were 3,240 90 watt incandescent lamps in the rooms, 800 T12 lamps in the rooms, and 490 20 watt incandescent lamps in the exit signs before the retrofit. It was estimated after interviewing the facility personnel that the room lamps operate 4,125 hours per year and exit signs operate continuously for 8,760 hours per year. It was verified on the day of the on-site survey that 2,000 27 watt CFL's were installed in the rooms, 1,240 13 watt CFL's were installed in the hallways and approximately 800 T8 lamps were installed at various locations in the facility.

These are the only measures in this application. The verification realization rate for this project is 0.71.

Scope of the Impact Assessments

The impact assessment scope is for the lighting end use measures in the SPC application covering the lighting efficiency retrofit, replacements and exit signs.

Summary of Results

Lighting loggers were not used to measure the operating hours of the lights in the rooms or the exit signs because it was not possible to place them without being seen by the guests staying in the rooms. Since, the lighting loggers were not allowed to be installed by the facility, the operating hours of the facility was determined based on the information provided by the facility. The average operating hours for a hotel facility according to Express Efficiency workpapers is 5,500 hours/year. According to the facility personnel, the occupancy rate for the facility is 75%. Therefore, the operating hours for the facility is determined to be 75% of the average operating hours of a hotel which is calculated to be 4,125 hrs/yr. The calculated operating hours are a reasonable representation for the facility.

The operating hours for 13 watt CFL's installed in the hallways and the LED exit signs was determined to be 8,760 hours. These operating hours were used to calculate the ex post savings. The results of the ex post impacts are tabulated below.

The replaced CFL fixtures and sized and the T8 fixtures are supported from an invoice obtained during the evaluation site visit.

Table 1: Ex Post Savings Calculation

Measures	Qty	#Op hrs	pre kW/ lamp	post kW/ lamp	Pre kW	pre kWh	post kW	post kWh	kW savings	kWh savings
Screw in CFL's >= 27 watts	2000	4,125	0.09	0.031	180	742,500	62	255,750	118	486,750
Screw in CFL's 5-13 watts	1240	8,760	0.09	0.015	111.6	977,616	18.6	162,936	93	814,680
Replacement of 4 ft T12 with T8 lamps	800	4,125	0.036	0.029	28.8	118,800	23.2	95,700	5.6	23,100
LED exit signs	126	8,760	0.04	0.004	5.0	44,150	0.5	4,415	4.5	44,265
Total					**325.4**	**1,883,066**	**104.3**	**518,801**	**221.1**	**1,368,795**

Table 2 summarizes the total metered energy use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility billing data and the additional data obtained from the customer. The baseline end use energy is the calculated energy use for the pre and post implementation evaluations for the specific quantities of the equipment listed in the specific measures Baseline end use for lighting was estimated at 30% of total kWh use and kW demand at this facility.

Table 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1329.0	8,872,940
Baseline End Use	398.7	2,661,882
Ex ante Savings	443.3	2,095,196
Ex Post Savings	221.1	1,368,795

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 33.4% decrease in total meter kW, 111.2% decrease in lighting end use kW, 23.6% decrease in total meter kWh, and 78.7% decrease in lighting end use kWh. The ex post results showed a 16.6% decrease in total meter kW,55.5% decrease in lighting end use kW, 15.4% decrease in total meter kWh, and 51.4% decrease in lighting end use kWh.

Table 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	33.4%	23.6%	16.6%	15.4%
Baseline End Use %	111.2%	78.7%	55.5%	51.4%

6. Additional Evaluation Findings

The ex post energy savings are considerably less than the ex ante energy savings because the ex ante savings overestimated the number of installed CFL fixtures. The ex ante calculations considered 4,566 CFLs to be installed whereas it was determined during the site visit that only 3,240 CFLs were installed in the facility. Some CFLs used in the hallways were smaller than those used in the workpapers which formed the basis for the ex ante savings. The ex ante savings were submitted as itemized measures and no additional documentation was provided to support their calculations. The ex-post calculations were more accurate as parameters used were based on actual site information provided through the evaluation site visit and by the facility personnel.

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. In addition to saving energy, the benefits of the project are better quality of lighting, longer lasting lights and less labor spent on the replacement of the lights. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program has increased the energy awareness of the facility and encouraged them to perform other energy efficiency projects.

We were unable to physically verify the pre-retrofit lighting fixture type, quantities and hours of operation for the facility. However, we are satisfied that these parameters have been accurately assessed and quantified based on our verification of accessible fixtures as a sample and discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $66,082 and $11,441 incentive, the project had a 0.20 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is substantially lower than the ex ante, and the estimated simple payback is 0.31 years. A summary of the economic parameters for the project is shown in Table 4.

7. Impact Results

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	12/2/2004	$66,082	443.3	2,095,196	0	$272,375	$11,441	0.20	0.24
SPC Program Review (Ex Post)	8/6/2007	$66,082	221.1	1,368,795	0	$177,943	$11,441	0.31	0.37

The utility tracking data are the approved estimates of ex ante savings. The utility tracking savings were 443.3 kW and 2,095,195 kWh. The ex post savings are 221.1 kW and 1,368,795 kWh. The engineering realization rate is the ratio of the ex post results to the utility tracking data. The engineering realization rate for this application is 0.50 for demand kW reduction and 0.65 for energy savings kWh. A summary of the realization rate is shown in Table 5. The Installation Verification Summary is shown in Table 6 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 7.

Table 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	443.3	2,095,195	-
SPC Installation Report (ex ante)	443.3	2,095,195	-
Impact Evaluation (ex post)	221.1	1,368,795	-
Engineering Realization Rate	0.50	0.65	NA

Table 6: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING	L		Replace 800 four foot T12 fixtures with T8 fixtures		800	2 lamp T8 fixtures with electronic ballasts	Physically verified lamp type and verified quantity from floor plan and documentation of previous inspectors.	1.00
LIGHTING	L		Replace incandescent lamps with >= 27 watss lamps		3,240	27 watts CFL lamp	Physically verified lamp type and verified quantity from floor plan and documentation of previous inspectors.	0.71
LIGHTING	L		Install LED exit signs		126	LED exit sign	Physically verified the fixtures and the quantity	1.00

Table 7: Multi Year Reporting Table

Program Name:		SPC 04-05 Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	174,600	114,066				
2	2005	2,095,195	1,368,795	443.3	221.1		
3	2006	2,095,195	1,368,795	443.3	221.1		
4	2007	2,095,195	1,368,795	443.3	221.1		
5	2008	2,095,195	1,368,795	443.3	221.1		
6	2009	2,095,195	1,368,795	443.3	221.1		
7	2010	2,095,195	1,368,795	443.3	221.1		
8	2011	2,095,195	1,368,795	443.3	221.1		
9	2012	1,920,595	1,254,729	443.3	221.1		
10	2013						
11	2014						
12	2015						
13	2016						
14	2017						
15	2018						
16	2019						
17	2020						
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	16,761,560	10,950,360				

Eight year life for CFL screw in replacements was used.

Final Site Report

SITE A082 (2004-182) PS- SA IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 3 END USE: Lighting

Measure	Comprehensive Lighting Retrofit
Site Description	Warehouse / Processing / Offices

1. Measure Description

Replace 367 high pressure sodium (HPS), high intensity discharge (HID) light fixtures with high efficiency four-foot, eight-lamp fluorescent fixtures with T8 lamps, electronic ballasts and reflectors; control these fixtures with 42 bi-level timer switches; replace 65 interior HPS fixtures with lower wattage metal halide fixtures and lamps; replace 35 incandescent lamps with screw-in compact fluorescent lamps; retrofit fifteen (15) fixtures using T-12 lamps with T-8 lamps and electronic ballasts; convert four (4) fixtures using T12 lamps to T8 or T5 lamps with removal of one lamp and one ballast; and install three (3) ceiling mounted and nine (9) wallbox occupancy sensors.

2. Summary of the Ex Ante Calculations

All measures reduce connected wattage or reduce lighting hours of operation.

Both calculated and itemized approaches were used to determine ex ante savings for the measures. As a result of the large size of the project and numbers of retrofitted fixtures, a series of adjustments were made to the submitted application. Fixtures and associated savings were then determined accurately and in accord with the program requirements. Following the installation inspection, the final program approved savings were 122.6 kW and 1,002,778.2 kWh; these figures matched the total savings in the utility tracking data.

The replacement of HPS fixtures with the high efficiency eight lamp T8 fixtures and associated timer switches provided the greatest estimated savings, as shown in the Installation Report Review (IRR).

For the conversion of HPS fixtures to high efficiency T8 lighting, the listed savings were 114.8 kW and 901,890 kWh. Additional savings calculated for the installation of bi-level control timer switches were 53,859 kWh. Combined, these savings total 114.8 kW and 955,749 kWh.

A pre-retrofit and post-retrofit algorithm, using fixture connected loads and hours of operation, was used for the ex-ante calculations. These are calculated measures, and the assumptions and methodology appear reasonable.

Specific documentation for the calculated savings that matched the listed savings was not provided in the review package; however the savings were summarized on the Measure Savings Worksheet and lighting tables were included in the application.

The lighting tables indicate that the fixtures on the main sorting floor comprise nearly all of the savings. The bi level control system controlling 268 of these fixtures accounts for a small quantity of savings according to the Measure Savings Worksheet.

The evaluation will focus on these fixtures.

Hours of operation range across the various market sector functions within the facility. On the main processing floor of the plant, work is year round, which is given as 8760 hrs/yr.

Calculations for the measures contributing the major portion of savings are as follows:

For HPS to T8 conversion (367 – 400 watt fixtures)

<u>Energy use for the higher wattage HPS fixtures</u>
8760 hours/year x 0.465 kW per fixture = 4,073.4 kWh/unit/year
367 fixtures x 4,073.4 kWh/unit/year = 1, 494,937.8 kWh/yr
367 fixtures x 0.465 kW/unit = 170.65 kW

<u>Energy use for lower wattage fixtures (T8)</u>
8760 hours/year x 0.180 kW per fixture = 1,576.8 kWh/unit/year
367 fixtures x 1,576.8 kWh/unit/year = 578,685.6 kWh/yr
367 fixtures x 0.180 kW/unit = 66.06 kW

<u>Savings: Pre-retrofit wattage – post retrofit wattage:</u>

1, 494,937.8 kWh/yr - 578,685.6 kWh/yr = 916,252.2 kWh/yr
kW savings are 170.65 kW – 66.06 kW = 104.59 kW

Estimates for savings from timer switches are dependent on the hours of use at the two lighting levels. The utility's installation inspector provided a conservative estimate. During the seven hours between 8 a.m. and 3 p.m., 33.3% of the fixtures were assumed to be at high light level and 66.7 % at low light level (with 4 of 8 lamps energized). During the seventeen peak working hours between 3 p.m. and 8 a.m., 100% of the fixtures were presumed to be operated at the high lighting level (all eight lamps per fixture are energized). In contrast, the sponsor's lighting table indicated use reduction from 8,760 hours to 5,869 hours, or a reduction of 33% resulting from the bi-level control switches.

Using the percentages suggested by the installation inspector (17 hours for maximum work activity and 7 hours for reduced work activity periods) applied to the 268 controlled fixtures, yield savings from timer switches as given by the following:

<u>Energy use for lower wattage (T8) fixtures and reduced work use</u>
33.3% of 268 fixtures at high light level (full fixture wattage) = 89 fixtures
89 fixtures x 0.18 kW/fixture = 16.02 kW/day during reduced work activity
66.7% of 268 fixtures at half light level (half fixture wattage) = 179 fixtures
179 fixtures x 0.09 kW/fixture = 16.11 kW/day reduced work activity
Daily reduced work activity energy use is (16.02 kW/day + 16.11 kW/day) x 7 hours/day = 32.13 x 7 hrs = 224.91 kWh/day

Without switches:
24 hrs/day x 0.18 kW/fixture x 268 fixtures = 1,157.76kWh/day
Annual energy use is 1,157.76kWh/day x 365.25 days/yr = 422,871.84 kWh/yr

With switches:
Energy use for lower wattage (T8) fixtures and maximum work activity use
100% of 268 fixtures at high light level (full fixture wattage = 0.18 kW at maximum `work activity period = 17 hours)
268 fixtures x 0.18 kW/fixture = 48.24 kW/day during maximum work activity (17 hrs)
Daily maximum work activity energy use is 48.24 kW/day x 17hours/day = 820.08 kWh/day
Total estimated daily kWh use for 268 fixtures is 224.91 kWh/day (over 7 hrs) + 820.08 kWh/day (over 17 hrs) = 1,044.99 kWh/day
Total estimated annual kWh use is for controlled fixtures is 1,044.99 kWh/day x 365.25 days/yr = 381,682.60 kWh/yr
Total estimated energy savings from switches is 422,871.84 kWh/yr - 381,682.60 kWh/yr = 41,189.24 kWh

Of the 367 - 400 watt fixtures, 268 are controlled with timer switches and 99 are on all the time. The 99 fixtures provide savings of 218,452 kWh and 21.28 kW

From the use of switches on the fixtures indicated in the lighting table and using the Installation Inspector's use percentages, annual energy savings are savings from reduced wattage fixtures and savings from timer switches.

916,252.2 kWh/yr + 41,189.2 kWh = 957,441.4 kWh

The calculated savings listed for the Bi level lighting controls were 53,859 kWh. The difference is presumed to be due to an increased number of fixtures controlled by the timer switches.

Total post retrofit savings for the reduced lighting of the controlled fixtures as indicated in the lighting tables is 669,088.8 kWh/yr + 41,189.24 kWh /yr = 710,278.04 kWh/yr

Including the small savings from the other measures and additional fixtures as indicated in the Summary of Approved Measures, the total savings are 710,278.04 kWh/yr + 279,830.2 kWh/yr = 990,108.24 kWh/yr.

This value corresponds to the savings indicated in the above calculations; the savings are slightly less than the total savings of 1,002, 778.2 listed in the Installation Report Review and appear reasonable.

3. Comments on the Ex Ante Calculations

The customer's sponsor used the calculated and itemized measures approaches to determine savings. This project was part of a much larger contract providing energy saving retrofits at numerous, similar locations.

This facility has mixed hours of operation according to zones of processing work and office work schedules. Estimated hours of operation were presented in the SPC Lighting Equipment Survey (LE1) form included with the Installation Inspection Report (IRR). The calculations from the LE1 survey provided pre and post fixture replacement or fixture retrofit energy savings defined on a per lamp or per fixture basis for some of the measures.

In addition, changes occurred between the initially proposed measures and those actually implemented or reported in the Installation Inspection Report. Some old fixtures were U-tube rather than straight tube lamps as reported in the Project Sponsor’s revised Installation Report. In addition, 42 time clocks actually were bi-level lighting controls on timer switches. These were incorrectly reported as a time clock control measure in the revised Installation Report itemized measures summary. The SPC utility administrator determined that the timer switches were ineligible for the itemized measures incentive and reassessed the measure using the calculated approach and more conservative savings, since the timer switch savings were difficult to estimate without monitoring the use.

The following paragraphs highlight other information regarding the ex ante calculations.

With respect to the timer switches, since the savings calculated above and the savings calculated by the installation inspector are nearly the same; it is presumed that the calculation assumptions for the measures evaluated are similar, though specific calculations were not provided in the paperwork.

For the lighting conversion of the 367 high intensity discharge fixtures to T8 fluorescent fixtures, the post installation savings calculated on the LE1 survey form conform to the expected kW/unit savings given the equipment operation.

The Summary of Approved Measures indicates replacement of all 435 uncontrolled and controlled high pressure sodium (HPS) fixtures (400-watt, 250 watt, 150 watt) and other fluorescent fixtures with the eight lamp T8 fixtures or metal halide fixtures provides the greatest savings (118.8 kW and 931,205 kWh per year). A portion (167) of these replacement fixtures appear to be energized all the time - 24 hours per day 7 days per week - functioning at the high light level (8 lamps on per fixture or with lower wattage metal halide lamps). The balance of controlled fixtures (268) provides the minimum daily lighting possible to unused work zones within the main processing floor of the facility. As daily work progresses through the facility into adjacent zones and during the peak hours of operations between 3 p.m. and 8:30 a.m., the lighting is increased to full level (8 lamps “on” per fixture) as increased light level demand is required for the work. Total savings for this measure are realized from reduced fixture wattage for the change from HPS to fluorescent and from reduced operation, when lamps are at low level (50% of lamps “on”). The low to high level lighting is controlled by electrical timed switches. Switches are manually turned on when higher lighting is desired. The switches control various numbers of fixtures/lamps per work zone (from approximately 1 to 10 fixtures or 4 to 40 lamps) and are set for three hour duration, after which they turn off four lamps per eight-lamp fixture. If, after three hours, there is still a lighting level demand by the workers, the switch is manually turned on. For an eight hour shift, the lighting switch may be manually adjusted approximately two times. After the work in that zone is complete, the lights may revert to the lower level or may be increased by the workers who clean and maintain the machinery during off-peak shifts.

Several factors affect the accuracy of the energy savings estimates. The application suggested that time clocks would be installed on individual fixtures; however, the timers control several fixtures as noted. In addition, several lights may be on for significantly greater durations than originally designed, as fewer timer switches were installed than originally proposed.

The savings for the bi-level lighting controls for the T8 lighting fixtures on the main processing floor of the facility were calculated using an assumed post installation usage hour reduction of 33.3% of the post installation wattage. The calculation does not appear to properly account for the total post-kWh usage based on hours and quantities of fixtures at high and low level lighting. This is an area of uncertainty and determination of actual bi-level operating hours would allow a more accurate estimate of savings.

The calculations can be checked for reasonableness using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation. The loads from 310 HID / retrofitted fixtures were used in these check calculations.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

The check calculations for the main measures (involving conversion from HID fixtures and installation of timers on these fixtures) were performed as follows:

- Pre-retrofit hours of operation: 8,760 hrs/yr
  Pre-retrofit wattage: 0.465 kW per fixture x 310 fixtures = 144.15 kW
  Annual kWh usage: 144.15 kW x 8,760 hrs/yr = 1,262,754 kWh/yr
- Post retrofit reduced wattage: 0.18 kW/fixture x 310 fixtures = 55.8 kW
- Annual post retrofit energy use: 55.8 kW x 8760 hrs/yr = 488,808 kWh/yr
  Savings from reduced wattage: 144.15 kW -55.8 kW = 88.35 kW
  Annual energy savings for these fixtures: 1,262,754 kWh/yr – 488,808 kWh = 773,946 kWh/yr

For the 268 switch controlled fixtures

- Post-retrofit hours of operation of controlled fixtures (based on 100% lamp use during peak work 17.5 hours/day and 33% lamp use at full power during the off peak work period of 6.5 hour per day with 66.7% lamp use at half power during the same non-peak work period.
- 17.5 hours = 73 % and 6.5 hours = 27% of each 24 hour period
- 8,760 hours x 0.73 = 6,395 hrs/year; 8760 x 0.27 = 2,365 hrs/year
  Post-retrofit wattage: 0.18 kW full power; 0.090 kW half power of eight-lamp fixture

  2,365 hrs/year x 0.18 kW/fixture x 268 fixtures = 114,087.60 kWh /yr (48.24 kW)
- 2,365 hrs/year x (0.33 x 0.18 kW/fixture + 0.67 x 0.090 kW/fixture) x 268 fixtures = 75,868.25 kWh/yr

- Energy use from reduced hours through lighting control are 419,842.37 kWh/yr
- Savings from lighting controls = 114,087.60 kWh/yr - 75,868.25 kWh/yr = 38,219.34 kWh/yr

Summer peak impacts from the changed lighting appear to have a marginal effect on building peak load because the peak period of operations at this facility is at night time. However, maximum activity at this facility begins at 3 pm daily, and the full kW reduction will be used for the coincident peak load. All lights on the main processing floor are energized during the summer coincident peak load period of 2 pm to 5 pm. If the ex post result shows a significant number of lights off at low power from 2 pm to 3 pm, the average kW reduction will be modified accordingly.

Coincident peak demand period savings = $kW_{pre} - kW_{post} + kW_{post}$ x (1 – diversity factor)

144.15 kW - 55.8 kW + 48.24 kW (1- 0.67) = 88.35 kW + 15.92 kW = 104.27 kW

The coincident peak demand of 125.74 kW and 812,165 kWh/yr are lower than the ex anted savings of 114.8 kW and 955,749 kWh/yr for these two measures.

4. Measurement & Verification Plan

The building is a two-story processing facility reported to have 313,000 square feet of floor area with offices at one end of the building on the first and second levels. Comments in the Installation Report indicate that the processing area lighting is set about 20 feet from the floor. The 1st and 2nd floor offices take up approximately 15 % of the building total square footage. The building is reported to be approximately 17 years old. There are skylights that provide daylighting. The building is occupied on a varying schedule, with some areas having continuous work year round and other areas where lighting was estimated at a range of usage of 730 hours/year to 6,325 hours per year. Maximum occupancy is approximately 750 people.

According to the paperwork, before the retrofit there were 367 metal halide fixtures using 400-watt lamps, 68 high pressure sodium fixtures with 150 and 250 watt lamps, and 976 fluorescent fixtures with one, two, three, and four T8 lamps. After the retrofit, there are 367 T8 four-foot / 8 lamp fixtures, 68 metal halide fixtures of 100, 150, or 175 watts, and 882 fluorescent fixtures, of which the majority were four-foot 2-lamp fixtures. A total of 46 timer switches were placed on 268 four-foot 8-lamp T8 fixtures at the sorting floor inside the facility; wall box and ceiling mounted motion sensors were placed in offices, conference rooms, and bathrooms.

This evaluation focuses on 268 fixtures on the main processing floor with 400 watt HPS lamps. These fixtures were converted to T8 fixtures and had attached timer controls. Specifically, savings are quantified in the lighting table for these 268 fixtures.

The project saves energy through the installation of lighting fixtures with a lower connected wattage and through the control of the lighting fixtures with manual timers to reduce the hours of operation.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

IPMVP Option C approach may be considered. The savings reported in the utility tracking system is approximately 12% of the kW and 14% of the kWh consumed based upon the pre-retrofit building use (peak demand is approximately 4,800 kW and annual energy use approximates 7,010,000 kWh per year according to billing estimates from the meter referenced in the application information). Utility billing and interval data should support this approach if there are no other significant loads (such as air conditioning) or other significant energy conservation activities which occurred in the months immediately following the retrofit. There is not expected to be significant seasonal variation and several months should be sufficient for comparison; however, a one to two year period would more fully capture actual variations and the persistence of savings. Interval data on a 15 minute basis during the summer months of June to September would be needed to accurately determine coincident peak period demand savings.

If Option C cannot be used due to changes in the facility or its operation in the time periods immediately before or after the retrofit, then a modified version of IPMVP Option A can be used. Lighting loggers would be set out to quantify hours of operation. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Summer peak demand period savings = kW_{pre} – kWpost + kW_{post} x ((energized $hours_{pre}$ - energized $hours_{post}$)) / energized $hours_{pre}$) during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in June, July, August, September.

Thus, to estimate total peak demand kW reduction, the increased lighting efficiency reduction in connected kW will be added to the post-retrofit connected kW load multiplied by the percent of deenergized time according to the above formulae. The derivation or extrapolation of the average percent of time energized used in the above formulae, for both the average peak demand period and the coincident peak demand periods, will be described.

The most significant variables to be quantified are the pre-retrofit and post-retrofit fixture hours of operation. Pre-retrofit hours will be confirmed with site personnel and interviews. The focus will be verifying that, prior to the retrofit, the entire complement of fixtures was completely energized during the hours listed in the IRR and that the listed hours/year were valid (for example, building or staff schedule logs for the pre-retrofit period could be examined, if available).

Monitoring with light loggers will be conducted on approximately 5% of the fixtures where feasible. A minimum of two sensors for each fixture would capture variations in the high and low level lighting periods at each fixture controlled by the timers. Additional sensors may be required, based on area usage and traffic patterns.

The use of fifteen sampling points is generally consistent with SPC program documentation from March 2001 (Appendix E, Sampling); this document suggests guidelines for determining sampling point requirements necessary to achieve an 80% confidence interval with 20% precision (using a coefficient of variation of 0.5).

A random sampling approach would involve setting up a grid for the main processing floor, labeling fixtures sequentially according to their location, and randomly selecting from the total number of fixtures using a random number generator. This approach will avoid overweighting or assigning a weighting factor for the high and low use areas of the processing floor. The majority of the lighting will need to be determined. The main production area is considered to be the usage group for the proposed number of fixtures to be sampled. Fixture numbering would be from one corner of the building to the adjacent corners.

The light loggers would be placed so as to be unaffected by fixtures not on timer switches or by ambient outside light.

If the light loggers cannot be placed in suitable locations and if the lighting circuits can be isolated, a current or power meter can be used to track multiple fixtures. The total current / power would be determined by activating all fixtures and by confirming loads using electrical drawings or electrical panel information. Between three and six current/power meters are expected to be needed, to capture a representative sample of the lighting fixtures.

The lighting loggers or current sensors would be left in place for a period of 7 to 14 days. Attention will be given to the time period for monitoring, in order to avoid periods of irregular usage patterns (e.g., during holidays or breaks). While longer periods might be preferable, these periods are appropriate given the scope of the evaluation and reported usage characteristics.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture hours of operation. The lighting fixture quantities seem to be well established and were sampled in utility post-installation inspection visits. The pre-retrofit and post-retrofit connected loads associated with various fixture types also are adequately quantified in the SPC lighting wattage tables and similar values were used in the LE1 Table provided by the sponsor.

Uncertainty for the savings estimate for the process industrial fixture retrofit and for the timer switches controlling these fixtures can be more fully understood by setting projected ranges on the primary variables.

<u>For lower wattage fixtures (T8 conversion from HID fixtures)</u>

- 310 fixtures expected, minimum 280, maximum 340 (+/- 10%)
- 8760 hours pre retrofit expected/reported, minimum 4380 hours, maximum 8760 hours (based on pre-retrofit operations analysis from the project application review)
- 123 kW expected, minimum 117 kW, maximum 129 kW (includes +/- 5% for number of fixtures and +/- 5% for fixture wattage difference)

<u>For timer switches controlling the above fixtures</u>

- 268 fixtures expected, minimum 241, maximum 295 (+/- 10 %)
- 6,083 hours post retrofit expected/weight calculated based on fixtures controlled, minimum 2,000 hours, maximum 8,040 hours (- 60% , + 30% based on judgment of use for site type; includes + / - 5% from annualizing estimates from short monitoring period)

There may be a small potential source of error introduced since measurement will not be performed on the smallest measures. This error is estimated at a maximum of + /- 2% and is not included in the analysis of uncertainty due to its size.

Accuracy and Equipment

The light loggers to be used are Dent TOU-L Lighting Smart*logger* dataloggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Annualizing that data from a 7 to 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

Current or power meters may also be used. The current loggers to be used, if this M&V technique is selected, would be HOBO U-12 loggers, with matched current transformers. The accuracy range is 4.5 %. The sensor would be calibrated to an Amprobe ACD-41PQ, with an accuracy of +/- 2%. An advantage of using current or power meters to monitor load is that the percent of time energized for an increased number of fixtures may be able to be captured.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 12, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representatives. Lighting fixture quantities and hours of operation were verified.

According to the facility's maintenance coordinator, the building is a 313,000 square foot processing facility for package and mail product processing and distribution. There is a second floor of offices over offices at the west end of the building. Administrative offices comprise approximately 15 % of the total floor area of the building. The end use of the measures is lighting, where retrofits and added lighting controls reduce overall wattage and use. High bay lighting is provided by 4-foot 8-lamp fluorescent fixtures in the main work area and 2-foot, 3-foot and 4-foot one and two lamp fluorescent fixtures provide lighting in the offices, corridors, work rooms, rest and locker rooms, stairwells and other rooms adjacent to the main work area. The building is reported to be approximately 23 years old. It has minimal windows (at the offices) and skylights (in the processing area); the skylights provide sufficient daylight during spring and summer months to allow a reduction in interior lighting at the processing floor. Bay doors open and close automatically throughout the day providing fast ingress and egress from the sorting area to the shipping area to maintain a steady flow of work. There are numerous sorting machines, conveyance motors, dust vacuums and bulk bin moving equipment throughout the main processing floor.

The building is occupied on a varying schedule, 24 hours per day 7 days per week, year round (8,760 hours per year). Work is constant and the facility never closes. Reduced occupancy occurs on holidays for some of the staff, but there is always a full complement of staff to maintain work and there is increased occupancy provided by temporary staff during some holiday periods of the year. There are three overlapping shifts according to the following schedule:

Shift 1:	11 p.m. to 7:30a.m. Work intensity starts to ramp down.
Shift 2:	7 a.m. to 3:30 p.m. Work intensity is completely ramped down to lowest intensity by approximately 9:30 a.m. Machines are maintained on this shift.
Shift 3:	3 p.m. to 11:30 p.m. Work ramps up to the greatest intensity of activity for the day.

Some of the spaces – offices and other non-sorting area rooms- have lights with wallbox occupancy sensors (42 sensors installed). The balance has normal single pole switches. At the sorting area and shipping dock, a portion of the lights are controlled by timer switches. When switched "on", 8 lamps are lighted for each fixture. After three hours the switches automatically shut off half of the lamps (4 lamps) of each fixture they control. If higher lighting levels are needed, then switches are turned on manually. There is a high demand for lighting because the greatest amount of work activity occurs during the night.

Maximum occupancy is approximately 750 to 800 workers during holiday periods. On most days, occupancy ranges from a low of 350 to 400 workers – during Shift 2 - to a high of approximately 700 workers at the peak work period (during Shift 3). Work is performed throughout the facility, but processed through specific zones on the sorting floor. The demand for lighting moves through the building as product is moved through the sorting process from zones with one kind of machine to zones with machines performing other functions. On Saturdays, the minimum occupancy is approximately 350 workers; on Sundays, the minimum is approximately 400 workers.

Timer switches controlling the 8-lamp high bay fixtures appear to operate properly, but judging from observation at the floor a large percentage(approximately 50%) are overridden manually during the lightest shift when the inspection was performed .The representative confirmed that the inspection was conducted during the part of the day when the work load is lightest. With approximately 400 additional employees working from 3 p.m. to 7:30 a.m., lighting demand is much greater due to night time work and greater activity levels throughout the processing floor and offices. Switches are turned on approximately two times per shift. Staff is accustomed to using the manual switches as needed.

Installation Verification

It was physically verified that eight lamp fluorescent fixtures were installed at the facility's processing floor. New one, two, and four lamp fixtures using T8 lamps were located in the offices and other areas at the east and south ends of the facility replacing all fluorescent fixtures using higher wattage ballasts and T8 lamps. The facility representative verified that the HPS fixtures were replaced on a one for one basis.

The number and type of fixtures and controls were observed and appear to be in agreement with the number and types that were used in the ex ante calculations. The itemization to support the quantities installed was provided by the LE1 table listing provided from the sponsor/contractor to the customer. Because this was part of a much larger contract to install lighting retrofits at numerous facilities, an itemized invoice for this site was not provided.

The measure providing approximately 90% to 95% of the savings was the HID to T8 lighting retrofit. It was verified that these fixtures were retrofit. This portion of the SPC project was evaluated. The verification realization rate for this project is 1.0. A verification summary is shown below in Table 6.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measures in the SPC application covering the lighting efficiency fixture replacements and timer switches at the main processing floor. Lighting measures are the only measures in this application.

Summary of Results

The greatest savings are derived from the HID fixtures replaced with lower wattage fluorescent fixtures. Of these, the fixtures controlled by the timer switches provide the most savings.

The calculated savings for the HPS replacement measures comprised 109.4 kW of the total 122.6 kW savings listed in the Installation Report Review. This includes all 435 high pressure sodium fixtures replaced by other lighting. In addition, the approximately 950 other 2, 3, and 4 lamp fluorescent fixtures represent an estimated additional 9.78 kW of connected load that was included in the calculated measure referenced as "Replace Indoor Lighting with High Efficiency T8 Lighting plus Reflector". The total ex ante calculated energy savings are 985,064 kWh/yr. The itemized measures savings totaled 3.8 kW and 17,714 kWh.

The ex post savings for this lighting retrofit project were determined using fixture wattages provided, hours of operations, and timer switch use as verified from loggers.

Billing Analysis

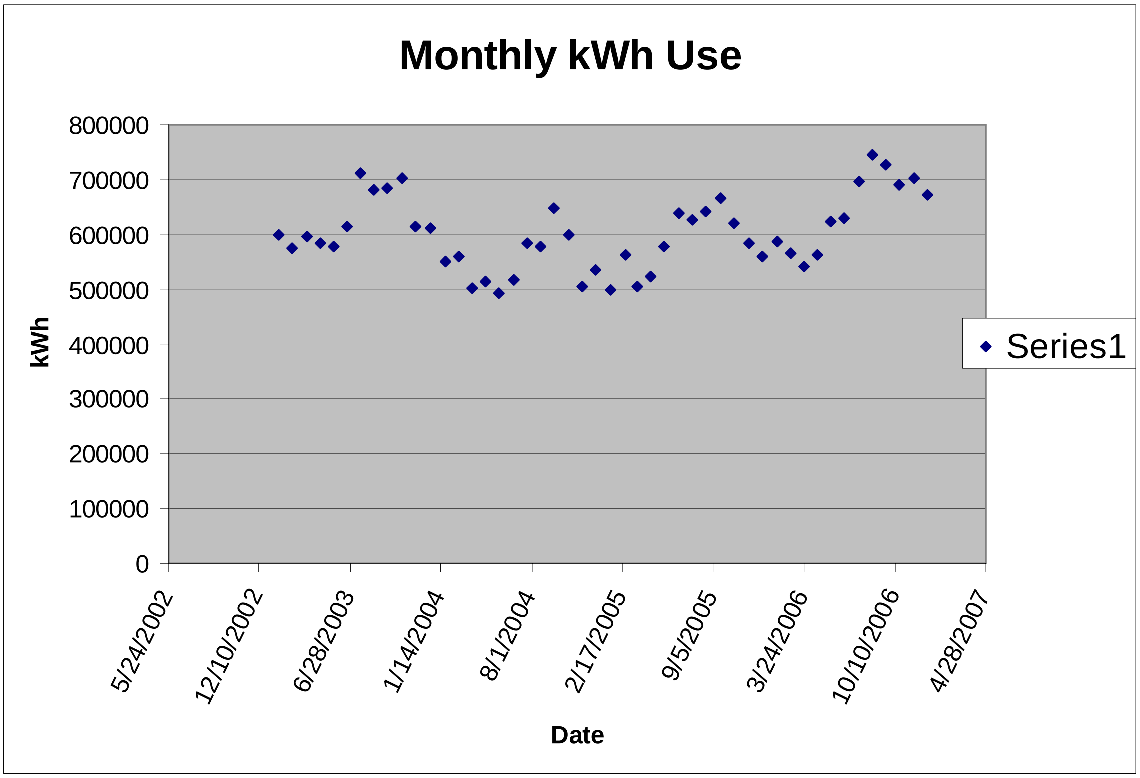
Billing analysis incorporating utility consumption data was attempted. Monthly kWh use (Figure 1) was plotted from two years prior to the retrofit until two years after the retrofit, to determine if there were major changes or instability in electricity use..

The electricity end-uses at this facility are lighting, electric cart charging, conveyor motors, sorting and bundling machines and office activities. The office space, which is approximately 16 % of the total space, is conditioned with a chilled water system and roof mounted package units over the offices. The facility representative indicated that there was a chiller replacement just prior to the lighting retrofit which could affect the electricity use patterns before the retrofit. No changes were made afterward other than maintenance to the light fixtures themselves.

The graph indicates a change in energy use in April 2004, after which energy use appears to be consistently lower - approximately 100,000 kWh lower each month – as compared to the previous year. However, it is noted that energy use appears to increase steadily over subsequent months.

The final Installation Report Review for the lighting retrofit was completed in January 2005. Utility bills were trending downward from a high of 711,729 kWh in July 2003 to May 2004 before the lighting retrofit in June / July of 2004; energy use was varied along a pattern with increases during the summer and fall months and decreases in the winter and spring months. This trend may be due to air conditioning load during these months After the retrofit, energy use appears to have decreased by approximately 50,000 kWh to 100,000 kWh. The metered energy use stayed below 700,000 kWh for 33 months on the energy use pattern with seasonal fluctuations, but with the energy use trend increasing slowly from the same months year to year. The facility representative had reported installation of new chillers at the facility but indicated there were no other changes in equipment, operation hours, or work shifts which may have affected energy use. The earlier downward trend may have been influenced by the pre-retrofit replacement of two 150-ton chillers with two more efficient 400 ton chillers, VFD pump motors, fan motor controls and valve controls for the facility air conditioning. Some rooftop package units that service the second floor offices and other areas were left on the roof and continue to be used.

Figure 1: Metered Energy Use



Graph of averaged use by monthly billing for December 2002 to December 2006

Using billing data, the kWh energy consumption in the twelve month period immediately before and immediately after the retrofits were compared and the difference of 149,083 kWh is determined to the unadjusted savings figure for annual energy savings in that period. However, the following year, energy use increased by 521,521 kWh over the reference post lighting retrofit year. This billing derived value, when compared with the calculated ex-post savings from the lighting retrofit, suggests that lighting retrofits may have contributed approximately two thirds of the total savings seen on the bills but other factors influence the energy use at the facility. The balance of savings may have been derived by reduced cooling load from the reduced heat generated by the lower wattage fixtures. It is noted the cooling load was for the office space adjacent to the processing floor which the representative said is not conditioned. Cooling loads were reduced following the installation of the reduced wattage light fixtures and comfort level for workers improved.

There were no adjustment or regression performed as weather dependency may be small for this facility. It is not clear that shipments or throughputs would affect lighting use in a significant manner. These parameters fluctuate during particular seasons of the year, but work is relatively constant every day.

The ex post impacts were calculated from utility consumption data as follows:

a) Pre retrofit kWh use is summed for the 365 day period from billing date 8/20/2003 to billing date 7/21/2004 for annual pre-retrofit kWh of 7,012,351 kWh.

Post retrofit kWh use is summed for the 365 day period from 9/20/2004 to 8/19/2005 for annual post-retrofit kWh of 6,863,268 kWh.

b) Pre-retrofit wattage was averaged over the months of June to September during the period from 2 pm to 5 pm for all weekdays in 2003 (adjusted for the kW demand percentage from the one interval meter) and found to be 921 kW

c) Post-retrofit wattage was averaged over the months of June to September during the period from 2 pm to 5 pm for all weekdays in 2004 (adjusted for the kW demand percentage from the one interval meter) and found to be 822 kW

d) The resulting annual kWh savings for the first year following the retrofit is 7,012,351 kWh/yr – 6,863,268 kWh/yr = 149,083 kWh/yr

e) Summer peak demand reduction impacts were estimated by subtracting average post-retrofit from average pre-retrofit peak load.
   Peak kW savings is 921 kW – 822 kW = 99 kW

As stated, the kWh savings may include significant indirect savings from reduced cooling due to the lighting fixtures and some savings due to chiller retrofits. Savings calculated for the 310 fixtures for which ex ante savings values are calculated in the lighting tables are 88.35 kw and 773,946 kWh, based on a fixture wattage reduction from 465 watts to 180 watts and listed hours of operation.

The ex ante kW savings are supported by billing analysis. Logger results will assist in evaluating the kWh savings.

<u>Partially Measured Retrofit Isolation</u>

Results of lighting logger monitoring were used to evaluate actual hours of operation and use of timer switches.

Analysis of the light logger results indicate that switched fixtures on average are on full 8-lamp illumination approximately 33% of the time. Energy savings from timer switch installation are expected to be higher than estimated in the ex ante calculations because the 100% lighting level presumed by the inspector during high activity periods overestimated the actual use during the period of peak activity in the processing plant.

All lights are expected to be available during the peak demand period defined as the hottest weekday periods between 2 pm to 5 pm, Monday to Friday, in the months of June, July, August and September.

The ex ante savings were listed as 1,002,778.2 kWh and 122.6 kW in the Installation Report Review Summary. The greatest variation between ex ante and ex post savings appears to be in the hours of operation and in the timer switch measure. Savings from reduced wattage associated with the 268 controlled fixtures were listed in the lighting tables as 76.38 kW and 669,089 kWh.

Ex post savings are calculated for the timer switches based on the lighting logger results applied to the 268 controlled fixtures; these new fixtures are energized at full wattage (0.18 kW) for 33% of the annual hours and at half wattage (0.090 kW) for 67 % of the annual hours.

Table 1: Lighting Logger Results

Fixture	Logger No.	Total Hours Off	Total Hours On	Total hours	Total days	Avg. on time %	
1							
	258	0.0	335.0	335.0	14.0	100%	100%
	101	213.6	21.0	234.6	9.8	9%	6%
2	349	0.1	334.9	334.9	14.0	100%	100%
	393	226.6	108.3	334.9	14.0	32%	32%
3	79	0.4	334.8	335.2	14.0	100%	100%
	340	12.4	18.9	31.3	1.3	61%	61%
Total 1		Average on time of primary 4 lamps in fixture					100%
Total 2		Average on time of other 4 lamps in fixture					33%

Annual hours of operation of controlled fixtures are 33% x 8760 hrs/yr = 2891 hrs/yr at full wattage and 67% x 8760 = 5869 hrs/yr at half wattage.

At full illumination: 0.18 kW x 268 fixtures x 2891 hrs/yr = 139,452 kWh/yr
At half illumination: 0.09 kW x 268 fixtures x 5869 hrs/yr = 141,560 kWh/yr

The energy use during these separate periods is 139,452.2 kWh/yr and 141,560 kWh/yr for total energy use on the controlled fixtures of 281,012 kWh/yr.

139,452 kWh/yr + 141,560 kWh/yr = 281,012 kWh/yr.

If there were no timers on the 268 fixtures the energy use would be:
Full illumination: 0.18 kW x 268 fixtures x 8760 hrs/yr = 422,582 kWh/yr

The calculated savings from the switches are 422,582 kWh/yr – 281,012 kWh/yr= 141,570 kWh/yr.

No coincident kW demand savings are expected as maximum occupancy occurs during the coincident peak load periods and all fixtures with timers are expected to be energized.

The ex ante savings associated with the timer switches listed in the IRR summary was 53,859 kWh.

The calculated savings from the timer switches combined with the reduced wattage savings for these fixtures is 104.6 kW and 141,570 kWh + 916,242 kWh/yr = 1,057,812 kWh (104.6 kW and 916,252 kWh/yr are the savings from Section 2 for 367 fixtures with reduced wattage).

The additional savings from the balance of fixtures in the lighting tables is: 7.8 kW and 47,029 kWh.

To derive the ex post savings, the calculated values are added to the ex ante savings for measures not evaluated in detail.

Ex post savings are thus: 104.6 kW and 1,104,851 kWh/yr.

Pre-retrofit annual consumption (for one year prior to retrofit) was 7,012,351kWh for the entire facility energy use. Average peak demand was estimated at 4,824 kW based upon interval meter data available and possible load factors.

All lights are functional when the building is occupied. Very few burned out lights were observed during the site visit. Burned out lights now are easily accessible and are replaced as groups of fixtures show signs of dimming or failure. Burned out lamps or failed ballasts prior to the retrofit were replaced. However, the representative indicated that ballasts and lamps of the new fixtures require more maintenance as lamp and ballast failures occur more often than occurred with the HID fixtures. There was no adjustment to the baseline or post retrofit lighting energy consumption due to burned out lamps.

Table 2 summarizes the total metered energy use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and the additional data obtained from the customer. The baseline end use energy is estimated to be 30% of total kWh use and 30% of total kW demand at this facility.

Table 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	4,824.0	7,012,351
Baseline End Use	1,447.2	2,103,705
Ex ante Savings	122.6	1,002,778
Ex Post Savings	104.6	1,104,851

Table 3 summarizes the percentages of savings obtained for calculated post installation and ex post measure inspection values compared to total metered and baseline end use kW and kWh energy.

Table 3: Percent Savings and Demand Reduction (Ex Ante, Ex Post)

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	2.5%	14.3%	2.2%	15.8%
Baseline End Use %	8.5%	47.7%	7.2%	52.5%

The summary in Table 3 showing the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations, indicate the ex ante results showed a 2.5 % decrease in total meter kW, an 8.5 % decrease in lighting end use kW, a 14.3 % decrease in total meter kWh, and a 47.7 % decrease in lighting end use kWh. The ex post results showed a 2.2 % decrease in total meter kW, a 7.2 % decrease in lighting end use kW, a 15.8 % decrease in total meter kWh, and an 52.5 % decrease in lighting end use kWh.

6. Additional Evaluation Findings

The ex post energy savings are approximately 10% higher than the ex ante energy savings because the timers were found to reduce hours longer than forecast for the ex ante calculations.

In addition to saving energy, the benefits of the project are increased clarity of light, increased light levels, increased employee comfort and yielded better working conditions. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. Participation in previous incentive programs has encouraged management to consider other energy efficiency projects including the participation in the 2004/2005 SPC Program. This lighting retrofit was one of the latest measures to reduce energy consumption. The incentives encourage continued participation. Awareness of the incentive programs is promoted by the energy services company (ESCO) working for this customer and the utility representative.

The pre-retrofit lighting fixture type, quantities, and hours of operation were not able to be physically verified. However, these parameters have been accurately assessed and quantified based on our discussions with the facility representative and in the application paperwork. The level of M&V and billing analysis employed at this site is sufficient to accurately determine the impacts of the installed measures, but could be improved through determining the actual wattage drawn by the eight lamp fixtures which replaced the HPS fixtures.

With a cost of $344,278 and a $49,806 incentive, the project had a 2.26 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is more than the ex ante, and the estimated simple payback is 2.05 years. A summary of the economic parameters for the project is shown in Table 4.

The utility tracking system indicated there was an energy management system for lighting controls as a measure of the program. However, an EMS was not mentioned in the application paperwork for the lighting retrofit. There is an EMS at the facility that controls the HVAC system – chillers, fans and valves. It does not, however, control the lighting. The savings value associated with the EMS was the number identified with the bi-level lighting controls.

Processing, shipping and receiving operations are not expected to change in the near future. Lighting needs are met now and will not need changing until a new retrofit is required.

The building and lights were at least 23 years old at the time of the measure implementation. The lights were functional with moderate maintenance problems requiring only routine lamp and ballast changes. In contrast, the maintenance representative reported current ballasts and lamps fail at a greater rate than was noticed before, requiring substantially more attention and competing with other maintenance work. Ballasts “have not lasted like the warranty indicated” and there has been significant failure of new ballasts and lamps. The representative complained about the increased failure (unreliability) of lamps and ballasts compared with the HPS fixtures, but allowed that the new fixtures are much cooler to work around than the HPS fixtures.

The new fixtures have made a noticeable improvement in light levels and in worker satisfaction with the quality, color, and intensity of the light. Energy reductions are noticeable according to the maintenance representative. One particular impact is the reduced cooling load on the building by the replacement of the 400 watt HPS fixtures with the much cooler 180 watt fluorescent fixtures, while improving the lighting levels.

The program did not spur other specific on-site measures because this was one of the last measures pursued in a series of cost cutting reductions. The customer has a contract with an energy services company that periodically audits the customer’s building and provides information about incentive and rebate programs as these opportunities are available. The service contractor is paid to provide the client with information regarding the latest incentive opportunities that might be applicable at the facility.

There has been no apparent increase in energy awareness at this processing company, other than the maintenance personnel and management. Management is aware of the economics and details of the retrofit, has seen the savings in the lighting and in other measures, and implements similar incentive retrofits at the facility when they are offered by the utility and are considered and approved at the corporate level.

7. Impact Results

The realization rate of the peak kW demand is 0.85 and the realization rate of the energy savings is 1.10 as summarized in Table 5. The Installation Verification Summary is shown in Table 6 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 7.

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	2/28/2005	$344,278	122.6	1,002,778	0	$130,361	$49,806	2.26	2.64
SPC Program Review (Ex Post)	7/18/2007	$344,278	104.6	1,104,851	0	$143,631	$49,806	2.05	2.40

Table 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	122.6	1,002,778	-
SPC Installation Report (ex ante)	122.6	1,002,778	-
Impact Evaluation (ex post)	104.6	1,104,851	-
Engineering Realization Rate	0.85	1.10	NA

Table 6: Installation Verification Summary

Measure Description	End-Use Category	Lighting Measure	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Lighting - Other	L	Replace 367 HPS fixtures with 367 eight-lamp T8 fluorescent fixtures; replace 68 HPS fixtures with lower wattage MH fixtures	425	8 lamp T-8 HE fixtures and lower wattage MH fixtures	Physically verified lamp type and verified quantity from floor plan and documentation of previous inspectors	1.00

Table 7: Multi Year Reporting Table

Program Name:		SPC 04-05 Evaluation Site A082					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	501,389	552,426	122.6	104.6		
2	2005	1,002,778	1,104,851	122.6	104.6		
3	2006	1,002,778	1,104,851	122.6	104.6		
4	2007	1,002,778	1,104,851	122.6	104.6		
5	2008	1,002,778	1,104,851	122.6	104.6		
6	2009	1,002,778	1,104,851	122.6	104.6		
7	2010	1,002,778	1,104,851	122.6	104.6		
8	2011	1,002,778	1,104,851	122.6	104.6		
9	2012	1,002,778	1,104,851	122.6	104.6		
10	2013	1,002,778	1,104,851	122.6	104.6		
11	2014	1,002,778	1,104,851	122.6	104.6		
12	2015	1,002,778	1,104,851	122.6	104.6		
13	2016	1,002,778	1,104,851	122.6	104.6		
14	2017	1,002,778	1,104,851	122.6	104.6		
15	2018	1,002,778	1,104,851	122.6	104.6		
16	2019	1,002,778	1,104,851	122.6	104.6		
17	2020	501,389	552,426				
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	16,044,451	17,677,616				

SITE A083 (2004-269) Kimb1 IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 2 END USE: Lighting

Measure	Lighting Upgrades
Site Description	Paper Manufacturing Facility

1. Measure Description

The measure is for the installation of high efficiency lighting systems at ten buildings in a large manufacturing facility. The facility is a paper manufacturing with production, storage, and office areas. This project constitutes the first of two phases of lighting upgrades at the facility partially funded through SPC incentives. The existing fixtures were primarily T12 lamps, high wattage high intensity discharge (HID) lamps, and incandescent lamps. The new fixtures consisted of T8 fluorescent fixtures, high efficacy HIDs, compact fluorescent lamps (CFLs), and LED exit signs. The existing fixtures are the baseline for this measure.

2. Summary of the Ex Ante Calculations

The ex ante savings estimates were calculated using the 2004 SPC Estimation Software. There were two types of measures: itemized measures and calculated measures. Itemized measures are those incented per unit. The incentive is a fixed rate per fixture and is independent of the energy savings. For calculated measures, the incentive rate is based upon the energy savings achieved through installing the new lighting.

The energy savings are a result of reducing the lighting load. The ex ante calculations list a total estimated annual savings of 2,201,042 kWh. An incentive of $122,295.05 is the sum for itemized and calculated measures. The ex ante program verification consisted of verifying all existing and proposed fixture counts and wattages.

The baseline and as-built energy usages were not included in the project file. However, the ex ante savings are shown below.

The ex ante impacts were as follows:

- Annual Energy Savings: 2,201,042 kWh/yr
- Demand Savings: 328.3 kW

The ex ante savings are slightly higher than those in the utility tracking system, which lists 2,201,038 kWh of savings and 325.93 kW.

The incentive for itemized measures was calculated as shown in Table 1.

Table 1: Incentives for Itemized Measures

Itemized Measure	Qty	Incentive Rate	Total Incentive
4' T8 installed	7,932	$4.25	$33,711.00
4' T12 delamped	1,140	$6.00	$6,840.00
400W high bay replaced w/ T8	96	$75.00	$7,200.00
2' T8 installed	17	$3.50	$59.50
LED exit sign installed	36	$27.00	$972.00
100W replaced w/ screw in CFL	25	$3.50	$87.50
			$48,870.00

The incentive for itemized measures was calculated as shown in Table 2.

Table 2: Incentives for Calculated Measures

Calculated Measure	Qty	kWh Savings	kW Savings	kWh Incentive	Total Incentive
250W HPS replacement w/ T8	909	1,457,200	166.3	$0.05	$72,860.00
150W HPS replacement w/ T8	10	11,301	1.3	$0.05	$565.05
					$73,425.05

The total incentive was calculated as follows:

- The total rebate was $48,870.00 + $73,425.05 = $122,295.05

3. Comments on the Ex Ante Calculations

For the energy savings calculations for the itemized measures, annual usage estimates were estimated by fixture type according to the estimates found in the Express Efficiency work papers. Hours of use and wattage reductions per fixture type for a given market sector are found in the work papers.

The project file lacks information on the different occupancy types and the schedules of these areas. The project file does not indicate installed wattages and fixture counts in each area for the itemized measures.

Additionally, the measure verification did not verify the operating hours and instead only verified the fixture counts and wattage confirmation.

The calculated measures for the high pressure sodium (HPS) fixture replacement were estimated to be in use 8,760 hours per year. The itemized measures appear to have varying operating hours between 4,000 and 8,250 annual hours. All of the itemized measures except the 400 watt high bay replacements and the two foot T8 lamp installations were calculated using approximately 4,600 annual hours. The high bay replacements and the 2' T8s were estimated to operate 4,000 and 8,250 hours, respectively. Occupancy sensors had been installed, but since the incentive amount had already been submitted, no occupancy sensor savings were included in the ex ante energy savings calculations.

4. Measurement & Verification Plan

The facility under consideration is a 1,200,000 square foot paper manufacturing facility that purchased 4,943,304 kWh from January 2004 to January 2005. This represents a small fraction of total plant electrical energy usage, since the plant includes a cogeneration facility with 15 MW of generation capacity.

This measure reduces energy usage by reducing the facility's lighting load. The fundamental premise in development of the measurement and verification plan was to determine the existing lighting loads and actual hours. The M&V plan was implemented in three basic steps:

1. Determine available data from site contact via telephone (operating schedule, etc.).
2. Verify lighting fixtures (counts and wattages). Monitor fixtures to obtain annual operating hours.
3. Calculate the reduction in annual energy consumption.

The requested data included the operational schedules of the lighting systems, the fixture counts, and the fixture wattages.

A fixture count for the entire project was unable to be performed as there was limited data available; the ex ante savings estimate were calculated using on a single count for the whole project. We used a combination of time-of-use lighting loggers installed at the light and current loggers installed at the lighting breaker panel to determine when banks of rooms on a common electric feeder were using their lights. There appear to be different-operating schedules for different types of lighting. Table 3 summarizes all different schedules for the whole building for different types of lighting.

Table 3: Estimated Operating Schedule of All Different types of Installed Lighting System

Itemized Measure	Qty	Ex-Ante hr/yr
4' T8 installed	7,932	4,557
4' T12 delamped	1,140	4,685
400W high bay replaced w/ T8	96	4,001
2' T8 installed	17	4,638
LED exit sign installed	36	8,267
100W replaced w/ screw in CFL	25	4,676

Calculated Measure	Qty	Ex-Ante hr/yr
250W HPS replacement w/ T8	909	8760
150W HPS replacement w/ T8	10	8760

Formulae and Approach

The metered time of use, fixture counts, and fixture wattages will be used to calculate baseline and proposed energy consumption. There are no seasonal variations in schedule at the facility; therefore, the metered data was extrapolated to represent an entire year. The following equations to determine energy savings

kWpre = (fixture count) x (pre retrofit fixture wattage)
kWpost = (fixture count) x (post retrofit fixture wattage)
kWh_{pre} = (pre retrofit kW) x (annual operating hours)
kWh_{post} = (post retrofit kW) x (annual operating hours)
Annual kWh Savings = $kWh_{pre} - kWh_{post}$

As the equations show, a key factor in the savings calculation was the annual operating hours, which were calculated from the metered data. We developed an appropriate annual savings calculation strategy which depended on field findings. Coincident peak kW savings will be calculated from estimated load reduction for the 2 PM to 5 PM period on the hottest summer weekdays (June to September).

Peak kW Savings = (pre retrofit kW) - (post retrofit kW)

The greatest uncertainties are in the fixture counts and annual operating hours.

- Fixture count
  Expected 10,165, minimum 9,148, maximum 10,673 (-10%, 0, +5%)
- Annual operating hours
  expected 8,760 hrs/yr, minimum 7,884hrs/ yr , maximum 8,760 hrs/yr (- 10%)
- Fixture wattages are believed to be relatively well qualified and an uncertainty of 5% may be expected.

Note that occupancy sensors had been installed and post retrofit hours may reflect this. The use of post retrofit hours determined by lighting loggers after the occupancy sensors were installed may serve to lower the energy savings estimates.

Accuracy and Equipment

HOBO on/off data loggers will be used to measure the time-of-use of the lighting systems. This meter has an adjustable light sensitivity threshold and records data at one-second intervals. The Hobos have a time accuracy of ±1 minute per week.

Either a DENT Elite or an ACR OWL 400 data logger will be used to meter the lighting at the breaker panel. The Elite loggers have three current transformers and can sample at intervals up to 3 seconds. Their accuracy is better than 1% of the reading. The accuracy of the current transformers is approximately ±1%. The OWL 400 data logger can record data at five second intervals. The logger accuracy is ±1% of full scale.

All data collected was reviewed to ensure it conformed to realistic values and was verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements was scrutinized and removed from the analysis, if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 5, 2007. Information on the lighting fixtures was collected by inspection and short-term metering of the lighting systems. In addition, data were collected by interviewing the facility representative.

Installation Verification

During the onsite visit, the evaluation team verified the lighting schedules, and fixture wattages. We were unable to verify the lighting counts since there was only one fixture count for the entire project. Typically, a sample of areas would be counted and the results of the comparison between evaluation the ex ante fixture counts for the sample would be applied to the entire project. Since there was only one fixture count, the only way the count could be verified was to count the entire project. The count would have taken several days and was not feasible. Lighting fixtures and lighting invoices were examined and the ex ante fixture count was accepted as accurate.

The lighting measures are the only measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 12 below.

Scope of the Impact Assessment

The impact assessment scope is for the efficient lighting measures in the SPC application. These are the only measures in the application for this site.

Summary of Results

HOBO Onset TOU lighting Loggers, Owl 400 amp loggers and Elite kW loggers were installed through out the facility for 20 days (from September 5, 2007-september 24, 2007) to measure the operating hours of a representative sample of the retrofit lighting fixtures. The facility representative also stated that the 20-day period had been representative of normal facility operation. It was found that on an average the lights are on 70.8 % of time compared to an average of 69.0 % assumed in ex ante calculation. The detailed comparison between ex ante and post field operating hours is shown in Table 4.

Table 4: Comparison between Ex ante and Ex post Operating Hours

	Ex-Ante hr/yr	Ex-Post hr/yr	% Ex ante On	% Ex post On
4' T8 installed	4,557	4298	52.0%	49.1%
4' T12 delamped	4,685	4298	53.5%	49.1%
400W high bay replaced w/ T8	4,001	6276	45.7%	71.6%
2' T8 installed	4,638	8375	52.9%	95.6%
LED exit sign installed	8,267	8760	94.4%	100.0%
100W replaced w/ screw in CFL	4,676	121	53.4%	1.4%
250W HPS replacement w/ T8	8,760	8,760	100.0%	100.0%
150W HPS replacement w/ T8	8,760	8,760	100.0%	100.0%
Over all Average			**69.0%**	**70.8%**

Figure 1, Figure 2, and Figure 3 shows the average daily operating schedule of all different types of lighting system.

Figure 1: Average Day Operating Profile of CLF and T817 Lamps

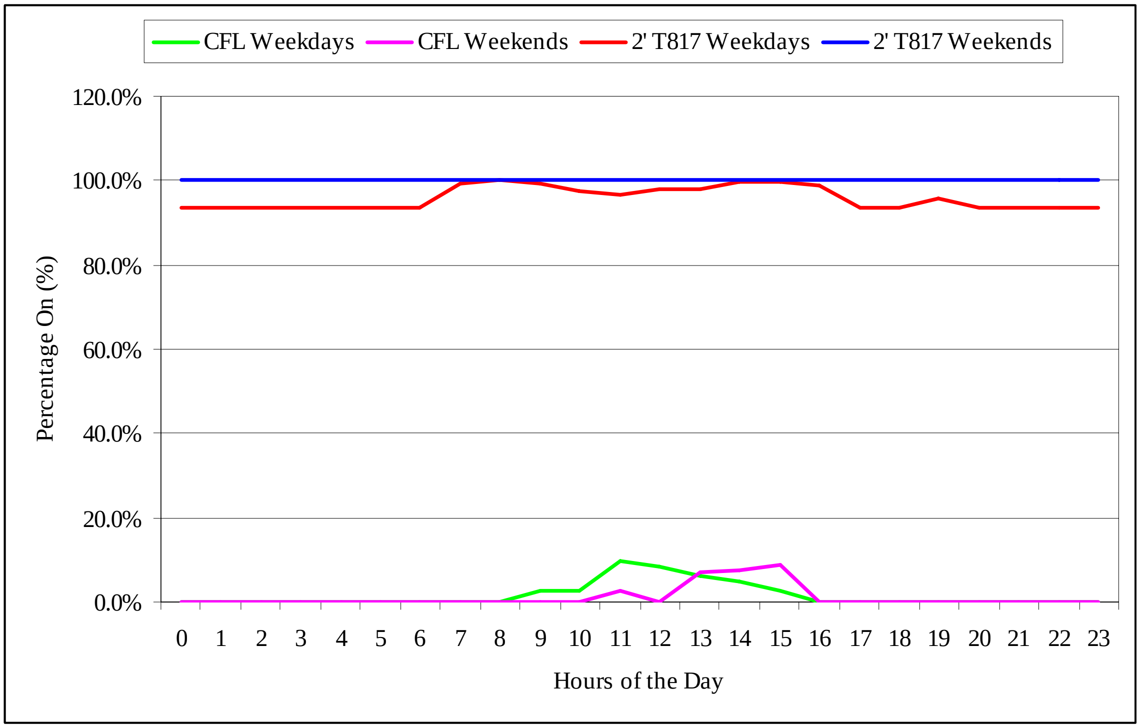


Figure 2: Average Day Operating Profile of 4LxT8 & 6LxT8 Lamps

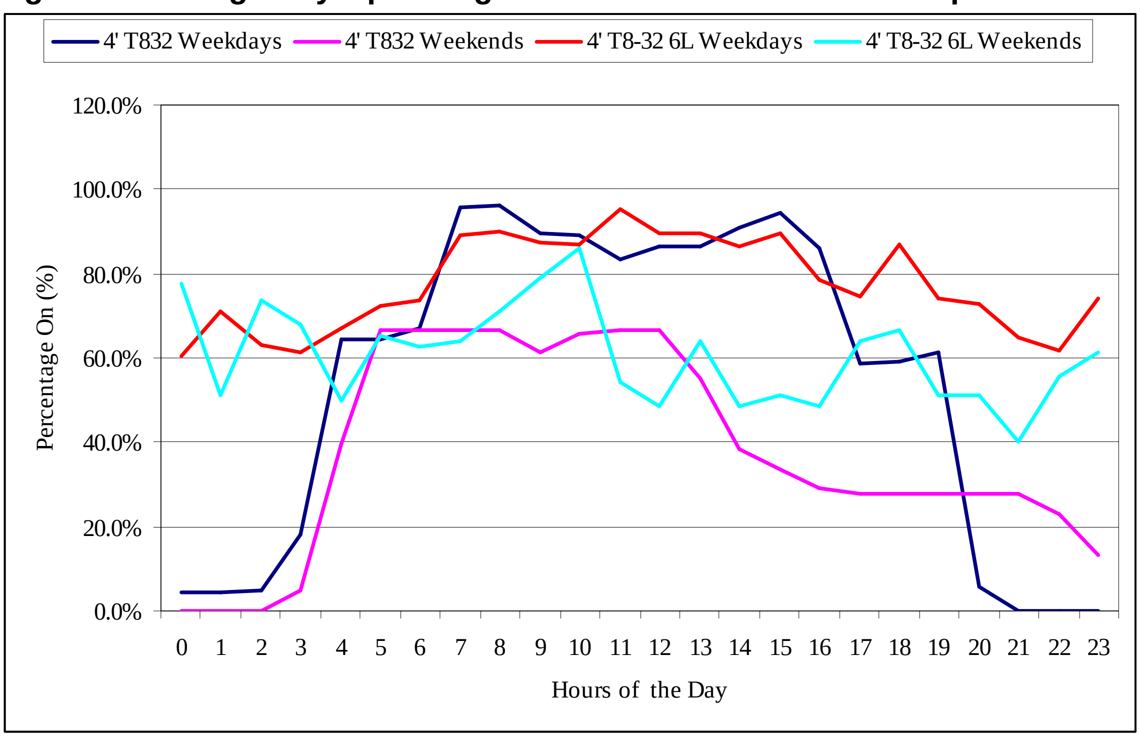
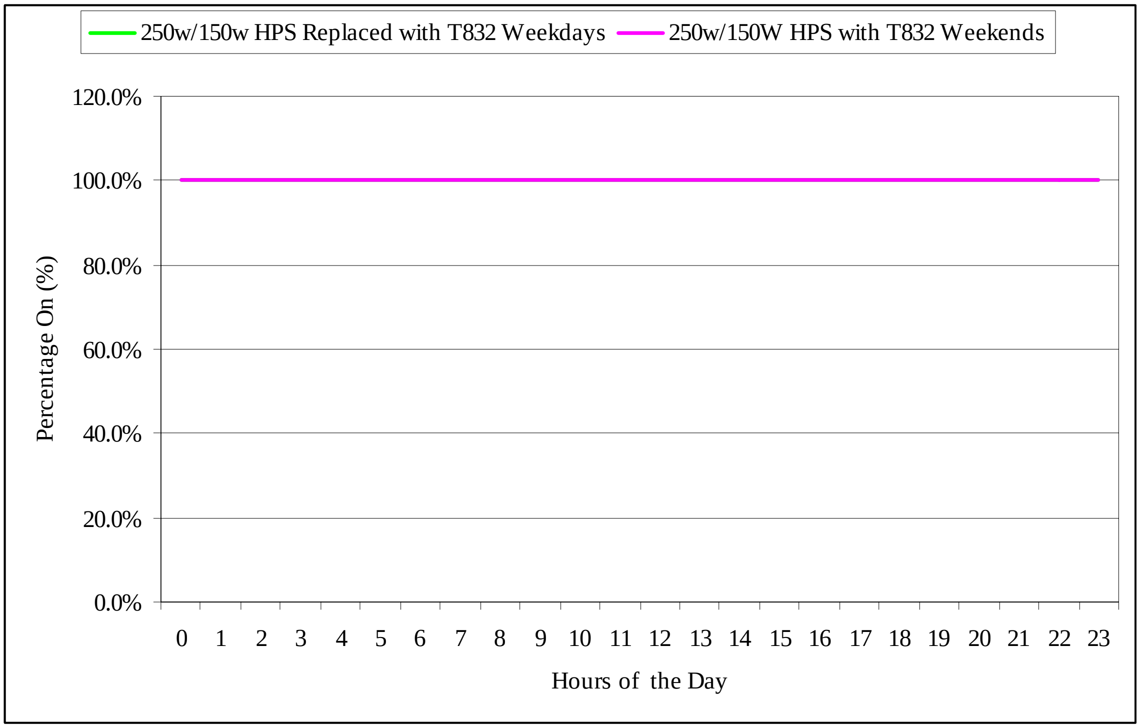


Figure 3: Average Day Operating Profile of Replaced 250w/150 W HPS Lamps with T8 Lamps



The ex ante calculations were performed using the SPC Estimation Software and itemized measure savings. The ex post impacts were calculated using a spreadsheet which contained information on annual operating hours obtained from metered data, fixture counts, and fixture wattages. Table 5 and Table 6 show summary of ex post savings calculation.

Table 5: Summary of Ex post Savings Calculation for Itemized Measure

Itemized Measure	Qty	Pre retrofit kW	Post retrofit kW	Ex post kW Savings	Estmated hrs/yr	Pre retrofitted kWh/yr	Post Retrofitted kWh/yr	Expost kWh/yr Savings
4' T8 installed	7,932	341.1	253.8	87.3	4,298	1,465,944.6	1,090,935.6	375,009.1
4' T12 delamped	1,140	49.0	-	49.0	4,298	210,688.0	-	210,688.0
400W high bay replaced w/ T8	96	43.8	17.3	26.5	6,276	274,738.2	108,449.3	166,288.9
2' T8 installed	17	0.46	0.29	0.17	8,375	3,844.1	2,420.4	1,423.8
LED exit sign installed	36	1.44	0.08	1.4	8,760	12,614.4	725.3	11,889.1
100W replaced w/ screw in CFL	25	2.5	0.8	1.7	121	302.5	99.8	202.7
Total		**438.3**	**272.3**	**166.0**		**1,968,131.8**	**1,202,630.4**	**765,501.4**

Table 6: Summary of Ex post Savings Calculation for Calculated Measure

Calculated Measure	Qty	Pre retrofit kW	Post retrofit kW	Ex post kW Savings	Estmated hrs/yr	Pre retrofitted kWh/yr	Post Retrofitted kWh/yr	Expost kWh/ yr Savings
250W HPS replacement w/ T8	909	268.2	101.8	166.3	8,760	2,349,037.8	891,838.1	1,457,199.7
150W HPS replacement w/ T8	10	1.9	0.6	1.3	8,760	16,644.0	5,168.4	11,475.6
Total		**270.1**	**102.4**	**167.7**		**2,365,681.8**	**897,006.5**	**1,468,675.3**

The ex post impacts were calculated as follows:

- Pre-retrofit annual kWh usage was 4,333,814 kWh/yr

Based on lighting logger data, post-retrofit hours of operation Post-retrofit annual kWh usage is 2,099,637 kWh/yr

- The resulting annual kWh savings is
- 4,333,814 kWh/yr - 2,099,637 kWh/yr = 2,234,177 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load, with an adjustment for the weekday 2 pm 5 pm average measured post-retrofit percent on value of 91.8% (the kW weighted average is shown on Table 10).

- Peak kW savings is (708.3 kW x 91.4 %) – (374.7 kW x 91.4%) = 304.5 kW.

The engineering realization rate for this application is 0.93 for demand kW reduction and 1.02 for energy savings kWh. The operating hours, fixture counts and fixture wattages found during the onsite inspection were very close to the ex ante estimates. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 8.

6. Additional Evaluation Findings

The ex post kW demand reduction are less than the ex ante estimate because we found out that the fixture wattage for some types of fixtures were incorrectly assumed for ex ante kW savings calculation. The ex post energy savings are greater than the ex ante savings because ex ante usage savings were underestimated the annual operating hours of some of the areas in the facility.

We were unable to physically verify the pre-retrofit lighting fixture type, quantities and hours of operation. We were unable to sample the number of fixtures because the ex ante estimate was based on a single count for the whole building.

The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

According to facility personnel, this measure increased energy awareness in the company and they continue to look for energy efficiency opportunities in the facility.

Although the evaluation team is confident in the ex post findings, actual post retrofit fixture count could have improved the impact analysis. Instead, the evaluation depended upon the ex ante count and actual operating hours extrapolated from the post field loggers. Monitoring before occupancy sensor installation would also provide more reliable pre and post retrofit operating hours (the occupancy sensors were not part of this evaluation).

The retrofit covers 3000 fixtures, and the total costs thus appear reasonable. Invoices were provided with the application paperwork.

With a cost of $425,802 and a $122,295 incentive, the project had a 1.06 years simple payback based on the ex ante calculation. The ex post savings estimate for the project are slightly greater than the ex ante, resulting in an estimated simple payback is 1.04 years. A summary of the economic parameters for the project is shown in Table 7.

The effective useful life of the lighting system is 16 years. Table 11 shows projected annual ex ante and ex post energy savings for multiple years 2004 through 2023.

7. Impact Results

Table 7: Economic Information

Description	Date	Project Cost	Esimated Demand	Estimated Energy	Estimated Gas	Estimated Annual Cost	SPC Incentive	Simple Payback	Simple Payback
Installation Approved Amount (Ex Ante)	11/29/2005	$425,802	328.3	2,201,042	-	$286,135	$122,295	1.06	1.49
SPC Program Review (Ex Post)	9/5/2007	$425,802	304.9	2,234,177	-	$290,443	$122,295	1.04	1.47

Table 8: Realization Rate Summary

	kW	kWh
SPC Tracking System	328.3	2,201,042
SPC Installation Report (Ex Ante)	328.3	2,201,042
Impact Evaluation (Ex Post)	304.9	2,234,177
Engineering Realization Rate	0.93	1.02

Table 9: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Installation of high efficiency lighting fixtures fhroughout the facility		10,165	HO T8 fixtures	Physically verified fixture quantity and wattage	1.00

Table 10: Project Wide Hourly Percentage On by Day Type

	Weekdays	Weekends
0	63.0%	62.8%
1	63.7%	60.9%
2	63.2%	62.5%
3	67.1%	63.5%
4	81.0%	72.5%
5	81.4%	81.4%
6	82.3%	81.2%
7	91.8%	81.3%
8	91.9%	81.8%
9	89.8%	80.8%
10	89.7%	82.7%
11	88.6%	80.6%
12	89.1%	80.2%
13	89.1%	78.1%
14	90.1%	72.0%
15	91.4%	70.7%
16	88.1%	69.3%
17	79.9%	70.0%
18	80.9%	70.2%
19	80.6%	69.1%
20	64.3%	69.1%
21	62.0%	68.3%
22	61.8%	68.0%
23	62.65%	65.45%

Table 11: Projected Multi Year Ex ante and Ex post Savings of the Lighting System

Program ID:		001 Application # A083					
Program Name:		SPC 04-05 Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	366,840	372,363			0	0
3	2006	2,201,042	2,234,177	328.3	304.9	0	0
4	2007	2,201,042	2,234,177	328.3	304.9	0	0
5	2008	2,201,042	2,234,177	328.3	304.9	0	0
6	2009	2,201,042	2,234,177	328.3	304.9	0	0
7	2010	2,201,042	2,234,177	328.3	304.9	0	0
8	2011	2,201,042	2,234,177	328.3	304.9	0	0
9	2012	2,201,042	2,234,177	328.3	304.9	0	0
10	2013	2,201,042	2,234,177	328.3	304.9	0	0
11	2014	2,201,042	2,234,177	328.3	304.9	0	0
12	2015	2,201,042	2,234,177	328.3	304.9	0	0
13	2016	2,201,042	2,234,177	328.3	304.9	0	0
14	2017	2,201,042	2,234,177	328.3	304.9	0	0
15	2018	2,201,042	2,234,177	328.3	304.9	0	0
16	2019	2,201,042	2,234,177	328.3	304.9	0	0
17	2020	2,201,042	2,234,177	328.3	304.9	0	0
18	2021	1,834,202	1,861,814	328.3	304.9	0	0
19	2022					0	0
20	2023						
TOTAL	**2004-2023**	**35,216,672**	**35,746,828**				

Final Site Report

SITE A084 (2004-460) LATM IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 5 END USE: Lighting

Measure	Lighting Retrofits
Site Description	Office

1. Measure Description

Replace 63 high bay HID fixtures with pulse start metal halide HID fixtures. Replace 711 four foot first generation T8 fixtures with third generation T8 fixtures. Install 93 LED exit signs. Retrofit fluorescent fixtures using 303 T12 lamps with T8 technology. Remove 61 four foot fluorescent lamps. Install 39 screw-in CFL lamps. Install 44 hard wired fluorescent fixtures in the 14 to 26 watt range.

2. Summary of the Ex Ante Calculations

The total ex ante kW demand and kWh savings approved in the Installation Report Review were 58.0 kW and 366,545.22 kWh. The majority of savings (75%) are obtained from two of the three calculated measures involving the replacement of 63 HID lamps and 711 first generation T8 lamps and fixtures. The third calculated measure involved replacement of T12 U tube fixtures with two foot T8 fixtures.

There is some documentation of fixture quantities and hours in various tables and spreadsheets provided with the application paperwork. However, no calculation methodology is given for the calculated measures.

There are also five itemized measures. The ex ante savings for the itemized measures are typically based on the Express Efficiency workpapers. The office market sector is used for this application. This results in 4000 hours/year of operation, with a coincident diversity factor of 0.81.

For screw in compact fluorescent lamps in the 14 – 26 watt range, the total wattage drops from 75 watts to 18 watts (for the lamp and ballast), for a noncoincident demand savings of 0.057 kW per lamp. Coincident demand savings for the office market sector is 0.058 kW and annual kWh savings of 267 kWh per lamp.

For hardwired fluorescent lamps in the 14 – 26 watt range, the total wattage drops from 100 watts to 26 watts (for the lamp and ballast), for a noncoincident demand savings of 0.074 kW per lamp. Coincident demand savings for the office market sector is 0.0785 kW and annual kWh savings of 346 kWh per lamp.

The workpapers cover conversion from 4 foot fixtures (using T12 lamps and energy saving ballasts) to 4 foot fixtures (using T8 lamps and electronic ballasts). The average of the two lamp fixture and three lamp fixture savings is used as the basis of the per fixture savings of .009 kW. Coincident demand savings for the office market sector is 0.009 kW and annual kWh savings of 42 kWh per lamp.

For removal of four foot lamps, the original fixture wattage is based on T-12, 34-watt lamps in fixtures employing energy savings ballasts and assumes removal of one lamp and its associated ballast. The work paper indicates the total wattage drops from 0.115 kW to 0.072 kW with a noncoincidental demand savings of 0.043 kW per lamp. The coincident kW and kWh savings are listed as 0.044 kW and 201 kWh for a office application.

The workpapers establish savings from installation of high efficiency LED exit signs, assuming replacement of older signs containing two 20-watt incandescent lamps. Total installed wattage drops from 0.040 kW to 0.004 kW. The noncoincident demand savings are 0.036 kW per LED fixture; with a 1.18 Demand Interactive Effects factor, the noncoincident demand savings are 0.042 kW. Fire code requires exit signs to operate all year, or 8760 hrs/yr. The savings are calculated as 0.036 kW x 8,760 hours/year x 1.114 = 351 kWh per year. The calculation includes 11.4% average Energy Interactive Effects. Coincident demand savings are 0.042 kW x 1.0 = 0.042 kW.

3. Comments on the Ex Ante Calculations

Calculations of energy savings resulting from all installed measures were not detailed. All supporting calculation documentation did not appear to be included in the application paperwork for this site.

For the itemized measures, the ex ante savings are shown in the Summary of Approved itemized Measures; the ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. The calculations performed with figures from those workpapers did not result in the exact kW and kWh savings listed for many sub-measures.

The workpapers prescribe savings based on certain conditions, which do not always apply to the installed conditions, and so do not accurately represent the actual situation evaluated.

The comments on the ex ante calculation will focus on the two major calculated measures. The savings of 12.7 kW for the HID retrofits appear reasonable.

The kWh savings are based upon 8,760 hours/year. This operation should be confirmed.

Based upon the wattage reduction resulting from the pre and post retrofit fixtures, as dictated by the fixture codes in the IR Review tables contained in the application paperwork, the savings of 30 kW for the 711 fluorescent fixtures may be reasonable; they may however, be overstated by 10% or more. The ex ante savings kWh figure is valid if these fixtures are operated for an average of approximately 6,000 hours per year. Since many areas are indicated to be 24 hour per year areas (8,760 hours per year), this is a possible result. Hours in the lighting tables are indicated to be 6,132 hours/year, 2411 hours/yr, and 520 hours/yr for various areas.

The ex ante savings figures were checked for reasonableness using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post}

The check calculations for the main measures were performed as follows:

Retrofit from T8 Generation 1 to Generation3 fixtures

- Pre-installation hours of operation: 6,132 hrs/yr

  0.029 kW per lamp x 711 lamps = 20.62 kW
  Annual pre measure kWh use: 20.62 kW x 6,132 hrs/yr = 126,442 kWh/yr
- Post -installation hours of operation: 6,132 hrs/yr

  0.024 kW per lamp x 711 lamps = 17.06 kW12
  Annual post measure kWh use: 17.06 kW x 6,132 hrs/yr = 104,612 kWh/yr

- kWh savings = 126,442 kWh/yr – 104,612 kWh/yr = 21,830 kWh/yr (verses 168,918.85 kWh/yr identified as the ex ante savings for this sub-measure)

- kW savings = 20.62 kW – 17.06 = 3.56 (versus 30 kW identified as the ex ante savings for this sub-measure)

The ex ante savings calculations are not equal to the kWh energy savings and kW peak demand savings reported in the Installation Report Review (IRR) .

4. Measurement & Verification Plan

The building serves offices and production floor areas. It is a two story structure encompassing 300,000 sf and is reportedly 25 years old.

There are two main measures: HID fixture retrofit (63), and calculated fluorescent fixture retrofit (711 fixtures).

For the evaluation of these measures, the exact counts of areas retrofit (wattages, lamp types and hours of operation) for the 711 fluorescent lamps will be determined to the extent possible. As-built lighting plans should be obtained and spot checks performed for lighting counts in 10% of the building spaces.

Important information to obtain will be an accurate determination of the lighting hours of operation – verifying that the HID lamps are energized for 8,760 hours per year (and that they are not operated by motion sensors or switched off) and the hours for the fluorescent fixtures.

According to the paperwork, older T8 fixtures were replaced with new T8 fixtures, as follows:

31 – three foot 4 lamp (89 watts) to 3 lamp (67 watts) fixtures
525 – four foot 3 lamp (89 watts) to 2 lamp (54 watt) fixtures
155 – three foot 4 lamp (112 watts) to 2 lamp (54 watts) fixtures

For the retrofit of 63 HID fixtures, the replacements were as follows:

28 - 1000 watt HPS to 750 watt metal halide
27 - 400 watt HPS to 320 watt metal halide
8 – 1000 watt metal halide to 750 watt pulse start metal halide

The following information will be obtained for the two main measures:

- The complete number of retrofit fixtures
- The operating hours before and after the installation of these fixtures, through placement of lighting loggers to determine the operating hours, if required
- Wattages of the lamps or fixtures controlled by the sensors through check with lighting drawings, old ballasts and lamps in stock, and new ballasts/lamps.
- The pre and post retrofit percent of burned out lamps
- The presence of motion sensors

If lighting loggers are required, ten to fifteen loggers would be placed in various office areas – primarily open office areas.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the lighting measures.

Formulae and Approach

A modified version of IPMVP Option A can be utilized. There will 8 – 15 lighting loggers installed in the facility to quantify hours of operation. The lighting loggers will be installed in office, production areas and other locations strategically. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = $kWh_{pre} - kWh_{post}$

.

Summer peak demand period savings = $kW_{pre} - kW_{post}$ during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, of the week with the hottest day in June, July, August, September

To estimate the average expected peak demand kW reduction, since this measure is not weather dependent, the average of all reductions during that periods as stated above could be used.

Uncertainty for the savings estimate for the T8 fixture retrofit can be more fully understood by setting projected ranges on the primary variables.

<u>For replacement of Gen1 with Gen3 T8 fixtures</u>

- 711 lamps expected to be retrofitted, minimum 640, maximum 780 (+ /- 10% expected range)
- 6,132 hours of operation, minimum 5,500 hours, maximum 6,500 hours (+ / - 10% expected range)
- kW savings: 30 kW for coincident peak kW expected, 27 kW minimum, 33 kW maximum (+/- 10% expected range).
- kWh savings: 168,918 kWh expected, 150,000 kWh minimum ; 185,000 kWh maximum (+ / - 10% for range of possible savings)

Accuracy and Equipment

The light loggers to be used are Dent TOU-L Lighting Smart *logger* data loggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Annualizing that data from a 7 to 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 15, 2007. Information on the retrofit and the operating hours were collected by inspecting the lighting fixtures and by interviewing the facility representatives.

Installation Verification

It was physically verified on the day of the on-site survey that the fixtures reported were installed at various locations on the building.

A sample of the lighting measures submitted in the report was verified. The verification realization rate for this project is 1.00.

Scope of the Impact Assessments

The impact assessment scope is for the lighting end use measures in the SPC application covering the lighting efficiency retrofit. These are the only measures in this application.

Summary of Results

The evaluation concentrated on the major energy saving measures. These measures are the conversion from T8 Generation 1 fluorescent fixtures to more efficient T8 Generation 3 fixtures and the retrofit of the HID fixtures; these constitute about 80% of the total energy savings. The wattages of the installed fixtures were verified were found to be similar to the reported wattages. Twelve (12) lighting loggers were installed at various locations to obtain the operating hours of the facility. The facility was at its typical operating schedule. The operating hours for fixtures reported as 8,760 hours were not logged. The facility had installed lighting controls only on a few fixtures and all the other fixtures were controlled manually.

Table 1A: Logger Data

	Start Time	Stop Time	Hours OFF	Hours ON	Days Monitored	On-Time	Annualized Hours
1	08/15/07	09/27/07	431.36	887.64	54.96	0.67	5,895
2	08/15/07	09/27/07	319.47	999.53	54.96	0.76	6,638
3	08/15/07	09/27/07	285.63	1033.37	54.96	0.78	6,863
4	08/15/07	09/27/07	285.33	1033.67	54.96	0.78	6,865
5	08/15/07	09/27/07	431.35	887.65	54.96	0.67	5,895
6	08/15/07	09/27/07	538.92	780.09	54.96	0.59	5,181
7	08/15/07	09/27/07	285.31	1033.69	54.96	0.78	6,865
8	08/15/07	09/27/07	285.23	1033.77	54.96	0.78	6,866
9	08/15/07	09/27/07	544.22	774.78	54.96	0.59	5,146
10	08/15/07	09/27/07	695.83	623.17	54.96	0.47	4,139
11	08/15/07	09/27/07	290.52	1028.48	54.96	0.78	6,831
12	08/15/07	09/27/07	464.61	854.39	54.96	0.65	5,674
	Average						**6,072**

Lighting loggers were used to measure the operating hours of the lights in the facility. A total of 12 loggers were installed to obtain samples of operating hours in various locations of the facility. The data collected from the loggers is showed in the table above. From the logger data obtained, it was determined that the average operating hours of the facility 6,072 hours/year. The operating hours of the areas operating continuously (8,760 hours per year) were verified with facility personnel and considered accurate; these areas are served by the HID lamps. The operating hours determined were used to calculate the ex-post savings. The wattages used for the fixtures are in coherence with the express efficiency workpapers. The results of the ex post impacts are shown in the following table:

Table 1B: Ex Post Calculation of Lighting Savings

Measures	Qty	Pre-Op hrs	pre watts/lamp	Pre kW	pre kWh	Post-Op hrs	post watts/lamp	post kW	post kWh	kW savings	kWh savings
F43ILL(G1) to F42ILL (G3)	130	2,412	0.089	11.6	27,907	2,412	0.051	6.6	15,992	4.94	11,915
F43ILL(G1) to F42ILL (G3)	332	6,132	0.089	29.5	181,188	*6,072**	0.051	16.9	102,811	12.616	78,377
F43ILL(G1) to F42ILL (G3)	64	8,760	0.089	5.7	49,897	8,760	0.051	3.3	28,593	2.432	21,304
F44ILL(G1) to F42ILL (G3)	6	364	0.112	0.7	245	364	0.051	0.3	111	0.366	133
F44ILL(G1) to F42ILL (G3)	22	2,412	0.112	2.5	5,943	2,412	0.051	1.1	2,706	1.342	3,237
F44ILL(G1) to F42ILL (G3)	109	6,132	0.112	12.2	74,859	*6,072**	0.051	5.6	33,754	6.649	41,105
F44ILL(G1) to F42ILL (G3)	18	8,760	0.112	2.0	17,660	8,760	0.051	0.9	8,042	1.10	9,618
F34ILL to F33ILL	31	8,760	0.087	2.7	23,626	8,760	0.067	2.1	18,195	0.62	5,431
HPS 1000 watt to 750 watt metal halide	28	8,760	1.1	30.8	269,808	8,760	0.818	22.9	200,639	7.90	69,169
HPS 400 watt to 360 watt metal halide	27	8,760	0.465	12.6	109,982	8,760	0.365	9.9	86,330	2.70	23,652
Metal halide 1000 watt to 750 watt pulse start metal halide	8	8,760	1.08	8.6	75,686	8,760	0.818	6.5	57,325	2.10	18,361
Totals				118.9	836,801			76.1	554,498	**42.76**	**282,304**

**Logged hours*

Table 2 summarizes the total metered energy use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and the additional data obtained from the customer. The baseline end use energy is the calculated energy use for the pre and post implementation evaluations for the specific quantities of the equipment listed in the specific measures Baseline end use was estimated at 30% of total kWh use and kW demand at this facility. The ex ante savings are those listed in the tracking system for all the measures, and the ex post savings include the calculated savings for the evaluated measures summed with the ex ante savings for the measures not evaluated.

Table 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1,735	51,798,000
Baseline End Use	520.5	15,539,400
Ex Ante Savings	58.0	366,545
Ex Post Savings	57.9	367,747

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 3.3% decrease in total meter kW, a 11.1% decrease in lighting end use kW, a 0.7% decrease in total meter kWh, and a 2.4% decrease in lighting end use kWh. The ex post results showed a 3.3% decrease in total meter kW, a 11.1% decrease in lighting end use kW, a 0.7% decrease in total meter kWh, and a 2.4% decrease in lighting end use kWh.

Table 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	3.3%	0.7%	2.5%	0.5%
Baseline End Use %	11.1%	2.4%	8.2%	1.8%

Note: Results are for two main submeasures only

6. Additional Evaluation Findings

The ex post energy savings are similar to the ex-ante energy savings. The operating hours used for the ex post calculations were determined using the lighting logger data. The operating hours considered in the ex-ante savings were reasonable and comparable to the calculated operating hours from the lighting logger data.

The ex-post calculations were more accurate as the parameters used were taken from data collected during the site visit and from information provided by the facility personnel.

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. In addition to saving energy, the benefits of the project are better quality of lighting and longer lasting lights. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program has increased the energy awareness of the facility.

We were unable to physically verify the pre-retrofit lighting fixture type, quantities and hours of operation for the facility. However, we are satisfied that these parameters have been accurately assessed and quantified based on our verification of accessible fixtures as a sample and discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $72,859 and $18,890 incentive, the project had a 1.13 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is similar to that of the ex ante, and the estimated simple payback is 1.13 years. A summary of the economic parameters for the project is shown in Table 4.

7. Impact Results

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Annual Cost Savings ($0.13/kWh) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	11/16/2004	$72,859	58.0	366,545	$47,651	$18,890	1.13	1.53
SPC Program Review (Ex Post)	8/15/2007	$72,859	57.9	367,747	$47,807	$18,890	1.13	1.52

The utility tracking data are the approved estimates of ex ante savings. The utility tracking savings were 58.0 kW and 366,545 kWh. For the two measures evaluated the ex post savings are 42.76 kW and 282,304 kWh. The ex post savings are equivalent to the ex ante savings for measures not evaluated. The engineering realization rate is the ratio of the ex post results to the utility tracking data. The engineering realization rate for this application is 1.00 for demand kW reduction and 1.00 for energy savings kWh. A summary of the realization rate is shown in Table 5. The Installation Verification Summary for major measures is shown in Table 6 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 7.

Table 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	58.0	366,545	-
SPC Installation Report (ex ante)	58.0	366,545	-
Impact Evaluation (ex post)	57.9	367,747	-
Engineering Realization Rate	1.00	1.00	NA

Note: Results are for two main submeasures only

Table 6: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING	L		Replace 1st Gen with 3rd Gen T8 fixtures		711	2 lamp T8 fixtures with electronic ballasts	Physically verified lamp type and verified quantity from floor plan and documentation of previous inspectors.	1.00
LIGHTING	L		High Bay HID retrofit		63	Metal Halide Fixutres	Physically verified lamp type and verified quantity from floor plan and documentation of previous inspectors.	1.00

Table 7: Multi Year Reporting Table

	Program Name:	Site A084 SPC 04-05 Evaluation					
Year	Calendar Year	Ex-ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	61,091	61,291				
2	2005	366,545	367,747	58.0	57.9		
3	2006	366,545	367,747	58.0	57.9		
4	2007	366,545	367,747	58.0	57.9		
5	2008	366,545	367,747	58.0	57.9		
6	2009	366,545	367,747	58.0	57.9		
7	2010	366,545	367,747	58.0	57.9		
8	2011	366,545	367,747	58.0	57.9		
9	2012	366,545	367,747	58.0	57.9		
10	2013	366,545	367,747	58.0	57.9		
11	2014	366,545	367,747	58.0	57.9		
12	2015	366,545	367,747	58.0	57.9		
13	2016	366,545	367,747	58.0	57.9		
14	2017	366,545	367,747	58.0	57.9		
15	2018	366,545	367,747	58.0	57.9		
16	2019	366,545	367,747	58.0	57.9		
17	2020	305,454	306,456	58.0	57.9		
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	5,864,720	5,883,948				

Final Report

SITE A085 (2004-xxx) Term IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 5 END USE: Lighting

Measures	Comprehensive Lighting Retrofit
Site Description	Warehouse

1. Measure Description

Replace two hundred forty eight (229) four hundred watt high pressure sodium (HPS) fixtures with metal halide (MH) fixtures of lower wattages, utilizing 150, 175 and 250 watt lamps; replace forty-eight (48) interior high bay HID fixtures with fluorescent fixtures; replace eight (8) two foot and 416 four foot T12 lamps with newer T8 or T5 lamps powered by electronic ballasts; replace sixteen (16) 300 and 500 watt quartz fixtures with 70, 100, 175 and 250 watt metal halide fixtures; remove fifty-four (54) fluorescent lamps; and install eight (8) LED exit signs

2. Summary of the Ex Ante Calculations

The total ex ante kW demand and kWh savings submitted were listed as 65.7 kW and 343,726.36 kWh in the Installation Report Review. These agree with the savings listed in the utility tracking system data (with rounding functions for the kWh savings).

The customer submitted the retrofits as itemized measures and calculated measures. The primary savings are obtained from the calculated measures, namely the retrofit of approximately 229 HPS fixtures using 400 watt lamps with MH fixtures using 250 watt lamps. This accounts for 224,420 kWh and 40.0 kW of savings, or over 60% of the total savings. The calculations were checked for this sub-measure and appear reasonable. Hours of operation were estimated at 5,600 hrs/yr.

The ex ante calculations for the itemized measures are typically based on utility Express Efficiency workpapers. The workpapers describe general descriptions of measures that are the basis for evaluation. The workpapers assumptions for the lighting measures implemented at this site include 3,550 annual operating hours and a coincident diversity factor of 0.84 where applicable.

The workpapers describe the replacement of a 400 watt metal halide fixture with T5 or T8 fixtures. The total installed wattage drops from 0.458 kW to 0.234 kW per fixture. For a warehouse market sector coincident demand savings is 0.205 kW and annual kWh savings is 843 kWh per fixture under the assumed operating hours and coincident diversity factor. It is believed that the fixtures retrofit were 400 watt high pressure sodium fixtures.

Other itemized measures are not evaluated in detail for this application and the workpaper calculations and assumptions for these measures are not investigated for this application.

3. Comments on the Ex Ante Calculations

The ex-ante savings for the calculated measure considers the wattage of the 250 watt metal halide fixture to be 290 watts, whereas the calculations use 295 watts for each fixture in the Express Efficiency workpapers.

As stated above, the ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. The workpapers prescribe savings based on certain conditions, which do not always apply to the installed conditions, and so do not accurately represent the actual situation evaluated.

Based upon usage figures obtained from the application paperwork, hours are listed as 5,600 hours/year, somewhat higher than the average stated in the workpapers for warehouse operations. Energy savings in this case would be higher than indicated by the workpapers. This applies to the itemized measures that comprise about 20% of the savings for this application.

The ex ante savings figures can be checked for accuracy using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x (1 – diversity factor)

The check calculations for two main measures – one calculated and one itemized - were performed as follows:

Retrofit from 400 watts H.P.S fixtures to 250 watt metal halide fixtures

- Pre-installation hours of operation: 5,600 hrs/yr

  0.465 kW per lamp x 229 lamps = 106.485 kW

  Annual pre measure kWh use: 106.485 kW x 5,600 hrs/yr = 596,316 kWh/yr

- Post -installation hours of operation: 5,600 hrs/yr

  0.295 kW per lamp x 229 lamps = 67.555 kW

  Annual post measure kWh use: 67.555 kW x 5,600 hrs/yr = 378,308 kWh/yr

- kWh savings = 596,316 kWh/yr – 378,308 kWh/yr = 218,008 kWh/yr (verses 224,220 kWh/yr identified as the ex ante savings for this sub-measure)

- kW savings = 106.5 kW – 67.6 = 38.9 kW (versus 40.0 kW identified as the ex ante savings for this sub-measure)

Retrofit from 400 watts HPS fixtures to high bay T5 fixtures

- Pre-installation hours of operation: 5,600 hrs/yr

  0.465 kW per lamp x 48 lamps = 22.32 kW
  Annual pre measure kWh use: 22.32 kW x 5,600 hrs/yr = 124,992 kWh/yr

- Post -installation hours of operation: 5,600 hrs/yr

  0.234 kW per lamp x 48 lamps = 11.232 kW
  Annual post measure kWh use: 11.232 kW x 5,600 hrs/yr = 62,899 kWh/yr

- kWh savings = 124,992 kWh/yr – 62,899 kWh/yr = 62,093 kWh/yr (verses 43,008 kWh/yr identified as the ex ante savings for this sub-measure)

- kW savings = 22.3 kW – 11.2 = 11.1 (versus 10.8 kW identified as the ex ante savings for this sub-measure)

4. Measurement & Verification Plan

The facility is a single story structure and encompasses 560,000 square feet. The building is used primarily as a warehouse and distribution center for dry and refrigerated goods. There are typically 40 employees; during the harvest season, this number swells to 80 employees. During the harvest season from May to July, there is weekend occupancy and operations are continuous. During other periods, occupancy is roughly from 6 am to 12 am from Monday to Friday. The facility dates back to 1940; several buildings were added in 1995.

The energy savings for the itemized measures in the installation report review were itemized measures and were not supported with other documentation. However, lighting tables were supplied in the application paperwork and calculation provided for the itemized measures.

The major portion of the energy savings come from two measures. The two measures are the replacement of 400 watt HPS with 250 watt metal halide fixtures in the freezers and replacement of 400 watt HPS fixtures with T5 or T8 fixtures in the loading dock areas.

There is a significant difference in the energy savings reported and the energy savings calculated using the Express Efficiency workpapers for the itemized measure.

The primary difference may be in the hours of operation. It is essential to get an accurate number of operating hours in order to determine the energy savings accurately.

According to the application paperwork, the 229 four hundred (400) watt HID fixtures were reported to have been retrofit with 250 watt metal halide fixtures. The wattage of the post retrofit fixtures was considered to 290 watts for the calculations in the application while the standard wattage in the workpapers for these fixtures is 295 watts.

The following information should be obtained for this measure:

- The complete number of retrofit fixtures should be verified.
- The operating hours before and after the installation of these fixtures should be determined.
- Lighting loggers should be placed to determine the operating hours if required. The customer has reported that the lights are energized on a fixed schedule. This should be confirmed with the placement of several loggers in representative areas covering the retrofit of HPS fixtures as described above.
- Wattages and model numbers of the lamps or fixtures should be determined through checking lighting drawings, old ballasts and lamps in stock, and new ballasts/lamps.
- As built drawings for the lighting retrofits can be obtained.
- If possible, where lighting circuits can be isolated, actual wattages can be checked through spot measurements at the lighting panels. Note that for metal halide fixtures, this can require the metal halide lamps to ramp up to full power after de-energization.

The other retrofit fixtures should be verified and compared to the submitted quantities.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

A modified version of IPMVP Option A can be utilized. Savings verification is expected to require 3 - 5 lighting loggers installed in the facility to quantify hours of operation. The lighting loggers will be installed in loading docks, freezers and other locations covering the submeasures to be evaluated. Power (kW) loggers will be used to check the wattages of the fixtures if possible. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = $kWh_{pre} - kWh_{post}$

Summer peak demand period savings = $kW_{pre} - kW_{post}$ during the three contiguous expected hottest days between 2 pm to 5 pm, Monday to Friday, in June, July, August, September.

To estimate the average expected peak demand kW reduction, since this measure is not weather dependent, the average of all reductions during that periods as stated above could be used.

<u>Uncertainty with 400 watt HID fixture 250 watt metal halide fixture</u>

- 229 lamps expected to be installed, minimum 218, maximum 240 (+ /- 5% expected range)
- 5,600 operating hours reported/expected, minimum 3,500 hours, maximum 6,500 hours (+ / - 20% expected range)

<u>Retrofit from 400 watts HID fixtures to high bay T5 fixtures</u>

- 48 fixtures expected to be controlled, minimum 32, maximum 64 (+ /- 30% expected range)

- 5,600 operating hours reported/expected, minimum 3,500 hours, maximum 6,500 hours (+ / - 20% expected range)

Accuracy and Equipment

The lighting loggers capture on/off cycles of the lighting equipment and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Annualizing the kWh data to the typical annual period is projected to result in a possible error in the final results of +/- 10 % (due to greater use in the harvest season).

Power meters may also be used to verify fixture wattages. The power meter to be used, if this M&V technique is selected, would be a model manufactured by Amprobe Model ACD-41PQ. The accuracy range is expected to be +/- 3.5%.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 27, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. The application indicated the greatest savings were from the replacement of 229 for hundred watt high pressure sodium fixtures with 250W metal halide fixtures in freezer areas. There were also HID fixtures retrofit with six lamp fluorescent fixtures utilizing T8 lamps in the loading dock areas. These fixtures were the focus of the M&V evaluation.

Installation Verification

The facility representative indicated that all the 400 watt HPS lamps were replaced on a one to one basis. Physical verification of all lighting retrofits was attempted but it was only possible to sample selected areas due to visual obstructions. This inspection, the post installation inspection and the lighting invoice served to verify the installation. The fixture counts in the sampled areas appeared to be representative of the total fixture count. All fixtures were operational at the time of the site visit. The paper work also indicated that the number of fixtures has been reviewed or verified prior to retrofit.

The complete list of lighting measures was reviewed with the facility representative and it was verified that the type and quantity of each measures listed had actually been installed.

The verification realization rate for this project is 1.0. A verification summary is shown in Table 5 below.

The paperwork suggests the installation was completed by the end of 2004 (the invoice is dated 1/11/05).

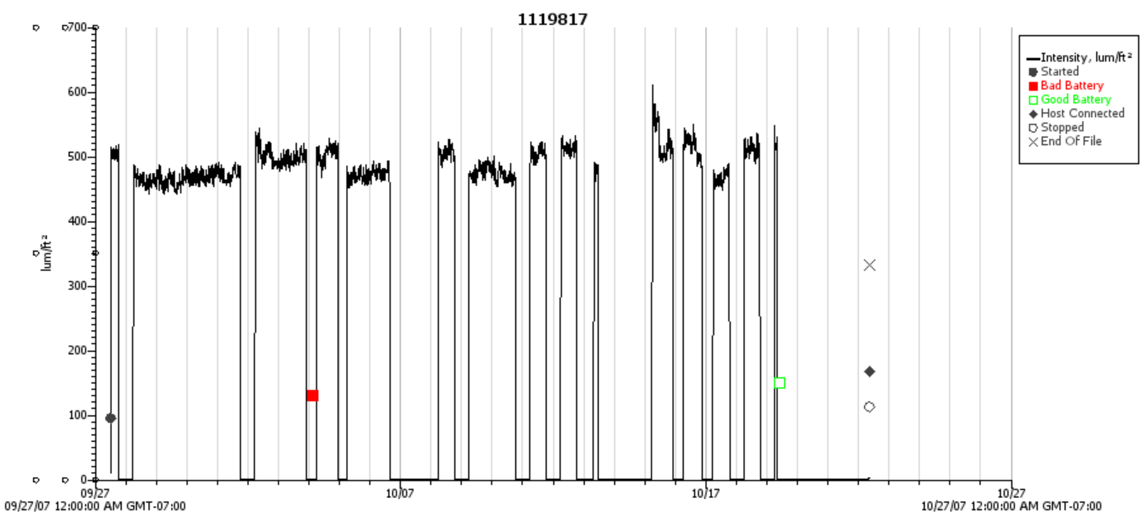
Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measures in the SPC application covering more efficient lighting fixtures and lamp removal. These are the only measures in this application.

Summary of Results

Six Hobo U12-012 lighting loggers were installed in three buildings (one in a freezer and one in the loading area of each main building). These loggers were left in place for 24 full days (September 27-October 21) in order to measure the operating hours of the retrofit lighting fixtures. The facility representative indicated that the work conducted presently was representative of normal facility operation. The average on-time for the freezer fixtures was 60% and for the loading docks it was 41%. It appeared that only the lights in one freezer remained energized – all other locations showed clear daily fluctuations, with lights off during unoccupied hours at nights and on weekends. Below is a typical lighting logger profile for one of the freezers.

Figure 1: Lighting Use Patterns



Approximately 74% of evaluated fixtures (169/229) were located in these freezers. The weighted average annual hours the fixtures were on was 4,816 hours/year (55%) compared to the ex ante assumption of 5,600 hours/year. This coincides closely with the reported schedules during this period (18 hours per day and five days per week with no holidays). A full year monitoring period could show longer hours of occupancy in the packing season (May to July) and some holiday closures. However, the data obtained will be used as these periods were unable to be measured. It is noted, however, that if continuous operating hours were assumed for the three month packing season, annual hours of use very similar to those used in the ex ante calculations.

During the expected coincident peak demand periods of 2 pm to 5 pm weekdays for the 24 days monitored days in September and October, the freezer fixtures were measured to be on an average 76.6% of the time and the loading dock fixtures were measured to be on an average of 70.4% of the time. The total weighted average percent on for all 229 MH fixtures is 75%. During normal weekdays, 100% of the fixtures could be expected to be energized, as there were no motion sensors. However, it was confirmed that only weekdays (i.e., no special holidays or off days) were included in the monitoring period. Thus, the average on times will also be used to calculate the actual kW load reduction.

For the freezers:

The ex post impacts for the main freezer retrofit is calculated as follows where kW per fixture are assumed to be the same as the ex ante calculations.

- Pre-retrofit hours of operation for all 250W MH fixtures was 8760 hrs/yr x 60% = 5,256 hrs/year.
- Pre-retrofit wattage was 0.465 kW per lamp x 229 lamps = 106.5 kW
- Annual kWh usage was 106.5 kW x 5,256 hrs/yr = 559,764 kWh/yr

The post-retrofit hours of operation are 5,256 hrs/year for the freezers and post-retrofit wattage is 0.290, for the actual metal halide fixtures installed.

- Post-retrofit wattage was 0.290 kW per lamp x 229 lamps = 66.4 kW
- Annual kWh usage is 229 fixtures x 0.290 kW x 5,256 hrs/yr = 349,051 kWh/yr
- The resulting annual kWh savings is 512,874 kWh/yr – 349,051 kWh/yr = 210,713 kWh/yr

For the loading docks:

- Pre-retrofit hours of operation for all 250W MH fixtures was 8760 hrs/yr x 41% = 3,592 hrs/year.
- Pre-retrofit wattage was 0.465 kW per lamp x 48 lamps = 22.3 kW
- Annual kWh usage was 22.3 kW x 3,592 hrs/yr = 80,102 kWh/yr

The post-retrofit hours of operation are 3,592 hrs/year for the loading docks and post-retrofit wattage is 0.171 kW, assuming all fixtures installed are six lamp standard T8 fixtures.

- Post-retrofit wattage was 0.171 kW per lamp x 48 lamps = 8.2 kW
- Annual kWh usage is 48 fixtures x 0.171 kW x 3,592 hrs/yr = 29,483 kWh/yr
- The resulting annual kWh savings is 80,102 kWh/yr – 29,483 kWh/yr = 50,619 kWh/yr

Other measures besides these two measures were not evaluated. The ex ante savings for these measures are 76,298 kWh/year and 14.9 kW.

The total ex post savings are 210,713 kWh/yr + 50,619 kWh + 76,298 kWh (other measures) = 337,227 kWh/yr.

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load, with an adjustment for the weekday average 2 pm to 5 pm measured usage factor of 76.6% and 70.4%.

Peak kW savings are (106.5 kW – 66.4 kW) x 76.6 % + (22.3 kW– 8.2 kW) x 70.4 %) = 30.7 kW + 9.9 = 40.6 kW.

The total ex post savings are 40.6 kW + 14.9 kW (other measures) = 55.5 kW.

The engineering realization rate for this application is 0.84 for demand kW reduction and 0.98 for energy savings kWh. The values shown in the tracking system substantially agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 4.

Utility billing data for the site was reviewed. In the 12 month period from December 2003 – December 2004 (pre-retrofit), the facility consumed 19,044,594 kWh. Peak demand was 492 kW in this period. Lighting use was estimated at 20% of total use for this facility. Table 1 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 13.3 % decrease in total meter kW, a 66.7% decrease in lighting end use kW, a 1.8 % decrease in total meter kWh, and a 9.0 % decrease in lighting end use kWh. The ex post results showed an 11.3 % decrease in total meter kW, a 56.4% decrease in lighting end use kW, a 1.8 % decrease in total meter kWh, and a 8.9% decrease in lighting end use kWh.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	492	19,044,594
Baseline End Use	98	3,808,919
Ex ante Savings	65.7	343,727
Ex Post Savings	55.5	337,227

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	13.3%	1.8%	11.3%	1.8%
Baseline End Use %	66.7%	9.0%	56.4%	8.9%

6. Additional Evaluation Findings

The ex post kW demand reduction varied from the ex ante estimate because the ex ante calculations, particularly for the main measure (HID retrofit with MH) were calculated using an estimated 5,600 hours of use per year. The actual post retrofit hours were slightly lower.

The measure costs provided in the application do seem somewhat high based upon experience with similar retrofits.

In addition to saving energy, the benefits of the project are better quality of lighting and increased light levels in some areas. One drawback of the project has been an increase in maintenance associated with the need to replace fluorescent lamps. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future.

However, workers have complained that the light in the fluorescent fixtures that were failing would cause an irritating, roving stroboscopic affect over their work areas, and this could cause some changes in the future.

The customer's participation in the 2004/2005 SPC Program has encouraged them to perform other energy efficiency projects, namely enhanced chiller controls and installation of variable speed drives. The customer is conscious of energy use and attempts to participate in incentive programs where possible. It is uncertain whether they participated in incentive programs for these other measures.

The cost was derived from one sponsor who guaranteed energy savings. It is uncertain whether the program was needed.

It was impossible to physically verify the pre-retrofit lighting fixture type, quantities and hours of operation. However, these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $90,551 and an $18,026 incentive, the project had a 1.62 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 1.82 years. A summary of the economic parameters for the project is shown in Table 3.

A summary of the multi-year reporting requirements is given in Table 6.

7. Impact Results

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	3/10/2005	$90,551	65.6	343,727	-	$44,685	$18,026	1.62	2.03
SPC Program Review (Ex Post)	9/27/2007	$90,551	55.5	337,227	-	$43,840	$18,026	1.65	2.07

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	65.7	343,727	-
SPC Installation Report (ex ante)	65.7	343,727	-
Impact Evaluation (ex post)	55.5	337,227	-
Engineering Realization Rate	0.84	0.98	NA

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Indoor System Replaceme nt – 229 HPS to MH fixtures, 48 HPS to T8 fixtures, other lighting retrofits		277		Physically verified lamp type and verified quantity from floor plan and documentat ion of previous inspectors.	1.00

Table 6: Multi Year Reporting Table

Program Name:	SPC 04-05 Evaluation A085						
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2005	343,727	337,227	65.7	55.5	0	0
2	2006	343,727	337,227	65.7	55.5	0	0
3	2007	343,727	337,227	65.7	55.5	0	0
4	2008	343,727	337,227	65.7	55.5	0	0
5	2009	343,727	337,227	65.7	55.5	0	0
6	2010	343,727	337,227	65.7	55.5	0	0
7	2011	343,727	337,227	65.7	55.5	0	0
8	2012	343,727	337,227	65.7	55.5	0	0
9	2013	343,727	337,227	65.7	55.5	0	0
10	2014	343,727	337,227	65.7	55.5	0	0
11	2015	343,727	337,227	65.7	55.5	0	0
12	2016	343,727	337,227	65.7	55.5	0	0
13	2017	343,727	337,227	65.7	55.5	0	0
14	2018	343,727	337,227	65.7	55.5	0	0
15	2019	343,727	337,227	65.7	55.5	0	0
16	2020	343,727	337,227	65.7	55.5	0	0
17	2021					0	0
18	2022	-	-	-	-		
19	2023	-	-	-	-		
20	2024	-	-	-	-		
TOTAL	**2005-2024**	5,499,632	5,395,632				

Final Site Report

SITE A086 (2005-xxx) SBCC **IMPACT EVALUATION**
SAMPLE CELL: ORIGINAL **TIER: 4** **END USE: Lighting**

Measure	Comprehensive Lighting Retrofit - Occupancy Sensors / Timeclocks / Electronic Ballasts / CFLs
Site Description	Educational Campus

1. Measure Description

Install 273 ceiling mounted occupancy sensors; install 477 wall box occupancy sensors; install 56 time clocks; install 248 CFL lamps in the 14 watt to 26 watt range; install 39 CFL lamps in the 5 watt to 13 watt range; and replace 727 four-foot and 26 two-foot T12 lamps with T8 lamps.

2. Summary of the Ex Ante Calculations

The total ex ante kW demand and kWh savings submitted were 168.519 kW and 789,512.92 kWh in the Installation Report Review. These figures agree with the utility tracking system (except for rounding functions).The customer submitted all retrofits as itemized measures. No calculations of demand or energy savings were provided.

The ex ante savings for the itemized measures are typically based on the Express Efficiency workpapers.

According to the workpapers, the college market sector shows annual operating hours of 3,900 hours per year and has a diversity factor of 0.68.

Measure E-L21 covers conversion from 2 foot T12 fixtures (20 watts lamps and energy saver ballast) to 2 foot T8 fixtures with two T8 lamps (17 watts each) and electronic ballast for each fixture. The total installed wattage drops from 0.050 kW to 0.029 kW for a non-coincident demand savings of 0.011 kW per lamp. Coincident demand savings for the college market sector is 0.009 kW and annual kWh savings is 49 kWh per lamp.

The workpaper section E-L23 measure covers conversion from 4 foot fixtures (using T12 lamps and energy saving ballasts) to 4 foot fixtures (using T8 lamps and electronic ballasts). The average of the two lamp fixture and three lamp fixture savings is used as the basis of the per fixture savings of 0.009 kW. Coincident demand savings for the college market sector is 0.007 kW and annual kWh savings of 40 kWh per lamp.

Section E-L66 replacement of a fixture consisting of a 60 watt incandescent lamp fixture with a fixture consisting of 13 watt fluorescent lamp driven by a magnetic ballast. The total installed wattage drops from 0.060 kW to 0.015 kW for a non-coincident demand savings of 0.045 kW per fixture. For the college market sector, coincident demand savings is 0.037 kW and annual kWh savings is 202 kWh per fixture under the assumed operating hours and coincident diversity factor.

Section E-L178 details replacement of a fixture consisting of a 100 watt incandescent lamp fixture with a fixture consisting of 26 watt fluorescent lamps driven by an electronic ballast. The total installed wattage drops from 0.100 kW to 0.026 kW for a non-coincident demand savings of 0.074 kW per fixture. For a college market sector coincident demand savings is 0.061 kW and annual kWh savings is 332 kWh per fixture under the assumed operating hours and coincident diversity factor.

In work papers section J – L82 for wall box mounted occupancy sensors, the workpaper documents savings based on the control of three (3) 4 foot 2 lamp fluorescent fixtures with 34 watt T-12 lamps, consuming 72 watts each including the ballast, in a private office. Savings are based on a reduction of usage from 2,550 hours/year to 1,500 hours/year (1,050 hours/year reduction). The workpaper reports a total of 266 kWh per sensor savings for all market sectors, which includes a 17% office sector energy interactive effects factor. The non-coincident peak reduction of 0.089 kW was derived from the 0.216 kW controlled wattage and a 41% reduction in hours. Coincident peak reduction was reported at 0.111 kW, which includes a 1.25 average office sector Demand Interactive Effects factor.

In section J – L83 for ceiling or wall mounted occupancy sensors, the workpaper documents savings based on the control of eight (8) 4 foot 2 lamp fluorescent fixtures with 34 watt T-12 lamps, consuming 72 watts each including the ballast, in an office conference room. Savings are based on a reduction of usage from 2,210 hours/year to 1,040 hours/year (1,170 hours/year reduction). The workpaper reports a total of 789 kWh savings for all sectors (674 kWh/year plus a 17% office sector energy interactive effects factor). The non-coincident peak reduction of 0.305 kW was derived from the 0.576 kW controlled wattage and a 45% reduction in hours. Coincident peak reduction was reported at 0.381 kW, which includes a 1.25 average office sector Demand Interactive Effects factor.

Section K – L36 details outside lights automatically controlled by a time clock. In this scenario, exterior lights operate 4,380 hours per year with the timeclock. Without the time clock, the exterior lights would operate for an additional 1,248 hours per year (assuming continuous energization on the weekends). For the savings calculation, the time clock is assumed to control four 70-watt high pressure sodium lamps (95 watts each including ballast). The noncoincident demand savings are 0.380 kW; coincident demand savings are 0.0.kW. Savings for all market sectors are 474 kWh per year.

3. Comments on the Ex Ante Calculations

Calculations of energy savings resulting from the installed measures were not detailed. All supporting calculation documentation did not appear to be included in the application paperwork for this site.

The ex ante savings are shown in the Measure Savings Worksheet. As indicated above, the ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. The calculations performed with figures from those workpapers did not result in the kW and kWh savings listed for many sub-measures.

In addition, the timeclock measure notes higher coincident peak savings and higher kWh savings as compared to the workpapers.

While the wattage controlled and the hours reduced through the use of motion sensors may be representative of this installation, the kW savings may be overstated. Analyzing controlled wattage and operation during peak periods will determine the accuracy of these estimates.

The ex ante savings figures can be checked for reasonableness using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x (1 – diversity factor)

The check calculations for the main measures (involving installation of ceiling mounted and wall box motion sensors) were performed as follows:

Ceiling mounted occupancy sensors

- Pre-installation hours of operation: 4,862 hrs/yr (given by customer)

  0.029 kW per lamp x 4,368 lamps = 126.7 kW (16 T8 lamps for each of 273 per sensors)

  Annual pre measure kWh use: 126.7 kW x 4,862 hrs/yr = 616,015 kWh/yr
- Based on 45% reduction due to occupancy sensors post -installation hours

  operation: 2,674 hrs/yr

  0.029 kW per lamp x 4,368 lamps = 126.7 kW

Annual post measure kWh use: 126.7 kW x 2,674 hrs/yr = 338,796 kWh/yr

- kWh savings = 616.015 kWh/yr – 338,796 kWh/yr = 277,219 kWh/yr (verses 390,096 kWh/yr identified as the ex ante savings for this sub-measure)

- kW savings = 126.7 x (1 – 0.68) = 40.5 (versus 83.2 kW identified as the ex ante savings for this sub-measure)

Note that savings would increase if more fixtures were controlled – sixteen lamps equals eight 2-lamp fixtures

Wall box occupancy sensors

- Pre-installation hours of operation: 4,862 hrs/yr

  0.029 kW per lamp x 2,862 lamps = 83.0 kW (6 T8 lamps for each of 477 per sensors)
  Annual pre measure kWh use: 83.0 kW x 4,862 hrs/yr = 403,546 kWh/yr

  Based on 45% reduction due to occupancy sensors post -installation hours

  operation: 2,674 hrs/yr

  0.029 kW per lamp x 2,862 lamps = 83.0 kW
  Annual post measure kWh use: 83.0 kW x 2,674 hrs/yr = 221,942 kWh/yr

- kWh savings = 403,546 kWh/yr – 221,942 kWh/yr = 181,604 kWh/yr (verses 198,892 kWh/yr identified as the ex ante savings for this sub-measure)

- kW savings = 83.0 kW x (1 – 0.68) = 26.6 kW (versus 42.45 kW identified as the ex ante savings for this sub-measure)

The timeclocks comprise over 10% of the kW and kWh savings, but these savings may be overstated.

It appears that both the controlled wattage and the hours of reduction will have a large effect on the actual savings.

The other measures – CFLs and fluorescent lamp retrofits – show ex ante savings that appear realistic. These measures in aggregate comprise 12% of the kW and kWh savings estimates. The ex ante savings estimates for these measures will not be analyzed in detail.

4. Measurement & Verification Plan

The educational campus encompasses over 20 buildings with a total floor area of over 1,000,000 sf. The lighting retrofit covers the majority of these buildings. The buildings are part of an educational campus with varying occupancy patterns.

According to the application paperwork, the initial operating hours were reported to be 3,500 hours while the ex ante savings given in the installation review report used operating hours of 4,862 hours (based upon an assessment by a college official). This is higher than the typical operating hours for a facility under the college market sector.

The operating hours seem higher than expected, based on a 16 hour day (8 am to 12 pm, to allow for night classes and cleaning), 5 days per week, and 48 weeks per year (allowing for holidays); this schedule totals 3,840 hours. The facility has noted partial occupancy on Fridays, and this would reduce hours as well.

The justification for the higher operating hours should be verified.

The primary energy saving lighting measures in the SPC application are the motion sensors and the timeclocks. Evaluation efforts will focus on those measures. The lighting contractor indicated that most motion sensors were installed in classrooms.

Determining accurate pre retrofit and post retrofit operating hours and estimated percentage reduction for the facility will be attempted by interviewing the facility personnel. Nighttime and weekend schedules for cleaning and maintenance and classroom occupancy schedules will also be obtained. Summer operation will be determined through interviews.

The connected wattages for the occupancy sensors will be determined to the extent possible (including the number of occupancy sensors per controlled space).

The total installed number of wall box and ceiling mounted occupancy sensors, and the controlled wattage for each type, will be determined.

The use of the timeclocks and their controlled wattage will be determined. The pre-retrofit control strategy and operating hour reduction will also be determined.

Post retrofit hours will be monitored in five to ten typical spaces (presumed to be classrooms and possibly offices) using light loggers for a period of at least seven days to capture a typical week.

The major portion of the energy savings come installation of wall box and ceiling mounted motion sensors. The following information regarding these measures will be obtained:

- The number of lamps controlled by the wall box sensors and ceiling mounted sensors
- The operating hours before and after the installation of these fixtures
- Pre retrofit information to be determined by lighting loggers on classrooms or offices without motion sensors (only if determined to be typical)
- Post retrofit hours verified through installation of lighting loggers to determine the operating hours
- Wattages of the lamps or fixtures controlled by the sensors through check with lighting drawings, old ballasts and lamps in stock, and new ballasts/lamps.

The other measure with significant savings is the installation of time clocks. The following will be verified to the extent possible:

- The operating hours before and after the installation of these fixtures
- Wattages of the fixtures/lamps through check with lighting drawings, old ballasts and lamps in stock, and new ballasts/lamps and also the number of lamps controlled by the time clocks
- Use lighting loggers if possible.

Other measures include replacement of T12 fixtures with T8 fixtures and installation of CFL 14-26 watts lamps. Verify the following:

- The number and operating hours for the T8 & CFL fixtures.
- Wattages of the pre and post retrofit fixtures through check with lighting drawings, old ballasts and lamps in stock, and new ballasts/lamps

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the lighting measures.

Formulae and Approach

A modified version of IPMVP Option A can be utilized. There will 5 - 10 lighting loggers installed in the facility to quantify hours of operation. The lighting loggers will be installed in class rooms and offices and other locations such as gyms, theatres and common areas. The class room schedules should be obtained from the facility in order to determine the operating hours and also the information would be used to compare to the operating hours obtained by the lighting loggers. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = $kWh_{pre} - kWh_{post}$

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Summer peak demand period savings = expected $kW_{pre} - kW_{post}$ during the hottest days between 2 pm to 5 pm, Monday to Friday, in June, July, August, September

To estimate the average expected peak demand kW reduction, since this measure is not weather dependent, the average of all reductions during that periods as stated above could be used. Alternately, the hottest days, from the climate data, as stated above, could be used.

Uncertainty for the savings estimate for the warehouse fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables.

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For ceiling mounted occupancy sensors

- 4,368 lamps expected to be controlled, minimum 2,200, maximum 6,800 (+ /- 50% expected range)
- 4,862 hours pre-retrofit reported/expected, minimum 2,400 hours, maximum 5,400 hours (+ 10% / - 50% expected range)
- 2,674 hours post-retrofit expected, minimum 1,300 hours, maximum 3,000 hours (+ 10% / - 50% expected range)
- 273 sensors expected, minimum 200, maximum 300 (-30%, + 10%)
- kW savings: 40.53 kW for coincident peak kW expected, 20 kW minimum, 60 kW maximum (+/- 50% expected range).
- kWh savings: 277,146 kWh expected, 185,000 kWh minimum ; 370,000 kWh maximum (+ / - 30% for range of possible savings)

For wall-box occupancy sensors

- 7,632 lamps expected to be controlled, minimum 2,450, maximum 8,300 (+ 10%, / - 70% expected range)
- 4,862 hours pre-retrofit reported/expected, minimum 2,400 hours, maximum 5,400 hours (+ 10% / - 50% expected range)
- 2,674 hours post-retrofit expected, minimum 1,300 hours, maximum 3,000 hours (+ 10% / - 50% expected range)
- 477 sensors expected, minimum 350, maximum 525 (-30%, + 10%)
- kW savings: 70.8 kW for coincident peak kW expected, 35 kW minimum, 105 kW maximum (+ / - 50% expected range).
- kWh savings: 484,205 kWh expected, 390,000 kWh minimum; 580,000 kWh maximum (+ / - 20% for range of possible savings)

There may be small potential source of error introduced since the measurement will not be performed on the smaller measures. This error is estimated at a maximum of + / - 5%.

Accuracy and Equipment

The light loggers to be used are Dent TOU-L Lighting Smart *logger* data loggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Power meters may also be used to verify fixture wattages. The power meter to be used, if this M&V technique is selected, would be Model PD41Q manufactured by Amprobe. The accuracy range is expected to be +/- 3.5%.

Annualizing that data from a 7 to 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on October 19, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and occupancy sensors and by interviewing the facility representative. The application indicated the greatest savings were from the ceiling and wall mounted occupancy sensors so these fixtures were the focus of the M&V evaluation.

Installation Verification

This inspection resulted in verification of 479 wall mounted occupancy sensors, 258 ceiling mounted occupancy sensors, and 56 digital time clocks. Measure quantities, locations and kW controlled were physically verified. The post installation inspection and the lighting invoice served to verify the installation of the measures. All occupancy sensors in the sample were operational at the time of the site visit. The paperwork also indicated that the number of occupancy sensors has been reviewed or verified prior to retrofit.

The verification realization rate for this project is 0.95 for the ceiling mounted occupancy sensors, 1.0 for the wall mounted occupancy sensors and 1.0 for the timeclocks. A verification summary is shown in Table 5 below.

The paperwork indicates that the installation was completed by the end of August 2005.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measures in the SPC application covering more efficient lighting fixtures, lamp removal, and the installation of lighting controls. This is the only measure in the application.

Summary of Results

Five Dent lighting loggers were installed in five buildings across campus. However, all the data appeared to not conform to realistic values and was therefore not used in this analysis. The majority of this impact evaluation was focused in verifying the kW controlled by each sensor and each timeclock. The percent reduction in hours of operation was assumed from the workpapers to be 41% for wall sensors, 47% for ceiling sensors and 22% for timeclocks. These figures will bias the savings on the high side; a reliable result from the lighting logger indicated an approximate 10% use factor.

The ex post impacts for these three measures were calculated as follows where the kW per sensor/timeclock was verified and summed per measure. For example, for the ceiling mounted occupancy sensors:

a.) Pre-retrofit hours of operation for all occupancy sensors were 4,862 hrs/year.
b.) The percent reduction was 47% according to the workpapers so:
    4,862 hrs/yr x 0.47 = 1,993.42 hrs/yr
c.) The total verified kW for all 258 sensors was 153.08 kW
    1,993.42 hrs/yr x 153.08 kW = 305,157 kWh/yr savings

Similarly the savings associated with the wall mounted occupancy sensors and the timeclocks was 144,501 kWh/yr and 13,305 kWh/yr respectively. Using 100,827 kWh/yr from the ex ante savings for the remaining measures the total ex post annual savings is 563,789 kWh/yr.

The coincident peak reduction was reported as 0.111 kW for a wall sensor, 0.0381 kW for a ceiling sensor, and 0.0 kW for a timeclock in the workpapers and was used in this analysis. The total number of each type of sensor/timeclock verified on-site was multiplied by each of these factors, and added to the ex ante kW savings of the other measures, for a total peak demand reduction of 173 kW.

The engineering realization rate for this application is 1.03 for demand kW reduction and 0.71 for energy savings kWh. The values shown in the tracking system substantially agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 4.

Utility billing data for the site was reviewed. In the 12 month period from January 2003 – December 2003 (pre-retrofit), the facility consumed 7,136,738 kWh. Peak demand was 3,258.8 kW in this period. Lighting use was estimated at 30% of total use for this facility. Table 1 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 5.2 % decrease in total meter kW, a 17.2% decrease in lighting end use kW, a 11.1% decrease in total meter kWh, and a 36.9% decrease in lighting end use kWh.

The ex post results showed a 5.3% decrease in total meter kW, a 17.7% decrease in lighting end use kW, a 7.9% decrease in total meter kWh, and a 26.3% decrease in lighting end use kWh.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	3,258.8	7,136,738.0
Baseline End Use	977.6	2,141,021
Ex ante Savings	168.5	789,513
Ex Post Savings	173.0	563,789

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	5.2%	11.1%	5.3%	7.9%
Baseline End Use %	17.2%	36.9%	17.7%	26.3%

6. Additional Evaluation Findings

The ex post kW demand reduction was similar to the ex ante estimate because both relied on the workpaper estimates of coincident peak demand reduction. The ex post kWh/yr reduction varied from the ex ante savings and the simple pre-and post retrofit check calculations in section 3, because the actual kW controlled by the occupancy sensors was less than the estimated controlled kW. The estimates of post retrofit controlled kW were more accurate because they were verified per room onsite.

In addition to saving energy, the benefits of the project are better quality of lighting and reduced maintenance. Some of the occupants needed to adjust to the use of occupancy sensors. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future.

The customer’s participation in the 2004/2005 SPC Program has encouraged them to perform other energy efficiency projects, namely mechanical equipment retrofits and stadium lighting modifications. The customer participated in SPC programs for these other measures.

The cost was derived from one sponsor with three contractor quotes. The costs seem reasonable, but are on the high side based upon experience with similar projects.

It was impossible to physically verify the pre-retrofit lighting fixture type, quantities and hours of operation. However, these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $134,880 and a $26,007 incentive, the project had a 1.06 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 1.49 years. A summary of the economic parameters for the project is shown in Table 3.

A summary of the multi-year reporting requirements is given in Table 6. Because this measure was installed approximately August of 2005, the energy savings in year #1 (2005) are assumed to be (33%) of the expected annual savings for this measure.

7. Impact Results

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings $0.13/kWh, $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	12/2/2005	$134,880	168.5	789,513	-	102,637	$26,007	1.06	1.31
SPC Program Review (Ex Post)	10/19/2007	$134,880	173.0	563,789	-	73,293	$26,007	1.49	1.84

Table 4: Realization Rate Summary

	kW	KWh	Therm
SPC Tracking System	168.5	789,513	-
SPC Installation Report (ex ante)	168.5	789,513	-
Impact Evaluation (ex post)	173.0	563,789	-
Engineering Realization Rate	1.03	0.71	-

Table 5: Installation Verification Summary

Measure Description	End-Use Category	Lighting Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING – OTHER	L	L-I2 Occupancy Sensor- Ceiling mounted	258		Sensor type, locations and quantity physically verified from floor plan and documentation of previous inspectors.	0.95
LIGHTING - OTHER	L	L-I1 Occupancy Sensor- Wall Box	479		Sensor type, locations and quantity physically verified from floor plan and documentation of previous inspectors.	1.00
LIGHTING - OTHER	L	L-K1 Timeclocks	56		Timeclock type, locations and quantity physically verified from floor plan and documentation of previous inspectors.	1.00

Table 6: Multi Year Reporting Table

Program Name:		SPC 04-05 Evaluation Site A086					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	260,539	186,051				
3	2006	789,513	563,789	168.5	173.0		
4	2007	789,513	563,789	168.5	173.0		
5	2008	789,513	563,789	168.5	173.0		
6	2009	789,513	563,789	168.5	173.0		
7	2010	789,513	563,789	168.5	173.0		
8	2011	789,513	563,789	168.5	173.0		
9	2012	789,513	563,789	168.5	173.0		
10	2013	789,513	563,789	168.5	173.0		
11	2014	789,513	563,789	168.5	173.0		
12	2015	789,513	563,789	168.5	173.0		
13	2016	789,513	563,789	168.5	173.0		
14	2017	789,513	563,789	168.5	173.0		
15	2018	789,513	563,789	168.5	173.0		
16	2019	789,513	563,789	168.5	173.0		
17	2020	789,513	563,789	168.5	173.0		
18	2021	528,974	377,739	168.5	173.0		
19	2022						
20	2023						
21	2024						
TOTAL	2004-2024	12,632,207	9,020,630				
		16 year life					

Final Site Report

SITE A087 US LB IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 2 END USE: Lighting

Measure	Lighting Retrofit / Occupancy Sensors
Site Description	Processing / Distribution Center / Offices

1. Measure Description

Replace 861 metal halide (MH) and 60 mercury vapor (MV) HID light fixtures with high efficiency fluorescent fixtures with T8 lamps, electronic ballasts, and reflectors; provide timer based bi-level lighting controls for 810 fluorescent fixtures; remove 60 mercury vapor fixtures; retrofit 173 two, three and four-lamp T8 fluorescent fixtures with energy saving electronic ballasts and high efficiency T8 lamps; replace 15 incandescent lamps with screw-in compact fluorescent lamps; retrofit 2,174 fluorescent fixtures using T-12 lamps to fixtures using T-8 lamps and electronic ballasts; remove 1,024 lamps from fluorescent fixtures; and install 62 wallbox occupancy sensors.

2. Summary of the Ex Ante Calculations

The customer's sponsor used the calculated and itemized approaches to determine savings for the measures. As a result of the large size of the project, a series of adjustments were made to the submitted application, so that fixtures and associated savings could be determined accurately and in accord with the program requirements. Following the installation inspection, the final program approved savings were 323.7 kW and 2,641,858.5 kWh.

The lighting measures included both calculated and itemized measures. The calculated measures included customized calculation submitted with the application paperwork; no kW or kWh calculations were provided for the itemized measures as deemed savings were used for the itemized measures.

3. Comments on the Ex Ante Calculations

The utility approved 247.8 kW and 2,289,272 kWh savings from calculated measures which included the 921 HID fixtures, the 1,673 fluorescent fixture retrofits, the 55 T12 to T8 conversions and the 95 wall box timer switches. The reviewed and approved savings calculations increased the savings submitted by the customer and were the basis of the final incentive.

Limited documentation for the calculated savings was provided in the application paperwork.

The primary calculated measure (accounting for 90% of the estimated savings) is the conversion of the MH fixtures to T8 fixtures. These fixtures operate 8,760 hours per year according to the facility representative. The ex ante savings calculations use 456 watts and 204 watts as pre and post retrofit fixture wattage and appear realistic.

The customer used the Itemized Measure Application to determine savings from itemized measures. The utility approved savings of 75.9 kW and 352,586.2 kWh for these itemized measures. The basis of the incentive payment for these measures was the itemized measures list. Under the itemized measures, the largest savings would be achieved from removal of 1,024 lamps and associated ballast retrofits in fluorescent fixtures. Additional savings were anticipated from new energy efficient fluorescent fixtures and from wall box occupancy sensors.

The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. For the following market sectors, the work papers assume 3,550 hours of operation and a diversity factor (DF) of 0.84 for warehouse market sectors; 6,650 hours and a 0.99 DF for process industrial; and 4,000 hours of operation and 0.81 DF for office market sectors.

As noted above, 400 watt MH lamps were replaced with 8-lamp fixtures with T8 4-foot lamps. The workpapers assume Metal Halide fixture wattage with ballast at 0.458 kW, four-lamp - HO T5 system wattage at 0.234 kW, and a total wattage drop from 0.458 kW to 0.234 kW per fixture for a non-coincident peak reduction of 0.224 kW per fixture. Coincident peak reduction is noted as 0.205 kW and kWh savings is noted as 843 kWh/year based on a warehouse market sector with the assumed operation hours and diversity factor. This scenario is for a high bay (warehouse) application and the fixtures would be retrofit with reflectors. Note that the workpapers pertain to retrofits involving T8 as well as T5 lamps.

For de-lamping, the workpapers discuss removal of 4 foot lamps from fluorescent fixtures. The original fixture wattage is based on T-12, 34-watt lamps with energy savings ballast and assumes removal of 1 lamp and its associated ballast. The work paper indicates the total wattage drops from 0.115 kW to 0.072 kW with a noncoincidental demand savings of 0.043 kW per lamp. The coincident kW and kWh savings are listed as 0.043 kW and 289 kWh for the Process Industrial market sector.

The calculations for replacement of lamps and ballast(s) in a 4-foot fluorescent fixture assume T-12 lamps and energy saving magnetic ballast(s) are replaced with an electronic ballast and 32 watt, T-8 lamps. Most 4-foot fixtures are either 2-lamp or 3-lamp fixtures. Savings data for the 2-lamp fixture are 0.014 kW per fixture and 0.031 kW for the 3-lamp fixtures. Savings are 0.006 kW and 0.008 kW per lamp respectively. For the process industrial sector, 6,650 hours of operation are assumed. The coincident kW and kWh savings are listed as 0.009 kW and 60 kWh for the Process Industrial market sector.

For savings calculation for wallbox units, the occupancy sensor is assumed to control three 4-foot 2-lamp fluorescent fixtures with 34 watt, T-12 lamps and energy saving magnetic ballasts (72 watts per fixture including ballast). The location that is modeled is a private office space. Without the occupancy sensor, lights are assumed to burn during building hours of operation (60 hours/week for 50 weeks/year) and be manually switched off 15% of the time, for a total of 2,550 hours/year. It is assumed that the office occupant spends six hours per day in the office for 50 weeks/yr, (1,500 hours/year) so that the occupancy sensor turns off lights for 1,050 hours/year (41% reduction over manual switching). Note that the coincident diversity factor (CDF) is not used in savings calculations, as the assumptions listed in this paragraph already account for the fact that not all of the savings will occur during the peak period. The work paper notes the total wattage drops from 0.216 kW for a noncoincident demand savings of 0.089 kW when controls shut off equipment with a presumed 41% reduction in operating hours(0.216 kW x 0.41 reduction in hours = 0.089 kW). The coincident kW savings are listed as 0.111 kW (0.089 kW x 1.25 average office sector Demand Interactive Effects = 0.111 kW) and the energy savings are 266 kWh per year, including 17% average office sector Energy Interactive Effects.

4. Measurement & Verification Plan

The building is a two-story storage and processing facility reported as 324,603 square feet with offices on a second level at one end of the building. The building is reported to be approximately 15 years old. The building is occupied on a varying schedule, with some areas having continuous work year round and other areas with ranges from 730 to 6325 hours/year.

According to the application, before the retrofit there were 861 metal halide fixtures using 400-watt lamps and 120 mercury vapor fixtures with 250 watt lamps, 55 fluorescent fixtures with T12 lamps, 118 FU2EE fixtures with 2 lamps, 15 incandescent lamps and fluorescent fixtures using 2,174 T12 lamps.

After the retrofit, there are 861 T8 4-foot / 8 lamp fixtures, thirty-seven 4-foot 3 lamp T8 fixtures, one 3-foot 2 lamp T8 fixture, 17 4-foot 2 lamp fixtures, 65 FU2ILL-R, and 53 FU22ILL two lamp T-8 fluorescent fixtures. In addition, sixty 4-foot 6 lamp fluorescent fixtures replaced 60 mercury vapor fixtures and an additional 60 MV fixtures were removed. Timers were placed on 810 of the 861 4-foot 8 lamp fixtures. The 60 wall box motion sensors mentioned presumably were placed in offices and conference rooms.

The project saves energy through the installation of lighting fixtures with a lower connected wattage and through the control of the lighting fixtures with manual timers and occupancy sensors to reduce the hours of operation.

The documentation in the application indicates that there is processing area and offices. The majority of fixtures are located above the processing areas. The U-tube fixtures are located in offices, locker and conference rooms. The fluorescent straight lamp fixtures are located in hallways, the reception, training room, and break room.

For this application, the pre-retrofit fixture types, quantities and hours of operation will be verified with the facility representative. The post-retrofit fixture quantities and fixture types will be physically verified through a sampling of the facility. Dent TOU-L lighting Smart Loggers in representative areas will be installed to capture a sampling of the hours of operation. These optically triggered loggers record lighting status (on or off).Additionally, a power meter will be utilized if a lighting circuit can be isolated.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

To estimate peak demand kW reduction, we will account for the reduction in connected kW due to the increased lighting efficiency and calculate the average percent of lights on from 2 pm to 5 pm. on weekdays. The M&V plan is a modified version of IPMVP Option A.

Formulae and Approach

Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kW = Fixture watts / 1,000 w/kW x Fixture quantity x Percent energized during peak demand period.

kWh = kW x Operating hours x Percent time energized

Estimates of the operating hours and for controlled fixtures the percent time energized will be calculated from the light logging data and extrapolated for a full year.

Uncertainty for the savings estimate for the warehouse fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables:

<u>For lower wattage fixtures (T5 conversion from HID fixtures)</u>

- 861 fixtures expected, minimum 820, maximum 900 (+/- 5 %)
- 8,760 hours pre retrofit expected/reported, minimum 8600 hours, maximum 8760 hours (based on holidays)
- 393 kW expected, minimum 350 kW, maximum 430 kW (includes +/- 5 % for number of fixtures and +/- 5 % for fixture wattage difference)

<u>For motion sensors controlling the above fixtures</u>

- 810 fixtures expected, minimum 770, maximum 850 (+/- 5 %)
- 5,869 hours post retrofit expected/reported, minimum 3000 hours, maximum 7,600 hours (- 50 % , +30 % based on judgment of use for site type; includes + / - 5% from annualizing estimates from short monitoring period)

There will be a small potential error estimated at +/- 1% to 2%, since M&V will not be performed on the smallest measures which contribute a small amount of savings. This is not included in the analysis of uncertainty due to its size.

Accuracy and Equipment

The loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data are deemed reasonable. The SPC lighting wattage tables and field verified fixture counts are considered to be 100% accurate.

Annualizing that data from a 7 to 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

Current or power meters may also be used. The current loggers to be used, if this M&V technique is selected, would be HOBO U-12 loggers, with matched current transformers. The accuracy range is 3.5 %. The sensor would be calibrated to an Amprobe ACD-41PQ, with an accuracy of +/- 2%. An advantage of using current or power meters to monitor load is that the percent of time energized for an increased number of fixtures may be able to be captured.

All data collected will be reviewed to ensure the data conform to realistic values and will be cross verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 11, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. The application indicated the greatest savings were from the replacement of HID fixtures with fluorescent fixtures and their associated timed switches. These fixtures were the focus of the M&V evaluation.

Eight lighting loggers were installed on four fixtures in representative areas of the facility within high activity and lower activity areas. Loggers were paired to capture the on off operation of the lamps. The fixtures over the processing floor are 8 –lamp T-8 fluorescent fixtures. The operation strategy and design has four lamps of each fixture energized-on all the time. The remaining four lamps are controlled by a wall mounted timer switch. One timer switch controls from one to several fixtures. The timer energizes the four lamps for three hours and then turns the lights off. If there is a need for lighting from a full complement of the eight lamps (rather than the minimum four lamps), a worker resets the light switch for another three hours by pressing the switch button. If light is not needed for an area, as when work progresses away from the fixtures to other areas of the facility, the switches can be turned off manually to limit the fixture lights to four lamps before the timer cuts the lamps.

Installation Verification

The final counts of fixtures sensors and controls were as indicated in the above paragraphs. These were verified in a second installation review report following the discovery of discrepancies in the original sponsor submittal and the inspection totals for quantities and fixtures specified.

It was verified that there are 214 eight-lamp T-8 fluorescent fixtures covering a floor area of approximately 60,000 sq.ft. The entire processing floor was measured at approximately 254,000 sq. ft. The 60,000 sq.ft. area is approximately 24% of the entire processing floor. The 214 fixtures are approximately 25% of the total 861 eight-lamp T-

8 fluorescent fixtures. The fixture count sample was deemed to be representative of the total fixture count.

All T-8 lamps are high lumen watt saving type. On average each wall switch controls a minimum of four fixtures and a maximum of ten to twelve fixtures. The paperwork indicated 810 of the 861 fixtures were on switched controls. Therefore, all eight lamps of 51 fixtures are energized 24 hours a day. Timed switches have a three hour limit. When a switch turns off, half the lamps (4) of each eight lamp fixture turn off for a maximum of approximately 48 lamps. On average 32 lamps are turned off by wall switch timer control for any switch.

There were a few fixtures (< 2%) that were not operating. The facility representative indicated these fixtures were out because the ballasts had failed. He pointed out several fixtures that were on the verge of failure. For the purposes of calculating energy savings these fixtures were include in the evaluation.

The paperwork indicates the installation was completed in August of 2004.

These are the only measures in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 5 below.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measures in the SPC application covering more efficient lighting fixtures, lamp removal, and the installation of lighting controls. These are the only measures in this application.

Summary of Results

Eight Pacific Science and Technology, Inc. Model TOU-L lighting Loggers were placed in pairs at four fixtures serving the main processing floor for 15 days (September 11, 2007 to September 26, 2007), in order to measure the operating hours of the retrofit lighting fixtures. The facility representative indicated that the work conducted presently was representative of normal facility operation. The lighting loggers indicated that four lamps of each fixture burned continuously during the logging period. The average on-time for the other four lamps was 17%. This indicates an estimated on-time of 58% for all lamps (or that each fixture utilized an average of 58% of full load power).

Additional logging at a lighting panel indicated similar results. Energy use at one lighting panel within the northern section of the facility was monitored with a Dent Elite-Pro datalogger. The average percent of full load power over the entire period, for kWh savings calculations, was determined to be power for energy use was determined to be 64% for the 271 estimated fixtures covered by this lighting panel (based upon average kW draw of 31.7 kw and maximum kW draw of 49.8 kW.

The logger showed the lowest energy use (consistently about 22.5 kW) between the hours of 5:00 a.m. and 6:30 p.m. During the expected coincident peak demand periods of 2 pm to 5 pm weekdays for eleven weekdays in September, the average power demand was 49% (based on a measured average of 24.3 kW for these periods and a maximum, corresponding to pre retrofit conditions, 49.8 for the new fixtures). Average energy use doubled (in a range from 38 kW to 45 kW with highest use peaks up to 49.8 kW) between the hours of 6:30 p.m. and 5:00 a.m. Maximum energy use (lighting demand) occurred between the hours of 10 p.m. and 1 a.m. nightly. Peak demand savings between 2 p.m. and 5 p.m. are calculated from the kW readings from the datalogger. The facility peak period with the highest lighting/energy demand is between 10 p.m. and 1 a.m. nightly.

Lighting levels over the processing floor were generally at half load at the time of the site visit (between 9 a.m. and 1 p.m.) but were sufficient to conduct work during the daytime (slow) shift. The representative said that workers were pleased with the greater level of light. The brightness and color improved their ability to focus on processing tasks.

Other than lighting, other electrical loads in the unconditioned processing floor include sorting and bundling machine motors, automatic air testing equipment, and battery chargers for the forklifts and carts. These loads are on separate electrical panels than the lighting panel monitored as described above.

The customer also occupies a large 2-story air conditioned office annex at this site and energy consumption for the office building is measured by the same meter as the processing floor.

The facility representative said that following the lighting retrofit over the floor the space, the work area was considerably cooler in the summertime with comments from the employees that the level of comfort had increased. The representative indicated summertime cooling loads in the offices were reduced, that the processing floor was not conditioned, and that new more efficient chillers were installed about the same time as the lighting retrofit.

The power logger at the lighting panel indicated relatively consistent daily energy use and is more indicative of actual conditions since it monitored a substantially greater number of the retrofit lighting fixtures.

The ex post calculations were modified for the major measures – the HID conversion to T8 lamps and the bi-level lighting system - and were performed using the hours as determined above. The lighting fixture wattages were taken from the SPC tables. The ex ante savings measures for the other smaller measures were accepted for the ex post calculation totals. `

The ex post impacts for the main measures are calculated as follows:

a) Pre-retrofit hours of operation for processing floor were 8,760 hrs/year.
Pre-retrofit wattage was .0458 kW per lamp x 861 lamps = 394.3 kW
Annual kWh usage was 394.3 kW x 8,760 hrs/yr = 3,454,068 kWh/yr

b) Based on power logger data, post-retrofit hours of operation are 8760 hrs/year for 51 fixtures and an average of 5,606 hrs/yr for 810 fixtures at two lighting levels. Average kW demand is 31.7 kW for approximately 216 fixtures.

c) Post-retrofit wattage is 0.204 kW per eight-lamp T8 generation 3 fixture (The post retrofit wattage from the ex ante calculations was used, although average kW demand of 31.7 kW for approximately 216 fixtures yielded 0.147 kW per fixture, due to uncertainty in the number of fixtures controlled and other energy users on the large lighting panel monitored) .

d) 810 fixtures x 0.204 kW + 51 x 0.204 kW = 165.2 kW + 10.4 kW = 175.6 kW

e) Annual kWh usage is 165.2 kW x 5,606 hrs/yr + 10.4 kW * 8760 hrs/yr = 926,111 kWh/yr + 91,104 kWh/yr = 1,017,215 kWh/yr

f) The resulting annual kWh savings is 3,454,068 kwh/yr – 1,017,215 kwh/yr = 2,436,853 kWh/yr.

g) The total ex post savings are 2,436,853 kWh/yr + 367,024 kWh (other measures) = 2,812,877 kWh/yr.

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load, with an adjustment for the weekday average 2 pm to 5 pm measured usage factor of 49%.

Peak kW savings is 394.3 kW – 175.6 + 165.2 kW x (100% - 49%) = 218.7 kW + 89.6 kW = 308.3 kW.

The total ex post savings are 308.3 kW + 75.3 kW (other measures) = 294.0 kW.

The engineering realization rate for this application is 0.91 for demand kW reduction and 1.06 for energy savings kWh. The values shown in the tracking system substantially agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 4.

Utility billing data for the site was reviewed. In the 12 month period from December 2003 – December 2004 (pre-retrofit), the facility consumed 9,380,058 kWh. Peak demand was 1212.5 kW in this period. Lighting use was estimated at 50% of total use for this facility. Table 1 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 26.7 % decrease in total meter kW, a 53.4 % decrease in lighting end use kW, a 28.2 % decrease in total meter kWh, and a 56.3 % decrease in lighting end use kWh. The ex post results showed a 24.2% decrease in total meter kW, a 48.5 % decrease in lighting end use kW, a 30.0 % decrease in total meter kWh, and a 60.0 % decrease in lighting end use kWh.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	1212.5	9,380,058
Baseline End Use	606.3	4,690,029
Ex ante Savings	323.7	2,641,858.5
Ex Post Savings	294.0	2,812,877

Table 2: Percent Savings and Demand Reduction

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	26.7%	28.2%	24.2%	30.0%
Baseline End Use %	53.4%	56.3%	48.5%	60.0%

6. Additional Evaluation Findings

The ex post kW demand reduction varied only slightly from the ex ante estimate because the ex ante calculations, particularly for the main measures (HID conversion and occupancy sensors on the main processing floor) were calculated using valid assumptions. The pre retrofit hours of use were known, since there was continuous operation. The estimates of post retrofit hours were estimated conservatively, but these (at 67%) were also accurate, as 64% was measured).

The measure costs provided in the application do seem somewhat high based upon experience with similar retrofits.

In addition to saving energy, the benefits of the project are better quality of lighting and increased light levels in some areas. One drawback of the project has been an increase in maintenance associated with the need to replace fluorescent lamps. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. However, workers have complained that the light in the fluorescent fixtures that were failing would cause an irritating, roving stroboscopic affect over their work areas, and this could cause some changes in the future.

The customer's participation in the 2004/2005 SPC Program has not encouraged them to perform any other energy efficiency projects for which they did not participate in an incentive program.

It was impossible to physically verify the pre-retrofit lighting fixture type, quantities and hours of operation. However, these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures. The application paperwork was not complete and clear for this site, however.

With a cost of $844,863 and a $131,073 incentive, the project had a 2.08 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 1.95 years. A summary of the economic parameters for the project is shown in Table 3.

7. Impact Results

Table 3:Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	2/13/2005	$844,863	323.7	2,641,859	0	$343,442	$131,072	2.08	2.46
SPC Program Review (Ex Post)	10/16/2007	$844,863	294.0	2,812,877	0	$365,674	$131,072	1.95	2.31

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	323.05	2,641,859	-
SPC Installation Report (ex ante)	323.7	2,641,858.5	-
Impact Evaluation (ex post)	294.0	2,812,877	-
Engineering Realization Rate	0.91	1.06	NA

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Replace 861 metal halide fixtures with 861 8-lamp T8 fluorescent fixtures and install timers to control 810 of these fixtures; miscellaneous other retrofits		1,239	8 lamp T-8 HO fixtures and timers	Physically verified lamp type and verified quantity from documentation of previous inspectors.	1.00

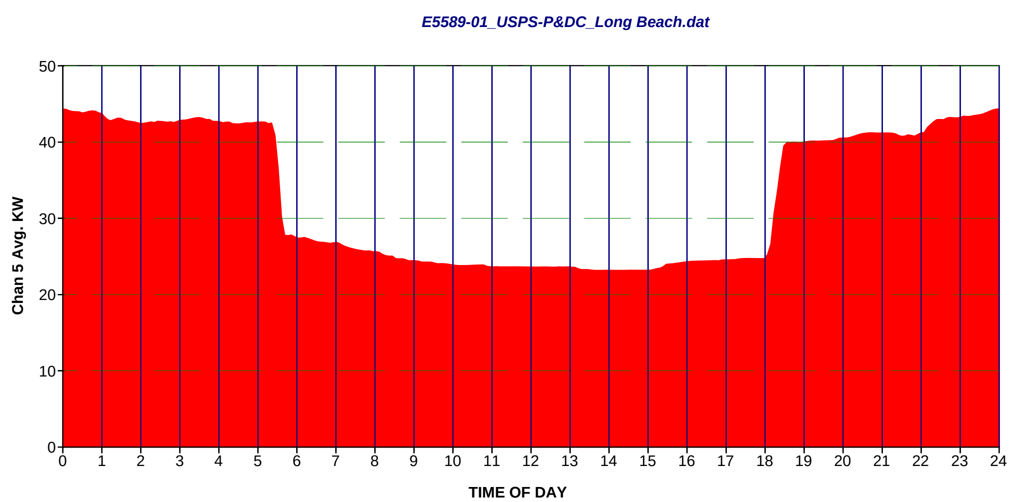
Table 6: Multi Year Reporting Table

Program Name:		SPC 04-05 Evaluation Site A087					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	220,155	234,406			0	0
2	2005	2,641,859	2,812,877	323.700	294.000	0	0
3	2006	2,641,859	2,812,877	323.700	294.000	0	0
4	2007	2,641,859	2,812,877	323.700	294.000	0	0
5	2008	2,641,859	2,812,877	323.700	294.000	0	0
6	2009	2,641,859	2,812,877	323.700	294.000	0	0
7	2010	2,641,859	2,812,877	323.700	294.000	0	0
8	2011	2,641,859	2,812,877	323.700	294.000	0	0
9	2012	2,641,859	2,812,877	323.700	294.000	0	0
10	2013	2,641,859	2,812,877	323.700	294.000	0	0
11	2014	2,641,859	2,812,877	323.700	294.000	0	0
12	2015	2,641,859	2,812,877	323.700	294.000	0	0
13	2016	2,641,859	2,812,877	323.700	294.000	0	0
14	2017	2,641,859	2,812,877	323.700	294.000	0	0
15	2018	2,641,859	2,812,877	323.700	294.000	0	0
16	2019	2,641,859	2,812,877	323.700	294.000	0	0
17	2020	2,421,704	2,344,064	323.700	294.000	0	0
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	42,269,736	44,771,626				

Table 7: Lighting Logger and Dent Logger Data Results

A087 Lighting Logger data summary								
Logger Number			Total Off	Total On	Total hrs	Total days	Avg. % time On	Annualized hours
330	outer	Monitored	317.27	44.73	362	15.08	0.12	1082
408	inner	Monitored	0.47	361.53	362	15.08	1.00	8749
267	outer	Monitored	301.06	60.94	362	15.08	0.17	1475
376	inner	Monitored	0.7	361.3	362	15.08	1.00	8743
93	outer	Monitored	325.65	36.35	362	15.08	0.10	880
130	inner	Monitored	1.01	360.99	362	15.08	1.00	8736
279	outer	Monitored	258.55	103.45	362	15.08	0.29	2503
461	inner	Assumed					1.00	8760
	Avg for controlled lamps						0.17	1485
	Avg power for fixture						0.58	
	Avg hrs for all lamps						0.58	5116

A087 Power Logging Summary for approximately 271 fixtures							
kWh calcs		kW avg	kW max	# fixtures	Fixture wattage	Average percent power for kWh	
		31.669	49.839	271	183.9077	64%	
				216	230.7		
kw calcs	2-5 pm	kW max	kW max			Average percent power for kW	
	weekdays	post	pre				
		24.3	49.839			49%	



9/25/2007	14:00:00	9/25/2007	14:00:00	8.436	0	22.59		22.59	22.629
9/25/2007	14:05:00	9/25/2007	14:05:00	8.426	0	22.584		22.584	
9/25/2007	14:10:00	9/25/2007	14:10:00	8.447	0	22.605		22.605	
9/25/2007	14:15:00	9/25/2007	14:15:00	8.461	0	22.629		22.629	
9/25/2007	14:20:00	9/25/2007	14:20:00	8.421	0	22.586		22.586	
9/25/2007	14:25:00	9/25/2007	14:25:00	8.443	0	22.59		22.59	
9/25/2007	14:30:00	9/25/2007	14:30:00	8.44	0	22.589		22.589	
9/25/2007	14:35:00	9/25/2007	14:35:00	8.404	0	22.554		22.554	
9/25/2007	14:40:00	9/25/2007	14:40:00	8.433	0	22.585		22.585	
9/25/2007	14:45:00	9/25/2007	14:45:00	8.474	0	22.621		22.621	
9/25/2007	14:50:00	9/25/2007	14:50:00	8.418	0	22.572		22.572	
9/25/2007	14:55:00	9/25/2007	14:55:00	8.433	0	22.589		22.589	
9/25/2007	15:00:00	9/25/2007	15:00:00	8.451	0	22.598		22.598	24.507
9/25/2007	15:05:00	9/25/2007	15:05:00	8.42	0	22.564		22.564	
9/25/2007	15:10:00	9/25/2007	15:10:00	8.472	0	22.624		22.624	
9/25/2007	15:15:00	9/25/2007	15:15:00	8.419	0	22.561		22.561	
9/25/2007	15:20:00	9/25/2007	15:20:00	8.453	0	22.605		22.605	
9/25/2007	15:25:00	9/25/2007	15:25:00	8.64	0	23.321		23.321	
9/25/2007	15:30:00	9/25/2007	15:30:00	8.953	0	24.507		24.507	
9/25/2007	15:35:00	9/25/2007	15:35:00	8.895	0	24.445		24.445	
9/25/2007	15:40:00	9/25/2007	15:40:00	8.868	0	24.401		24.401	
9/25/2007	15:45:00	9/25/2007	15:45:00	8.926	0	24.468		24.468	
9/25/2007	15:50:00	9/25/2007	15:50:00	8.902	0	24.449		24.449	
9/25/2007	15:55:00	9/25/2007	15:55:00	8.843	0	24.391		24.391	
9/25/2007	16:00:00	9/25/2007	16:00:00	8.892	0	24.429		24.429	24.471
9/25/2007	16:05:00	9/25/2007	16:05:00	8.835	0	24.381		24.381	
9/25/2007	16:10:00	9/25/2007	16:10:00	8.884	0	24.425		24.425	
9/25/2007	16:15:00	9/25/2007	16:15:00	8.933	0	24.471		24.471	
9/25/2007	16:20:00	9/25/2007	16:20:00	8.886	0	24.419		24.419	
9/25/2007	16:25:00	9/25/2007	16:25:00	8.869	0	24.414		24.414	
9/25/2007	16:30:00	9/25/2007	16:30:00	8.907	0	24.454		24.454	
9/25/2007	16:35:00	9/25/2007	16:35:00	8.888	0	24.424		24.424	
9/25/2007	16:40:00	9/25/2007	16:40:00	8.897	0	24.43		24.43	
9/25/2007	16:45:00	9/25/2007	16:45:00	8.876	0	24.402		24.402	
9/25/2007	16:50:00	9/25/2007	16:50:00	8.881	0	24.416		24.416	
9/25/2007	16:55:00	9/25/2007	16:55:00	8.873	0	24.407		24.407	
9/25/2007	17:00:00	9/25/2007	17:00:00	8.889	0	24.434			
9/23-25/07	2-5- pm	Avg reduction							23.67956
9/24-25/07	2-5- pm	Avg reduction	Excl Sunday						23.54933

24.3 kW use 9/11-07 to 9/25/07 inclusive 2pm – 5pm weekdays (average of 33 periods)

Final Site Report

SITE A088 Homxx (2004-xxx)   IMPACT EVALUATION
SAMPLE CELL: ORIGINAL   TIER: 5   END USE: Lighting

Measure	High Bay T5 Lighting Retrofit
Site Description	Warehouse / Offices

1. Measure Description

Replace 407 high intensity discharge metal halide fixtures using 400 watt lamps with 400 fluorescent fixtures using six T5 lamps.

2. Summary of the Ex Ante Calculations

The customer used the Itemized Measure Application Form. The Summary of Approved Itemized Measures indicated 407 fixtures were installed at this site. The ex ante savings in the Installation Report Review are listed as 91.17 kW and 364,672.0 kWh. These values conform to fixture wattage savings of 0.224 kW, fixture energy savings of 896 kWh, and 4000 hours of operation. The basis of the incentive payment of $30,525.00 was the itemized incentive list. A cost of $71,309.00 was noted. These figures agree with the utility tracking system.

The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. These workpapers note that a conversion from metal halide fixtures to four lamp high output (HO) T5 fixtures results in a wattage reduction from 0.458 kW to 0.234 kW, for a non-coincident peak reduction of 0.224 kW. For a retail store with a diversity factor of 0.88, the coincident peak reduction per fixture is noted as 0.235 kW and kWh savings per fixture is noted as 1,106 kWh/year. The hours of operation for a retail application are fixed in the workpapers at 4,450 hours/year.

The workpapers note a diversity factor of 88% for the retail market sector.

3. Comments on the Ex Ante Calculations

This site provides retail services within a warehouse environment. Use of the workpaper retail annual operating hours, coincident diversity factor, coincident kW, and annual kWh savings may overstate or understate these values for this retail environment. The workpaper values may not adequately cover actual hours of operation for this retail market sector as annual operating hours may be substantially greater than those listed in the workpapers for the retail market sector.

The calculations in the previous section are considered to be the ex ante calculations and were formulated using the Express Efficiency workpapers. For the lighting conversion from high intensity discharge fixtures to T5 fluorescent fixtures, the values in the application generally conform to the lighting workpapers previously mentioned with the exception of the number of hours calculated. The exception is the kWh savings for the T5 conversion from the metal halide fixtures (996.8 kWh was used in the ex ante calculations, as opposed to 1,106 kWh in the workpaper). It is noted that the workpapers refer to 4-lamp fixtures with T5 HO lamps and electronic ballasts. The fixtures installed at this site were 6-lamp fixtures with T5 HO lamps and electronic ballasts with a kW per fixture rating of 0.351 kW.

The following paragraphs highlight other notable discrepancies regarding the ex ante calculations.

Verification of installation was completed by document review and by sampling 4 of 22 stores or 18 percent of the stores where similar retrofits occurred within very similar floor plan and retail environments. The facility under this review was not inspected to verify installation but was approved from adequate documentation submitted by the contractor.

The itemized measure application form and the lighting equipment survey table provided in the documentation indicated 400 F46PHL/3 fluorescent fixtures (0.351 kW/fixture) replaced 400 MH400PS/1 fixtures (0.456 kW/fixture). This is a per fixture savings of 0.105 kW. The application Itemized Measures Summary and the Installation Review Report indicate savings calculations and incentives based on 407 fixtures. The contractor invoice included with the documentation package for this site indicates 492 fixtures (order line numbers 8 & 12) to be delivered to the contractor's facility. This does not clarify the exact number installed at the site.

Interpreting from the Summary of Approved Itemized Measures suggests 4,000 hours per year as the operating hours, versus the 4,450 hours per year in the workpapers. Using the 4000 hours suggested by the values in the project application, the annual per fixture saving is 420 kWh ((0.456 kW – 0.351 kW) x 4,000 hrs = 420 kWh) as compared to the 1,106 kWh annual savings for a retail market sector using 4,450 hours of operation from the workpapers or the 996.8 kWh per fixture from the ex ante calculations presented earlier also based on 4,450 hours.

The calculations can be checked for reasonableness using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation. Corresponding to the ex ante savings figures, 4,000 annual hours of operation were used in these check calculations.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x (1 – diversity factor) (the diversity factor is 1.0 or 100% and does not apply since motion sensors are not used and all lamps are energized during summer weekdays)

The check calculations for the main measures (involving conversion from MH fixtures to lower wattage fluorescent fixtures) were performed as follows:

- Pre-retrofit hours of operation: 4,000 hrs/yr
  Pre-retrofit wattage: 0.458 kW per fixture x 407 lamps = 186.4 kW
  Annual kWh usage: 182.4 kW x 4,000 hrs/yr = 745,600 kWh/yr

- Post-retrofit hours of operation (presumed to be the same): 4,000 hours
  Post-retrofit wattage: 0.351 kW per six-lamp fixture x 407 fixtures
  = 142.9 kW
  Annual kWh usage: 142.9 kW x 4,000 hrs/yr = 571,600 kWh/yr
- The resulting annual kWh savings: 745,600 kWh/yr – 571,600 kWh/yr = 174,000 kWh/yr

These kWh savings are less than half those reported in the Installation Report. This discrepancy is due to the different number of fixtures used (400 versus 407) and the higher fixture wattage of the actual fixtures installed compared to ex ante savings in the Installation Report Review numbers based on 4-lamp (0.234 kW) instead of 6-lamp (0.351 kW) fixtures.

However, based on interviews, the hours of use are expected to approximate 85% on average for all fixtures. The use of 7,500 hours per year (verses 8,760 total hours per year) results in an energy savings of 326,250 kWh/ year. The increased hours cancel out the effects of the reduced wattage savings.

Summer peak impacts were simply estimated by subtracting post-retrofit from pre-retrofit connected load.

Summer peak demand reduction is calculated as follows:
- Reduction in connected kW load use: (186.4 kW – 142.9 kW) = 43.5 kW

4. Measurement & Verification Plan

The building is listed as a retail warehouse in the SPC Application. It is a single level unconditioned warehouse that holds construction materials for retail sales. The square footage and age of the building are unknown. The building has minimal windows and skylights. It is anticipated the store is operated on a varying schedule approximately 11 hours a day for retail sales and is occupied additional hours for receiving deliveries and restocking shelves. Maximum occupancy is approximately 20 employees and varying numbers of patrons at any given time. According to the application, before the retrofit there were 407 metal halide fixtures using 400-watt lamps. After the retrofit, there are 407 six-lamp T-5 fluorescent fixtures. The measure only applied to interior lighting. The project saves energy through the installation of lighting fixtures with a lower connected wattage. Hours of operation are not expected to change.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

IPMVP Option C approach should be considered. The savings reported in the utility tracking system are approximately 50% of the kW and kWh consumed based upon the pre-retrofit building lighting use.

Utility billing and interval data should support this approach if there are no other significant loads or other significant energy conservation activities which occurred in the months immediately following the retrofit. There is not expected to be significant seasonal variation and several months should be sufficient for comparison; however, a one to two year period would more fully capture actual variations and the persistence of savings. Interval data on a 15 minute basis during the summer months of June to September would be needed to accurately determine coincident peak period demand savings.

If Option C cannot be used due to changes in the facility or its operation in the time periods immediately before or after the retrofit, then a modified version of IPMVP Option A can be utilized. Lighting loggers would be used to quantify hours of operation. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Summer peak demand period savings = $kW_{pre} – kW_{post}$ during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in June, July, August, September.

Thus, to estimate peak demand kW reduction, the reduction in connected kW due to the increased lighting efficiency will be added to the post-retrofit connected load multiplied by the percent of energized time according to the above formulae. The derivation or extrapolation of the average percent of time energized used in the above formulae, for both the average peak demand period and the coincident peak demand periods, will be described.

The most significant variables to be quantified are the pre-retrofit and post-retrofit fixture hours of operation. Pre-retrofit hours will be confirmed with site personnel and interviews. The focus will be on verifying that, prior to the retrofit, the entire complement of fixtures was completely energized during the hours listed and that the listed hours/year were valid (for example, building or staff schedule logs for the pre-retrofit period could be examined if available). In order to establish a realistic baseline for energy use, appropriate modifications for the savings calculations would be made to the pre-retrofit usage figures as warranted by different numbers of fixtures, different area uses (where fixtures are turned off), and hours of lighting operation.

Monitoring with light loggers may be conducted on approximately 25% of the aisles and center aisle where feasible. The intent would be to determine the percent of time fixtures are off during each day. A minimum of two sensors for 6 aisles and one sensor per central aisle (3) could be used requiring fifteen (15) sensors. Additional sensors may be required, based on usage and operation hours of specific areas within the building. The customer would be interviewed to confirmed usage patterns. The use of fifteen sampling points is generally consistent with SPC program documentation from March 2001 (Appendix E, Sampling); this document suggests guidelines for determining sampling point requirements necessary to achieve an 80% confidence interval with 20% precision (using a coefficient of variation of 0.5).

A random sampling approach would involve setting up a grid for the warehouse, labeling fixtures sequentially according to their location, and randomly selecting from the total number of fixtures using a random number generator. This approach will avoid overweighting or assigning a weighting factor for the central aisles. The majority of the lighting is presumed over side aisles with racked storage. A percent of the front floor area is used for the front retail aisle and main aisle opposite the entrance. The warehouse is considered to be one usage group for the purposed of assigning fixtures to be sampled. Fixture numbering would be from one corner of the buildings to the adjacent corners.

The light loggers would be placed so as to be unaffected by other fixtures or by ambient outside light.

If the light loggers cannot be placed in suitable locations, it was considered that, where the lighting circuits can be isolated and it can be determined that only lighting loads for the warehouse fixtures are controlled by that lighting circuit, a current or power meter could be used to track multiple fixtures. The total current / power would be determined by activating all fixtures and by confirming loads using the electrical drawings. Between three and six current/power meters are expected to be needed, to capture a representative sample of the lighting fixtures.

The lighting loggers or current sensors would be left in place for a period of 7 to 14 days. Attention will be given to the time period for monitoring, in order to avoid periods of irregular usage patterns (e.g., during holidays or breaks). While longer periods might be preferable, these periods are appropriate given the scope of the evaluation and reported usage characteristics.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture hours of operation and the lighting fixture quantities. The lighting fixture quantities are not yet established with any certainty and were based on similar retrofits at other locations and the numbers of fixtures submitted by the customer to the utility. The numbers in the post-installation inspection report were based on visits to other sites. The pre-retrofit and post-retrofit connected loads associated with various fixture types are also adequately quantified in the SPC lighting wattage tables. The actual hours of operation provide the greatest uncertainty.

Uncertainty for the savings estimate for the warehouse fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables.

<u>For lower wattage fixtures (T5 conversion from HID fixtures)</u>

- 407 fixtures expected, minimum 387, maximum 427 (+/- 5%)
- 7,500 hours expected/reported, minimum 7,000 hours, maximum 8760 hours (based on interviews and store use)
- 43.5 kW expected, minimum 40 kW, maximum 48 kW (includes +/- 5% for number of fixtures and +/- 5% for fixture wattage difference)

Accuracy and Equipment

The light loggers to be used are Dent TOU-L Lighting Smart*logger* dataloggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data are deemed reasonable.

Annualizing that data from a 7 to 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

Current or power meters may also be used. The current loggers to be used, if this M&V technique is selected, would be HOBO U-12 loggers, with matched current transformers. The accuracy range is 4.5 %. The sensor would be calibrated to an Amprobe ACD-41PQ, with an accuracy of +/- 2%. An advantage of using current or power meters to monitor load is that the percent of time energized for an increased number of fixtures may be able to be captured.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted in September 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixtures and by interviewing the facility representative. The only measure on the application was the replacement of 407 high intensity discharge metal halide fixtures using 400 watt lamps with 407 fluorescent fixtures using T-5 lamps, therefore these fixtures were the focus of the M&V evaluation.

Installation Verification

The facility representative indicated that all the 407 watt HID lamps were replaced on a one to one basis. Physical verification of all lighting retrofits was performed. A total of 408 fixtures was counted. This inspection, the post installation inspection and the lighting invoice served to verify the installation. All fixtures were operational at the time of the site visit.

The verification realization rate for this project is 1.0. A verification summary is shown in Table 5 below.

The paperwork indicates that the installation was completed by March 2005.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measures in the SPC application covering more efficient lighting fixtures and lamp removal. These are the only measures in this application.

Summary of Results

The ex post savings estimations were performed using IPMVP Option C, Utility billing analysis. This approach does not confirm the ex ante savings in the application document.

Utility Billing Analysis

Lighting levels are a function of hours of operation. Thus, as long as no significant changes have occurred regarding the number of hours and the time of day lights are on, this analysis method should provide a reasonable level of accuracy.

By comparing the monthly average total kWh in a 12 month period, it is possible to determine the annual kWh savings. The post retrofit period was a one year time period beginning in November 2004. The formulas below were used to determine the kWh savings and the % increase or decrease in kWh used.

$kWh / day_{(2003)} - kWh / day_{(2004)} = kWh/day_{(saved)}$

$kWh/day_{(saved)}$) x 365.14 days per year = kWh saved

The energy savings from November October 2003 to October 2004 was used to represent the annual kWh pre retrofit.

The month of October was used to compare daily kWh savings. This month showed 763.7 kWh/ day reduced.

The annual kWh savings are thus:

763.7 kWh/day x 365.14 days/yr = 278,857 kWh yr.

This is used as the ex post kWh savings. Note that the highest kWh / day reduction of 856.6 kWh / day occurred in September. The average for all months was 523.3 kWh / day.

Full weather normalization may have yielded slightly different results but are expected to be in line with these figures.

Summer peak impact estimates were to be calculated as the average maximum daily kW saved in the pre to post retrofit period. By subtracting post-retrofit maximum connected load from pre-retrofit maximum connected load for the weekday 2 pm to 5 pm period then averaging over the entire period, the average peak savings were calculated as 26.6 kW. However, this was inconsistent with the kW h savings derived from the billing data. The kW savings were increased to the expected value of 43.5 kW, as shown in Section3.

The engineering realization rate for this application is 0.48 for demand kW reduction and 0.76 for energy savings kWh. The values shown in the tracking system substantially agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 4.

Utility billing data for the site was reviewed. In the 12 month period from January 2003 – January 2004 (pre-retrofit), the facility consumed 2,171,425 kWh. Peak demand was 299.8 kW. Lighting use was estimated at 50% of total use for this facility. Table 1 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 30.4 % decrease in total meter kW, a 60.8% decrease in lighting end use kW, a 16.8% decrease in total meter kWh, and a 33.6% decrease in lighting end use kWh. The ex post results showed a 15.2 % decrease in total meter kW, a 30.5% decrease in lighting end use kW, a 12.8% decrease in total meter kWh, and a 25.7% decrease in lighting end use kWh.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	299.8	2,171,425
Baseline End Use	149.9	1,085,713
Ex ante Savings	91.2	364,672
Ex Post Savings	43.5	278,857

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	30.4%	16.8%	14.5%	12.8%
Baseline End Use %	60.8%	33.6%	29.0%	25.7%

It should be noted that actual ex post savings are somewhat higher than the ex post savings based on expected usage. Actual savings may be close to 36 kW (than 26.6 kW).

6. Additional Evaluation Findings

The main reason the ex post kW demand and kWh annual reduction varied from the ex ante estimate because the ex ante calculations referred to a four lamp T-5 fixture with a wattage of 234, when six lamp T-5 fixtures (wattage 0.351) were observed during the site visit.

The measure costs provided in the application do seem reasonable based upon experience with similar retrofits. The initial estimates of cost were 250% of the costs submitted. The revised costs were supported by contractor invoices for similar retrofits provided in the application.

In addition to saving energy, the benefits of the project are unclear. The store manager noted that the measure "probably" helped in increasing energy awareness in the company. The project was part of a corporate energy program encompassing many stores. Other benefits were increased clarity of light, increased light levels, increased employee comfort and better working conditions. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. Participation in the 2004/2005 SPC Program was most likely a part of overall corporate energy policy and may encourage other marginal energy efficiency projects.

It was impossible to physically verify the pre-retrofit lighting fixture type, quantities and hours of operation. However, these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $71,309 and a $30,525 incentive, the project had a 0.86 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 1.13 years. A summary of the economic parameters for the project is shown in Table 3.

A summary of the multi-year reporting requirements is given in Table 6.

7. Impact Results

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	3/30/2005	$71,309	91.2	364,672	-	47,407	$30,525	0.86	1.50
SPC Program Review (Ex Post)	11/21/2007	$71,309	43.5	278,857	-	36,251	$30,525	1.13	1.97

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	91.2	364,672.0	-
SPC Installation Report (ex ante)	91.2	364,672.0	-
Impact Evaluation (ex post)	43.5	278,857	-
Engineering Realization Rate	0.48	0.76	-

Table 5: Installation Verification Summary

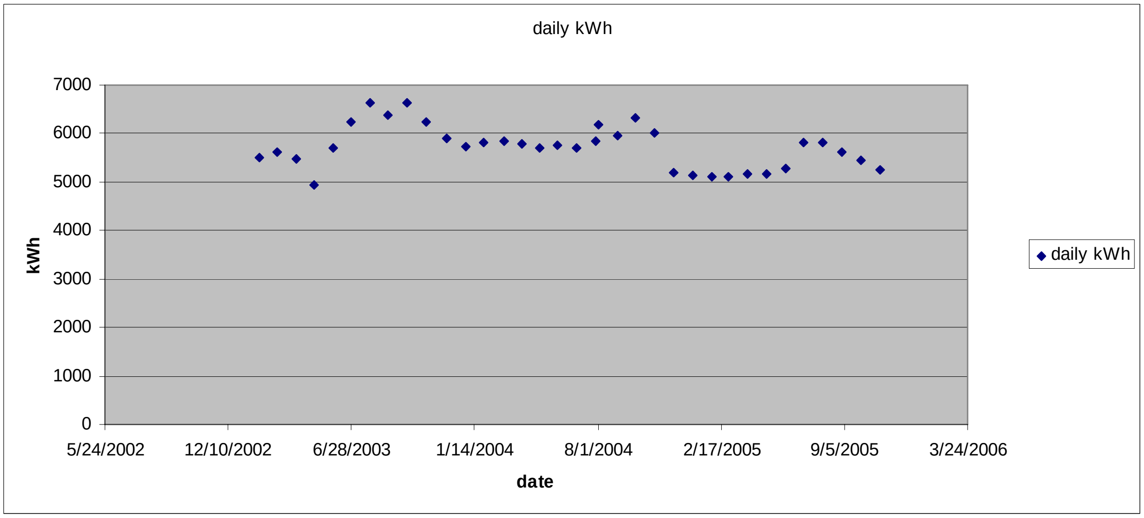
Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		L-H1 Interior High Bay Fixture 6 lamp T-5 Fixtures		408		Physically verified lamp type and verified quantity from documentation of previous inspectors, and the lighting invoice.	1.00

Table 6: Multi Year Reporting Table

Program ID:	Application # A088						
Program Name:	SPC 04-05 Evaluation						
Year	Calendar Year	Ex-ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	60,779	46,476				
2	2005	364,672	278,857	91.2	43.5		
3	2006	364,672	278,857	91.2	43.5		
4	2007	364,672	278,857	91.2	43.5		
5	2008	364,672	278,857	91.2	43.5		
6	2009	364,672	278,857	91.2	43.5		
7	2010	364,672	278,857	91.2	43.5		
8	2011	364,672	278,857	91.2	43.5		
9	2012	364,672	278,857	91.2	43.5		
10	2013	364,672	278,857	91.2	43.5		
11	2014	364,672	278,857	91.2	43.5		
12	2015	364,672	278,857	91.2	43.5		
13	2016	364,672	278,857	91.2	43.5		
14	2017	364,672	278,857	91.2	43.5		
15	2018	364,672	278,857	91.2	43.5		
16	2019	364,672	278,857	91.2	43.5		
17	2020	303,893	232,381	91.2	43.5		
18	2021						
19	2022						
20	2023						
TOTAL	2004-2023	5,834,752	4,461,712				

Lighting measure with 16 year life

Figure 1: Site A088 Daily kWh Usage Patterns



SITE A089a (04-0524) Kimb2 IMPACT EVALUATION
SAMPLE CELL: Backup TIER: 4 END USE: 4-P

Measure	Lighting Upgrades
Site Description	Paper Manufacturing Facility

1. Measure Description

The measure involves the installation of high efficiency lighting systems at ten buildings in a large manufacturing facility. The facility is a paper manufacturing with production, storage, and office areas. This project constitutes the second of two phases of lighting upgrades at the facility partially funded through SPC incentives. The existing fixtures were primarily T12 lamps, high wattage high intensity discharge (HID) lamps, and incandescent lamps. The new fixtures consisted of T8 fluorescent fixtures, high efficacy HID lamps, and LED exit signs. The existing fixtures are the baseline for this measure.

2. Summary of the Ex Ante Calculations

There were two types of lighting measures: itemized measures and calculated measures. Itemized measures are those incented per fixture. The incentive is a fixed rate per fixture and is independent of the energy savings; energy savings are also fixed per unit installed. For calculated measures, the incentive rate is based upon the anticipated energy savings to be achieved by upgrading the lighting.

The energy savings are a result of reducing the lighting load. The ex ante calculations list a total estimated annual savings of 1,283,605 kWh. An incentive of $72,045.66 was calculated from both itemized and calculated measures. The ex ante program verification consisted of verifying all existing and proposed fixture counts and wattages.

The baseline and as-built energy usages were not included in the project file. However, the ex ante savings are shown below.

The ex ante impacts were as follows:

- Annual Energy Savings: 1,283,605 kWh/yr
- Demand Savings: 180.6 kW

The ex ante savings are slightly higher than those in the utility tracking system, which lists 1,283,604 kWh and 180.1 kW.

The incentive for itemized measures was calculated as shown in Table 1.

Table 1: Incentives for Itemized Measures

Itemized Measure	Qty	Incentive Rate per Fixture	Total Incentive
4' T8 installed	1,781	$4.25	$7,569.25
4' T8 delamped	215	$6.00	$1,290.00
T12 replaced w/ T8	142	$75.00	$10,650.00
Metal halide pulse-start installed	50	$45.00	$2,250.00
LED exit signs installed	22	$27.00	$594.00
			$22,353.25

The incentive for calculated measures was calculated as shown in Table 2.

Table 2: Incentives for Calculated Measures

Calculated Measures	kWh Savings	kW Savings	Incentive Rate per kWh	Total Incentive
HID Lighting Replacement	992,096	113.3	$0.05	$49,604.80
U-tube Lighting Replacement	1,752	0.2	$0.05	$87.60
				$49,692.40

The total incentive was calculated as follows:

- The total rebate was $22,353 + $49,692 = $72,045.66

3. Comments on the Ex Ante Calculations

For the itemized measures energy savings calculations, annual usage was calculated by fixture type according to the estimates documented in the Express Efficiency workpapers found in the project file. Hours of use and wattage reductions per fixture type for a given market sector are found in the workpapers.

The project file lacks information on the different occupancy types and the schedules of these areas. The project file does not indicate installed wattages and fixture counts in each area for the itemized measures.

Additionally, the measure verification did not verify the operating hours and instead only verified the fixture counts and wattages.

The calculated measures for the metal halide (MH), high pressure sodium (HPS) and U type fluorescent fixture replacement incorporated use of 8,760 hours per year.

The savings for the itemized measures appear to be valid given varying operating hours between 3,964 and 8,489 annual hours. The 350 watt MH pulse start lamps were calculated to be in operation 3,964 annual hours. The two foot T8 lamps replacing 400 watt high bay lamps and the T8s replacing T12s were calculated to be operating 4,001 and 4,555 hours annually.

There is a certain amount of uncertainty involved in the annual usage estimates. If the hours were obtained through measurement, there may be a ± 10% uncertainty involved due to grouping together similar occupancy types. If the hours were obtained through self-reporting, there may be ± 15% uncertainty (or more) involved in the energy savings.

4. Measurement & Verification Plan

The facility under consideration is a 1,200,000 square foot paper manufacturing facility that purchased 4,943,304 kWh from January 2004 to January 2005. This represents a small fraction of total plant electrical energy usage, as the plant includes a cogeneration facility with 15 MW of generation capacity.

This measure reduces energy usage by reducing the facility's lighting load. The savings realized by this measure is the energy (kWh) required to compensate for the additional lighting wattage. The fundamental premise in development of the measurement and verification plan is to determine the existing lighting loads and hours. The M&V plan will be implemented in three basic steps:

1. Determine available data from the site contact via telephone (operating schedule, etc.).
2. Verify lighting fixtures (counts and wattages). Monitor fixtures to obtain annual operating hours.
3. Calculate the reduction in annual energy consumption.

We will use a combination of time-of-use lighting loggers installed at the light fixtures and current loggers installed at the lighting breaker panels to determine when banks of rooms on a common electric feeder were utilizing lighting fixtures.

Formulae and Approach

The metered time of use, fixture counts, and fixture wattages will be used to calculate pre retrofit and post retrofit energy consumption. Since there are no seasonal variations in schedule at the facility; the meter data will be linearly extrapolated to represent an entire year. We will use the following equations to determine the energy savings.

kWpre = (fixture count) x (pre retrofit fixture wattage)
kWpost = (fixture count) x (post retrofit fixture wattage)
kWh_{pre} = (pre retrofit kW) x (annual operating hours)
kWh_{post} = (post retrofit kW) x (annual operating hours)
Annual kWh Savings = $kWh_{pre} - kWh_{post}$

As the equations show, the key factor in the savings calculation is the annual operating hours, which will calculated from the metered data. We developed an appropriate annual savings calculation strategy which depends on field findings. Coincident peak kW savings will be calculated from estimated load reduction for the 2 PM to 5 PM period on the hottest summer weekdays (June to September).

$$\text{Peak kW Savings} = (\text{pre retrofit kW}) - (\text{post retrofit kW})$$

The greatest uncertainties are in the fixture counts and annual operating hours.

- Fixture count
  Expected 2,685, minimum 2,416, maximum 2,819 (-10%, 0, +5%)
- Annual operating hours
  Expected 8,760 hrs/yr, minimum 7,884 hrs/yr , maximum 8,760 hrs/yr (-10%, 0, +0%,)

Fixture wattages are believed to be relatively well qualified and an uncertainty of 5% may be expected due to this variable.

Accuracy and Equipment

A HOBO on/off data logger will be used to measure the time-of-use of the lighting systems. This meter has an adjustable light sensitivity threshold and records data at one-second intervals. The Hobos have a time accuracy of ±1 minute per week.

ACR OWL 400 data loggers will be used to meter the lighting at the breaker panel. The OWL 400 data logger can record data at five second intervals. The logger accuracy is ±1% of full scale.

All data collected will be reviewed to ensure it conforms to realistic values and will be verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis, if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on October 4, 2007. Information on the lighting fixtures was collected by inspection and short-term metering of the lighting systems. In addition, data were collected by interviewing the facility representative

Installation Verification

During the onsite visit, the evaluation team verified the lighting schedules and fixture wattages. We also physically verified the lighting counts. Three were 970 4’ T8 lamps, 102 4’ 6 lamp T8 fixtures, 22 LED signs, 398 4’ 4 lamp T8 fixtures (replacement of 250 watt MH), 67 4’ 4 lamp T8 fixtures (replacement of 250 watt HPS), 48 350 watt pulse start metal halide, 172 2lamp T8 fixtures (replacement of 150 watt MH) and 10 4’ 2 lamp T8 (replacement of U type T12 fixtures) throughout Buildings 1, 8 and 9.All lamps were high output.

There is a greater amount of uncertainty involved in the fixture count because there was no delineation found among the buildings 1, 8 and 9 in the lighting tables. Hence, lighting fixtures and lighting invoices were examined. Table 3 shows a comparison between ex ante and post field count and their respective power consumption.

Table 3: Comparison Between Ex ante and Post field Lighting Counts

Pre retrofit Ltg	Proposed Ltg	Ex ante Count	Post Field Count	Ex ante kW	Post retrofitted kW	Veification Realization Rate
4' T12 Fluorescent Lamps	4' T8 installed	1,781	970	57.0	31.04	0.54
4' T12 Fluorescent Lamps	4' T12 delamped	215	215	6.9	6.9	1.00
400 W Metal Halide	w/ T8	142	102	25.6	18.36	0.72
400 W Metal Halide	350 W Metal halide pulse-start insta	50	48	20.0	19.2	0.96
Incandscent Lamp	LED exit signs installed	22	22	0.0	0.0	1.00
250 W MH	4 L T832	450	398	50.4	44.6	0.88
250 W HPS	4 L T832	47	67	5.3	7.5	1.43
150 W MH	2L T832	183	172	10.8	10.1	0.94
T12 U type Fluorescent Lamp	2L T832	10	10	0.5	0.5	1.00
		2,900	**2,004**	**176.4**	**138.3**	**0.78**

The lighting measures are the only measures in this application. The verification realization rate for this project is 0.78. A verification summary is shown in Table 11.

Scope of the Impact Assessment

The impact assessment scope is for the efficient lighting measures in the SPC application. These are the only measures in the application for this site.

Summary of Results

HOBO Onset TOU lighting Loggers and Owl 400 amp loggers were installed throughout the facility for 25 days (from October 4, 2007 - October 29, 2007) to measure the operating hours of a representative sample of the retrofit lighting fixtures. The facility representative also stated that the 25-day period had been characteristic of normal facility operation. It was found that on average the lights are on 76.8% of the time compared to an average of 77.2% assumed in ex ante calculation. The detailed comparison between ex ante and ex post operating hours is shown in Table 4.

Table 4: Comparison between Ex ante and Ex post Operating Hours

	Ex ante hours	Actual Hours	% Ex ante On	% Actual On
4' T8 installed	4,555	1,684	52.0%	19.2%
4' T12Delamped	4,708	4,708	53.7%	53.7%
400 W Metal Halide to T8	4,001	6,887	45.7%	78.6%
400 W Metal Halide to 350 W MH PS	3,964	6,505	45.3%	74.3%
LED exit signs	8,589	8,589	98.0%	98.0%
250 W Metal Halide to 4 L T832	8,760	8,035	100.0%	91.7%
250 W HPS to 4 L T832	8,760	8,035	100.0%	91.7%
150 W Metal Halide to 2L T832	8,760	8,035	100.0%	91.7%
T12 U type Fluorscent to 2L T832	8760	8,035	100.0%	91.7%
Over all Average			**77.2%**	**76.8%**

Figure 1, 2, and 3 show the average daily operating schedule of the different types of lighting system.

Figure 1: Average Day Measured Operating Profile of 4' 4L T8 and 4'6LT8

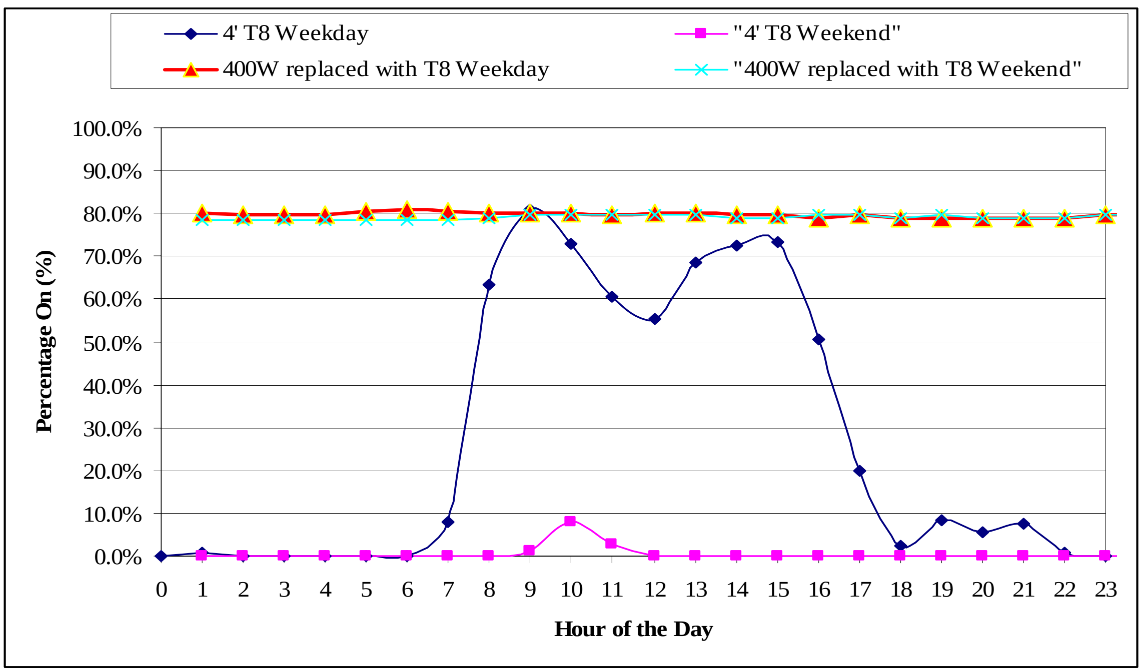


Figure 2: Average Day Measured Operating Profile of 350 w PS MH and LED

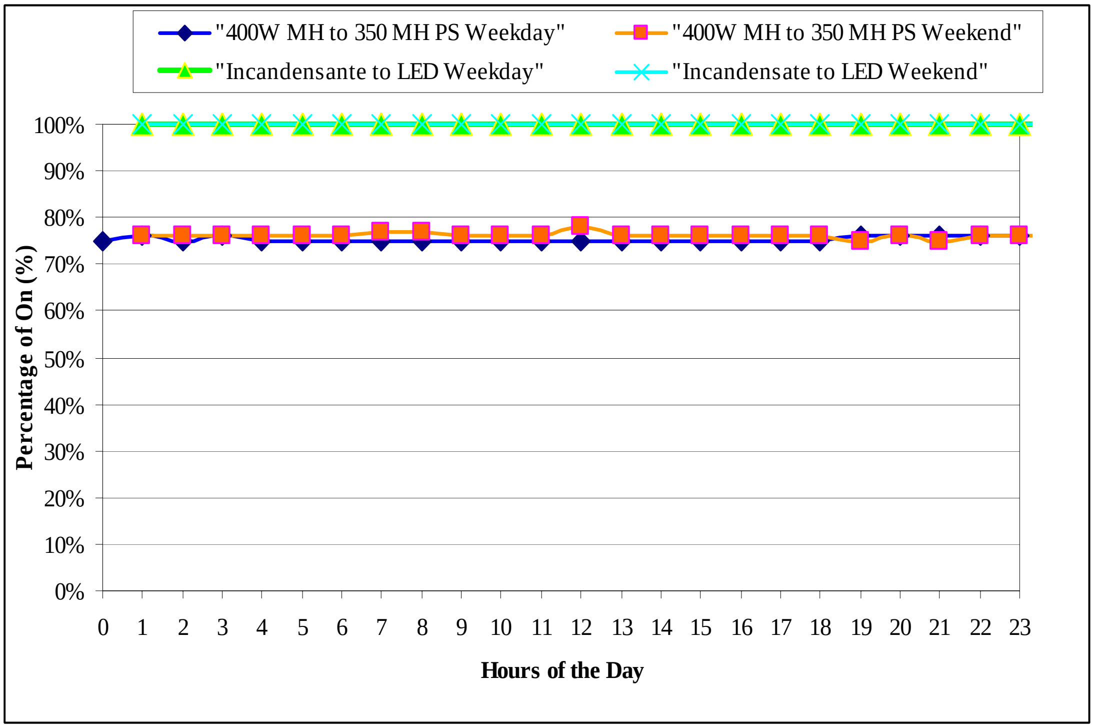
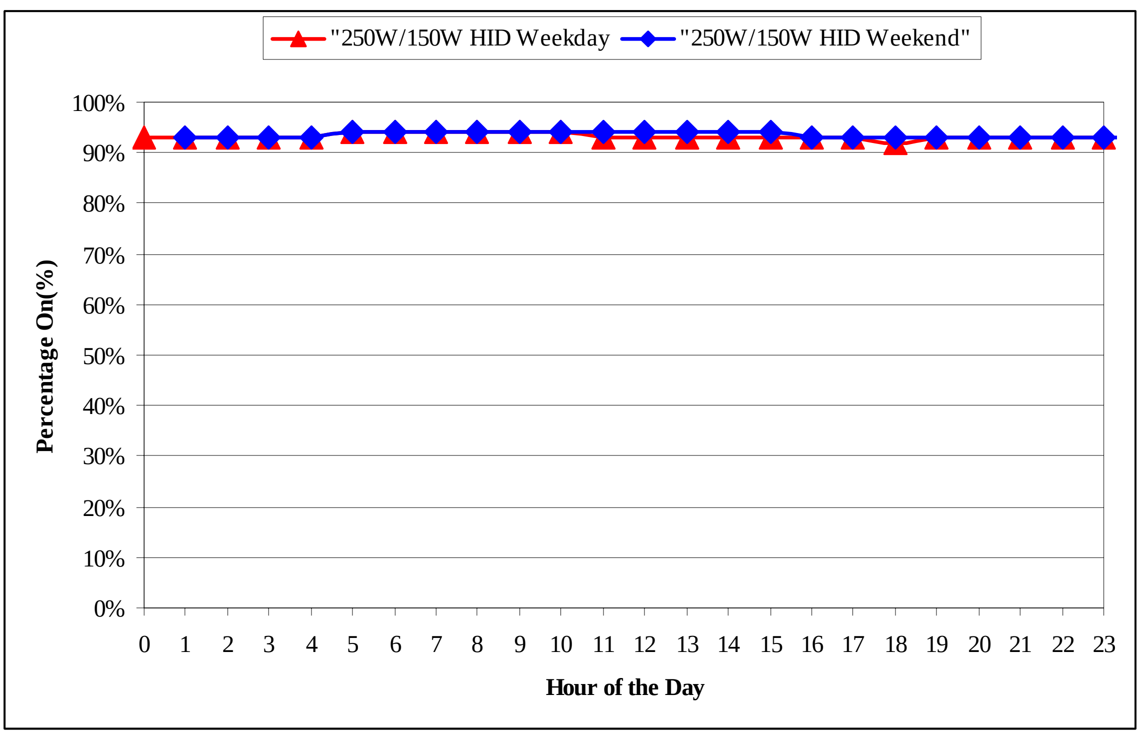


Figure 3: Average Day Measured Operating Profile Calculated Measures



The ex ante calculations were performed using the SPC Estimation Software and itemized measure calculation. The ex post impacts were calculated using a spreadsheet which contained information on annual operating hours obtained from metered data, fixture counts, and fixture wattages. Table 5 **Error! Reference source not found.**and Table 6**Error! Reference source not found.** show summaries of the ex post savings calculation.

Table 5: Summary of Ex post Savings Calculation for Itemized Measure

Pre retrofit Ltg	Proposed Ltg	# Pre retrofit count	# Post retrofit Count	Post Retrofit hrs/yr	Estimeted Pre retrofit kW	Post retrofit kW	Ex post kW Savings	Pre retrofit kWh	Post retrofit kWh	Ex post kWh Savings
4' T12 Fluorescent Lamps	4' T8 installed	1781	1,781	1,684	76.6	56.99	19.59	128,938.0	95,953.8	32,984.1
4' T12 Fluorescent Lamps	4' T12Delamped	215	0	4,708	9.2	0.00	9.25	43,525.5	-	43,525.5
400 W Metal Halide	6L T8	142	142	6,887	65.0	25.56	39.48	447,916.6	176,037.1	271,879.5
400 W Metal Halide	350 W MH PS	50	50	6,505	22.8	20.00	2.80	148,312.1	130,098.3	18,213.8
Incandscent Lamp	LED exit signs	22	22	8,589	0.9	0.02	0.90	7,936.2	204.1	7,732.2
Total			**1,995.0**		**174.6**	**102.6**	**72.0**	**776,628.4**	**402,293.3**	**374,335.0**

Table 6: Summary of Ex post Savings Calculation for Calculated Measure

Pre retrofit Ltg	Proposed Ltg	# Pre retrofit count	# Post retrofit Count	Post Retrofit hrs/yr	Estimeted Pre retrofit kW	Post retrofit kW	Ex post kW Savings	Pre retrofit kWh	Post retrofit kWh	Ex post kWh Savings
250 W MH	4 L T832	268	450	8,035	79.1	50.40	28.66	635,269.0	404,977.9	230,291.0
250 W HPS	4 L T832	229	47	8,035	67.6	5.26	62.29	542,823.1	42,297.7	500,525.4
150 W MH	2L T832	183	183	8,035	34.8	10.80	23.97	279,386.6	86,756.9	192,629.7
T12 U type Fluorescent Lamp	2L T832	10	10	8,035	0.7	0.52	0.20	5,785.4	4,178.3	1,607.1
Total			**690**		**182.1**	**67.0**	**115.1**	**1,463,264.0**	**538,210.8**	**925,053.2**

The ex post impact calculations were performed as follows:

Pre-retrofit annual kWh usage was 2,239,892 kWh/yr
Based on lighting logger data, post-retrofit annual kWh usage is 940,504 kWh/yr

- The resulting annual kWh savings is
- 2,239,892 kWh/yr – 940,504 kWh/yr = 1,299,388 kWh/yr

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load, with an adjustment for the weekday 2 pm 5 pm average measured post-retrofit percent on value of 86.7% (the kW weighted average by hour is shown in Table 12).

- Peak kW savings is 356.7 kW – (169.6 kW x 86.7%) = 209.8 kW.

The engineering realization rate for this application is 1.17 for demand kW reduction and 0.98 for energy savings kWh. The operating hours, fixture counts and fixture wattages found during the onsite inspection were very close to the ex ante estimates. The values shown in the tracking system slightly lower than those shown in the installation report for this application. A summary of the realization rate is shown in Table 10.

Table 7 summarizes the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 8 is a summary of the percent of energy savings for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 50.5% decrease in lighting end use kW, and a 57.3 % decrease in lighting end use kWh. The ex post results showed a 58.8 % decrease in lighting end use kW, and a 58.0% decrease in lighting end use kWh.

Table 7: Ex Ante, Ex Post Results

	Peak	Annual
	Demand kW	kWh
Total Meter	NA	NA
Baseline End Use	356.7	2,239,892
Ex ante Savings	180.05	1,283,604
Ex Post Savings	209.8	1,299,388

Baseline end use is only for fixtures evaluated; actual ex ante savings in the IRR is 180.6 kW.

Table 8: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	NA	NA	NA	NA
Baseline End Use %	50.5%	57.3%	58.8%	58.0%

6. Additional Evaluation Findings

The ex post kW demand reduction is greater than the ex ante estimate because the fixture wattage for some fixtures were incorrectly used in the ex ante kW savings calculations. The ex post energy savings are just slightly less than the ex ante savings because ex ante savings overestimated the annual operating hours in some of the areas in the facility.

The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

According to facility personnel, this measure increased energy awareness in the company and they continue to look for energy efficiency opportunities in the facility.

With a cost of $211,809 and a $72,046 incentive, the project had a 0.84 years simple payback based on the ex ante calculations. The ex post savings estimate for the project are slightly greater than the ex ante, resulting in an estimated simple payback is 0.83 years. A summary of the economic parameters for the project is shown in Table 9.

The effective useful life of the lighting system is 16 years. Table 13 shows projected annual ex ante and ex post energy savings for years 2004 through 2023.

7. Impact Results

Table 9: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	9/5/2005	$211,809	180.1	1,283,604	0	$166,869	$72,046	0.84	1.27
SPC Program Review (Ex Post)	10/4/2007	$211,809	209.8	1,299,388	0	$168,920	$72,046	0.83	1.25

Table 10: Realization Rate Summary

	kW	kWh
SPC Tracking System	178.8	1,323,931
SPC Installation Report (ex ante)	180.1	1,283,604
Impact Evaluation (ex post)	209.8	1,299,388
Engineering Realization Rate	1.17	0.98

Table 11: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		Installation of high efficiency lighting fixtures throughout the facility		2,900	6 lamp T-8 fixtures, 4 lamp T-8 fixtures,2 lamp T8 and 350W pulse start MH	Physically verified lamp type and verified quantity from floor plan and documentation of previous inspectors.	0.78

Table 12: Project Wide Hourly Percentage On by Day Type

	WD	WE
0	79.66%	79.22%
1	79.61%	79.22%
2	79.51%	79.22%
3	79.52%	79.22%
4	79.81%	79.79%
5	80.54%	79.79%
6	80.39%	79.81%
7	81.01%	79.96%
8	86.47%	80.21%
9	88.21%	80.90%
10	87.27%	80.38%
11	85.63%	80.13%
12	85.12%	80.10%
13	86.26%	79.95%
14	86.65%	79.95%
15	86.57%	79.52%
16	84.49%	79.52%
17	81.30%	79.37%
18	79.01%	79.51%
19	80.19%	79.37%
20	79.92%	79.36%
21	80.10%	79.37%
22	79.61%	79.52%
23	79.52%	79.52%

Table 13: Projected Multi Year Ex ante and Ex post Savings of the Lighting System

Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	213,934	216,565			0	0
3	2006	1,283,604	1,299,388	180.1	209.8	0	0
4	2007	1,283,604	1,299,388	180.1	209.8	0	0
5	2008	1,283,604	1,299,388	180.1	209.8	0	0
6	2009	1,283,604	1,299,388	180.1	209.8	0	0
7	2010	1,283,604	1,299,388	180.1	209.8	0	0
8	2011	1,283,604	1,299,388	180.1	209.8	0	0
9	2012	1,283,604	1,299,388	180.1	209.8	0	0
10	2013	1,283,604	1,299,388	180.1	209.8	0	0
11	2014	1,283,604	1,299,388	180.1	209.8	0	0
12	2015	1,283,604	1,299,388	180.1	209.8	0	0
13	2016	1,283,604	1,299,388	180.1	209.8	0	0
14	2017	1,283,604	1,299,388	180.1	209.8	0	0
15	2018	1,283,604	1,299,388	180.1	209.8	0	0
16	2019	1,283,604	1,299,388	180.1	209.8	0	0
17	2020	1,283,604	1,299,388	180.1	209.8	0	0
18	2021	1,069,670	1,082,824	180.1	209.8	0	0
19	2022					0	0
20	2023						
TOTAL	**2004-2023**	**20,537,672**	**20,790,211**				

Final Site Report

SITE: A090 DERF IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: HVAC OTHER

Measure	High Performance Reflective Window Film
Site Description	High Rise Office Building

1. Measure Description

Install high performance reflective window film on 35,091 square feet of windows on a 20 story office building, replacing deteriorated window film.

2. Summary of the Ex Ante Calculations

The calculated kW and kWh savings submitted with the application were 102.2 kW and 443,000 kWh. These calculated savings were the basis of the incentive payment.

The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. These workpapers note specific assumptions used in the simulation runs of the California New Construction Calculator 2001 (based on DOE-2).

These assumptions include:

a. Base case windows are single-pane, and SHGC = 0.95.
b. The simulated window shall have SHGC = 0.39.
c. Small retail and small office building types shall be used as the model for Express Efficiency program savings.
d. The window-to-wall ratio for building types shall be 0.20.
e. Building areas for purposes of this analysis shall be defaulted at 8,000 sq. ft.
f. Buildings shall be studied for all California Thermal Zones (CTZ) located in the utility service territory.

The Express Efficiency workpapers list the window film energy savings at 12.44 kWh/sq.ft.

The calculations for energy savings were performed using the DOE eQuest building design simulator based on 35,240 sq. ft. and 4,000 operating hours per year. The annual baseline usage listed in the application summary information was 3,789,600 kWh and the proposed usage following the window film installation was 3,346,600 kWh. The calculated savings from the eQuest simulator were 443,000 kWh/yr.

The simplified building simulation performed using the eQuest software uses standard load values per square foot of floor space in the simulation. For this eQuest simulation, the input value for the shading coefficient of the existing window film was derived from measurements of solar transmittance through a window under existing, pre-measure, conditions and an adjacent window with the new window film installed on a test basis. The measurement under full sun through the existing window film was 90 BTU/Hr/Sq.Ft. while the measurement at the same time through the new window film was 40 BTU/Hr/Sq.Ft. The new window film shading coefficient (SC) is 0.39.

The effective SC of the existing deteriorated film was estimated by multiplying the new film SC by the ratio of the measured existing film BTU/Hr/Sq.Ft. to the measured new film BTU/Hr/Sq.Ft.

$$\text{Existing film SC} = \text{New Film SC} \times \frac{\text{90 BTU/Hr/Sq.Ft.}}{\text{40 BTU/Hr/Sq.Ft.}} = 0.39 \times 2.25 = 0.88$$

Pre and post installation simulations were run. The baseline using the derived coefficient was run for windows on all four walls of the building. The simulation for the new film was run with the film specifications input for the East, South, and West wall exposures as allowed under the program guidelines. The north wall would have the baseline SC specification.

The annual electrical energy savings were:
3,789,600 kWh - 3,346,600 kWh = 443,000 kWh/yr

Savings were further reduced in the IR because 42 eligible windows on the 5^{th} floor were unable to be retrofitted due to the tenant in that space. The energy and demand savings were reduced by the ratio of windows retrofitted to those proposed. Coincident peak reduction is 98.2 kW and the kWh saving is 425,693 kWh/year in the Installation Report Review. These figures agree exactly with those in the tracking system.

Conditions for approval of window film for incentives within the SPC program procedures manual are described by the following:

Measure H-C. Reflective Window Film

Film must have a minimum five-year manufacturer’s warranty. Itemized incentives are not available for windows with northern exposure. Space must be cooled by vapor-compression air conditioner (evaporatively-cooled space not eligible). Film must have either a solar heat gain coefficient (SHGC) <= 0.39 and be applied to clear, single-pane glass, or film can have an SHGC <=0.47 and visible transmittance/solar heat gain coefficient (VT/SHGC) ratio > 1.3. Specification must be documented on the invoice, as well as square footage installed. To convert Shading Coefficient (SC) to SHGC the following equation is used: SHGC = SC x .87.

3. Comments on the Ex Ante Calculations

The use of window film reduces the amount of infra red solar gain through the glass. The reduced solar gain reduces the cooling load on the facility’s air conditioning system, which results in energy savings. For this building the windows are double-pane (however, the onsite evaluation visit confirmed that the windows are actually single pane) and therefore the measure was not eligible for an itemized incentive. An incentive was available under the calculated approach. Table 3 of the pre-installation inspection paperwork indicates that each floor (3 sides and 3 corners) has 1,755 square feet (sq.ft.) of glazing for a total of 35,091 sq. ft. for the office tower.

The window film replaced old, deteriorated window film, which was removed before application of the new film. Before the installation a comparison test of the old film and new film was performed to provide a means to calculate savings.

The warranty on the window film is 5 years. Typically window film life is longer than the manufacturer's warranty.

The ex ante calculations and were performed using the DOE2 e-Quest building simulation tool using the derived SC value for the old film and the rated SC for the new film as the basis for the calculated approach.

The following paragraphs highlight other notable discrepancies regarding the ex ante calculations.

The original window film simulation was run using a total of 35,240 square feet of window area covered with high performance reflective film on the East, South, and West sides of the building. The window square footage covered with film on these surfaces verified for the application in the application review and pre-installation inspection was 35,091 sq. ft. The 20 story building space is conditioned with two centrifugal chillers.

The reported energy savings from the H-C1 itemized measures (SPC Calculator) were 456,189 kWh/yr and the peak demand savings with the verified square footage were 105.3 kW. The application report reviewer ran the eQuest simulation using the verified window square footage of 35,091 sq. ft. The ratio of the submitted eQuest calculated savings to the H-C1 savings is 97%.

443,000 kWh/yr / 456,189 kWh/yr = 0.9711

Therefore the estimated and approved peak demand savings listed in the application are:
0.97 x 105.3 kW = 102.2 kW

There is some uncertainty in the reported kWh energy savings, from the application review simulation. The savings appear to be greater with less window area covered by the film.

In the installation report the inspector indicated 1,158 windows on the East, South, and West facing sides rather than 1200 as originally proposed had received the window film. The reviewer verified that 42 south facing windows in one suite were not coated with the new film due to tenant issues. In total 33,863 square feet of windows received the new film. The savings were recalculated using the ratio of verified to the originally submitted square footage times the savings, yielded the post installation inspection savings.

33,863 sq.ft / 35,240 sq.ft = 0.9609
0.9609 x 443,000 kWh/yr = 425,690 kWh/yr

The reviewer reported savings of 425,693 kWh/yr

The demand savings were calculated in a similar way. 0.9609 x 102.2 kW = 98.2 kW

In general, the savings figures in the final Installation Report Review (IRR) would be expected to be identical to the utility tracking system savings figures. The total savings in the final Implementation Report were given as 425,693 kWh/yr and 98.2 kW. The utility tracking system notes a total savings of 425,693 kWh/yr and 98.2 kW. The utility tracking system figures will be used to calculate the realization rate.

Note that another simulation using the eQuest model was not run on the new numbers of windows. The simulation may have derived lower savings if the specific number of "south" facing windows had been entered in the input data set. Any difference between the savings as calculated above and the model simulation would depend on the sensitivity of the model to the building orientation. The building appears to be oriented at an approximate angle of 45 degrees from the cardinal directions. The resulting solar exposures and energy savings may be significantly different than those calculated if the accurate building orientation was not taken into account.

The question raised could be answered by running the eQuest simulation using the revised, verified, and final window square footage and building orientation. Additionally, if the building has an energy management system with recorded building energy use data, the pre and post energy savings could be obtained or could be calculated from real building data provided by the EMS.

Pre- retrofit and post-retrofit cooling loads and energy use can be estimated using actual annual operating hours.

4. Measurement & Verification Plan

The building is a 22 story (20 office stories) 245,768 sf conditioned office building. It is reported to be 36 years old. The exterior of the building has numerous windows that allow light and views to each of 20 floors of offices. The building operation schedule was not included in the application paperwork. Annual operation hours are presumed to be approximately 4000 hours; however, the building mechanical systems may work substantially more hours than this. Building operation hours will be verified during the M&V inspection and if available EMS energy use / operations data will be obtained.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful life of the measure.

Formulae and Approach

IPMVP Option C approach should be considered. The savings reported in the utility tracking system is approximately 10% of the kW and kWh consumed based upon the pre-retrofit building use (annual peak demand is approximately 1,133 kW and annual energy use approximates 4,275,000 kWh per year according to the utility billing summary in the application). Seasonal fluctuations in energy use may obscure differences in pre and post installation energy demand and use. Utility billing and interval data may support a billing analysis approach if there are no other significant loads or other significant energy conservation activities which occurred in the months immediately following the retrofit. There is not expected to be significant seasonal variation and several months should be sufficient for comparison; however, a one to two year period would more fully capture actual variations and the persistence of savings. Interval data on a 15 minute basis during the summer months of June to September would be needed to accurately determine coincident peak period demand savings.

If Option C cannot be used due to changes in the facility or its operation in the time periods immediately before or after the retrofit, then a modified version of IPMVP Option A can be used. Interview evaluation or EMS data may be used to quantify hours of operation. Collected data can be input into the eQuest model to develop energy savings. Pre-retrofit and post-retrofit calculations of cooling loads, which consider occupancy, lighting loads, miscellaneous energy use and internal window shading parameters will be used to evaluate savings.

Summer peak demand period savings are complicated due to the cycling nature of AC equipment. Thus, to estimate peak demand kW reduction, the ratio of the calculated energy savings to the itemized energy savings will be applied to the itemized peak demand savings, as was done for the ex ante calculations.

Documentation provided indicates that the window film savings will be approximately 10% of the pre-retrofit energy use. Accurate data collection of occupancy, hours of operation, building characteristics and construction, and cooling efficiency would be the primary target areas for evaluation efforts. Evaluation will, for this reason, focus on these parameters.

The significant variables to be quantified are the pre-retrofit and post-retrofit hours of operation. Pre-retrofit hours will be confirmed with site personnel and interviews. The focus will be on verifying that no significant changes to the hours of operation during the hours listed (4,000 hours/year) have changed and that the listed hours/year was valid. For example, building or schedule logs for the pre-retrofit period could be examined if available or tenant occupancy can be verified. The activity type and level of equipment per floor should be estimated as accurately as possible. Significant variations in the design and activity intensity per floor will be considered. Business hours and operating schedules will be recorded and HVAC operating schedules and settings will be obtained. HVAC equipment type, number and sizes will be recorded. The heating and cooling capacities and fan settings will be obtained.

The building and window wall orientation to the cardinal directions and the actual floor areas will be verified with plans if available. Floor areas and the window construction type and glazing performance characteristics and window film characteristics will be verified. Lighting densities per floor should be confirmed as accurately as possible and compared with eQuest default values.

Appropriate modifications to the input data for the savings calculations would be made to the pre-retrofit usage figures, if required, in order to establish a realistic baseline for energy use associated with impacts from the window film.

Accuracy and Equipment

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 10, 2007. Information on installation and operating conditions was collected by interviewing the facility representative and by inspection of the interior and exterior of the building. Window film material, area, window type, and cooling system type and efficiency were verified.

The building is a 21 story, office building, with interior spaces rented to various tenants. The ground level is an atrium which was not retrofit with the window film. The chiller is located in the basement, along with an air handler serving the lower 10 floors of the building. The air handler serving the upper 10 floors is located on the roof.

The building is occupied weekdays from 7am to 7pm, and as needed by the tenants on weekends and holidays. Occupancy is approximately 850 people on weekdays, 100 people on Saturdays, and just a few people on Sundays and Holidays. The building is conditioned all the time, 7 days a week, with individual tenant temperature control in each office space. Operations are not expected to change. The conditioned spaces will not be altered.

The windows had been previously coated with a window film which was 19 years old, deteriorating and needed replacement. The facility representative indicated that there was at most 5 years of useful life left in the old film. The building won an award in 2002 for Energy Efficiency. The window film is one of the last efficiency measures to be implemented at this building.

Installation Verification

It was physically verified that window film was applied to the windows at this site. The facility representative verified that although some windows were not completed in time for the rebate, eventually all the windows were coated with the film. Photographs from the outside of the building confirmed that all windows had the same appearance, indicating that they were all coated with the film.

The retrofit was completed in November 2005.

This is the only measure in this application. The verification realization rate for this project is 1.0 (33,863 / 33,863). A verification summary is shown in Table 8 below.

Scope of the Impact Assessment

The impact assessment scope is for “other” end use measures in the SPC application covering the application of the window film. This is the only measure in this application.

Summary of Results

The window film savings at this site were determined by re-running the e-Quest model used for the ex ante savings, updating variables where the ex post inspection revealed significantly different values from those used in the ex ante model.

The ex post evaluation inspection of the site revealed two significant differences in the building characteristics from those that were initially used in the e-Quest model. The first is that the building is not oriented in the cardinal directions, as modeled, but is oriented at 45 degrees to the cardinal directions. The North façade in the ex ante model actually faced North-West; The West façade actually faced South-West; The South façade actually faced South-East, and the East façade actually faced North-East.

The second change noted at the ex post inspection is that the actual efficiency of the chiller is better than the efficiency used in the ex ante model. The model numbers and nameplate data of the HVAC equipment were recorded at the site visit. The order report was obtained from the manufacturer based on the serial number of the chiller. It was confirmed with the manufacturer that Performance kW and Tons of Refrigeration were the input and output energy values for the chiller at ARI test conditions. Efficiency was determined as follows:

(Performance kW - Prim) / (Tons of Refrigeration - Prim) = 216 kW /383 Tons = 0.56 kW/ton

Calculations based on the manufacturer's data, shown in Table 1, yield reasonable estimates of the Electric Input Ratio for the cooling system at this site. (Electric Input Ratio is a unitless ratio of the input energy over the output energy of the chiller.) Several unit conversions yield an Electric Input Ratio of 0.159 for the ex post e-Quest model.

Table 1: Cooling Equipment Efficiency from Manufacturer's Data

Model	Trane CVHE500	
Input Energy/Output Energy	0.56	kW/Ton
conversion	12000	Btuh/Ton
conversion	3413	Btuh/kW
Electric Input Ratio	0.159273	

E-Quest is a complicated building model (using DOE2.2 as the calculation engine) with many input variables. The window film saves energy by blocking some of the solar heat gain into the building through the windows. The magnitude of the energy saved is dependent on the square footage of window area, the cardinal direction the windows face, the latitude and cloud cover experienced by the building, the shading coefficient of the windows, the ventilation rate of the building and the efficiency of the cooling system used to remove heat from the building.

The ex ante e-Quest file was requested and received from the engineering firm employed by the utility to calculate the window film savings projections for the SPC application. This allows us to know the exact input variables that were used, and to repeat the calculation exactly. The modeled building included only floors 2 through 21, and included windows only on the east, west and south sides of the building, since the windows on the north side and the windows in the atrium on the ground floor were not included in this application. These modifications should not affect the ex ante savings from the installed film. An error was found in the input file which will affect the savings from the window film. The window area in the modeled building was 34,241 square feet instead of 35,240 square feet noted in the text of the report accompanying the e-Quest model in the application paperwork. The smaller window area would reduce the solar heat load on the building, and therefore reduce the savings from the window film. The glass area verified in the Installation Review was 35,091 square feet, so this the number used in the ex post model.

We received only the input file for the retrofit case and not the baseline case, but this should be sufficient because the only difference between the retrofit case and the baseline case should be the Shading Coefficient of the windows. When the retrofitted case was run independently, the building cooling energy use result was within 0.05 percent of the results reported in the application paperwork. However, when the shading coefficient was changed and the model re-run for the baseline case the result was 1.61 percent higher than that reported in the application paperwork, resulting in savings that are 13.4 percent larger than those reported in the application paperwork.

The two differences noted at the evaluation inspection, orientation of the building and the electric input ratio, were each changed individually to see the effect on the building cooling energy use. The new orientation reduced savings by 18%, and the increased chiller efficiency reduced savings by 12%. (The percent change is with respect to the re-calculated ex ante savings).

The post installation inspector found that 42 windows on the 5th floor were not retrofitted with the new film. He adjusted the savings by the ratio of windows retrofitted (96%), but did not run an adjusted e-Quest model. As part of the evaluation effort, the model was run without the 42 windows retrofitted, and the savings were 96% of the fully retrofitted case.

The ex-post model takes into account the actual orientation of the building, the actual chiller efficiency, and the windows not retrofitted. The input variables changed between the ex ante and ex post models and output values generated by e-Quest for the window film are shown in Table 2. The ex post savings are 97% of the ex ante savings.

Table 2: Input Variables and Results from E-Quest Model

	E-Quest/DOE 2.2 Model			
	ex ante		ex post	
	Baseline	Retrofitted	Baseline	Retrofitted
Shading Coefficient	0.88	0.39	0.88	0.39
Visible Transmittance	0.37	0.17	0.37	0.17
Building Orientation	N	N	NW	NW
Electric Inpput Ratio	0.1706	0.1706	0.159	0.159
Glazing Area, old film	34,241	-	35,091	1,228
Glazing Area, new film	-	34,241	-	33,863
Cooling (MWh)	3,789.6	3,346.6	3,692.8	3,281.4
Savings (MWh)	443,000		411,400	
IR Adjustment	425,679			
Percent of Ex Ante Savings			97%	

The application paperwork states that the demand reduction was calculated by taking a ratio of the modeled energy savings to the itemized savings for the verified window area, and applying this ratio to the itemized demand savings. The same calculation was done in the ex post case, yielding 95.0 kW peak demand savings, as shown in Table 3.

Table 3: Peak Demand Savings

Peak Demand Savings		
	kW	kWh/yr
H-C1 savings for 35,091 sq. ft.	105.3	456,189
Ex Post	95.0	411,400

Table 4 summarizes the total metered use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers. The total meter annual kWh is determined from the 2004 year. The baseline use is calculated as 30% of the total electricity use for the facility; the percent dedicated to HVAC assumes 40% for lighting and 30% for other uses.

Table 5 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results show energy savings as 10.0% of the total meter and 33.2% of the baseline end use. Demand savings are 11.5 percent of the total meter and 38.3% of the baseline end use. The ex post results for the window film show similar energy savings of 9.6% of the total meter and 32.1% of the baseline end use. Ex post demand savings are 11.1% percent of the total meter and 37% of the baseline end use.

Table 4: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	855.4	4,275,120
Baseline End Use	256.6	1,282,536
Ex ante Savings	98.2	425,693
Ex Post Savings	95.0	411,400

Table 5: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	11.5%	10.0%	11.1%	9.6%
Baseline End Use %	38.3%	33.2%	37.0%	32.1%

6. Additional Evaluation Findings

The building manager noted that the window film was implemented partly due to concerns regarding carpet fading, comfort of occupants near the windows, and the aesthetics of the blue sky and ocean viewed through the windows, as well as for energy savings. Installation costs appear to be realistic.

It does not appear that participation in the SPC program stimulated involvement in other energy efficiency efforts or programs.

7. Impact Results

The pre-retrofit window film type was not able to be physically verified. However, the application paperwork adequately documented the shading coefficient of the pre-existing window film needed for analysis. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $145,200 and a $34,055 incentive, the project had a 2.01 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is similar the ex ante, and the estimated simple payback is 2.08 years. A summary of the economic parameters for the project is shown in Table 6.

Table 6: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	5/12/2005	$145,200	98.2	425,693	0	$55,340	$34,055	2.01	2.62
SPC Program Review (Ex Post)	9/10/2007	$145,200	95.0	411,400	0	$53,482	$34,055	2.08	2.71

The engineering realization rate for this application is 0.97 for energy savings. The engineering realization rate is the same for the demand savings and the energy savings because in both the ex ante and ex post case the demand savings are calculated based on the ratio of calculated to itemized energy savings. According to the installation report, the ex ante savings are 425,693 kWh annually and demand reduction is 98.2 kW. A summary of the realization rate is shown in Table 7.

Table 7: Realization Rate Summary

	kW	KWh	Therm
SPC Tracking System	98.2	425,693	-
SPC Installation Report (ex ante)	98.2	425,693	-
Impact Evaluation (ex post)	95.0	411,400	-
Engineering Realization Rate	0.97	0.97	NA

1. Tracking System values used for realization rate calculations.

The Installation Verification Summary is shown in Table 8.

The savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 9.

Table 8: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Other Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
H-C1 Special Window Glazing & Glazing Treatments	O			Install reflective window coating on east, west and south facing windows	33,863 ft^2	Window Film	Physically verified window film type and area.	1.00

Table 9: Multi Year Reporting Table

Program Name:		SPC 04-05 Evaluation Site A090					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	35,474	34,283				
3	2006	425,693	411,400	98.2	95.0		
4	2007	425,693	411,400	98.2	95.0		
5	2008	425,693	411,400	98.2	95.0		
6	2009	425,693	411,400	98.2	95.0		
7	2010	425,693	411,400	98.2	95.0		
8	2011	425,693	411,400	98.2	95.0		
9	2012	425,693	411,400	98.2	95.0		
10	2013	425,693	411,400	98.2	95.0		
11	2014	425,693	411,400	98.2	95.0		
12	2015	390,219	377,117	98.2	95.0		
13	2016						
14	2017						
15	2018						
16	2019						
17	2020						
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	4,256,930	4,114,000				

Final Site Report

SITE A091 (2005-0369) AVIA IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 5 END USE: Other

Measure	Cool Roof
Site Description	Warehouse / Offices

1. Measure Description

This measure is for the installation of a white, acrylic, cool roof over 28,000 square feet of a manufacturing facility located in California. The new cool roof product is Hidrocoat by RoofCool. Cool roofs are reflective (usually white) coatings or membranes applied to a flat or minimally sloped roof to reduce adsorption of solar insolation to the building space below the roof. The effective cooling load in a conditioned area is reduced by the minimization of solar heat gain through the roof. The cool roof was applied over both conditioned and unconditioned space.

2. Summary of the Ex Ante Calculations

The customer calculated savings using the 2005 SPC Software, Cool Roofs module. The kWh savings submitted were 13,336 kWh. No kW savings were submitted. The input data were deemed reasonable.

The relevant inputs discussed in the workpapers and inputs to the SPC calculator are recorded in the application paperwork. These include the city (weather location), the roof R-value, solar reflectance of the applied material, infrared emittance, air conditioner efficiency, and the roof area.

3. Comments on the Ex Ante Calculations

The total savings in the Installation Report Review were recorded as 13,336 kWh/year and 0.0 kW; these figures agree with the utility tracking system. Installation inspection notes confirmed a cool roof reflective white coating was applied to 28,000 square feet of roof surface. The Installation Report Review states that the applicant utilized the Cool Roofs model located in the 2005 SPC Estimation Software and that the customer supplied the inputs for the equipment specifications which were verified in the review process. However, neither the inputs nor a printout of the SPC calculator results are included in the hardcopy or electronic paperwork. The facility manufactures aerospace parts. There was no mention of the specific building occupancy or uses within the facility although it is indicated in the paperwork that only part of the roof received the cool roof coating. The hours of operation for the buildings and the air conditioning system should be considered in the evaluation. Also, the extent, if any, of insulation should be examined.

Other than a discrepancy in the total square footage (nominally 28,000 sq. ft. in the application versus the roofing contractor's value of 28,700 sq. ft.) of the cool roof project, all other conditions of the SPC program guidelines appeared to be met. Photographs of the new and old roof indicate the presence of skylights and roof top mounted package units.

No summer peak kW impacts are expected, based on the relatively low heat load reductions and the intermittent cycling nature of the roof mounted package air conditioning equipment at the facility.

4. Measurement & Verification Plan

The cool roof measure was applied to 28,700 square feet of roof, over both the conditioned and unconditioned space of an aerospace equipment manufacturing company. Another portion of the building, which covers conditioned offices and unconditioned hallways, work or storage space at the facility initially did not receive the cool roof application. The paperwork for the cool roof measure did not indicate any application of exterior insulation before the roofing material was installed. The age of the single story building was listed as 40 years. Photographs indicated approximately 6 skylights in the roof which received the cool roof coating.

The documentation in the application indicates that adhesive, polyester fabric and acrylic top coating were applied to 28,700 square feet of roof area. Note that 28,000 sq. ft. was the value used in the application and the installation report review.

The measure saves energy by increasing roof reflectivity, and limits heat buildup in the roof and heat transmission through the roofing materials to interior spaces.

The goal of the M&V plan is to estimate the actual peak annual kWh reduction over the expected useful life of the measure.

Formulae and Approach

A modified version of IPMVP Option A can be utilized, incorporating the SPC calculator. Some parameters, such as pre-retrofit roof surface characteristics and HVAC equipment efficiency, will be stipulated according to manufacturers' data.

The condition of the roof will be inspected for wear, as the customer reported peeling in come places. The square footage will be determined accurately from the drawings and rooftop equipment areas/penthouses will be deducted. Any shading from adjacent structures or landscaping will be noted. Additionally, the conditioned area will be determined.

The 2005 SPC calculator will be used to calculate the savings with the measured and stipulated variables. The inputs to the model used in the SPC calculator are the location of the building, solar reflectance (SR), infrared emittance (IE), roof insulation value (R), air conditioner efficiency, and roof area. The solar reflectance of the new roof may be measured with an albedometer. The parameters that have the most effect on the savings are the roof R value, solar reflectance, and roof area. The focus will be on determining these variables accurately for the pre and post retrofit situations.

The SPC calculator cool roof calculation code was examined to ascertain the approach used. The calculations all involve polynomial equations of the second or third order which appear to be fitted to empirical data. There are no notes as to the source of the empirical data; a possible source is the Demonstration of Energy Savings of Cool Roofs project by the Heat Islands Group at Lawrence Berkeley National Lab. (http://eetd.lbl.gov/HeatIsland/PROJECTS/DEMO/)

Thickness of building components for the insulation R value calculation will be measured to the extent possible, and the type of insulation material determined. Building plans will be consulted for roof construction and slope.

The complexity of the building systems and heat transfer variables, along with the magnitude of the savings for this measure, preclude the use of a calibrated building model. A calibrated building model constructed for this purpose should take into account many variables, such as reflectivity, emissivity, interior building configuration, insulation value, and actual cooling equipment efficiencies. The development of a model based on the size and type of this particular project is generally very complicated. A building model *may* also be largely inaccurate for this type of evaluation because the magnitude of change between the pre and post conditions is small compared to the total building energy use. Furthermore, many models rely on empirical data for cool roof savings estimations, calling into question validity of an entirely calculated approach.

If a large uncoated area is not available for measurement, the uncertainty associated with the older roof reflectivity introduces a large source of error, also limiting the building model approach. Direct measurements using a pyranometer and other tools to measure the post retrofit reflectivity are possible. However, reflectivity values specified by the manufacturer of the cool roof could also be used. It should be noted that these are typically values for the reflectivity of a new cool roof; weathered values have a lower reflectivity and should be used if available.

Uncertainty for the savings estimate for the retrofit can be more fully understood by setting projected ranges on the primary variables.

<u>For the SPC calculator inputs</u>

- Location (+/- 5% for changes in weather due to distance of 20 miles)
- U = 1/R; R = 5 for standard un-insulated roof assembly (+/- 5%)
- Solar Reflectance: pre 0.16, post 0.85 (+/- 40% pre, +/- 10% post due to degredation)

- Infrared Emittance: pre 0.91, post 0.90 (+/-15% pre, and +/- 5% post due to degredation)
- Area = 28,000 sf; +/- 3% (based on application paperwork)
- SEER = 10; +/- 20%

Accuracy and Equipment

If necessary, measuring wheels will be used to record roof area.

Standard measurement devices for area and insulation thickness calculation will be made to the nearest 0.5 inch and converted to two decimal places for area calculations. Error is expected to be less than 2%.

Roof Surface Albedometer if used: spectral range: 305 - 2800 nm, resolution: 1 W/m2, estimated accuracy +/- 5%.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 26, 2007. Information on installation and operating conditions was collected by interviewing the facility representative and by inspection of the interior and exterior of the building. Construction materials, hours of operation, and measurements of the installed cool roof were verified. The manufacturer is a tenant in the building and the building owner had the cool roofing installed.

The facility’s maintenance coordinator indicated the building is a one story 44,000 square foot (sf) manufacturing facility. [This value may be overstated based on measurement of the roof lineal foot (lf) dimensions (200 lf by 200 lf)]. There is a conditioned clean room on the south side of the building, unconditioned manufacturing floor at the middle of the building, and conditioned offices and storage at the north of the building. The area of the cool roof, submitted for the SPC application, covered the roof area from the parapet wall to the south side of the building, measured as 28,000 sf, or 70% of the total roof surface (40,000 sf measured). The cool roof area is the south and middle of the building. The area of the offices and storage to the north was not covered with the reflective roofing material at the time when the original cool roof measure was implemented.

The southern roof surface of this production facility was coated with RoofCool corporation’s Hidrocoat Platnum Roof Coating, classified as a cool roof product because of its high reflectivity (0.89, Cool Roof Rating Council, CRRC) and high emissivity

(0.86, CRRC). This product will decrease the heat gain to the area under the roof. Roof construction consists of nominal ¾ to 1 inch plywood on 2 by 4 inch rafters supported by larger girders, beams, and posts. There is no insulation in any of the joist bays. Approximately 80% of the interior roof area (including all of the roof area pertinent to this application) has reflective aluminized craft paper suspended from the lower ends of the 2 by 4 inch rafters. The balance of this roof area does not have the radiant insulating paper. The clean room to the south and the offices to the north are framed floor to ceiling to separate their conditioned spaces from unconditioned space of the manufacturing floor.

The exterior roof is built-up asphalt, rolled roofing that has been covered with the cool roof coating. There are short parapet walls that extend up approximately 10 inches from the roof surface at the building perimeter and at a support wall which was the division between the original cool roof measure and the balance of the roof over the offices and storage. The roof area (12,000 sf) that was not included in the cool roof measure under this SPC program application has since been covered in the white cool roof material.

The building is occupied on two regular 8-hour schedules that overlap and run on Monday through Friday from approximately 6 a.m. to 3:30 p.m. There are occasional Saturdays where there is a half day and work sometimes occurs on Saturdays and Sundays when there is an order to complete or a deadline to meet. However, overtime work generally is discouraged. The facility is closed at other periods and also closed on 10 holidays per year. The only part of the facility that is continuously conditioned, to maintain temperature and to control climate, is the clean room. The offices are not conditioned during hours when the business is closed. There are four heating and cooling package units on the south side (clean room) and four on the north side (offices) of the building. The south side also has four vent stacks one of which has two large fans for mechanical draft ventilation. These appear to be located over the central manufacturing floor area.

Operations are not expected to change. The conditioned spaces will not be altered.

The building and roofing were 40 years old at the time of the measure implementation. The maintenance coordinator indicated that before the cool roof was installed, there were numerous leaks. The roof was functional but with significant maintenance problems, which required substantial time patching leaks during rains. The roof provided poor and unacceptable performance at the time of the cool roof work. The roof was not meeting the technical and performance needs of the facility. Leaks were contacting the electrical panel. The re-roofing work was required of the owner as a condition of continuing the tenant lease agreement.

The tenant's representative indicated the owner installed the roofing and the financial analysis for the cool roof measure was performed by the owner. After the cool roof installation there were fewer leaks, but patching still is needed.

Installation Verification

It was physically verified that 28,000 square feet of roof coating was applied at the facility. The dimensions of the roof were measured as 140 ft. by 200 ft. Approximately 80% of this area, however, is disqualified from the SPC program, and does not contribute to savings, because the space below it is not conditioned. The space that is conditioned consists of a clean room and a small office space. The majority of the warehouse is not conditioned and has large doors to the outside that were observed to be open at the time of the site visit.

Temperature and reflectance measurements were obtained from representative areas of the roof where the cool roof was clean and where airborne particulates had accumulated in numerous low puddle areas causing a darker gray appearance. The darker areas had higher temperatures and reduce reflectance. The formerly white, now somewhat gray, areas had lower temperatures and greater reflectance as measured in foot candles. The temperature measurements show qualitatively that the clean white roof surface is more effective at reducing the roof temperature than the areas obscured by surface deposits.

The retrofit was completed in August 2005.

This is the only measure in this application. The verification realization rate for this project is 0.19 (5,456 / 28,000), covering the conditioned area only. A verification summary is shown in Table 8 below.

Scope of the Impact Assessment

The impact assessment scope is for the cool roof end use measures in the SPC application covering the application of the acrylic cool roof coating. This is the only measure in this application.

Summary of Results

In 2004, all cool roof measures were itemized, and savings were calculated based on the workpapers. In 2005, when this application was submitted to SPC, a cool roof measure was included in the SPC calculator (however, the print out of the ex ante calculations from the SPC calculator were not included in the paperwork for this site.) The 2005 SPC calculator is the modeling tool that is used to calculate the ex ante and ex post savings for this site. As a check on the SPC calculator tool, savings for a different site in the SPC evaluation effort were also calculated using e-Quest/DOE 2.2, and the result is compared to the result from the SPC Calculator. The e-Quest/DOE 2.2 program has the limitation, however, that it does not model changes in infrared emittance. For many applications, this is acceptable because a black asphalt roof and cool roof products have high infrared emittance, usually about 90%, as is the case at this site. The savings calculated with e-Quest/DOE 2.2 agreed very well with the SPC calculator for that site, so it was not deemed necessary to use the e-Quest model at subsequent sites.

The radiative properties of the cool roof were determined by values listed in the Cool Roof Rating Council (CRRC) products directory. The CRRC administers a Rating Program under which companies can label roof surface products with radiative property values rated under a strict program administered by the CRRC. All radiative property testing is conducted by accredited testing laboratories. Solar reflectance can be measured in accordance with ASTM test methods C1549, E1918, E903 and CRRC-1 Method #1: Test Method for Certain Variegated Products. Thermal emittance is measured in accordance with ASTM C1371. For aged ratings, product samples are exposed for three years at the CRRC Approved Test Farm. Product ratings are verified periodically through the CRRC's Random Testing Program. The product used in this application, "Hidrocoat Platnum" manufactured by RoofCool Corporation, is listed with a solar reflectance of 0.86 and an infrared emittance of 0.89 in the CRRC directory.

The radiative properties of the pre retrofit roof surface were determined by values listed in the Cool Roofing Materials Database prepared by the Heat Island Project at Lawrence Berkeley National Laboratory. The properties of asphalt shingle roofs are determined by measurements taken at the Florida Solar Energy Center and at Lawrence Berkeley National Laboratory. The solar reflectance of 0.16 is an average of five measured values for varying colors of grey asphalt shingle. The infrared emittance was equal to 0.91 for all five roof colors.

Table 1: Physical Characteristics of Roofing Materials

	Grey Asphalt Shingle	Cool Roof
Solar Reflectivity	0.16	0.86
Infrared Emittance	0.91	0.89

The roof area was determined from roof dimensions measured with a measurement wheel to calculate gross floor area, and then subtracting the area for the HVAC equipment observed on the roof. The calculated roof area, 27,280 square feet, is somewhat smaller than the original ex ante roof area of 28,000 square feet given in the SPC application. The evaluation site visit revealed that only a portion of this roof covers air-conditioned space. The area of conditioned space was not measured, but comprises about 20% of the roof retrofitted in this measure. The uncertainty in this parameter is +/- 10%.

The model numbers of the HVAC equipment were recorded at the site visit, and were queried in the ARI Unitary Directory. Exact matches for the model numbers were not found, but systems were found that are believed to be in the same series yielding reasonable estimates of the EER of the cooling systems at this site. The EER ratings of the three systems can be found in Table 2. The average EER value of 9.6 is used in the calculation.

Table 2: Cooling Equipment Model Numbers

Model number of Unit on roof	Model number in ARI Directory	EER
Carrier 48TJD008---521GA	Carrier 48TJD02457/67	8.6
BDP 655ANX066000AAAG	Bryant 538ANX036-B	11.0
Nordyne R4GA-036K072X	Gibson GR4GA-036C072(C,X)	9.3
Average		**9.6**

The roof was observed to have no insulation, but it did have a radiant barrier. This should have disqualified the project from the program, according to the 2005 SPC Program Guidelines. The existence of the radiant barrier decreases the savings from the cool roof, however there is very little literature available to quantify the savings reduction. Hashem Akbari of the Lawrence Berkeley National Laboratory Heat Islands Group stated (personal communication 10/5/07) that he had used Micropass to analyze the effect of radiant barriers in residential applications on cool roof performance, and had found that they could degrade the savings by up to 50%. The SPC calculator does not take account of any radiant barrier effects on savings since these buildings are normally excluded from the program. The ex post savings calculations exclude the effect of the radiant barrier.

The input and output values used in and generated by the SPC Calculator for this cool roof are shown in Table 3.

Table 3: Ex Post Results of SPC Calculator

SPC Calculator - Ex Post		
	Baseline	Cool Roof
Solar Reflectance	0.16	0.86
Infrared Emmittance	0.91	0.89
EER	9.6	9.6
R-value	5	5
Net Roof Area	5,456	5,456
CA Climate Zone	9	9
Space Cooling (kWh)	8,701	1,926
Savings (kWh)	6,775	

The paperwork for this site did not include the input values to the SPC calculator. The ex post savings calculated with the 2005 SPC Calculator (6,775 kWh/year) are 59% lower than the reported ex ante savings (13,336 kWh/year). The difference is primarily due to the decreased floor area in the ex post calculations. The savings may still be overstated because the solar reflectance and infrared emittance values used in the calculation refer to a newly installed cool roof, whereas the roof at this location showed some degradation.

It has been noted that the installation of the cool roof application was in mid 2005. By the inspection in September 2007 significant "graying" of the white roof surface had occurred during the intervening two years of weathering. Air born sediments had accumulated on the white surfaces of the roof turning the brilliant white to a light gray color at the higher areas and to darker shades of gray in the lower areas where puddles form on the roof after a rain. This effect diminishes the reflective properties of the installation and increases the surface temperature of the roof.

Table 4 summarizes the total metered use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers. The total meter annual kWh is from the 2004 year. The baseline use is calculated as 30% of the total electricity use for the facility; the percent dedicated to other uses assumes 40% for lighting and 30% for air conditioning equipment. The total meter peak demand is not applicable for this site. There are no results for peak period kW demand savings because the SPC calculator does not calculate these savings due to the cycling nature of the AC equipment.

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results show energy savings ranging from 1.0 % to 3.2%. The predicted savings were a very small portion of the total energy use and the baseline end use for this site. The ex post results for the cool roof show smaller savings ranging from 0.5% to 1.6%.

Table 4: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	-	1,389,205
Baseline End Use	-	416,762
Ex ante Savings	0.0	13,336
Ex Post Savings	0.0	6,775

Table 5: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	N/A	1.0%	N/A	0.5%
Baseline End Use %	N/A	3.2%	N/A	1.6%

6. Additional Evaluation Findings

The building manager noted that the cool roof was implemented due to concerns regarding water-tightness and for enhanced extended roof life more than for energy savings. Installation costs appear to be realistic.

It does not appear that participation in the SPC program stimulated involvement in other energy efficiency efforts or programs.

7. Impact Results

The pre-retrofit roof type was not able to be physically verified. However, the facility representative was very knowledgeable about the pre-existing roof, and was able to characterize its characteristics sufficiently for the needed analysis. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $48,790 and a $1,067 incentive, the project had a 27.53 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is smaller than the ex ante, and the estimated simple payback is 54.18 years. A summary of the economic parameters for the project is shown in Table 6.

Table 6: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	9/8/2005	$48,790	-	13,336	0	$1,734	$1,067	27.53	28.14
SPC Program Review (Ex Post)	9/26/2007	$48,790	-	6,775	0	$881	$1,067	54.18	55.40

The engineering realization rate for this application is 0.51 for energy savings. According to the installation report, the ex ante savings are 13,336 kWh annually and demand reduction is not calculated because of the cycling nature of air conditioning equipment. A summary of the realization rate is shown in Table 7.

Table 7: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	-	13,336	-
SPC Installation Report (ex ante)	-	13,336	-
Impact Evaluation (ex post)	-	6,775	-
Engineering Realization Rate	-	0.51	NA

1. Tracking System values used for realization rate calculations.

The Installation Verification Summary is shown in Table 8.

The savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 9.

Table 8: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Installation of a Cool Roof	O- Other			Installation of a Cool Roof using SPC calculator	5456 ft^2	Cool Roof	Physically verified cool roof type and area.	0.19

Table 9: Multi Year Reporting Table

Program ID Program Name		SPC 2004 Application # A091 2004 – 2005 SPC Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	4,445	2,258				
3	2006	13,336	6,775	-	-		
4	2007	13,336	6,775	-	-		
5	2008	13,336	6,775	-	-		
6	2009	13,336	6,775	-	-		
7	2010	13,336	6,775	-	-		
8	2011	13,336	6,775	-	-		
9	2012	13,336	6,775	-	-		
10	2013	13,336	6,775	-	-		
11	2014	13,336	6,775	-	-		
12	2015	13,336	6,775	-	-		
13	2016	13,336	6,775	-	-		
14	2017	13,336	6,775	-	-		
15	2018	13,336	6,775	-	-		
16	2019	13,336	6,775	-	-		
17	2020	8,891	4,517	-	-		
18	2021						
19	2022						
20	2023						
TOT	**2004-2023**	200,040	101,625				

Final Site Report

SITE A092 (2004-xxx) Dair IMPACT EVALUATION
SAMPLE CELL: TIER: 3 END USE: AC&R

Measure	Ice Builder Retrofit System
Site Description	Dairy Creamery

1. Measure Description

This measure is composed of several sub-measures, which are designed to improve the operation of an existing ice building system, resulting in reduced run-time on the facility's chillers and chilled water plant. The 7 sub-measures listed in the application are:

1. Install ice thickness monitoring system in the ice banks.
2. Repair agitators in the ice bank to allow proper and uniform ice formation around the coils.
3. Install automatic control valves (On/Off) on the refrigerant liquid side of each coil to shut off flow to liquid ammonia to the coils when the correct thickness of ice has been reached at each coil.
4. Install modulating controls and pressure sensors on the gas discharge side of each coil to control the ice burn rate.
5. Install HOA (Hand-Off-Automatic) switches and controls on the pumps, along with differential pressure sensors across supply and return headers so that the chilled water pumps can be shut off when not needed.
6. Monitor the condenser head pressure so that condenser fans can be shut off when the head pressure is below the setpoint
7. Insulate refrigerant lines.

The post-installation inspection report also lists these additional items that were completed:

8. Insulate chilled water lines.
9. Install or modify PLC controllers: Each of the two existing compressors is provided with a dedicated stand-alone PLC controller. Compressor staging is managed by its corresponding PLC based on pressure difference generated by the automatic valve control system regulating the ammonia flow through the coil.
10. Install new stand-alone controller to control ice production, pumps and agitator sequencing, and refrigerant rate through coils.

2. Summary of the Ex Ante Calculations

The ex ante calculation for the project is a two page hand calculation that generally calculates reduced daily run hours for the two compressors and other equipment as a result of implementing the project.

The baseline usage was estimated by calculating the kW required to run both compressors, evaporative condenser fans, and a condenser water pump. Baseline runtime was assumed to be that everything must run in the existing case for 24 hours in order to maintain the proper temperature. The calculations, do, however, use an 82% diversity factor in calculating the baseline usage. The compressors are stated to be 205 tons and 326.5 bhp each, each with a 3-hp oil pump. The combined horsepower including the oil pumps is 659 hp, which was converted to kW by multiplying by 0.746 kW/hp to obtain 491.6 kW. The total heat rejection supplied by the evaporative condenser is calculated to be 8,820 MBH, which is stated as exactly equal to the heat rejection of an Evapco Model 600. It appears that, for this condenser, the horsepower of the two fans are 20-hp and 10-hp, and the water pump is stated to be 7½-hp. These three loads are added together to get 37.5 hp, which is converted to 27.98 kW by multiplying by the 0.746 kW/hp conversion factor. The two kW demands are added together to get a total baseline demand of 519.6 kW.

The existing (baseline) usage is calculated using the following formula:

Total kWh/year = 519.6 kW x 24 hrs/day x 365 days/yr x 0.82 diversity factor

= **3,732,391 kWh/yr**.

The proposed usage was estimated using a calculated number of reduced daily hours of plant operation, which is 14.63 hrs/day. The two equations listed in the calculation that equal that number are as follows:

Plant Load – 250 ton-hrs x 24 hours = 6,000 tons.
6,000 tons / 410 tons-hrs = 14.63 hours

It is believed that the way this is stated is not correct, the intent was something more like this:

Plant Load – 250 tons x 24 hours = 6,000 ton-hours.
6,000 ton-hours / 410 tons = **14.63 hours**

The post retrofit usage was then calculated using the following equation:

Total kWh/year = 519.6 kW x 14.75 hrs/day x 365 days/yr =
= **2,797,397 kWh**

Even though 14.63 hours was calculated as the expected run-hours per day for the compressors the annual kWh calculation used 14.75, most likely as an attempt to round the hours to the nearest quarter hour. This adds conservatism to the calculation of annual savings.

The total annual savings were calculated as:

kWh/year Savings = 3,732,391 kWh – 2,797,397 kWh =
= **934,994 kWh**

kW savings = 519.6, as the entire load is expected to be able to be shifted to off peak hours.

This number is the ex ante savings figure identified in the IRR and in the utility tracking system (except that the kW savings was rounded to 519.0 in the utility tracking system).

The incentive was capped at $59,939 (50% of the project costs). The project costs were reportedly supported by invoices provided upon request by the utility and were not included in the application paperwork.

3. Comments on the Ex Ante Calculations

The first issue to note is that the way the post-retrofit hours were calculated seems at odds with the parameters that are listed above, although the final result may be valid. For the ex ante savings to be correct, the 250 ton value as the continuous plant load would have to be confirmed. The 410 tons used as the denominator in the second equation is equal to the combined capacity of two 205 ton compressors (and not 1,100 tons).

The pre-installation report indicates that each of these compressors is rated at 1,100 tons, although there is no mention of this anywhere else in the information packet. The post-installation report states that they are 400-hp screw ammonia compressors. For an approximate kW of 350 (using the 326.5 bhp listed in the calculation and a 93% efficient motor), the efficiency for 1,100-ton compressors would be ~0.3 kW/ton. This is very unlikely given that these are 25 year old compressors. The 205 ton capacity per compressor seems to be a more valid value.

Another issue is the continuous plant load. It appears that a value of 250 tons was used. The pre-installation report describes that in a typical 24 hour day, the plant runs for 20 hours and the remaining 4 hours are reserved for cleaning in place (CIP). It goes on to say that during the CIP cycle, the process loads are minimal, and that during those times the demand on the process cooling is also reduced. It is not understood if the 250 tons of average plant load takes into account this 4 hours of reduced load.

It is not clear that if the hourly load is 250 tons, why two 205 ton compressors would need to run at full capacity all the time in the base case since this combined capacity of 410 tons is much greater than required. In the post case, when the hours needed to charge the ice builder system are calculated, the full 410 tons of capacity is used to calculate the 14.63 required hours.

Another item that causes some confusion is the sub-measure to repair the agitators in the ice bank. The reason given for this is to allow proper and uniform ice formation around the coils. This makes sense. However, in the post installation inspection report, it states that “the new control system limits the agitators to work only during the chilled-water discharge mode. During the ice-making mode, the agitators are disabled.” This does not make sense if the purpose of the agitators is to assure proper ice formation.

The kW savings calculated and claimed are 519.6 kW. According to the calculation, this is based on the fact that the post case compressors will not run during the on-peak hours, but they will run during the off peak hours to build the ice. The calculation claims 0 kW for the post retrofit kW, so it would appear that the kW savings are not really savings, but rather a kW shift to the off-peak period.

The calculation only addresses electrical usage of the compressors, the condenser fans, and condenser water pump. It does not address energy usage of the 5 chilled water pumps, each rated at 25-hp. It is stated that before the project these pumps all run all the time, but that after the project some of these pumps could be shut down based on a differential pressure across the supply and return. An example of this would be during the cleaning time when the process demand is lowered. Savings associated with turning off these pumps are not calculated.

The way some of the kW values are calculated leads to some inaccuracy by using the 0.746kW/hp conversion factor without accounting for the actual brake horsepower (Bhp) and motor efficiency.

4. Measurement & Verification Plan

The goal of the measurement and verification (M&V) plan is to estimate the actual peak kW and actual annual kWh reduction of the refrigerant compressors and supporting equipment, through quantifying hours of operation and energy use during these hours. over the useful life of the equipment.

This site is a large dairy creamery. There are a total of four plants (Plants 1, 2, 3, and 4) which process an estimated 13 million gallons per day of milk. The other products are butter, cheese, and dry milk powder. Of the four plants, only plants 1 and 2 are impacted by the proposed retrofit of the process cooling system.

According to the pre-installation inspection report, the plant runs on a 24x7 schedule throughout the year. As mentioned above, it also states that in a typical 24 hour day, 20 hours are reserved for processing dairy products and 4 hours are reserved for cleaning in place, during which time the process loads and the process cooling loads are reduced.

Chilled water flow is apparently provided by five 25-hp chilled water pumps, supplying chilled water at 34ºF, returning at 42ºF. These pumps are stated to operate all the time in the pre-retrofit condition. The system has two ice banks. The original intent of the system was to build ice in the off-peak hours and then utilize the ice during peak hours. The chilled water is produced by two 1982 MyComp ammonia compressors, believed to be 205 tons each (the pre-inspection report says they are 1,100 tons each).

Each ice bank has an overall dimension of 10' H x 11' W x 40' L. Each bank has two coils through which liquid ammonia evaporates to provide the cooling effect for ice generation. Prior to the implementation of the project, inadequate or improper controls within the ice banks made it difficult to control ice production optimally. The measures described in the first section were implemented to alleviate these problems.

Formulae and Approach

The M&V plan proposed is a modified version of IPMVP Option A.

The operating hours and the demand will be measured to determine the new electrical kWh usage. The equipment to be evaluated will be the two compressors, the chilled water pumps, and the condenser fans.

The proposed data collection will be continuous amperage measurement of the two compressor motors, the run time of the five chilled water pump motors and the run time of the four condenser/tower fan motors with portable datalogging equipment for the duration of the monitoring period. Spot voltage measurements will be taken at each motor during the site visit as well as spot amperage measurements of the motors for which only the run time will be monitored.

During discussion with the customer on the phone it was determined that plant load is not weather dependent. Based on the information provided, it appears that the main variable affecting the plant load is whether they are in process or cleaning mode. Any other variables affecting the load will need to be ascertained with the customer.

Data will be collected for two weeks. This data will be extrapolated to a full year, based on what variables are identified that may cause the load to change and need to be accounted.

The baseline usage calculation will be adjusted based on information obtained from the customer that is different from the assumptions listed in the calculation.

The greatest uncertainties in the ex ante savings estimate are the pre-retrofit operating hours of the compressors, whether they both in fact operated 24/7, and the post retrofit compressor operating hours. The base case operation can only be pinpointed through mostly anecdotal information provided by the customer. The post-retrofit operation can be established through the M&V data collection described herein.

All measures within the application will be verified for completeness.

The above approach will require the following data collection and verification:

Data Element	Proposed Means of Collecting Data
Base case equipment configuration	Confirm via customer interview and review of customer records.
Base case compressor duty	Confirm via customer records of compressor capacity rating. Interview customer to determine pre-retrofit control strategy.
Base case system operating hours	Confirm via customer interview and review of customer records the planned maintenance schedule for each compressor, fan and pump.
Base case control scheme	Confirm via customer records and interview, pre-retrofit compressor control. Verify manual start/stop vs auto lead-lag.
Post case compressor duty	Obtain two weeks of hourly (or more frequently) amperage data for each of the two MyComp compressors.
Post case equipment configuration	Confirm via site survey, customer interview, and review of customer records. Obtain manufacturers' data sheets for equipment and equipment nameplate information. Review control settings and sequence of operation for compressor and pump staging.
Post case system operating hours	Confirm via customer interview and review of customer records and the planned maintenance schedule for each compressor and pump.
Post case pump and fan data	Obtain two weeks of hourly (or more frequently) run time data for the five chilled water pumps and the condenser fans.

Uncertainty is estimated to be ±10% for aggregate kW and ±20% for hours

Accuracy and Equipment

A Fluke 321 Clamp Meter with accuracy for amperage of 3% and for voltage of 1.2% will be used

Power/Amps (Dent Model 4C Loggers) have an accuracy of ±1%, exclusive of sensor accuracy; the current transformers have an accuracy of ±2.5%

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 18, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the plant equipment and by interviewing the facility representative. Datalogging equipment was installed on the two compressors to record amperage and runtime loggers were installed on the two condenser fans and the five chilled water pumps from September 18 through October 9, 2007. In addition, spot voltage and amperage readings were taken on all equipment.

Installation Verification

The installation of equipment as described in the post installation report was physically verified to the extent practical. The immersion probes that monitor ice thickness were seen on the top of the ice banks. The customer opened the top of the tank so that the ice formation could be felt. This was to demonstrate the proper operation of the repaired agitators in ensuring proper and uniform ice formation around the coils. The customer did confirm that the agitators operate during ice-making mode, not during discharge mode. The stand alone controller that controls ice production, pump and agitator sequencing, and ammonia flow through the coils and its display panel was viewed. All refrigerant and chilled water lines appeared to be insulated. The verification rate is 1.00 for this measure as shown in Table 7.

Scope of the Impact Assessment

The impact assessment scope is for the ice builder retrofit end use measure in the SPC application. As discussed in Section 2 above, the ex-ante calculations determined a reduced runtime on the compressors and condenser fans (also included oil pump and water pump which are much smaller loads). The pre-inspection report stated that the addition of the system controls would allow for the reduction of chilled water pump usage from the constant operation of all five pumps. No savings for this were part of the ex ante calculations. Run time loggers were installed on all five pumps to ascertain whether any savings had resulted.

Summary of Results

Two (2) Dent Model 4C amp loggers were installed on each of the two compressors for 21 days (from September 18, 2007-October 9, 2007) to measure the amps at 15 minute intervals and calculate the power demand of the compressors. During the site inspection, spot voltage readings (line to line and line to ground) were taken on each compressor using a Fluke 321 clamp meter. In addition, two (2) Dent Maglogger run time loggers were installed on each of the two condenser fan motors for the same period. Finally, five (5) Dent Maglogger run time loggers were installed on each of the five chilled water pumps. Spot voltage and amperage measurements were taken at the time of logger installation on the condenser fans and chilled water pumps.

The ex ante calculations were based on the two compressors each running a maximum of 14.75 hours/day. The system is actually being operated such that compressor 10 runs almost constantly and compressor 11 cycles as needed. The datalogging of these two compressors showed that compressor 10 ran 96.8% of the time during the datalogging period; compressor 11 ran 39.4% of the time. To determine the kW associated with each amperage reading, the line-to-line spot voltage measurements were averaged, and a power factor (PF) of 0.8 was assumed. The kW was calculated using the following formula for each data point:

$$kW = Amps \times Volts \times PF \times 1.732 / 1000$$

For each compressor, a maximum kW and an average kW were determined, and for compressor 11 an average running kW was also determined, since this unit is off more than it is on. These values are shown in Table 1.

Table 1: Compressor Electrical Demand Values

Compressor	Maximum kW	Average kW	Average On kW
#10	317.9	262.1	
#11	290.1	72.1	183.0

According to the customer, there is no seasonal variation in the load, because it is all process, but the weather can affect the system performance. It is assumed that since the datalogging was performed in the early fall that the recorded data should provide a good representation of the yearlong seasonal variation, as a good midpoint between the heat of summer and the cold of winter.

For compressor 10, the annual kWh usage was calculated by multiplying the average kW recorded, 262.1, by 8,760 hours, to obtain an annual usage of 2,296,200 kWh. For compressor 11, the kWh usage was calculated by multiplying the average running kW recorded, 183.0, by 8,760 hours and by the recorded percentage on time, 39.4%, to obtain an annual usage of 631,641 kWh. Mathematically these two calculations are the same; the alternative presentation of the compressor 11 kWh calculation was to better represent the cyclic nature of the compressor's operation.

For the condenser fans, a spot measurement of the amperage and voltage was taken and used to calculate a kW demand assuming a 0.9 power factor. The kWh usage was calculated by multiplying the calculated kW by 8,760 hours and by the recorded percentage on time to obtain an annual kWh usage. These values are shown in Table 2.

Table 2: Condenser Fan Electrical Demand & Usage Values

Condenser Fan*	Measured Amps	Calculated kW	Percent On Time	Calculated kWh/yr
#1	18.2	13.5	61.3%	72,563
#2	13.1	9.8	88.4%	75,547

* Each Condenser actually has two fans that are driven by one motor. In this Table and the discussion that follows, a reference to Condenser Fan #1 will actually refer to the motor that serves the two fans on Condenser #1; same applies for Condenser #2.

The run time on the chilled water pumps was recorded, as well as spot voltage and amperage readings taken. The chilled water pumps are basically running all the time, as shown by the percent-on times shown in Table 3. So it appears that the implementation of the project has not caused a change in chilled water pump operation, so no further evaluation of chilled water pumps was performed.

Table 3: Chilled Water Pump Runtimes

Chilled Water Pump	Percent On Time
#1	99.9%
#2	99.9%
#3	99.9%
#4	98.5%
#5	99.9%

The baseline kW and kWh were re-calculated, since the ex ante savings were based on estimated, not measured, kW values.

The baseline kWh values were adjusted based on current operation vs. the baseline constant operation. For compressor 10 the calculated annual post kWh was divided by the current percent runtime to determine the baseline kWh for that compressor. For compressor 11, the measured average on kW was multiplied by 8,760 to determine the baseline kWh for that compressor. For condenser fan 2, no adjustment was made because it operated significantly more than the other condenser fan. Condenser fan 1 was adjusted by multiplying the calculated kW by the run time percentage of condenser 2 and by 8,760; in this way the run time on condenser 1 was adjusted to match the run time of condenser 2. This was done because currently compressor 10 is operating a high percentage of the time (96.8%) and the condenser it is tied to, condenser 2, operated 88% of the time. If in the baseline case the other compressor, #11, operated a high percentage of the time, 95-100% as described above, it logically follows that the condenser tied to it, #1, would have a run time percentage similar to #2.

The baseline kW values for the compressors were adjusted by taking the maximum calculated kW and calling that the baseline kW for each unit. In this way the maximum kW values were compared to the average calculated kW values to establish a kW reduction. This approach assumes that the compressors will operate at their maximum value much less as a result of the project. For the condenser fans, it was assumed that the kW demand before and after the project will be the same, no kW savings were claimed for this equipment. See the discussion below in Section 6 regarding the ex ante demand savings.

The ex post impacts are shown as follows:

Table 4A: Ex Post Annual Savings Summary

System Component	Baseline		Post Retrofit		Savings	
	kW	kWh/yr	kW	kWh/yr	kW	kWh/yr
Compressor 10	282.6	2,108,090	233.0	2,041,067		
Compressor 11	257.9	1,425,242	162.7	561,459		
Cond Fan 1	13.5	104,593	13.5	72,563		
Cond Fan 2	9.8	75,547	9.8	75,547		
Total	563.8	3,713,472	419.0	2,750,636	144.8	962,836

Table 4B: Multi Year Reporting Summary

Program Name:		SPC 04-05 Evaluation A092					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004	155,832	160,473				
2	2005	934,994	962,836	520	145		
3	2006	934,994	962,836	520	145		
4	2007	934,994	962,836	520	145		
5	2008	934,994	962,836	520	145		
6	2009	934,994	962,836	520	145		
7	2010	934,994	962,836	520	145		
8	2011	934,994	962,836	520	145		
9	2012	934,994	962,836	520	145		
10	2013	934,994	962,836	520	145		
11	2014	934,994	962,836	520	145		
12	2015	934,994	962,836	520	145		
13	2016	934,994	962,836	520	145		
14	2017	934,994	962,836	520	145		
15	2018	934,994	962,836	520	145		
16	2019	779,162	802,363	520	145		
17	2020						
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	14,024,910	14,442,540				

The engineering realization rate for this application is 0.28 for demand kW reduction and 1.03 for kWh energy savings. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 6.

6. Additional Evaluation Findings

The ex post energy savings are greater than the ex ante due to the ex post savings using a calculated average kW for the affected equipment and elimination of the assumed 82% diversity factor. The ex post kW demand reduction is less than the ex ante estimate because the ex ante estimate appears to have looked at the project as a load shift in which none of the equipment would by required to operate during peak period. This is clearly not the way the plant is being operated. Even if it was being operated as claimed, the demand savings as calculated in the ex ante approach are not a savings, but rather a load shift.

With a cost of $119,877 and a $59,939 incentive, the project had a 0.5 year simple payback based on the ex ante calculation of annual savings. The annual ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is revised to 0.4 years. A summary of the economic parameters for the project is shown in Table 5.

The project has resulted in increased energy awareness at the site and they have implemented other energy projects. These include installing a heat recovery system on their boilers and replacing an electric air compressor with a steam powered air compressor. They are also considering a possible HID lighting conversion in one of their buildings.

Additionally, the customer has made additional changes to the ice builder/chilled water system operation that were completed on Friday, Nov 16, 2007. These changes were all started after monitoring was complete and thus are not accounted for in the ex-post evaluation. The main changes were to remove evaporator 6 from ice bank system service, and instead use it to serve what they call the glycol system (which is a separate refrigeration and compressor cycle), and VFD's have been added to the condenser fans. These changes have allowed them to shut down both compressors and associated condenser fans and pumps for 8 hours a day (during monitoring compressor 10 ran 24/7) from 8 am-4 pm. The customer believes that even with that load added to the other system it is overall more efficient. The customer also says that the VFDs on the condenser fans have reduced the head pressure on the refrigeration system, and as a result the running amps on the compressors are now lower.

7. Impact Results

Table 5: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	11/8/2004	$119,877	519.6	934,994	0	$121,549	$59,939	0.5	1.0
SPC Program Review (Ex Post)	11/19/2007	$119,877	144.8	962,836	0	$125,169	$59,939	0.5	1.0

Table 6: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	519.6	934,994	-
SPC Installation Report (ex ante)	519.6	934,994	-
Impact Evaluation (ex post)	144.8	962,836	-
Engineering Realization Rate	0.28	1.03	NA

Table 7: Verification Table

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
ICE BUILDER RETROFIT	A	This measure is composed of several sub-measures, which are designed to improve the operation of the ice building system, which will result in reduced run-time on the facility's chillers and chilled water plant.			N/A	The affected equipment is two Mycom 216 ton 400 HP ammonia screw compressors and their associated evaporatively cooled condensers. The run time on this equipment is to be reduced due to the equipment installed as part of the ice builder retrofit project.	To the extent possible physically verified equipment described in the post intallation report. Much of the new equipment installed is integral to the ice bank system or computer/software based, so physical verificaton is not possible.	1.15

May be an "Other" end use category measure, even though affecting refrigeration system, since this measure mainly involves controls.

Table 8: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	9,974	85,888,977
Baseline End Use	563.8	3,713,472
Ex ante Savings	519.6	934,994
Ex Post Savings	144.8	962,836

Table 9: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	5.2%	1.1%	1.5%	1.1%
Baseline End Use %	92.2%	25.2%	25.7%	25.9%

Final Site Report

SITE A093 (04-0137) Albe2 IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: Other

Measure	Refrigeration Control Upgrade
Site Description	Refrigerated Warehouse

1. Measure Description

This project in a refrigerated distribution warehouse facility included the addition of refrigeration controls, control programming, and installation of premium-efficiency motors on one condenser unit. The four principal strategies implemented included:

- EEM1 - Floating Head Pressure Control: A wet bulb approach differential temperature control strategy was implemented to control four water-cooled condenser fans.
- EEM2 - Evaporator Fan Control: A temperature-based evaporator fan cycling strategy was implemented (supplanting continuous operation).
- EEM3 - Floating Suction Pressure and Compressor Integration: A suction pressure control strategy was implemented to reduce compressor loading and evaporator fan run time. An optimized compressor sequencing strategy was implemented for the medium pressure compressor group.
- EEM4 - Premium Efficiency Motors: New premium efficiency motors were installed on one 15-hp fan and one 7.5-hp pump in one evaporative condenser.

2. Summary of the Ex Ante Calculations

The ex ante calculations for the control upgrade were based on an annual hourly load/performance model (DOE2 based) developed by the project sponsor. The preliminary savings estimates and the final savings and incentive amount after the SCE post-installation review are shown in Table 1.

Table 1: Summary of Ex Ante Impact Estimates for A093

EEM	Description	Scope	Sponsor Initial		SCE Review	
			kWh	Peak kW	kWh	Peak kW
EEM1A	Floating Head Pressure Control - Hardware	(3) 15-hp VFDs; (1) 7.5-hp VFD;(1) 5-hp VFD; digital control hardware totaling 56 points; New Dell computer; Interface hardware	140,054	2.5		
EEM1B	Floating Head Pressure Control - Controls	Programming 10 digital input points, 18 digital outputs; 2 analog inputs; and 5 analog outputs.	140,054	2.5		
EEM2	Air Unit Evaporator Fan Cycling	Programming existing controls	446,492	33		
EEM3	Floating Suction Pressure and Compressor Integration	Programming EEM1 controls	179,395	-40		
EEM4	Premium Efficiency Motors on Condenser	15-hp and 7.5-hp condenser fan motors replaced.	22,587	5		
Individual ECMs calculated separately			928,582	3		
ECMs 1-4 combined [1]			**927,064**	**50**	**893,093**	**36**
1 - The "combined" impacts were proposed as the basis for the incentives. The file does not provide an explanation of the minor kWh discrepancy between total for the "ECMs calculated Separately" and ECMs 1-4 combined. Although the kW discrepancy is significant, it was not material to the incentive so the differences were not explained in the preliminary report.						
(2) The kWh and peak kW impacts were adjusted downward slightly based on the post-installation inspection and impact estimate review. The review inspection revealed a minor discrepancy in the fan kW used in EEM4 savings estimate. It also revealed that the banana room fans (15 kW of the total 105 kW or 14% of the kW) were not being cycled as was anticipated in the initial analysis.						
Total Project Cost verified by the reviewer was $146,294.						

Summary of Pre- and Post- installation Site Observations

The pre and post installation savings reviews and site visits were conducted on 4/2/04. The pre-installation site observations verified the site equipment and pre-installation control strategies to the degree that the strategies were observable. The basic refrigeration system and equipment were found to match the model inputs with a couple of small discrepancies (described in the following paragraph). The VFDs, the control points, and the control strategies for EEMs 1 and 2 were not in place prior to the retrofit. Although the control points were in place for EEM 3 and EEM 4, the software necessary to implement the control strategies for EEMs 3 and 4 was not in place. Also, neither floating head pressure control nor optimal compressor sequencing was programmed prior to the project.

The post installation inspection file included photographs of the control screens that were installed to allow management of the new control strategies. The post-installation file and site review and associated interviews identified three small discrepancies between the input file for the savings estimates and what was observed on site. These include the following:

- The banana room evaporator fans are not cycled by the system as originally anticipated
- The actual kW for the pre-retrofit and post-retrofit banana room evaporator fans differed slightly from the values used in the model
- The banana room fan supply flow differed from the modeled values

These discrepancies were reported to the sponsor who re-ran the model to adjust the savings. The initial savings estimates were reduced by 34,157 kWh to 893,093 kWh and by 14 kW to 36 kW based on the revised inputs.

3. Comments on the Ex Ante Calculations

The ex ante savings estimate calculations were performed using a DOE2 simulation model. Based on a review of the printed summary of the DOE2 input and output files and the post-installation review comments, we believe that the DOE model was thorough and reflected the system operation and performance adequately, as adjusted subject to the small discrepancies that were identified in the post-installation site inspection and file review.

Note that the measure is listed in the utility tacking system as an AC&R (HVCAR) measure. The correct end use category is ‘Other’ (previously ‘Process Other’ or ‘P’).

4. Measurement & Verification Plan

The goal of the measurement and verification (M&V) plan is to document the first year ex-post annual kWh and peak kW reduction for the project, and to estimate the degree of certainty of those values given the precision of the data available.

Formulae and Approach

A whole-building billing analysis methodology (IPMVP Option C) was utilized. The total kWh consumption for 24 billing periods prior to the project installation and 24 periods after installation were compared. The billing periods compared did not include the period during which the installation was completed or the month immediately after to allow for adjustments and programming. The average pre-retrofit and post-retrofit kWh per day for each billing month during the corresponding pre- and post- periods were calculated. The annual kWh/year savings was calculated by multiplying the difference in kWh/day by 365 days as follows:

$$AnnualkWhSavings = \left[\frac{\sum_{x=1}^{x=24} kWh_x}{\sum_{x=1}^{x=24} BillingDays_x} - \frac{\sum_{y=1}^{y=24} kWh_y}{\sum_{y=1}^{y=24} BillingDays_y} \right] \times 365 Days / yr$$

Where x represent the 24 billing periods prior to the project and y represent the 24 billing periods following the project.

Accuracy and Equipment

SCE revenue meter data will be used. If necessary, NOAA weather data will be used to normalize the results. These sources are expected to be >98% accurate. No on-site measurement equipment is expected to be used. Site verifications involved control system observation data and interviews.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

Pre- and post-retrofit electric bills were obtained from SCE. Weather data for local area conditions was obtained from NOAA. The kWh and temperature data vs time are shown in Figure 1.

Figure 1: Monthly Temperature and kWh Data Plot

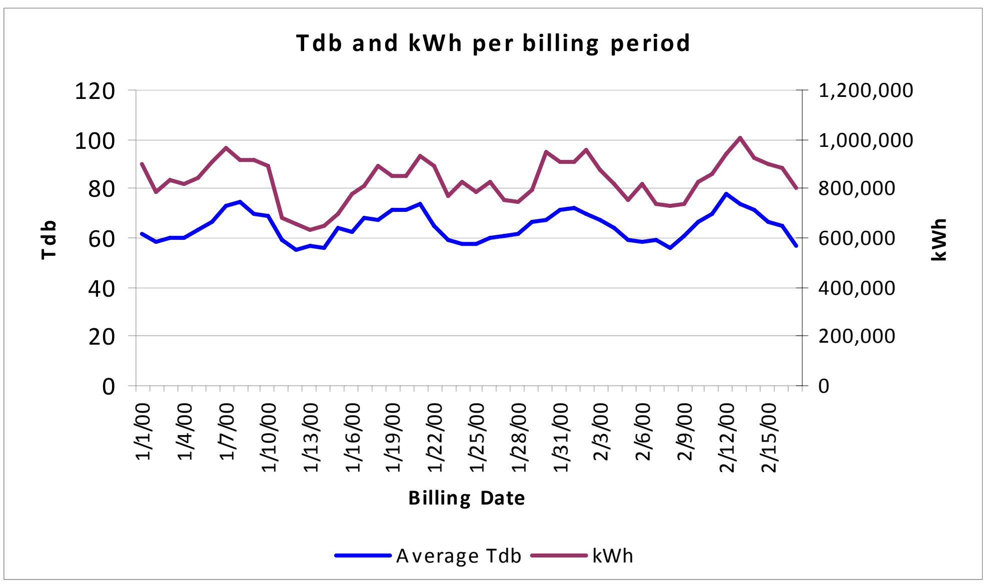


Table 2: Electricity Consumption, Days and Average Dry Bulb Temperature

Date	Bill Days	kWh	Date	Average Temp. (db Deg F)	Average kWh/day
1/22/03	33	899,488	1/22/03	61.4	27,257
2/21/03	30	789,984	2/21/03	58.0	26,333
3/24/03	31	835,684	3/24/03	60.1	26,958
4/22/03	29	815,760	4/22/03	59.6	28,130
5/21/03	29	840,272	5/21/03	63.1	28,975
6/20/03	30	910,984	6/20/03	66.1	30,366
7/22/03	32	964,956	7/22/03	73.2	30,155
8/20/03	29	917,596	8/20/03	74.3	31,641
9/19/03	30	918,420	9/19/03	70.1	30,614
10/21/03	32	891,372	10/21/03	69.1	27,855
11/20/03	30	677,428	11/20/03	59.4	22,581
12/22/03	32	652,876	12/22/03	55.2	20,402
1/22/04	31	634,428	1/22/04	56.4	20,465
2/23/04	32	652,528	2/23/04	55.6	20,392
3/23/04	29	700,644	3/23/04	64.3	24,160
4/21/04	29	781,804	4/21/04	62.7	26,959
5/20/04	29	811,928	5/20/04	68.3	27,998
6/21/04	32	889,436	6/21/04	67.6	27,795
7/21/04	30	850,828	7/21/04	71.7	28,361
8/19/04	29	852,540	8/19/04	71.1	29,398
9/20/04	32	935,740	9/20/04	73.5	29,242
10/21/04	31	887,940	10/21/04	65.0	28,643
11/19/04	29	771,432	11/19/04	59.3	26,601
12/21/04	32	828,000	12/21/04	57.4	25,875
1/21/05	31	786,084	1/21/05	57.6	25,358
2/22/05	32	828,736	2/22/05	59.6	25,898
3/23/05	29	750,956	3/23/05	60.5	25,895
4/21/05	29	747,712	4/21/05	61.9	25,783
5/20/05	29	794,972	5/20/05	66.3	27,413
6/21/05	32	947,720	6/21/05	67.6	29,616
7/21/05	30	905,348	7/21/05	71.3	30,178
8/19/05	29	909,724	8/19/05	72.5	31,370
9/20/05	32	955,512	9/20/05	70.0	29,860
10/21/05	31	876,044	10/21/05	67.0	28,259
11/21/05	31	822,692	11/21/05	64.2	26,538
12/21/05	30	757,636	12/21/05	59.2	25,255
1/23/06	33	815,168	1/23/06	58.4	24,702
2/22/06	30	741,380	2/22/06	59.1	24,713
3/23/06	29	727,480	3/23/06	56.2	25,086
4/21/06	29	736,772	4/21/06	60.9	25,406
5/22/06	31	824,504	5/22/06	66.3	26,597
6/21/06	30	855,472	6/21/06	70.0	28,516
7/21/06	30	942,980	7/21/06	78.0	31,433
8/21/06	31	1,001,640	8/21/06	73.6	32,311
9/20/06	30	924,504	9/20/06	71.4	30,817
10/20/06	30	899,336	10/20/06	66.3	29,978
11/20/06	31	881,636	11/20/06	64.6	28,440
12/20/06	30	800,572	12/20/06	57.1	26,686

Note – The project was completed on December 8, 2004.

The monthly kWh for 19 months prior to the project implementation date was plotted against the average dry bulb temperature for the period. (Five months of data prior to the project were not used as the kWh usage was abnormally low for uncertain reasons.) A second order polynomial curve and equation for the relationship was plotted using the Excel curve-fit tool. Similarly, kWh data for 24 post-retrofit months were also plotted against monthly average daily temperature. The pre- and post– project kWh/weather relationships are shown in Figure 2 and 3.

Figure 2: Pre Project Billing Period kWh, Days and Average Dry Bulb Temperature

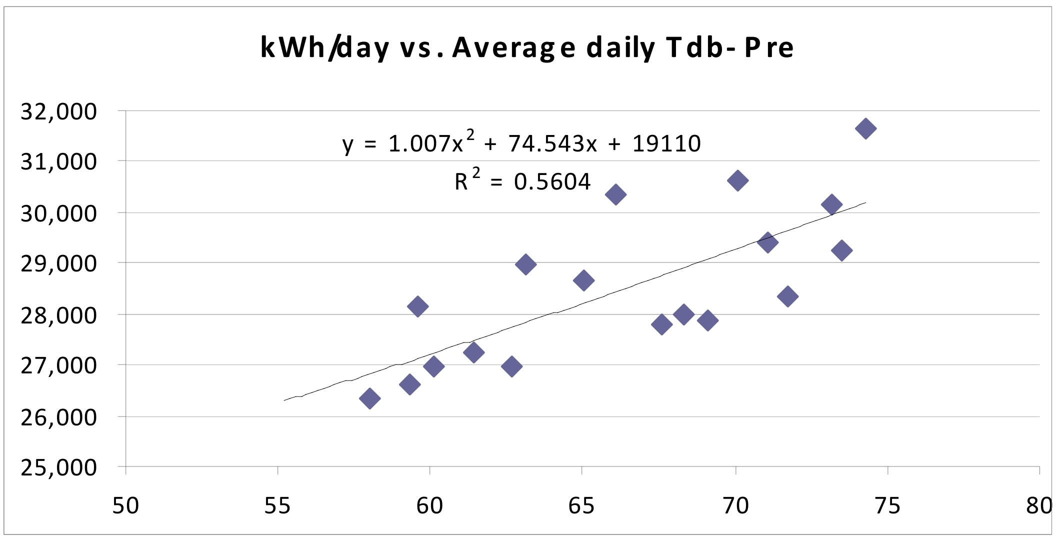
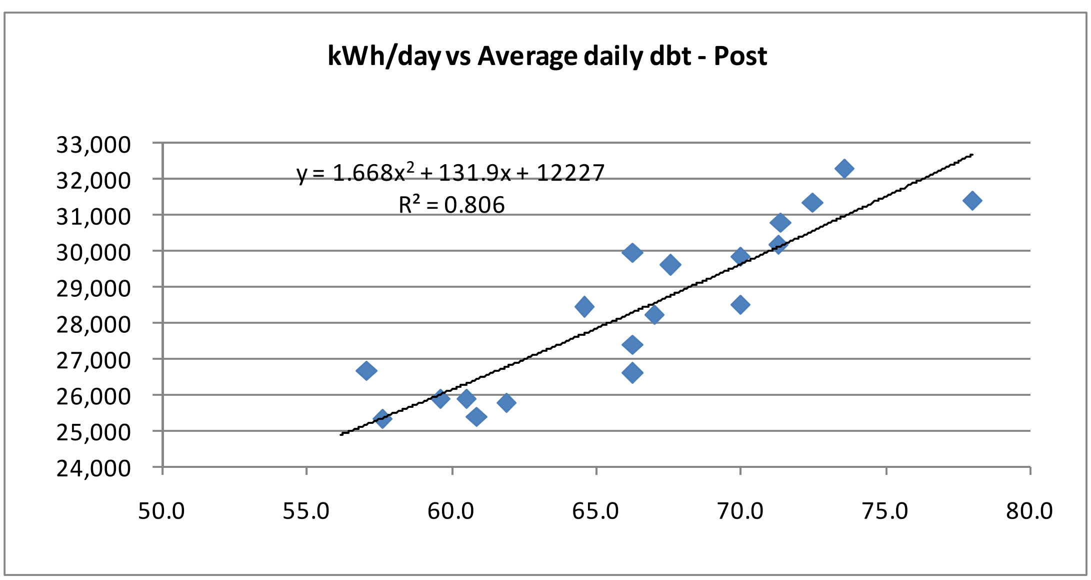


Figure 3: Post Project Billing Period kWh, Days and Average Dry Bulb Temperature



The results of this analysis are shown in Table 3.

Table 3: Summary of Results

Account TOU-8 3-011-4329-10 Read Date	Days	Calculated average daily kWh*	Calculated billing period kWh (kWh x days)	Post-Rretrofit kWh (from SCE bills)	kWh Savings
1/21/05	31	26,744	829,079	786,084	42,995
2/22/05	32	27,130	868,147	828,736	39,411
3/23/05	29	27,306	791,861	750,956	40,905
4/21/05	29	27,582	799,891	747,712	52,179
5/20/05	29	28,478	825,875	794,972	30,903
6/21/05	32	28,751	920,021	947,720	(27,699)
7/21/05	30	29,544	886,319	905,348	(19,029)
8/19/05	29	29,807	864,409	909,724	(45,315)
9/20/05	32	29,262	936,387	955,512	(19,125)
10/21/05	31	28,625	887,363	876,044	11,319
11/21/05	31	28,046	869,425	822,692	46,733
12/21/05	30	27,052	811,558	757,636	53,922
1/23/06	33	26,898	887,620	815,168	72,452
2/22/06	30	27,033	810,977	741,380	69,597
3/23/06	29	26,480	767,911	727,480	40,431
4/21/06	29	27,384	794,143	736,772	57,371
5/22/06	31	28,478	882,832	824,504	58,328
6/21/06	30	29,262	877,863	855,472	22,391
7/21/06	30	31,051	931,521	942,980	(11,459)
8/21/06	31	30,051	931,582	1,001,640	(70,058)
9/20/06	30	29,566	886,974	924,504	(37,530)
10/20/06	30	28,478	854,354	899,336	(44,982)
11/20/06	31	28,128	871,957	881,636	(9,679)
12/20/06	30	26,649	799,484	800,572	(1,088)
			Total (net) kWh Savings		352,975
			Total Days		729
			Annualized kWh Savings		176,730

*Where kWh = $1.007 * Tav^2 + 74.54 \times Tav + 19{,}110$

Using the results obtained in Table 3, the average kW impact was calculated as shown in Table 4.

Table 4: Average Peak Demand Impact

kW Impact			
	Summer Billing	Summer kWh	Avg. kW
2005	123	-111,168	-37.7
2006	121	-96,656	-33.3
Total/Avg.	244	-207,824	-35.5

6. Additional Evaluation Findings

The project sponsor was interviewed by telephone. The sponsor indicated that he had installed the control hardware and set up the programming but he was not given an opportunity to review the control settings or system operation or response since the installation. The sponsor claimed that interest and follow-up support from the plant engineering management and technical staff was limited.

The corporate energy management engineer, the chief operating engineer for the site and the facility refrigeration engineer were each interviewed as part of the site review. The project sponsor was also interviewed to identify any other conditions or factors related to energy use at the site that may have changed during the pre- to post-installation period. They were specifically asked whether any of the following had occurred during the two year period prior to, or since the SPC project.

- Changes in product throughput or character
- Changes in refrigeration temperature settings due to changes in products or operating standards
- Changes in activity (such as receiving and picking), or the duration and schedule of activities
- Any changes in refrigeration load that might have taken place (like the addition of flash freezing or other new equipment)

All agreed that other than the SPC project, there was no change in equipment, product throughput, operating schedule or procedures that would cause a change in energy use.

7. Impact Results

Tables 5 through 10 summarize the results of the impact analysis.

Table 5: Economic Summary

Description	Date	Project Cost	Estimated Demand Savings kW	Estimated Energy Savings kWh	Estimated Gas Savings therms	Estimated Annual Cost Savings ($0.13/kWh)	SPC incentive	Simple Payback w/incentive, years	Simple Payback w/o Incentive, years
Installation Approved Amount (ex ante)	12/8/04	$ 146,294	36	893,093	0	$116,102.09	$ 71,447.44	0.6	1.3
SPC Program Review (ex post)	11/1/07	$ 146,294	0	176,730	0	$ 22,974.90	$ 71,447.44	1.7	6.4

Table 6: Realization Rate Summary

	kW	kWh	therms
SPC Tracking System	36.0	893,093	0
SPC Installation Report (ex ante)	36.0	893,093	0
Impact Evaluation (ex post)	-35.5	176,730	0
Engineering Realization Rate	0%	20%	0

The principal explanation for the discrepancy between the ex ante estimate and the evaluation result is a difference in methodology and, we believe differences between the system performance projected in the model and the actual system operation. The ex ante estimates were based on a theoretical system performance model as embodied in DOE 2. The evaluation impacts were based on metered electricity energy use records as adjusted for weather differences. No other factors were identified that would be expected to change the energy use levels.

Table 7:Verification Summary

Measure Description	End Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified	Verification Realization Rate
Process - Refrigeration	P	not applic.	not applic.	Floating Head Pressure Control - Hardware	1	Control Sensors and interface Hardware	Yes 10/5/06	100%
Process - Refrigeration	P	not applic.	not applic.	Floating Head Pressure Control - Programming	1	Software and programming	Yes 10/5/07	100%
Process - Refrigeration	P	not applic.	not applic.	Evaporator Fan Cycling	1	Software and programming	Yes 10/5/07	100%
Process - Refrigeration	P	not applic.	not applic.	Floating Suction Pressure Control Integration	1	Software and programming	Yes 10/5/07	100%
Process - Refrigeration	P	not applic.	not applic.	Premium Efficiency Motors on Two Condenser Fans	1	1-7.5 and 1-15 hp premium effic. motors	Yes 10/5/07	100%

Table 8: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	612	9,552,185
Baseline End Use	612	9,552,185
Ex Ante Savings	36.0	893,093
Ex Post Savings	-35.5	176,730

Table 9: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	5.9%	9.3%	-5.8%	1.9%
Baseline End Use %	5.9%	9.3%	-5.8%	1.9%

Table 10: Multi Year Reporting Summary

Program ID:		001 Application # A0137					
Program Name:		**SPC 04-005 Evaluation**					
Year	**Calendar Year**	**Ex-ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004	0	0	0	0	0	0
2	2005	893,093	176,730	36	-36	0	0
3	2006	893,093	176,730	36	-36	0	0
4	2007	893,093	176,730	36	-36	0	0
5	2008	893,093	176,730	36	-36	0	0
6	2009	893,093	176,730	36	-36	0	0
7	2010	893,093	176,730	36	-36	0	0
8	2011	893,093	176,730	36	-36	0	0
9	2012	893,093	176,730	36	-36	0	0
10	2013	893,093	176,730	36	-36	0	0
11	2014	893,093	176,730	36	-36	0	0
12	2015	893,093	176,730	36	-36	0	0
13	2016	893,093	176,730	36	-36	0	0
14	2017	893,093	176,730	36	-36	0	0
15	2018	893,093	176,730	36	-36	0	0
16	2019	893,093	176,730	36	-36	0	0
17	2020	0	0	0	0	0	0
18	2021	0	0	0	0	0	0
19	2022	0	0	0	0	0	0
20	2023	0	0	0	0	0	0
TOTAL	**2004-2023**	13,396,395	2,650,950				

FINAL SITE REPORT

SITE A094a 2004-xxx Irv2 IMPACT EVALUATION
SAMPLE CELL: Backup TIER: 3 END USE: Other

Measure	Install VSDs on HVAC supply fans
Site Description	Office Building

1. Measure Description

The customer installed VFDs on the AHU fans for 20 facilities. Forty-two (42) AHU fans motors had VFDs installed with a combined 1,430 HP.

2. Summary of the Ex Ante Calculations

The AHU VFD installation is an itemized measure. No kW or kWh savings calculations were provided. The basis of the incentive payment of $78,693 was the itemized incentive rate in the Measure Savings Worksheet. The ex ante calculations for the itemized measures are typically based on the Express Efficiency work papers. The Express Efficiency work papers state that the impacts for the installation of VFDs on HVAC fan motors are 753.0 kWh/HP and 0 kW demand reduction. Multiplying 1430 HP by 753 kWh/HP yields 1,076,790 kWh. This value agrees with the Installation Report Review and the utility tracking system. However, the tracking system lists the savings in the H category (previously HVACR, currently A or AC&R). The correct end use category is O fro “Other”.

3. Comments on the Ex Ante Calculations

The AHU VFD installation is an itemized measure. No kW or kWh savings calculations were provided. The ex ante calculations for the itemized measures are typically based on the Express Efficiency work papers. The Express Efficiency work papers state that the impacts for the installation of VFDs on HVAC fan motors are 753.0 kWh/HP and 0 kW demand reduction. No credit is taken for any demand reduction due to the installation of the VFDs on the fan motors. This is a conservative assumption. Other aspects of the workpapers do not apply to the exact conditions of this installation.

4. Measurement & Verification Plan

These measures are installed in various office locations, in approximately 20 different buildings. The hours of occupancy vary by space, ranging from continuous (24/7) operation to typical daytime office hours. Periods of peak occupancy are expected to occur Mondays through Fridays from 7:00 AM to 11:00 PM. The post-installation system includes the installation of new HVAC fan motor VFDs, which reduces the energy consumption of the system.

The goal of the M&V plan is to estimate the actual kWh reduction due to the installation of the VFDs on the AHU fans, over the expected useful life of the measure.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. Seasonal variation is expected to be predictable and one week should be a sufficiently long enough measurement period to calibrate an energy savings model for both measures. Interval data collected on a 15-minute or less basis, preferably during the summer months of June to September, would be needed to accurately determine coincident peak period demand savings.

Measurement of the AHU fan motor input power relative to outdoor air temperature will provide the necessary information for comparison of the new fan motor actual operation to the predicted operation forecast by the workpapers.

The HVAC fan airflow and motor power draw is not expected to remain consistent enough for single input power measurements to be representative of the average usage. Logged input power measurements will be required.

Pre-retrofit and post-retrofit calculations of demand and energy loads will be calculated using the following formulae:

AHU kW = kW at maximum Outdoor Air Temperature (either measured or predicted if the max OAT does not occur during the measurement period)

AHU measured input power (kW) with corresponding outdoor air temperature will be used to create an AHU input power curve unique to this facility. An input power formula as a function of outdoor air temperature will be developed using a curve fit function. Then the formula can be used in a spreadsheet bin analysis calculator. The basic calculation is the summation of:

$\text{AHU kWh}_{\text{(bin temp)}} = \text{Calculated kW}_{\text{(bin temp)}} \times \text{hours/yr}_{\text{(bin temp)}}$

The total annual energy usage is the summation of all the temperature bins.

The most significant variables to be quantified are the pre-retrofit and post-retrofit hours of operation and the pre and post retrofit kW demand profiles of the air-handling units. Pre-retrofit hours will be confirmed with the site personnel to verify that the running hours listed in the application are valid. If required, appropriate modifications for the savings calculations will be made to the pre-retrofit usage figures, possibly based on post-retrofit monitoring, in order to establish a realistic baseline for energy use.

The installation of the AHU VFDs will be physically verified during the onsite visit.

The installation of the VFDs will be physically verified during the onsite visit at no less than four (4) facilities. The post-installation energy consumption will be verified by utilizing the customer’s on-site EMS software to log the kW and kWh of the units for a minimum of 7 days.

If the demand and energy consumption is not available from the EMS software, the post-installation energy consumption of the AHU VFDs will be verified by installing Hobo

FlexSmart data loggers with WattNode WNA-3D-480-P Watt-hour transducer and Magnalab SCT-0750-050 current transformers on the inputs of no less than five (5) AHU VFDs. The energy consumption will be logged with a sampling delay of no greater than 1 minute, for a minimum of 7 days to verify the post-installation energy consumption.

In addition, the outdoor air temperature and relative humidity at the facility will be monitored using no less than one (1) Hobo H8 logger. The logged kWh will then be used in conjunction with temperature to calibrate the model and determine the annual usage.

The greatest uncertainty in the ex ante savings estimate are associated with the pre-installation and post-installation utilization factors for the AHU VFDs. The utilization factor is a derivative of the load profile and the performance curve throughout the course of the entire year.

For the pre retrofit conditions, the AHU fan VFD utilization factor is determined through the use of utility defined kWh/hp savings values. No pre-retrofit or post-retrofit demand or energy usage values were calculated, therefore, typical load factors and utilization factors had to be used to accommodate the utility savings value.

Uncertainty for the savings estimate for the HVAC VFD retrofit projects can be more fully understood by setting projected ranges on the primary variables.

<u>For the Pre-Installation AHU Fans</u>

- 1,230.1 kW expected for the AHU fan motors, maximum of 1,325.9 kW, minimum of 1,134.3 kW (±7.8%, based on judgment of deviation from expected typical efficiency, typical load factor, and maximum load condition)
- 5,904,516 kWh expected for the AHU fan motors, maximum of 7,571,852 kWh, minimum of 4,237,180 (±28.2%, based on judgment of deviation from expected typical efficiency, typical utilization factor, typical load factor, and hours of operation)

<u>For the Post-Installation AHU Fans</u>

- 1,308.6 kW expected for the AHU fan motors with VFDs, maximum of 1,414.6 kW, minimum of 1,202.6 kW (±8.1%, based on judgment of deviation from expected typical efficiency, typical load factor, and maximum load condition)
- 4,827,726 kWh expected for the AHU fan motors with VFDs, maximum of 6,195,266 kWh, minimum of 3,003,393 (+28.3 %, -37.8 %, based on judgment of deviation from expected typical efficiency, typical utilization factor, typical load factor, and hours of operation)

<u>For the AHU Operation</u>

- 6,000 facility hours of operation expected, maximum of 8,100 hours, minimum of 3,900 hours (±35%, based on customers description of hours of operation and typical deviation in hours of similar facilities)

- 1,076,790 kWh expected for the AHU fan motor VFD retrofit, maximum of 2,447,618 kWh, minimum of 427,837 (+127.3 %, -60.3 %, based on conditions listed above)

Accuracy

The Hobo FlexSmart loggers have a time accuracy of ±10 seconds. The WattNode Watt-Hour transducers have an accuracy of ±0.45%+0.05%FS, and the Magnelab current transformers have an accuracy of ±1.5%. The Hobo H8 temperature and relative humidity loggers have an accuracy of ±1.3F (within the range of –4F to 104F) for temperature and ±5% for relative humidity.

The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to Microsoft Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 12, 2007. Information on the retrofit equipment and operating conditions was collected by inspection and by interviewing the facility representative. Trend data for all AHUs was obtained from the facility's EMS software.

5.1. Installation Verification

The facility representative verified that the pre-retrofit air handling units did not have VFDs but were instead controlled by discharge dampers.

It was physically verified that the air handling units had VFDs installed on them. The facility representative stated that the retrofit was completed in August 2005. It was discovered that of the 42 motors with VFDs installed, eight (8) did not match the submitted information. Six were found to be smaller than the submitted information and two were found to be larger. For the original analysis, the total motor horsepower totaled 1,430 HP; the actual motors installed only totaled 1,380 HP.

These are the only measures in this application. The verification realization rate for this project is 1.0 based on number of VSDs (0.97 based on installed or controlled motor horsepower). A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Other Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
VFD on 42 AHU Fans	O			VFD on AHU Fans	42	VFDs on HVAC Fan Motors	Physically verified installation of VFDs	1.00

5.2. Scope of the Impact Assessment

The impact assessment scope is for the VFD installation on forty-two (42) AHU fan motors. This is the only measure in this application.

5.3. Summary of Results

EMS data was obtained for the HVAC fans for 6 days (from August 31 to September 5, 2007) to measure the operating hours and power consumption. The facility representative stated that the monitoring period is representative of normal facility operation. The facility representative stated that this facility is occupied approximately twelve (12) hours per day on weekdays and six (6) hours per day on Saturdays.

It was determined from the EMS data that the AHU fans are only in operation during occupied periods, which per the facility representative only occurs 66 hours per week. Fan speed of the AHUs fluctuates during occupied periods as needed. A curve for percent speed compared to temperature was developed. This percent speed relation was then used in conjunction with affinity laws to develop a post-retrofit kW for each temperature bin. The pre-retrofit kW for each bin was developed using the Danfoss Graham HVAC Energy Analysis Program, using discharge dampers as the pre retrofit control method.

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit peak power draws.

The ex post impacts are calculated in Table 2 below:

Table 2: Energy and Demand Formulae

Pre-Retrofit Demand kW_{peak}	= Motor BHP x 0.746 x Load $Factor_{peak}$ / Motor Efficiency
Post-Retrofit Demand kW_{peak}	= Motor BHP x 0.746 x Load $Factor_{peak}$ / Motor Eff. x VFD Efficiency
Peak kW Savings	= Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak} = 891.0 kW – 928.1 kW = (37.1) kW
Pre-Retrofit kWh	= Pre-Retrofit $Demand_{Bin}$ x $Hours_{Bin}$ = 2,793,663 kWh/yr
Post-Retrofit kWh	= Post-Retrofit $Demand_{Bin}$ x $Hours_{Bin}$ = 1,772,865 kWh/yr
kWh Savings	= Pre-Retrofit kWh – Post-Retrofit kWh = 2,793,663 kWh/yr – 1,772,865 kWh/yr = 1,020,798 kWh/yr

The data logged during the on-site visit was used to create a graph of kW usage versus ambient temperature for the logging period. This graph was then used along with local temperature bin data to predict energy usage for the year.

The ex ante calculations did not include demand savings.

The ex post energy savings is slightly less than the ex ante energy savings. Because the ex ante energy savings were determined from itemized standard kWh/hp values, it is difficult to determine where the discrepancy lies. It should be noted however, that when the original analysis is corrected to account for the difference in expected to installed motor horsepower, the utility kWh/hp values are within 2% of the ex post values.

Higher divergence from the ex ante savings may have been expected for other applications than this office building, as this sector closely conforms to the assumptions in the workpapers.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the vendor invoice for the work performed for the project and is an accurate reflection of the project cost. The costs are inline with expectations based upon similar installations. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program has encouraged them to perform any other energy efficiency projects, the majority of which were under utility programs.

We were unable to physically verify the pre-retrofit equipment or hours of operation. However, these parameters have been accurately assessed and quantified based on discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine impacts of installed measures.

7. Impact Results

Based on the ex ante savings of 1,076,790 kWh, the engineering realization rate for this application is 0.95 for energy savings kWh. A summary of the realization rate is shown in Table 3.

Table 3: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	-	1,076,790	-
SPC Installation Report (ex ante)	-	1,076,790	-
Impact Evaluation (ex post)	(37.1)	1,020,798	-
Engineering Realization Rate	N/A	0.95	N/A

Utility billing data for the site was not available and therefore was not able to be reviewed. Therefore, no comparison could be made for total meter energy or demand reductions. Table 4 summarizes the baseline end use energy (for the AHU fans only), the ex ante savings and the ex post calculation results.

Table 4: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	N/A	N/A
Baseline End Use	891.0	2,793,663
Ex ante Savings	0.0	1,076,790
Ex Post Savings	-37.1	1,020,798

Table 5 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations.

Table 5: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	N/A	N/A	N/A	N/A
Baseline End Use %	0.0%	38.5%	-4.2%	36.5%

With a cost of $157,386 and a $78,693 incentive, the project had a 0.56 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 0.59 years. A summary of the economic parameters for the project is shown in Table 6. Note that average rates were used to calculate the estimated annual cost savings, which can significantly affect savings and payback.

Table 6: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), ($1.10/therm) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	9/21/2005	$157,386	-	1,076,790	-	$139,983	$78,693	0.56	1.12
SPC Program Review (Ex Post)	9/26/2007	$157,386	(37.1)	1,020,798	-	$132,704	$78,693	0.59	1.19

It was determined that the VFD installation project was defined as an Adjustable Speed Drive measure in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the VFDs were assumed to have a useful life of fifteen (15) years. A summary of the multi-year reporting requirements is given in Table 7. Because this measure was installed in August of 2005, the energy savings in year #1 (2005) are assumed to be 5/12 of the expected annual savings for this measure.

Table 7: Multi-Year Reporting Requirements

Program Name:		SPC 04-05 Evaluation A094a					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	448,663	425,333	-	-	-	-
3	2006	1,076,790	1,020,798	-	(37.1)	-	-
4	2007	1,076,790	1,020,798	-	(37.1)	-	-
5	2008	1,076,790	1,020,798	-	(37.1)	-	-
6	2009	1,076,790	1,020,798	-	(37.1)	-	-
7	2010	1,076,790	1,020,798	-	(37.1)	-	-
8	2011	1,076,790	1,020,798	-	(37.1)	-	-
9	2012	1,076,790	1,020,798	-	(37.1)	-	-
10	2013	1,076,790	1,020,798	-	(37.1)	-	-
11	2014	1,076,790	1,020,798	-	(37.1)	-	-
12	2015	1,076,790	1,020,798	-	(37.1)	-	-
13	2016	1,076,790	1,020,798	-	(37.1)	-	-
14	2017	1,076,790	1,020,798	-	(37.1)	-	-
15	2018	1,076,790	1,020,798	-	(37.1)	-	-
16	2019	1,076,790	1,020,798	-	(37.1)	-	-
17	2020	628,128	595,466	-	(37.1)	-	-
18	2021	-	-	-	-	-	-
19	2022	-	-	-	-	-	-
20	2023	-	-	-	-	-	-
TOTAL	**2004-2023**	16,151,850	15,311,975			-	-

Final Site Report

SITE A095 albe1 IMPACT EVALUATION
SAMPLE CELL: TIER: 2 END USE: Other

Measure	Refrigeration, Control Upgrade & Modifications
Site Description	Retail Food Stores

1. Measure Description

The measure selected for evaluation included addition of new sensors and controls to manage evaporator pressures, condenser pressures and temperatures of central "rack" display-case refrigeration systems in order to affect energy savings. Other measures installed as part of the same control project at the same time included:

- New sensors and control interface to provide night shutoff of central HVAC fans
- New sensors and control interface to provide nighttime HVAC temperature control
- Installation of new control interface to shut off some case and ceiling lighting at night (these are in the lighting category and are not evaluated as part of application)

The measures were installed in 14 separate retail grocery stores. The refrigeration control measure subject to evaluation amounted to 58.537% of the total ex ante savings for all of the measures at each of the fourteen sites. The HVAC control measures also subject to evaluation amounted to 24.39% of the total ex ante savings for all of the measures at each of the fourteen sites.

2. Summary of the Ex Ante Calculations

The total ex ante savings for the entire control system installation project that were submitted and approved were 1,946,422 kWh/yr and 0 kW. The total incentive approved and paid was $141,539. The total savings for the refrigeration measure subject to this evaluation was 1,139,137 kWh, and 0 kW. The total savings for the HVAC control measures also subject to this evaluation was 474,737 kWh, and 0 kW. The total savings for measure in the "Other" category are 1,613,874 kWh/yr. The prorated incentive for the evaluated measures is $ 117,374.

Measure	Energy Savings (kWh)	Demand Savings (kW)	N. Gas Savings (therms)	Incentive Paid ($)
Refrigeration Controls	1,139,137	0	0	$82,835
Other Measures	807,285	0	0	$58,704

The ex ante calculations for each control upgrade for each facility were based on the following general equation:

$$\text{Annual kWh Savings} = \frac{\text{Annual kWh Use}}{365\ \text{days/yr}} \times \text{End Use Fraction} \times \text{Savings Fraction} \times 365\ \text{days/yr}$$

The variable factors in this equation were derived from three principal sources:

- The annual kWh use for each facility was obtained from utility billing records. The annual period used and the raw data were not shown in the billing data or file information that was provided, but it appeared to be a period between 1/1/2002 and 12/31/2003. “eLutions” was also referenced as a source of consumption information but neither the calculations nor the raw data used in the eLutions estimates were provided in the project files.
- The End Use Fraction for each end use (refrigeration, lighting, HVAC compressor and HVAC fans) was based on the results of a prior EPRI study that focused on supermarket energy use and energy savings. The citation of the date and source for the study was not provided in the file, however, an extracted pie chart from the study showing the end use fractions was provided in the project file.
- The savings fraction that would result from the control retrofit for each end use was estimated by the sponsor based on rough “conservative” fractional savings derived from the customer’s reported savings from 39 similar projects that were reportedly carried out between 1999 and 2001 in the same utility’s service territory. The savings for the prior projects were calculated using the “eLutions” software. The detailed data on the prior projects were not provided in the hard copy or electronic files.

A summary of the total project and prorated measure kWh savings and incentives are shown in Table 1. The ex ante calculations of energy savings by store and by measure are shown in Table 2.

Table 1: Energy Savings and Prorated Incentives by Measure

	Total Annual kWh	Percent of Total	Cost (1)	Incentive (1)	Ex Ante $ Savings (at $.11/kWh - no peak savings)
Total kWh Savings Refrig.	1,139,369	58.537%	$ 82,851.86	$ 82,851.86	$125,330.63
Total kWh Savings Lighting	332,316	17.073%	$ 24,165.13	$ 24,165.13	$ 36,554.77
Total kWh Avgs HVAC Fans	221,544	11.382%	$ 16,110.08	$ 16,110.08	$ 24,369.85
Total kWh Svgs HVAC Ht/Cool	253,193	13.008%	$ 18,411.52	$ 18,411.52	$ 27,851.25
Grand Total	1,946,423		$583,618.64	$ 141,538.59	
(1) Prorated as per the fraction of total savings represented by the refrigeration measure					

Table 2: Ex Ante Savings Calculation Detail

Store #	6510	6129	6108	6139	6148	6151	6176	6197	6303	6515	6517	6521	6534	6538
Annual kWh	1,194,575	2,684,575	2,555,000	2,106,415	2,304,245	1,638,585	1,567,675	3,000,300	1,970,635	1,829,015	2,956,135	2,024,290	1,997,280	2,060,425
Avg. kWh/day	3,273	7,355	7,000	5,771	6,313	4,489	4,295	8,220	5,399	5,011	8,099	5,546	5,472	5,645
"eLutions" kWh/day	5,355	7,355	7,000	5,771	6,313	7,229	4,295	8,220	5,399	5,011	8,099	5,546	5,472	5,645
Product Refrigeration Savings (based on 9-10% savings for 5 degree increase in evaporator temperature based on Copeland compressor performance data, plus an (undocumented) 2% savings for a condenser differential temperature control strategy)														
Percent Use -	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%
Refrigeration % Savings	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%
Refrigeration Compr. Savings kWh/day	192.8	264.8	252.0	207.8	227.3	260.2	154.6	295.9	194.4	180.4	291.6	199.7	197.0	203.2
Refrigeration Compr. Savings kWh/year	70,365	96,645	91,980	75,831	82,953	94,989	56,436	108,011	70,943	65,845	106,421	72,874	71,902	74,175
% of Total for Site	58.54%	58.54%	58.54%	58.54%	58.54%	58.54%	58.54%	58.54%	58.54%	58.54%	58.54%	58.54%	58.54%	58.54%
Interior Lighting Savings (25% shutoff for 6 hours per day: 25% x 25% = 6.25% - rounded down to 5% to be "conservative")														
Typical Interior Lighting Use (1)	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%
Lighting Percent Savings (2)	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Lighting Savings (kWh/day)	56.2	77.2	73.5	60.6	66.3	75.9	45.1	86.3	56.7	52.6	85.0	58.2	57.5	59.3
Lighting Savings (kWh/year)	20,523	28,188	26,828	22,117	24,195	27,705	16,461	31,503	20,692	19,205	31,039	21,255	20,971	21,634
% of Total Site	17.07%	17.07%	17.07%	17.07%	17.07%	17.07%	17.07%	17.07%	17.07%	17.07%	17.07%	17.07%	17.07%	17.07%
Space HVAC Fan Savings (Assumes 7% HVAC use and a "conservative" estimate of 10% HVAC for "better control algorithms and night setbacks" which are expected to reduce HVAC compressor operation 6 hours per night)														
Percent HVAC Fan Use (1)	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%
Percent HVAC Fan Savings (2)	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
HVAC Cooling Savings kWh/day	37.49	51.49	49.00	40.40	44.19	50.60	30.07	57.54	37.79	35.08	56.69	38.82	38.30	39.52
HVAC Fan Savings (kWh/year)	13,682	18,792	17,885	14,745	16,130	18,470	10,974	21,002	13,794	12,803	20,693	14,170	13,981	14,423
% of Total Site	11.38%	11.38%	11.38%	11.38%	11.38%	11.38%	11.38%	11.38%	11.38%	11.38%	11.38%	11.38%	11.38%	11.38%
Space HVAC Heating and Cooling Savings (Assumes 4% HVAC fan use, and a "conservative" estimate of 20% HVAC fan savings for 6 hours shutoff per night)														
Percent HVAC Ht. Cool Use (1)	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Percent HVAC Ht. Cool Savings (2)	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
HVAC Ht. Cool Savings kWh/day	42.8	58.8	56.0	46.2	50.5	57.8	34.4	65.8	43.2	40.1	64.8	44.4	43.8	45.2
HVAC Ht. Cool Savings (kWh/year)	15,637	21,477	20,440	16,851	18,434	21,109	12,541	24,002	15,765	14,632	23,649	16,194	15,978	16,483
% of Total Site	13.01%	13.01%	13.01%	13.01%	13.01%	13.01%	13.01%	13.01%	13.01%	13.01%	13.01%	13.01%	13.01%	13.01%
TOTALS for Site														
Total Savings (kWh/day)	329.33	452.33	430.50	354.92	388.25	444.58	264.14	505.53	332.04	308.18	498.09	341.08	336.53	347.17
Annual Savings	120,206	165,101	157,133	129,545	141,711	162,273	96,412	184,518	121,194	112,484	181,802	124,494	122,833	126,716
										Total Annual kWh				1,946,423
Percent kWh Savings	10.063%	6.150%	6.150%	6.150%	6.150%	9.903%	6.150%	6.150%	6.150%	6.150%	6.150%	6.150%	6.150%	6.150%
Percent Lighting of	17.073%	17.073%	17.073%	17.073%	17.073%	17.073%	17.073%	17.073%	17.073%	17.073%	17.073%	17.073%	17.073%	17.073%
(1) Usage percentages are derived from a study attributed to EPRI (A pie chart is shown but documentation for the study was not provided in the file) (2) Percentages based on "experience" at other stores in prior projects with calculations shown intended to provide a rough explanation														
Lighting Annual kWh	20,523	28,188	26,828	22,117	24,195	27,705	16,461	31,503	20,692	19,205	31,039	21,255	20,971	21,634
Other Annual kWh	99,683	136,913	130,305	107,427	117,516	134,568	79,951	153,015	100,502	93,280	150,763	103,239	101,861	105,082

Summary of Pre- and Post- Installation Site Observations

The pre-project review supporting the ex ante estimates included pre-installation site visits to three of the 14 stores. The site visits were intended to document representative pre-installation equipment and operating conditions. The site observations noted estimates of the capacity of the refrigeration and HVAC equipment and lighting system in each store. Details on the pre-installation controls and control strategy were very limited. Table 3 summarizes the pre-installation observations for the three stores.

Table 3: Pre Installation Site Observations

Store #	A	B	C
Lighting Type	T8	2LT8, "50% removed"	T8, "adequately spaced"
Lighting Control	Manual	Automatic	Manual
Refrig. Condition	average age eqpt & controls	"older eqpt. & controls, possibly oversized"	"newer eqpt & controls"
Refrigeration	3 suction grps of 3 cmprs each, 88 hp total each grp	typ Compr: Copeland - 460V, 44.3 Amp; 9 compressors totaling 137.5 hp, 658.3 mbh; COP est'd. to be 1.88.	11 compressors totaling 508.9amps/460V; 779 mbh; COP est'd. to be 1.95.
HVAC	No info	No info	2 x 25 hp Bohn AHUs; HCL50AMA
Comment	No additional information on pre-installation equipment, equipment capacity, or lighting fixture type or count, or schedule, control strategy, setpoints, etc.		

Post-Installation Verification: Following installation as reported by the sponsor, four sites were visited by the SPC project management technical support consultant to observe the post-installation equipment and control status. Table 4 summarizes the site observations that were provided in the file for these sites.

Table 4: Utility Post-Installation Verification Summary

Store #	3	4	2	13
Location				
Control Syst.:	Com-Trol	Com-Trol	Danfoss	Danfoss
Lighting	Verified schedule	Verified schedule	Verified schedule	Not verified
Refrigeration	Verified schedule	Verified schedule	Verified schedule	Not verified
HVAC	Verified schedule	Verified schedule	Verified schedule	Not verified
Password Protection	Not protected	Verified protected	Verified protected	Not observed
Sponsor estimated savings	900 kWh for 1 month before/after	1500 kWh for 1 month before/after	No info	No info
Other Information				Verification aborted; Manager very upset due to loss of product.
Comment	No quantitative information on post-installation equipment, equipment capacity or lighting fixture count, or schedule , control strategy, setpoints, etc.			

No other information (regarding the specific equipment affected, implemented control strategies, schedules, or set points) was provided in the project file.

3. Comments on the Ex Ante Calculations

The ex ante savings were approximate figures based on the present energy use at the 14 project sites and savings fractions reported at 26 prior sites retrofitted by the customer with the support of the sponsor during the period 1999 to 2001. The average annual savings for the 26 sites was reported to be “270,000 to 300,000 kWh” based on an “eLutions” impact model. According to the sponsor, this was a savings of “700 – 800 kWh per day”. The sponsor projected that, as a “conservative” estimate; about half of the 700-800 kWh, or 380 kWh per day, was a reasonable estimate of savings for the 14 project stores. The sponsor then developed a “rational” calculation of the savings for each store by multiplying the store annual kWh consumption for an annual period by the end use fraction from the “EPRI documents” (not cited) and a “reasonable” savings fraction for each end use, which totaled to approximately 380 kWh per site per day. This level of savings approximates 5% of the daily energy use at the subject stores. The savings estimates do not therefore represent a site-specific estimate based on system characteristics but rather “typical” fractional savings that were “observed” at other similar customer sites that had reportedly experienced similar retrofits in previous years.

Other than the total annual kWh starting point for each site, no site-specific equipment capacity and performance factors, operating parameters, set points, end use fractions, or operating schedules are provided in the project documents, nor were they used in the ex ante impact estimates.

We note that three sites were visited pre-installation and four-sites were visited post-installation. The pre-installation and post-installation comments and observations are very limited. With the exception of some detail on the main refrigeration rack compressors, there is no information on the pre-installation refrigeration system operation, HVAC / lighting equipment type, capacity, condition, performance, schedule, set points or control strategy.

We also note that the equipment installed and the control strategies put in place varied from one store to the next depending on the state and condition of the existing control system. With the possible exception of information that might be gleaned from interviews with the sponsor or the customer, it is impossible to establish with any degree of certainty the state of the equipment or degree of control that was exercised prior to the installation. We understand that some degree of control for some of the measures was in place (by, for instance, time switches) prior to this project. Table 5 Summarizes the Tracking System information.

Table 5: Tracking System Savings and Incentive Summary

App. ID	Application Number	Site Addr	Site Sqft	Sic Desc	Site kwh (total for 14 sites)	Site kW	Measure Description	Target End-Use	Sample Strata	End-Use by Record	Savings for Record (kWh)	Savings for Record (kW)	Savings for Record (therms)	Incentive for Record
A095	xxx	14 Locs		Super-market			Installation of refrigeration compressor control systems	O	2	2-O	1,613,874	0	0	$ 117,374

The ex ante kWh and kW savings in the utility tracking system figures for the evaluated measure agree with the impacts shown in Table 2. The tracking system reported incentive for all measures is $141,539. The incentive calculated by multiplying the total project cost by the fraction of savings represented by this measure would be $117,374.

4. Measurement & Verification Plan

The goal of the measurement and verification (M&V) plan is to document the first year ex-post peak kW and the first year ex-post annual kWh reduction for the project, and to estimate the degree of certainty of those values given the precision of the data used. As a second year of post-project data is now available, two years of ex post kW and kWh data will be collected and used in the analysis.

There are 14 sites involved in this project with a similar (but not identical) scope at each site. We propose to use “pre” – “post” whole-building metered energy use (IPMVP Option C) to estimate the project impacts. The approach is detailed in the following sections.

Formulae and Approach

A whole-building weather-adjusted billing analysis methodology was used. The kWh consumption for 24 billing periods prior to the project installation and 24 periods after installation will be compared. The billing periods compared do not include the period during which the installation was completed. The following steps were followed:

- In order to account for weather and billing period day differences, the daily average kWh during the 22 to 24 pre-installation billing periods for which data were available was regressed against average ambient temperature for the period. A linear equation for the relationship was identified.
- The projected average daily kWh for each *post* project billing period in the absence of the project was then calculated by applying the pre-project kWh/temperature equation to the post-project average ambient dry bulb temperature.
- The post project average daily kWh for each billing period was calculated by dividing the total billing period kWh by the number of billing days.
- The kWh savings for each billing period were then calculated by subtracting the actual post-project average daily kWh from the average daily kWh calculated

from the pre project equation and multiplying by the number of days in the billing period.

- The total number of days and the total kWh savings were calculated by summing the respective days and total kWh for the post retrofit periods.
- The average daily kWh savings were calculated by dividing the total kWh savings by the total post-retrofit days.
- The annual kWh savings for each of the 14 sites were then calculated by multiplying the average daily kWh savings by 365.
- The total project kWh impact was calculated by summing the results for the 14 sites. (Note only 12 of the sites are presently open so two sites had 0 kWh savings.)
- The total kWh Savings for all active sites is multiplied by the fraction of ex ante savings represented by the refrigeration measure (82.93%) to calculate the measure fraction of the total ex post savings

The annual savings for each of the project stores will be calculated by

$$\text{Annual kWh Savings}_{\text{Store}} = 365 \text{ Days/yr} \times \sum_{1}^{24} \frac{\text{kWh}_{\text{pre-retrofit}}}{\text{Billing Days}_{\text{pre-retrofit}}} - \frac{\text{kWh}_{\text{post-retrofit}}}{\text{Billing Days}_{\text{post-retrofit}}}$$

for 22 to 24 similar pre- and post-retrofit billing periods.

The total project savings will be calculated as:

$$\text{Total Annual kWh Savings} = \sum_{1}^{14} \text{Annual kWh Savings}_{\text{store}}$$

Since the evaluation covers the "Other" (refrigeration) end use only, the lighting savings will be removed from the total annual kWh savings.

$$\text{Total Annual Other kWh Savings} = \text{Total Annual kWh Savings} \times 0.8293$$

Lighting and HVAC equipment and control will be verified as part of the M&V activities. If possible, lighting control strategies (pre-retrofit and post-retrofit) will be determined from interviews and interrogation of the control systems. The control systems will also be queried to extract lighting use and savings figures if available.

Four sites were visited to conduct the verification activities.

<u>Uncertainty with various factors</u>

- kWh: 1,946,422 kWh expected; 1,926,000 kWh minimum; 1,966,000 kWh maximum (±1% for utility metering)
- NOAA data: (±1%)
- Percent Refrigeration control to total savings (+/- 30%)

Accuracy and Equipment

The utility meters capture 15 minute interval data and for the purposes of the evaluation are considered to be 99% - 100% accurate where reviewed data is deemed reasonable.

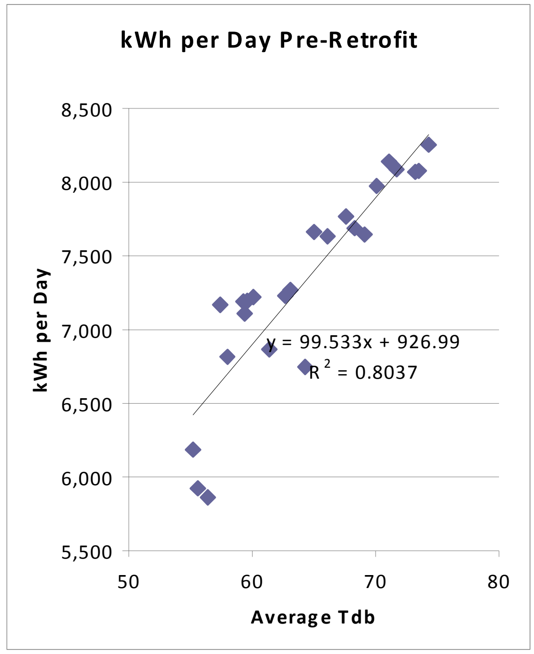
All data collected was reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. No data were removed from the analysis due to variance from expected ranges of values.

IOU revenue meter data will be used. The revenue meter data and weather data is believed to be >98% accurate. No on-site measurements were used.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The procedure described in Section 4 was carried out for twelve of the fourteen remaining sites. Two sites have been closed or sold. A sample of the impact analysis for one store was prepared as described in Section 4 and is shown in Table 6.

Table 6: Sample of Weather Adjusted Savings Analysis for Sample Store



Read date	Billing days	Billing usage	Avg. temp. db	kWh/day Pre			
1/22/2003	33	226,611	61.4	6,867			
2/21/2003	30	204,485	58.0	6,816			
3/24/2003	31	223,846	60.1	7,221			
4/22/2003	29	208,636	59.6	7,194			
5/21/2003	29	210,777	63.1	7,268			
6/20/2003	30	228,994	66.1	7,633			
7/22/2003	32	258,254	73.2	8,070			
8/20/2003	29	239,371	74.3	8,254			
9/19/2003	30	239,208	70.1	7,974			
10/21/2003	32	244,654	69.1	7,645			
11/20/2003	30	213,277	59.4	7,109			
12/22/2003	32	197,970	55.2	6,187			
1/22/2004	31	181,718	56.4	5,862			
2/23/2004	32	189,559	55.6	5,924			
3/23/2004	29	195,678	64.3	6,748			
4/21/2004	29	209,615	62.7	7,228			
5/20/2004	29	222,951	68.3	7,688			
6/21/2004	32	248,564	67.6	7,768			
7/21/2004	30	242,595	71.7	8,087			
8/19/2004	29	236,049	71.1	8,140			
9/20/2004	32	258,439	73.5	8,076			
10/21/2004	31	237,524	65.0	7,662			
11/19/2004	29	208,490	59.3	7,189			
12/21/2004	32	229,397	57.4	7,169			
1/21/2005	31	218,796	57.6	7,058	Calc'd kWh	Period Savings	Completed 1-15-05
2/22/2005	32	229,211	59.6	7,163	6,859	(9,727)	
3/23/2005	29	208,703	60.5	7,197	6,948	(7,198)	
4/21/2005	29	206,142	61.9	7,108	7,088	(596)	
5/20/2005	29	214,346	66.3	7,391	7,526	3,900	
6/21/2005	32	241,750	67.6	7,555	7,655	3,214	
7/21/2005	30	221,771	71.3	7,392	8,023	18,931	
8/19/2005	29	212,353	72.5	7,323	8,143	23,789	
9/20/2005	32	250,427	70.0	7,826	7,894	2,181	
10/21/2005	31	225,068	67.0	7,260	7,595	10,390	
11/21/2005	31	224,518	64.2	7,243	7,317	2,301	
12/21/2005	30	201,120	59.2	6,704	6,819	3,452	
1/23/2006	33	234,901	58.4	7,118	6,739	(12,499)	
2/22/2006	30	211,964	59.1	7,065	6,809	(7,690)	
3/23/2006	29	201,034	56.2	6,932	6,520	(11,940)	
4/21/2006	29	201,629	60.9	6,953	6,988	1,031	
5/22/2006	31	225,222	66.3	7,265	7,526	8,076	
6/21/2006	30	230,242	70.0	7,675	7,894	6,578	
7/21/2006	30	246,895	78.0	8,230	8,690	13,812	
8/21/2006	31	252,134	73.6	8,133	8,252	3,688	
9/20/2006	30	244,264	71.4	8,142	8,033	(3,264)	
10/20/2006	30	233,359	66.3	7,779	7,526	(7,587)	
11/20/2006	31	236,669	64.6	7,634	7,357	(8,616)	
12/20/2006	30	216,757	57.1	7,225	6,610	(18,455)	
	698		Total kWh Savings			13,771	
			Avg. savings per Day			19.7	
			1 Year Savings - Weather Adjusted			7,201	

Several technical representatives for the customer and the sponsor were interviewed in an attempt to find the specific hardware and control schedule and set point modifications made at each of the stores. The sponsor principal contact (located in Boise, Idaho) was first interviewed to gain an overview of the project from his perspective and to request additional technical information. He referred us to a second corporate individual (located in Atlanta, GA) who was responsible for monitoring and for carrying out the sponsor's ongoing savings estimates and energy use tracking support to the customer.

We interviewed the customer's corporate contact person identified in the file. We also interviewed the customer's regional energy manager who discussed additional aspects of the projects.

The corporate data analyst and regional energy manager verified that the systems at 12 of the sites still owned by the customer were in operation (to varying degrees) and they believed that the general control strategies that were reported put in place at the time of installation were still in effect. However, they were not able to confirm specific set points and control strategies for each store.

Although the verbal description of the project improvements made by each of the contacts was consistent with the file description of the projects, none of the contacts was able (or willing) to provide additional specifics regarding the exact scope of work carried out such as equipment installed, or programming changes made at the individual sites.

The contacts were advised of our preliminary findings and offered an opportunity to explain or comment. The Sponsor's project monitoring specialist provided a summary of the Sponsor's savings estimates for all of the sites, and an example calculation of the methodology that they used for estimating savings at the sites. No other response was received from the sponsor or customer representatives.

Verification visits were made to four of the project sites. We targeted the four sites with the largest discrepancies between the preliminary ex post findings and the ex ante savings estimates. The visits were carried out in October 2007. A detailed questionnaire including equipment inventories and specifications was completed at each of the four sites. In each case, the store manager or assistant manager on duty at the time of the visit was interviewed in order to attempt to asses the degree of familiarity with the system and its operation and settings.

6. Additional Evaluation Findings

Regarding timing, the file documents indicate that 8 of the site installations were completed between 11/1/04 and 12/15/04 and 6 of the site installations were completed between 1/15/05 and 1/31/05. The SPC Contract was signed on 12/27/04 by the Sponsor and 12/31/05 by the Utility Director of Energy Efficiency. The Application "date received" is indicated to be 10/11/2004. The completion dates for some of the projects differed slightly (up to 30 days) from the completion dates provided by the Sponsor. We suspect that this is explained by a lag in the time that the projects were reported as complete to the SPC Project Manager.

We discussed the project sponsor's tracking methodology and discussed the projects with the sponsors tracking representative. The projects were referred to as "retrocommissioning" projects by the tracking representative, although it is clear that in most cases, equipment was modified or replaced in addition to implementing new and improved control strategies. The sponsor tracking representative did not express surprise that some of the sites exhibited increases in energy use as he explained that at some of the sites, systems were restored to operation that may have been deficient in the past.

The sponsor forwarded a sample analysis of on-going savings estimates. We were not able to discern the Sponsor's savings estimation methodology from the information that was provided.

We should also point out that it was our observation from the sites visited that some of the control strategies may have already been in place to some degree prior to the retrofit, either through earlier electronic control systems (without remote interface capability), manual controls, or electro-mechanical time switches.

7. Impact Results

The impact results are summarized in Table 7 to 13.

Table 7: Detailed Evaluation Site Results

Site #	Total Pre-Project kWh	Site Activity	Total Store Savings kWh/year (Weather Adjusted)	Ex Post Savings Other Measures kWh/year	Ex Post Peak Demand kW Savings
1	1,194,575	None	86,032	71,344	0
2	2,684,575	SCE Post-Install Verif.	59,683	49,493	0
3	2,555,000	SCE Post-install Verif.; Eval. Verif. Visit	285,142	236,460	0
4	3,000,300	SCE Post-Install Verif.; Eval. Verif. Visit	136,045	112,818	0
5	1,829,015	None	33,691	27,939	0
6	2,304,245	SCE Pre-visit	152,404	126,384	0
7	1,970,635	None	(136,499)	-113,194	0
8	2,956,135	SCE Pre-visit; Eval. Verif. Visit	(60,459)	-50,137	0
9	1,638,585	None	7,201	5,972	0
10	1,567,675	SCE Pre-visit	59,204	49,096	0
12	2,024,290	Eval. Verif Visit	(57,052)	-47,311	0
12	1,997,280	None	(75,016)	-62,209	0
13	2,106,415	Store Closed	0	0	0
14	2,060,425	Store Closed	0	0	0
		Total	490,377	406,655	0

Table 8: Verification Summary

Measure Description	End Use Category	AC&R Measure Description	Lighting Measure Description	Other Measure Description	Count	Equipment Description	Installation Verified	Verification Realization Rate
Controls - Refrigeration	Other	not applic.	not applic.	3-O Controls	12 of 14 stores still in business	Control system hardware installation and programming for refrigeration control.	4 of 12 sites site-verified; 8 other sites verified by telephone interview with customer and sponsor; 2 sites closed.	86%
Controls - Lighting	Lighting	not applic.	1-L Lighting Controls EMS	not applic.	12 of 14 stores still in business	Control system hardware installation and programming for lighting control.	4 of 12 sites site-verified; 8 other sites verified by telephone interviews with customer and sponsor; 2 sites closed.	86%
Controls - HVAC Fans	HVAC	not applic.	not applic.	3-O Controls	12 of 14 stores still in business	Control system hardware installation and programming for HVAC Fan control.	4 of 12 sites site-verified; 8 other sites verified by telephone interview with customer and sponsor; 2 sites closed.	86%
Controls - HVAC Ht. And Cool	HVAC	not applic.	not applic.	3-O Controls	12 of 14 stores still in business	Control system hardware installation and programming for HVAC Heat/Cool control.	4 of 12 sites site-verified; 8 other sites verified by telephone interview with customer and sponsor; 2 sites closed.	86%

Table 9: Economic Summary

Description	Date	Project Cost (82.93% of total project cost)	Estimated Demand Savings kW	Estimated Energy Savings kWh	Estimated Gas Savings therms	Estimated Annual Cost Savings ($0.13/kWh)	SPC incentive (82.93 % of total incentive)	Simple Payback w/incentive, years	Simple Payback w/o Incentive, years
Installation Approved Amount (ex ante)	6/1/05	$ 483,995	0	1,613,874	0	$ 209,804	$ 117,374	1.7	2.3
SPC Program Review (ex post)	11/10/07	$ 483,995	0	406,655	0	$ 52,865	$ 117,374	3.7	9.2

Table 10: Realization Summary

	kW	kWh	therms
SPC Tracking System	0	1,613,874	-
SPC Installation Report (ex ante)	0	1,613,874	-
Impact Evaluation (ex post)	0	406,655	-
Engineering Realization Rate	-	25%	-

Table 11: End Use Summary Reductions

End Use Summary		
	Peak Demand kW	Annual kWh
Total Meter	-	29,889,150
Baseline End Use	-	8,966,745
Ex Ante Savings	0	1,613,874
Ex Post Savings	0	406,655

Table 12: Percent Savings and Demand Reduction, Ex Ante, Ex Post

Percent Savings/Demand Reduction				
	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	-	5.4%	-	1.4%
Baseline End Use %	-	18.0%	-	4.5%

Table 13: Multi-Year Savings

Program ID:		001 Application # A095					
Program Name:		SPC 04-05 Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program KWh Savings	Ex-Post Gross Evaluation Confirmed Program KWh Savings	Ex-Ante Gross Program-Projected Peak Program KW Savings	Ex-Post Gross Evaluation Projected Peak KW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005						
3	2006	1,613,874	406,655				
4	2007	1,613,874	406,655				
5	2008	1,613,874	406,655				
6	2009	1,613,874	406,655				
7	2010	1,613,874	406,655				
8	2011	1,613,874	406,655				
9	2012	1,613,874	406,655				
10	2013	1,613,874	406,655				
11	2014	1,613,874	406,655				
12	2015	1,613,874	406,655				
13	2016	1,613,874	406,655				
14	2017	1,613,874	406,655				
15	2018	1,613,874	406,655				
16	2019	1,613,874	406,655				
17	2020	1,613,874	406,655				
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	24,208,110	6,099,818				

The evaluation technical realization rate is 25%. We believe that there are two principal reasons for the discrepancy with the estimates.

- Two of the fourteen sites were sold or closed by the customer. No information was available regarding their operation. Savings for these two sites were assumed to be zero. This explains about 23% (278,000 kWh) of the total savings (kWh) discrepancy.

- The remainder can be attributed to a difference in methodology combined with differences in performance of the systems from what was expected (or due to limited application of the new control strategies offered by the new system). The evaluation was based on a weather-adjusted pre- and post-project billing analysis. The ex ante estimates were based on total pre-project annual kWh multiplied by reported fractions of savings expected for control improvements multiplied by typical fractions of total kWh for the corresponding end use.

The ex ante and tracking kW savings were 0 kW. No ex ante analysis was provided in the project documents; however it appears that no analysis was performed as the improvements are all intended to impact non-peak energy use. On review, we agree with this assumption and we concur with the 0 kW estimate.

Final Site Report

SITE A096 (2004-XXX) McL IMPACT EVALUATION
SAMPLE CELL: TIER: 3 END USE: AC&R

Measures	VSD's on Evaporator Fans, Demand Based Defrost Controls, Floating Head Pressure Controls
Site Description	Refrigerated Warehouse

1. Measure Descriptions

Three refrigeration control measures are evaluated including variable speed drives on evaporator fan motors, demand based defrost control, and floating head pressure control for the refrigeration compressors.

- Installing variable speed drives (VSDs) on evaporator fan motors allows these fans to run at slower speeds to maintain refrigeration room space temperatures.

- The demand based defrost control measure converts the system from a fixed daily defrost schedule to defrosting only as necessary based on the frost buildup on the refrigerant coils.

- The floating head pressure control measure allows the compressor discharge head pressure to float downward to a lower pressure than the constant baseline value. This will result in reduced compressor usage since the compressors will do less work against a lower head pressure while the system produces the same (or better) refrigeration effect. Compressor savings are partially offset by the increased condenser fan work needed to reduce the condensed refrigerant temperature.

A total of eleven measures were considered for this facility. In addition to the above evaluated measures, the following 6 measures were also installed:

- Replace loading dock seals
- Office area HVAC control upgrades
- Shut off condenser water circulation pumps when not needed
- Install door alarms on freezers
- Replace air compressor with new VSD compressor
- Install a VSD on a chilled water pump

One measure that was approved that was not installed was the installation of high efficiency evaporator fan motors.

2. Summary of the Ex Ante Calculations

Measure	Energy Savings (kWh/yr)	Demand Savings (kW)	Natural Gas Savings (therms/yr)	Incentive Paid ($)
Evaporator Fan VSDs	636,393	0.0	0	$89,095
Demand Based Defrost	51,397	0.0	0	$4,112
Floating Head Pressure Controls	70,703	0.0	0	$9,898
Other Measures	567,485	27.0	0	$45,399

These measures agree with the utility tracking system; however, measure 1 and measure 3 were combined in the tracking system. The total savings in the AC&R category are 758,493 kWh/yr and the total incentive is $103,105.00.

A CD with the ex ante calculations was provided with the utility file. The CD was thoroughly reviewed, but it was not possible to verify the calculations. The project sponsor was contacted to provide a more complete documentation for the savings calculation for the measures. However, nothing was received prior to the site visit. During the site visit, the customer representative made a second request for calculations from American Energy. This information was received a few weeks after the first site visit.

The calculations for all measures were done using a MS Excel based model that used hourly facility refrigeration loads for one year to calculate the hourly usage of various plant equipment to meet those loads. A baseline model was calibrated to match current operating conditions and then each different measure was modeled. The post retrofit model from one measure then became the base case for the next measure.

3. Comments on the Ex Ante Calculations

According to the application reviewer’s comments, the applicant utilized the hourly spreadsheet to predict annual energy savings of 636,393 kWh/year. The reviewer analyzed all assumptions, logged data, and calculations presented by the applicant and deemed these savings to be reasonable.

Although as mentioned above, the logic of the savings calculations could be seen from information provided, and most of the cells throughout the calculation contained numbers, not formulas. The exact methodology employed to calculate a particular result could not always be determined. In some cases, the methodology could be ascertained using engineering judgment; however, in several instances, the ex ante results could not be matched to hand calculations exactly, most likely meaning there was some factor that was included in the calculation that was not obvious.

4. Measurement & Verification Plan

The goal of the measurement and verification (M&V) plan is to estimate the actual annual kWh reduction of the evaporator fans and refrigerant compressors, through quantifying hours of operation and energy use, over the useful life of these measures.

This site is a 250,000 square foot distribution warehouse that receives product from various manufacturers and then sorts and fills orders to be shipped out to customers. Approximately 50% of the facility contains refrigerated and frozen food warehousing, with the remainder of the facility being non air-conditioned space.

The facility operates 24 hours a day, 5 days per week. The first shift of the week starts at approximately 10:00 p.m. on Sunday night. The facility then continues to operate around the clock until approximately 10:00 p.m. on Friday night. There is light activity on Saturdays and virtually no activity on Sundays. Even though the building is not generally occupied during the weekends, the refrigeration equipment continues to operate on weekends in order to maintain required temperatures in the refrigerated spaces.

Electrical power is provided to the facility at a time of use rate. To minimize its peak demand charges, the facility shuts down the refrigeration system during weekday on-peak demand periods, allowing the temperatures of the refrigerated spaces to gradually rise during the day until the on-peak demand window has passed. The facility then puts the refrigeration system on line to pull the space temperatures back down to set point prior to the next on-peak shutdown.

Prior to implementing the VSD measure, the evaporator fans in each refrigerated room operated at constant speed, cycling on and off as necessary to maintain the set point temperature. The project installed VSDs on the evaporator fan motors serving each cooler and freezer box to regulate the speed of the fans and reduce energy use.

For the demand based defrost measure, the intent was to go from a daily scheduled defrost on all the evaporators to an approach where the defrosting, and subsequent higher use by the compressors to remove the heat added to the box during the defrost cycle, would be performed only when necessary.

For the floating head pressure control measure, the intent was to go from a fixed head pressure of 135 psig to a floating head pressure, allowing the pressure to decrease to 120 psig. By lowering the head pressure, the compressor does less work for the same or higher refrigeration effect. Compressor energy savings are offset slightly by the extra condenser fan power used to reduce the condensing temperature which causes the lowered head pressure.

Formulae and Approach

The M&V plan proposed is a modified version of IPMVP Option A.

The operating hours and the demand profile will be established so as to determine the post-retrofit kWh electrical usage. The equipment to be evaluated will be the refrigeration evaporator fans and the refrigeration compressors.

The proposed data collection will be the amperage of four evaporator fans, 2 in freezer rooms and 2 in cooler rooms. The data collected will be extrapolated to the total of 19 evaporator fans. Also, the amperage of the high temperature and low temperature compressors will be logged. Spot voltage and amperage measurements of this equipment will be made during the site visit.

The customer's energy management system will be used to provide data trends for each refrigeration system's head pressure which will serve as the basis for calculating the savings associated with the floating head pressure control.

All other measures within the application will also be verified.

The greatest uncertainty of the ex-ante savings calculation for the evaporator fan VSDs is the current level of operation of the fans, i.e., how many hours the fans operate at different speeds over time. Because the fans serve the interior of the refrigerated boxes, the expectation is that variables affecting the fans' operation are process related, not weather related. It is therefore expected that kW data collected over a 2-3 week period will be representative of operation throughout the year and can be readily extrapolated to determine the current annual kWh usage.

The greatest uncertainty of the ex-ante savings calculation for the demand based defrost is the pre retrofit amount of defrosting that is done on a daily basis and how much work the compressor does after each defrost cycle to remove the defrost heat added to the system and restore the temperature.

The greatest uncertainty of the ex-ante saving calculation for the floating head pressure controls is to what degree and for how long the head pressure is reduced.

<u>Evaporator Fan VSD</u>
It will be assumed for the evaporator fan VSD measure that the post-retrofit refrigeration load will be the same as the baseline refrigeration load, and that the baseline evaporators will be providing the same tons of cooling as the post-retrofit evaporators. Since the heat transfer capacity of a direct expansion coil is proportional to the velocity of the air stream[1], the baseline operation will be the constant speed fans providing equivalent volumes of air as the measured post-retrofit fans (same total refrigeration load).

Measured post-retrofit fan speeds will be used to develop a baseline fan operating profile. Fan speed data will be obtained from the customer's EMS and trended for the monitoring period. If this data is not available from the customer's EMS, then a spot reading of the fans

[1] 2000 ASHRAE Handbook HVAC Systems and Equipment, page 21.7 Equations 2a and 2b.

at full speed will be made and this will be used with the monitored data to determine the % full speed using Tables 4.2 and 4.3 from the Adjustable Speed Drives Application Guide[2].

Fan speed bins (% of full speed) will be created from the monitored data. These bins will be used to determine baseline run times at constant speed. Since air volume (and velocity) is proportional to fan speed, it will be assumed that the baseline fan run time will be equal to the speed bin times the post-retrofit hours of operation in the speed bin. For example, a post-retrofit fan operating at half speed for 2 hours will provide the same volume of air as the baseline fan operating at full speed for one hour (50% x 2 hours). Baseline demand for each fan motor will be calculated as:

$$kW_{Baseline} = \frac{hp_{Baseline} \times 0.746 kW/hp \times \text{Load Factor}}{\text{Motor Efficiency}_{Baseline}}$$

And the baseline kWh in the monitoring period for each fan will be

$$kWh_{Baseline} = \sum kW_{Baseline} \times \text{Hours}_{\text{Speed Bin}}$$

Energy savings for each fan during the monitoring period will be the calculated baseline kWh for the monitoring period minus the measured kWh in the monitoring period. Annual kWh for the facility will be the sum of the savings for the freezer fans, the cooler fans, the loading dock fans and the candy room fans.

$$\text{Annual kWh Savings} = \sum\left[\frac{8{,}760\ \text{Hrs/yr}}{\text{Hours in Monitoring Period}_{\text{Fan Type}}} \times \text{Qty Fans}_{\text{Fan Type}} \times \left(kWh_{Baseline} - kWh_{Post-retrofit}\right)_{\text{Fan Type}}\right]$$

Since both the baseline and post-retrofit refrigeration equipment is controlled off during the on-peak period, there will be no kW demand savings.

Demand Based Defrost

The kW demand for the high and low temperature compressors will be measured and recorded throughout the monitoring period. The kW profile for each day will be inspected to identify any large spike in the kW, indicating that part of the system has completed a defrost cycle and is purging the defrost heat. The increased kW above what it was prior to the initiation of defrost recovery will be determined, and the time period for which the higher kW occurs will also be calculated. In this way, a current daily kWh usage for each system associated with defrost recovery can be calculated.

This daily usage for the total monitoring period will be reviewed. It will be assumed that the worst case daily usage during that period will be a day that most closely emulates the pre-retrofit condition. By assuming that this worst case usage occurred daily during the pre-

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[2] Adjustable Speeds Drive Application Guide, Electric Power Research Institute, Final Report 1992; pages 105 and 106, Table 4-2 Motor efficiency correction factor table and Table 4-3 ASD efficiency versus speed fraction table.

retrofit period, a daily kWh savings can be calculated. These savings will then be averaged over the monitoring period. This average will then be extrapolated to 365 days.

$$\text{Annual kWh Savings} = \sum\left[\frac{365\ \text{Days/yr}}{\text{Days in Monitoring Period}_{\text{System Type}}} \times \left(\text{kWh}_{\text{Baseline}} - \text{kWh}_{\text{Post-retrofit}}\right)_{\text{System Type}}\right]$$

Floating Head Pressure Controls

Customer supplied trend data of the head pressure for each of the two refrigeration systems will be used to determine the extent of this measure's effectiveness. The baseline condition for the minimum head pressure is 135 psig. This correlates to a condensing temperature of 78.7 ºF. The enthalpy of the superheated vapor for that temperature can be determined, along with the enthalpy of saturated vapor at the suction pressure. The difference between those two values defines the work done by the compressor on a per pound-mass basis.

$w_{comp} = h_{sv} - h_g$

Also, the enthalpy of the saturated liquid at that pressure can be subtracted from the enthalpy of the saturated vapor to determine the heat transfer, or refrigeration effect that occurs in the evaporator.

$\Delta h_{evap} = h_g – h_l$

Taking the system tonnage (converted to Btuh) and dividing by the evaporator heat transfer calculates the mass flow rate, in pounds-mass per hour (lb_m/hr).

$m_{evap.}$ = System tons x 12,000 Btu/hr-ton / Δh_{evap}

This flow rate multiplied by the compressor work (Btu/lb_m) yields the compressor work in Btu/hr, which can then be converted to kW.

$W_{comp} = m_{evap.} \times w_{comp} = W_{comp}$ (Btu/hr) / 3,413

$= W_{comp}$ (kW)

Thus for each data point in which the head pressure is below 135 psig, a kW can be calculated and compared to the kW at that pressure. The difference multiplied by the interval period defines a kWh savings. These kWh savings can be summed for each day during the monitoring period and an average daily savings will be calculated. These average savings values will be extrapolated to a full year. The savings will be the combined total for the low temperature and medium temperature systems.

$$\text{Annual kWh Savings} = \sum\left[\frac{365\ \text{Days/yr}}{\text{Days in Monitoring Period}_{\text{System Type}}} \times \left(\text{kWh}_{\text{Baseline}} - \text{kWh}_{\text{Post-retrofit}}\right)_{\text{System Type}}\right]$$

The above approach will require the following data collection and verification:

Data Element	Proposed Means of Collecting Data
Base case equipment configuration	Confirm via customer interview and review of customer records.
Base case equipment duty	Confirm via customer records of evaporator capacity rating. Interview customer to determine pre-retrofit control strategy.
Base case system operating hours	Confirm via customer interview and review of customer records and the planned maintenance schedule for affected equipment.
Base case control scheme	Confirm via customer records and interview, pre-retrofit control.
Post case equipment duty	Obtain two weeks of hourly (or more frequent) amperage data for four evaporator fans and compressors. Obtain head and suction pressure of both compressors from the customer's EMS.
Post case equipment configuration	Confirm via site survey, customer interview, and review of customer records. Obtain manufacturers' data sheets for equipment and equipment nameplate information. Review control settings and sequence of operation for affected equipment.
Post case system operating hours	Confirm via customer interview and review of customer records and the planned maintenance schedule for affected equipment.

Accuracy and Equipment

A Fluke 321 Clamp Meter with accuracy for amperage of 3% and for voltage of 1.2% will be used.

Power/Amps (Dent Model Elite Pro and 4C Loggers) have an accuracy of ±1%, exclusive of sensor accuracy; the current transformers have an accuracy of ±2.5%.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 19, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the plant equipment and by interviewing the facility representative. Datalogging equipment was installed on four evaporator fans (two freezer and two cooler fans) and the two ammonia compressors to record amperage from September 19 through October 10, 2007. In addition, spot voltage and amperage readings were taken during the site visit.

Installation Verification

The installation of equipment as described in the post installation report was physically verified to the extent practical. The VFDs for each of the 19 fans were verified. They are Danfoss drives, each corresponding to the expected horsepower. The new refrigeration control system panel was observed. This system controls the demand based defrost and floating head pressure, as well as the condenser water pump shutoff. Additional measures verified included the new loading dock seals, freezer door alarms, the VSD on the chilled water pump and the new air compressor. The verification rate is 1.00 for the AC&R measures and 0.99 for all measures at this site (the high efficiency motors on the evaporator fans measure was not installed).

Scope of the Impact Assessment

The impact assessment scope is for the evaporator fan VFD, the floating head pressure controls, and the demand based defrost measure in the AC&R (refrigeration) end use category in the SPC application. The intent was to thoroughly evaluate all three measures, including the floating head pressure controls measure, as described in Section 4. However; data from the customer's EMS has not been provided in a format which would allow the data to be accessible for use in this evaluation. Considerable effort was exerted in attempting to convert the provided data to a useful format; however, all efforts have been unsuccessful. For that reason, there is no specific assessment of the savings of this measure at this time. There is a reasonable belief that the ex-ante savings for this measure would be fully realized. Thus, for this measure, the ex-ante savings are accepted and have been added to the total achieved savings in the tables that follow as ex-post savings.

The ex-ante calculations for the evaporator fan VFDs totaled to 636,393 kWh/yr. This number included savings for the evaporator fans as well as savings for compressor and condenser energy use. Of the total savings, 505,343 kWh/yr (79.4%) are attributed to fan savings, while the balance of the savings are attributed to the compressors, 115,990 kWh/yr (18.2%), and to the condensers, 15,060 kWh/yr (2.4%). The ex-post savings evaluation described below does not include any savings associated with the compressors or condensers. The installation of the VFDs, through the benefit of the fan affinity laws, allows for the evaporator fan motors to operate such that they use less energy. However, since the refrigeration load does not change (just by the addition of evaporator fan VFDs), the loads met by the low temp or medium temp compressors do not change and are not affected in any way that should produce savings. Thus no compressor or condenser fan savings were calculated for this measure.

Summary of Results

Four (4) Dent Model 4C amp loggers were installed on four evaporator fan motors, two on freezer units and two on cooler units, for 21 days (from September 19, 2007 - October 10, 2007), to measure and record the amps at 5 minute intervals and calculate the power demand of the fans. Additionally two (2) Dent Elite Pro loggers were installed on the two refrigerant compressors, low temp and medium temp, to measure amps at 15 minute intervals during the same time frame as the evaporator fans. During the site inspection, spot voltage readings (line to line and line to ground) were taken on both compressor motors and some of the fans using a Fluke 321 clamp meter as well as the Dent Elite Pro Logger.

Savings for the evaporator fan VFDs were determined by utilizing the recorded data to establish the post retrofit use profile. This information was also utilized to calculate the baseline use profile. Prior to the installation of the VFDs, the fans were cycled on and off to meet the load as necessary to maintain the box temperature. It is assumed that the load inside the box is the same before and after VFD installation. Although that load is affected by other measures, the savings for each measure are evaluated individually. To determine the kW associated with each amperage reading, the line-to-line spot voltage measurements were averaged, and a measured power factor (PF) of 0.86 was used. The kW was calculated using the following formula for each data point:

kW = Amps x Volts x PF x 1.732 / 1,000

For each hourly kW, a corresponding fan speed (flow) was determined using a logarithmic equation developed from the following table of percent of full flow vs. VFD power consumption for fans developed by EPRI in the guide referenced in Section 4.

Percent of Full Flow	VFD % Full Flow Power
100%	105.0%
95%	92.0%
90%	77.0%
85%	64.0%
80%	51.0%
75%	42.0%
70%	33.0%
65%	27.0%
60%	22.0%
55%	18.0%
50%	14.0%
45%	11.0%
40%	9.0%
35%	7.0%
30%	6.0%
25%	4.0%
20%	3.0%

These values were graphed and a curve was fit to the line. The equation for that line, full flow power as a function of percent of full flow, is as follows:

$$y = 0.0148 \cdot (e^{4.4042x})$$

The percent of full flow, or x, is then:

$$x = [\ln(y/0.0148)]/4.402$$

A percent of full flow (x) was calculated for each calculated kW value. The values of x were averaged for each day of the 21 day monitoring period. The daily average run times were then assumed to be the baseline daily fan run times at full speed. The baseline run times were multiplied by the full load kW to establish a daily base case kWh usage. This base case kWh usage was then compared to the actual measured/calculated kWh to determine a daily kWh savings value. All of the 21 daily kWh savings values were averaged and then multiplied by 365 days/year to determine an annual savings. These values are shown in Tables 1 and 2.

There are a total of 19 fans that had the VFDs installed, 4 were monitored. The 19 fans are comprised of (4) 15-hp fans for the cooler, (5) 15-hp fans for the freezer, (6) 15-hp fans for the loading dock and (4) 3-hp fans for the candy room. The four that were monitored were two cooler fans and two freezers fans. The two annual savings values for the cooler fans were averaged, and that average was applied to the other two cooler fans. Likewise, the two annual savings values for the freezer fans were averaged and that average was applied to the other three freezer fans. The cooler fan average was also extrapolated to the loading dock fans which were the same size and had the same operating schedule (6 pm to 10 am). For the candy room fans, the cooler fan averages were adjusted by a ratio to account for the smaller horsepower and by a ratio to account for more operating hours (candy room fans are enabled 24 hours a day).

Table 1: Cooler Room Evaporator Fan VFDs (Logged Units)

Unit No.	Calculated Baseline Usage (kWh/yr)	Calculated Post Case Usage (kWh/yr)	Annual Energy Savings (kWh/yr)
#1	28,541	21,229	7,312
#3	9,173	4,423	4,751
Average	18,857	12,826	6,031

Table 2: Freezer Room Evaporator Fan VFDs (Logged Units)

Unit No.	Calculated Baseline Usage (kWh/yr)	Calculated Post Case Usage (kWh/yr)	Annual Energy Savings (kWh/yr)
#3	34,882	32,686	2,196
#5	23,843	17,848	5,994
Average	29,362	25,267	4,095

For the demand based defrost controls, savings for each of the compressors were established by analyzing monitored amperage/kW data and by identifying large abrupt changes in the kW and assigning those periods as the times when the post defrost recovery of the affected box was occurring, for the duration of time until the kW returned to near the pre-increase level. For both the low temperature and medium temperature boxes, the increased kWh usage for each day was calculated. It was assumed that the highest case for the 21 days was comparable to the daily occurrence in the pre-retrofit case. Thus the kWh usage for each of the monitored days was compared to that highest value to determine a daily savings. For the low temperature boxes there was a reduction from 11.3 hours to 8.9 hours of daily defrost recovery; for the medium temperature boxes there was a reduction from 6.5 hours to 2.4 hours of daily defrost recovery. The average of these values was calculated, and then multiplied by 365 to extrapolate the savings to an annual value.

The ex post impacts are shown as follows:

Table 3: Ex Post Annual Savings Summary-Evaporator Fan VFDs

Room Type	Calculated Baseline Annual Usage (kWh)	Calculated Post Annual Usage (kWh)	Annual Energy Savings (kWh)
Coolers	56,572	38,478	24,125
Freezers	93,607	83,220	20,477
Loading Dock	113,144	76,956	36,188
Candy Room	22,629	15,391	7,238
Total	263,322	198,654	88,028

No kW savings are possible for this measure as this equipment is purposefully shut off during peak periods for both the ex ante and ex post operation.

Table 4: Ex Post Annual Savings Summary-Demand Based Defrost

System	Calculated Baseline Annual Usage (kWh)	Calculated Post Annual Usage (kWh)	Annual Energy Savings (kWh)
Medium Temp	29,991	9,391	20,600
Low Temp	162,765	103,554	59,211
Total	192,756	112,945	79,811

No kW savings are possible for this measure as this equipment is purposefully shut off during peak periods for both the ex ante and ex post operation.

Table 5: Multi Year Reporting Summary

Program ID:		A096					
Program Name:		SPC 04-05 Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	126,416	39,757				
3	2006	758,493	238,542				
4	2007	758,493	238,542				
5	2008	758,493	238,542				
6	2009	758,493	238,542				
7	2010	758,493	238,542				
8	2011	758,493	238,542				
9	2012	758,493	238,542				
10	2013	758,493	238,542				
11	2014	758,493	238,542				
12	2015	758,493	238,542				
13	2016	758,493	238,542				
14	2017	758,493	238,542				
15	2018	758,493	238,542				
16	2019	758,493	238,542				
17	2020	632,078	198,785				
18	2021						
19	2022						
20	2023						
TOTAL	2004-2023	11,377,395	3,578,132				

The engineering realization rate for this application is 0.31 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 7.

6. Additional Evaluation Findings

The ex post energy savings are less than the ex ante due to the ex ante savings assuming a higher refrigeration load than was measured ex post. This resulted in longer runtimes for the base case evaporator fans and higher base case kWh. Also, the ex-ante savings included compressor and condenser fan savings for the evaporator fan VSD installation; these savings are not present in the ex-post evaluation.

The total ex-ante savings for all measures was 1,325,978 kWh annually. The annual utility usage for the year (normalized to 365.25 days) before the project was 5,256,943 kWh and the utility usage for the year following the project completion was 4,529,415 kWh. This is a difference of 727,528 kWh, or 55% of the ex-ante savings. Since no other changes in operation or schedule were apparent at this site, it appears that the savings from the projects did indeed fall well short of the ex ante claim.

No kW savings are possible as this equipment is purposefully shut off during peak periods for both the ex ante and ex post operation.

With a cost of $259,538 and a $103,105 incentive, the project had a 1.8 year simple payback based on the ex ante calculation of annual savings. The annual ex post savings estimate for the project is much lower than the ex ante, and the estimated simple payback is 5.9 years. A summary of the economic parameters for the project is shown in Table 6.

There does not appear to be any carryover affect from this project in terms of other energy efficiency activity or awareness at this facility.

7. Impact Results

Table 6: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	11/21/2005	$285,379	0	758,493	0	$98,604	$103,105	1.8	2.9
SPC Program Review (Ex Post)	12/20/2007	$285,379	0	238,542	0	$31,010	$103,105	5.9	9.2

Table 7: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	-	758,493	-
SPC Installation Report (ex ante)	-	758,493	-
Impact Evaluation (ex post)		238,542	-
Engineering Realization Rate		0.31	NA

Table 8: Verification Table

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Variable Speed Drives of Evaporator Fans	AC&R	Install VSDs on a total of 19 different evaporator fans.			N/A	Danfoss VSDs installed on 5 freezer evaprarator fans, 4 cooler evaparator fans, 6 loading dock evaporator fans, and 4 candy room evapaporator fans. Candy room fans are 3 HP, all others are 15 HP.	Was able to physically see and inspect all 19 VSD were installed on the 19 evaporator fans. Fifteen (15) of the VSDs are 15 HP, four (4) are 3 HP.	1.00
Demand Based Control of Evaporator Coils	Other	Change from time based defrost cycle to demand based.			N/A	Low Temperature compressor is a 300 HP model FES 270, medium temp compressor is a 250 HP model FES 180.	To the extent possible physically verified equipment described in the post intallation report. Much of the new equipment installed is computer/software based, so physical verificaton is not possible.	1.00
Floating Head Pressure Controls	AC&R	Change from fixed head pressure to floating head pressure, allowing the compressors to work less by operating at a lower head pressure.			N/A	Low Temperature compressor is a 300 HP model FES 270, medium temp compressor is a 250 HP model FES 180.	To the extent possible physically verified equipment described in the post intallation report. Much of the new equipment installed is computer/software based, so physical verificaton is not possible.	1.00

Table 9: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh/yr
Total Meter	218.9	5,253,345
Baseline End Use	0.0	2,488,815
Ex Ante Savings	0.0	758,493
Ex Post Savings	0.0	238,542

Table 10: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh/yr	kW	kWh/yr
Total Meter %	0.0%	14.4%	0.0%	4.5%
Baseline End Use %	0.0%	30.5%	0.0%	9.6%

SITE A097 2004-xxx Tamc IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 3 END USE: Other

Measure	Install VSD controls on baghouse fans
Site Description	Steel Mill

1. Measure Description

The incented measure was the installation of a variable speed drives on two 1500 hp baghouse fans. The baghouse functions as air pollution control device, capturing flue dust, impurities and dirt produced in the arc furnace. The VSD controls the speed of the two fans to maintain a minimum air quality standard, thus reducing the load and saving fan energy. The facility is a steel mill where steel scrap is converted into reinforcing steel bar (rebar). The steel mill operates 24 hours per day year round with approximately 50 days of downtime.

2. Summary of the Ex Ante Calculations

The energy savings are a result of controlling fan flow via motor speed instead of preexisting inlet dampers. The ex ante calculations show an annual savings of 1,089,704 kWh and 102.0 kW demand savings. These are both in the Installation Report Review (IRR) and in the utility tracking system. An incentive of $87,176 was calculated based on kWh saved. The program verification consisted of verifying VSD installation, collecting power data on the motor, and verifying operating time. The baghouse is operated year round. The plant production is shut down approximately 50 days per year for maintenance and during those 50 days the baghouse operates 20 days for cleaning the ducting system. The preexisting fans were controlled by inlet vanes. The original savings calculations assumed the existence of outlet dampers and once the actual control method was verified, the savings estimates were revised.

The baseline and as-built energy usages were not included in the project file.

The ex ante impacts were as follows:

- Energy savings: 1,089,704 kWh/ yr
- Demand savings: 102 kW

The incentive was calculated as follows:

- $0.08 per kWh
  Incentive was $0.08 x 1,089,704 = $87,176.32

3. Comments on the Ex Ante Calculations

The program file does not contain details of the ex ante calculation. The savings estimates were calculated using ABB's SoftSave Program. Critical input variables used in the calculator to estimate the energy savings are not indicated in the project file and there was limited documentation. No easily traceable calculation methodology, actual algorithms, or other details were provided that would provide insight into ABB's SoftSave Program.

The ex-ante savings and incentive were based on the assumed difference of baseline power consumption and proposed power consumption. The baghouse fans were retrofit with two 1750 hp 4160V ABB VSDs. The baseline assumptions included 90% motor loading, a motor efficiency of 96.4%, a design flow of 367.5 CFM, annual operating hours of 5200 hours and inlet vane damper control. With the VSD controls, the fans were estimated to ramp down to 73% of full load speed 46% of the time and 54% of full load speed 54% of the time.

The assumptions used above seem reasonable for this project. The facility production logs 5,434 production hours of operation from 2005, making the original operating hours assumption very reasonable. The project file does not state whether or not the other inputs were verified by measurement or production logs or simply assumed using engineering judgment or experience.

The primary source of uncertainty involved in the ex-ante estimation is the projected load profile.

4. Measurement & Verification Plan

This measure reduces electrical usage by reducing motor speed. The fundamental the measurement and verification plan steps are as follows:

- Verify installation
- Acquire short-term interval data
- Project annual usage and peak demand from interval data
- Estimate pre-retrofit usage and peak demand
- Calculate savings

The initial contact by phone with the client will be an essential first step in the development of this plan and will help further define the monitoring scope. During the phone call, the evaluation team will attempt to establish any metered data that the facility possesses and whether the data are available for this evaluation.

Facilities of this type typically monitor their processes to some degree and many keep records of monitored data, operational schedules and product throughput. The existence of these data and the willingness of the client to share these data with the evaluation team will ultimately determine the M&V approach. The requested data will include:

- Annual operational schedules of the fan/process
- Pre and post implementation trend data

Using existing data streams always introduces some uncertainty, but when a site is fully instrumented it is usually the most cost effective way to proceed. If facility monitored site data is exists, redundant spot measurements will be taken to compare with the site monitored data. Our on-site verification will strive to determine the overall quality of the monitoring installation and attempt to verify that the measurements are taken at the correct physical locations. If any major discrepancies are identified, an alternative M&V plan will be developed.

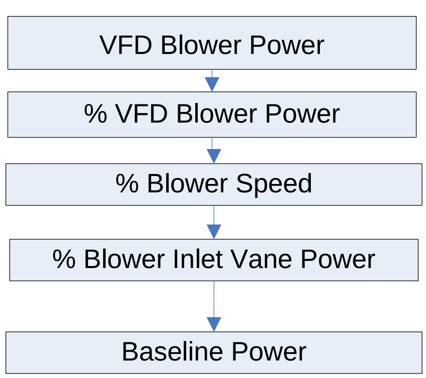
If no data are available for pre-retrofit conditions, the evaluation team will resort to an approach that will estimate pre-retrofit usage from engineering concepts. If no post-retrofit data are available, the baghouse fans will be monitored with loggers that record true power. If information acquired during the initial contact leads to more metering opportunities, the team will revise the metering plan.

On-site verification of motor data (model number, efficiency, horsepower, speed) and motor quantity and spot watt measurements of the motors monitoring real-time motor power draw will be performed.

As the bag house blowers were controlled by an inlet vane control at the pre-retrofit condition, the full load baseline power consumption is 109 %[1]of the rated power consumption of the blower.

We will use blower curves for the VSD blower and inlet vane blower from EPRI's relative energy consumption of different fan control strategies. The blower curves were used to extrapolate from the monitored VSD blower power to baseline blower power. Figure 1 illustrates the order in which the calculations will be performed for the blowers.

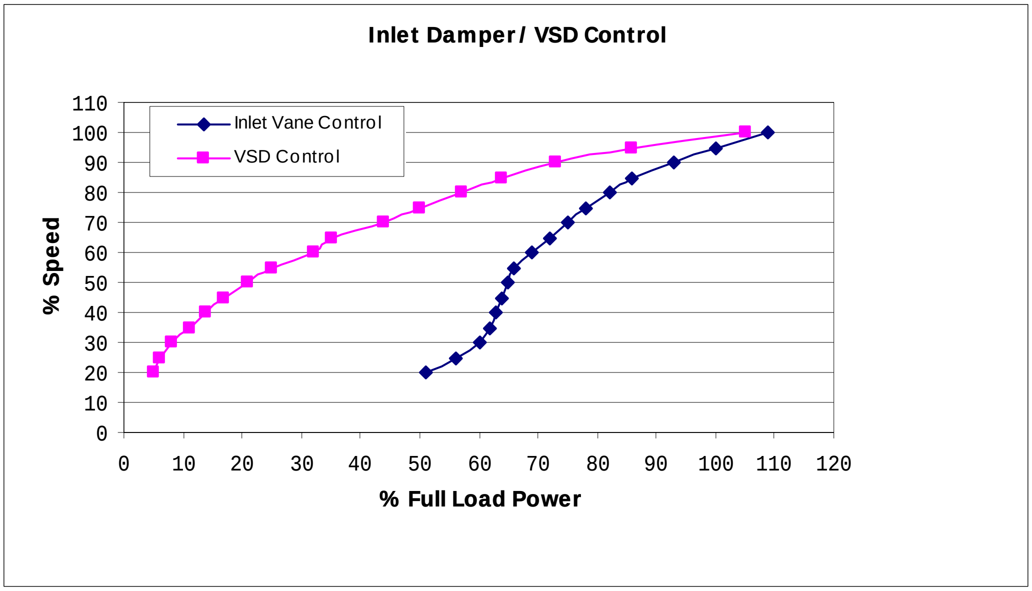
Figure 1: Bag House Blower Pre-Retrofit Power Consumption Calculation Sequence



[1] From EPRI's relative energy consumption of different fan control strategies

First, the percent power that the VSD uses will be calculated by dividing the metered power by the measure or rated full load motor power. This will be done not only for the average power draw, but for every metered point, which will be taken at fifteen-minute intervals. Next, the VSD percent speed will be calculated using the blower curve shown in Figure 2.

Figure 2: EPRI's relative energy consumption of different fan control strategies



The speed ratio is the same for the pre-retrofit and post retrofit condition. This means the speed ratios will be calculated in the previous step could be used in the power/speed curve for the pre-retrofit condition. The final step in the calculation is to simply convert the power ratio to actual baseline power by multiplying by the rated input power.

The evaluation calculation for savings will use basic electrical conversions, annual operating hours, and the difference in baseline and as-built motor speed and power consumption.

Formulae

If available, pre-retrofit meter data will be used to calculate the baseline load and power consumption. Either facility operational data or metered motor data will be used to calculate post-retrofit energy consumption. First, an hourly motor profile will be created from the data for each day of the week. If all days are similar, the hourly profile will be an average of all days or two profiles, weekday/weekend can be used if there marked differences between the day types. The metered energy consumption will be extrapolated to represent a full year. The following equations were used to determine pre and post installation energy consumption:

$$kW_{reduced} = kW_{baseline} - kW_{proposed}$$

Where,

$kW_{reduced}$ = Reduced Power Consumption (kW)
$kW_{baseline}$ = Baseline Power Consumption (kW)
$kW_{proposed}$ = Metered Power Consumption (kW)

The annual savings then become:

$$\text{Annual kWh Savings} = kW_{reduced} * \text{Annual Hours}$$

As the equations show, a key factor in the savings calculation is the annual operating hours, which will be calculated from the metered data. The exact methodology for annual savings calculation strategy will depend on field findings.

Uncertainty for the savings estimate for the VSD fan motor can be more fully understood by setting projected ranges on the primary variables.

Accuracy of load profiles: +/- 20%
Accuracy of hours/year: +/- 5%

Accuracy and Equipment

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

The largest source of uncertainty stems from using self-reported production schedules to annualize energy usage from short term meter data. If the production schedule is consistent throughout the year, and fan power draw is consistent, a 10% uncertainty is a reasonable estimate. However if the fan power draw is highly variable or the production schedule is complex, an uncertainty of 30% could be argued in the annualization of energy usage.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 25, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the variable frequency drives on the blowers and by interviewing the facility representative. One-minute kW interval data along with the speed for the VSD retrofitted bag house blowers were collected from the facility monitoring system for an entire year from September 2006 to August 2007.

Installation Verification

The installation of VSDs on the 1500 hp bag house blowers was verified via visual inspection. Both the General Electric bag house blowers are retrofitted with ABB variable frequency drives. The facility representative stated that the retrofit was completed by October 2005.

This is the only measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 5.

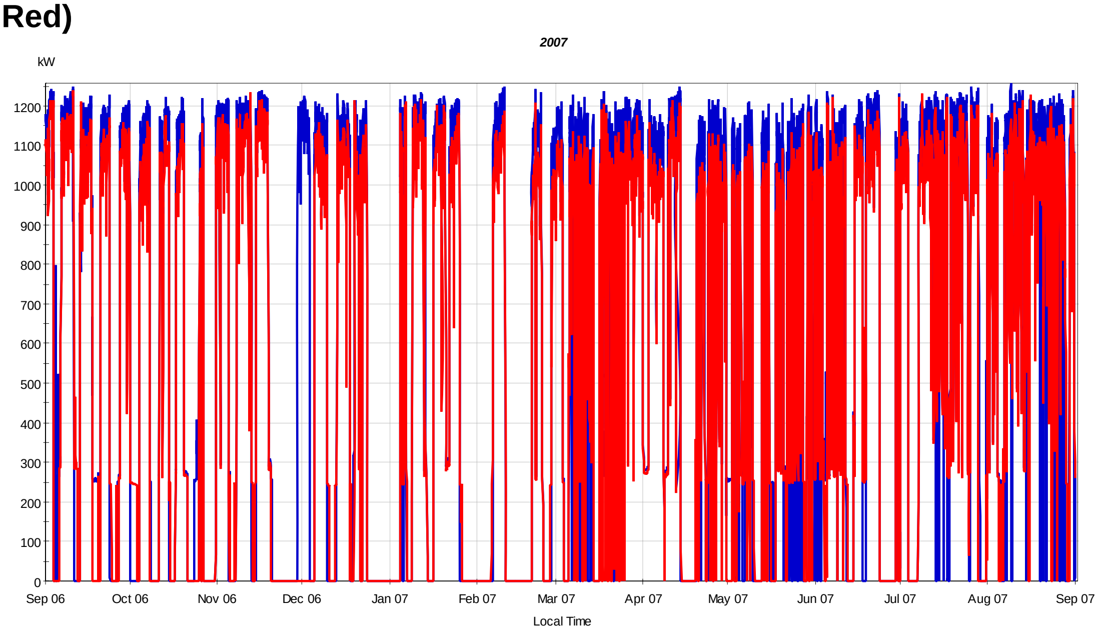
Scope of the Impact Assessment

The impact assessment scope for this application is for the "Other" end use category in the SPC application (covering the motor controls retrofit). This is the only measure in this application.

Summary of Results

The collected kW data for an entire year period from September 2006 to August 2007 from the facility monitoring system were collected. Figure 3 shows the power profiles of both the post-retrofitted blowers. The meter data showed the north side blower operates 5,741 hours per year and the south side blower operates 5,779 hours per year. The plant personnel also stated that the metered data is representative of a typical year. The facility runs the blowers when there is a production demand.

Figure 3: 1500 hp Bag House Blower Raw Meter Data (North-Blue & South-Red)



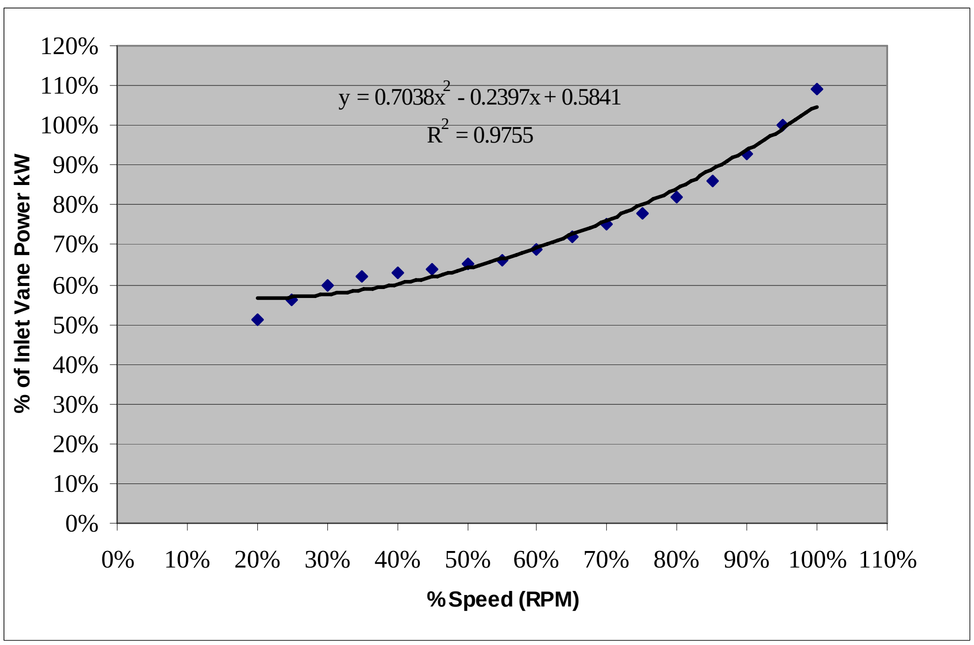
The ex post calculations were performed using the blower kW data retrieved onsite. The obtained interval kW data for both the blowers were plotted against their corresponding speeds. It was found that the power consumption of the blowers varies with the speed of the motor.

We developed a pre-retrofitted power consumption profile of the blowers before the VFD retrofit based on the post-retrofitted operating conditions. The process of this method are described in Figure 4.

Each metered hourly kW was divided by the full load power to obtain the % of the full load power. Similarly, the corresponding metered speed was divided by full load speed to determine the % of full load speed. The percentage of speed is same for both pre-retrofit and post retrofit condition. By using EPRI's speed/power curve for relative energy consumption of different fan control strategies % of power for each hour was determined from the corresponding % of speed. The curve is presented in Figure 4.

Then pre-retrofit power for specific interval will be calculated simply by as full load power times the % power.

Figure 4: Estimated Pre-retrofitted % of Full Speed v.1 % Power Curve



Then the ex-post savings were calculated simple by comparing the hourly kW profile of the pre-retrofit and installed blowers. Figure 5 and Figure 6Figure show the comparison of power profile of actual post-retrofitted blower with the estimated pre-retrofitted blowers respectively.

Figure 5: Comparison of Actual Post Retrofitted kW Data with Estimated Pre-Retrofitted Power Draw (North Blower)

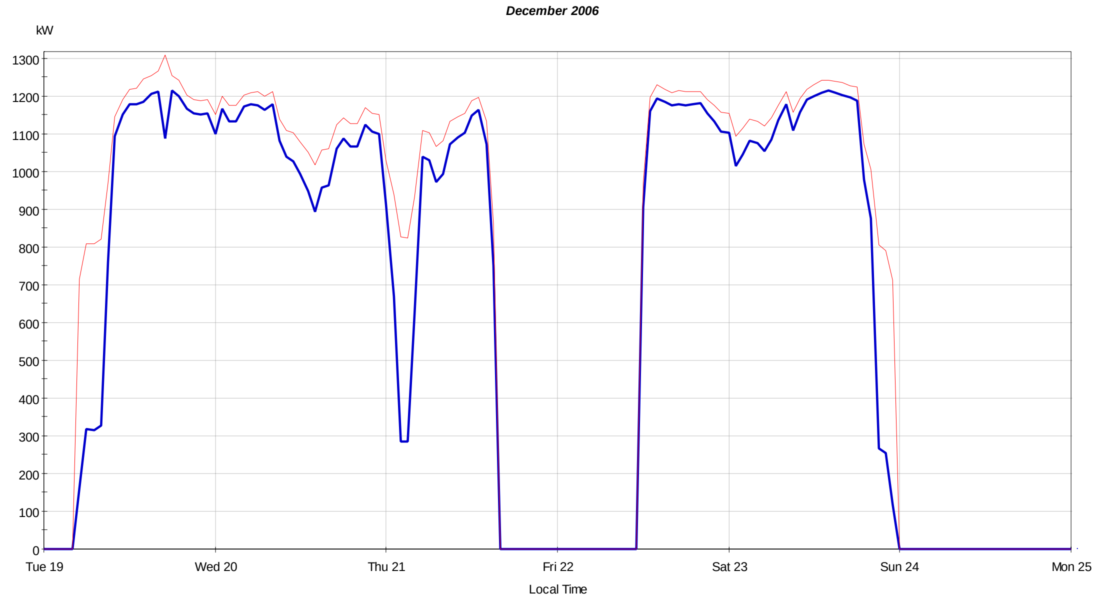


Figure 6: Comparison of Actual Post Retrofitted kW Data with Estimated Pre-Retrofitted Power Draw (South Blower)

The ex post impacts are calculated as follows:

- Estimated pre-retrofitted energy usage: 12,426,517 kWh/ yr
- Estimated pre-retrofitted demand: 1443.7 kW
- Post-retrofit energy usage: 10,607,856 kWh/ yr
- Estimated post-retrofitted demand: 1254.8 kW

- The resulting annual kWh savings are 12,426,517 kWh/ yr – 10,607,856 kWh/yr = 1,818,661 kWh/yr.

Summer peak impacts were estimated by subtracting post-retrofit from estimated pre-retrofit connected load for the weekday 2 pm to 5 pm.

- Peak kW savings is 1443.7 kW – 1254.8 = 188.9 kW.

The engineering realization rate for this application is 1.67 for energy savings (kWh) and 1.9 for demand reduction (kW). The values shown in the tracking system agree with those shown in the installation report for this application. The total meter, ex ante and ex post energy consumption is shown in Table 1.

Table 1 summarizes the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 2 is a summary of the percent of energy savings for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 7.1% decrease in blower end use kW and a 8.8% decrease in blower use kWh. The ex post results showed a 13.1% decrease in blower end use kW, and a 14.6% decrease in baseline end use kWh.

Table 1: Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh	
Total Meter	NA	NA	
Baseline End Use	1,443.7	12,426,517	
Ex Ante Savings	102	1,089,704	
Ex Post Savings	188.9	1,818,661	

Baseline is the energy use of this process system. Total energy use was not available.

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	NA	NA	NA	NA
Baseline End Use %	7.1%	8.8%	13.1%	14.6%

6. Additional Evaluation Findings

The ex post energy savings are greater than the ex ante energy savings because the discovered the ex ante savings estimates of energy consumption were underestimated compared to the monitored data received from the facility.

The data showed that the variable frequency drive retrofitted blowers saves more energy than predicted, because we found that the full load power draw of the individual blower was 1,240 kW, where as the ex-ante savings was calculated based on a full load power of 851.2 kW. Essentially, the motor load factor for the fans was much higher than anticipated, and the savings are directly proportional to load factor.

The evaluation team physically verified the VFD retrofits, and the bag house blower motors and used plant data to verify operating hours. The evaluation team is satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $401,000 and a $87,176 incentive, the project had a 2.2 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is more than the ex ante, and the estimated simple payback is 1.3 years. A summary of the economic parameters for the project is shown in Table 3.

7. Impact Results

Table 3: Economic Information

Description	Date	Project Cost, $	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, Therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ Incentive, yrs	Simple Payback w/o Incentive, yrs
Installation Approved Amount (Ex Ante)	2/8/2006	401,000	102	1,089,704		141,662	87,176	2.22	2.83
SPC Program Review (Ex Post)	9/25/2007	401,000	188.9	1,818,661		236,426	87,176	1.33	1.70

Table 4: Realization Rate Summary

	kW	kWh
SPC Tracking System	102	1,089,704
SPC Installation Report (Ex-ante)	102	1,089,704
Impact Evaluation(ex-post)	188.9	1,818,661
Engineering Realization Rate	1.9	1.67

Table 5: Installation Verification Summary

Measure Description	End-use category	Other Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Other	O	Install VFD on Two Bag House Blowers	2	1500 hp Bag House Blower	Physically Verified VFD and the Blowers	1.0

Table 6: Multi Year Reporting Table

Application A097

Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	181,617	303,110				
3	2006	1,089,704	1,818,661	102	188.9		
4	2007	1,089,704	1,818,661	102	188.9		
5	2008	1,089,704	1,818,661	102	188.9		
6	2009	1,089,704	1,818,661	102	188.9		
7	2010	1,089,704	1,818,661	102	188.9		
8	2011	1,089,704	1,818,661	102	188.9		
9	2012	1,089,704	1,818,661	102	188.9		
10	2013	1,089,704	1,818,661	102	188.9		
11	2014	1,089,704	1,818,661	102	188.9		
12	2015	1,089,704	1,818,661	102	188.9		
13	2016	1,089,704	1,818,661	102	188.9		
14	2017	1,089,704	1,818,661	102	188.9		
15	2018	1,089,704	1,818,661	102	188.9		
16	2019	1,089,704	1,818,661	102	188.9		
17	2020	908,087	1,515,551	102	188.9		
18	2021						
19	2022						
20	2023						
TOTAL	**2005-2023**	**16,345,560**	**27,279,916**				

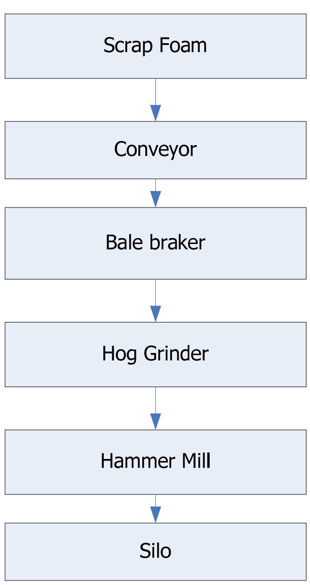
SITE A098 (04-0507) Foam **IMPACT EVALUATION**
SAMPLE CELL: ORIGINAL TIER: 3 END USE: Other

Measure	Install efficient grinder and pre-grinder
Site Description	Foam Manufacturing Facility

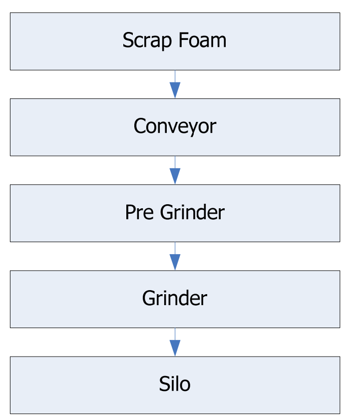
1. Measure Description

The measure involves the installation of two efficient 200 hp grinder motors and one 150 hp pre-grinder motor. The new equipment eliminates the need for existing equipment, including a hammer mill and blower, granulator and blower, bale breaker blowers, hog grinder and blower, and torit blower. The facility produces foam material for furniture, bedding, and similar products. The manufacture of these products generates scrap material. This scrap material is made into carpet padding using the new grinders, pre-grinder, and other equipment. The process of producing the carpet padding has changed due to the installation of the new equipment. The existing and proposed production processes are shown below, illustrating the eliminated equipment.

Existing System



Proposed System



2. Summary of the Ex Ante Calculations

The ex-ante calculations were based on the differential energy consumption between the pre-existing grinding system and the proposed grinding system. The savings were calculated as follows:

$$\text{Energy Savings (kWh)} = [(BL_{hp}/\eta_b) \times LF_m \times H] - [PL_{hp}/\eta_p) \times LF_p \times H] \times 0.7456\ \text{kW/hp}$$

Where,

BL_{hp}	=	baseline output power (hp)
PL_{hp}	=	proposed output power (hp)
LF_m	=	measured load factor
η_b	=	efficiency of baseline system
η_p	=	proposed efficiency
LF_p	=	proposed load factor
H	=	annual operating hours of the system (hr/yr)

The baseline output power of the existing equipment totaled 1000 hp. The baseline energy consumption was calculated by using Title 24 minimum motor efficiencies, a measured average load factor of 57.1% and annual operating hours of the system. The proposed system has a total output power of 450 hp. The proposed energy use calculations were based on submitted efficiencies, an estimated average load factor of 46.7% and annual operating hours of the system. The facility hours were reported to be twenty-four hours per day, six days a week, with eleven holidays annually.

The ex ante impacts were calculated as follows:

The baseline and as-built energy usages were as follows:

- Baseline energy usage: 3,193,009 kWh/ yr
- Baseline peak demand: 588.5 kW
- Proposed post installation energy usage: 1,457,081 kWh/ yr
- Proposed post installation peak demand: 290.7 kW

The ex ante impacts were as follows:

- Energy savings: 3,193,009 kWh/yr - 1,457,081 kWh/yr = 1,735,928 kWh/ yr
- Demand savings: 588.5 – 290.7 =297.8 kW

The incentive was calculated as follows:

- $0.08 per kWh
  Incentive was $0.08 x 1,735,928 = $138,874.24
- No measure cost adjustment needed since the incentive was less than 50% of total project cost.

These figures are listed in the Installation Report Review (IRR). The annual kwh savings in the utility tracking system agree with the IRR. However, the kW savings in the tracking system and the IRR are noted as 290.7 kW (verses 297.8 kW in the spreadsheet calculations).

3. Comments on the Ex Ante Calculations

The ex-ante savings and incentive were based on the difference in power consumption between the two systems. The proposed system uses a 150 hp pre-chopper motor with 95.8% efficiency and two 200 hp grinder motors with 95% efficiency. The existing equipment that was removed and the proposed equipment installed are shown below. Altogether, there is a 450 hp reduction.

Existing Removed Equipment	HP
Hammer Mill	350
Hog Mill	100
Hammer Mill Blower	40
Hog Mill Blower	30
#1 Bale Breaker, blower 2	75
#1 Bale Breaker, blower 4	75
Torit Blower 2	30
#2 Granulator	250
#2 Granulator Blower	50
Total Removed	1000

Proposed Equipment	HP
Grinder (2 at 200 hp)	400
Pre-grinder	150
Total Installed	550

The baseline was calculated using measured average kW for each piece of equipment removed, which was 57.1% of the rated kW, on average. The proposed energy consumption was calculated by multiplying the percentage load factor by the proposed horsepower over the horsepower reduction (effectively assuming that the new grinders have the same load and consume the same energy as the hammer mill and hog mill). In other words, it was calculated as [57.1% x (450 hp / 550 hp)] equaling 46.7%. The result was an existing and proposed energy consumption of 3,193,009 kWh and 1,475,081 kWh, respectively.

Overall, the project file is fairly informative in terms of savings calculations. However, there is still some uncertainty associated with the facility operating hours since they were only verified verbally. This uncertainty of the self reported operating hours is estimated at ±15%. Furthermore, the baseline monitoring could have significant uncertainty since the monitoring period was only one hour. The uncertainty can be estimated at ±20% for both the baseline and proposed power consumption.

4. Measurement & Verification Plan

The facility where the measure was implemented is a 230,000 square feet foam manufacturing facility. This measure reduces electricity usage by reducing the rated power needed to complete the process. The fundamental premise in development of the measurement and verification plan is to determine the amount of electricity consumed by the proposed system through temporary measurements and short-term monitoring. The evaluation baseline will use the baseline load from the project file since the power draw of these motors was monitored. However, the baseline energy consumption (kWh) may change if the operating hours differ from that in the project file. The M&V plan will be implemented in four basic steps:

1. On site verification of installed grinder system
2. Instantaneous power measurement of the all the motors in the proposed system
3. Collect trend kW data on all grinder motors
4. Grinder motors' name plate data (model number, efficiency, horsepower, speed) a

The initial contact by phone with the client is an essential first step in the development of this plan and will help further define the monitoring scope. During the phone call, there will be an attempt to verify the schedule of the motors and establish what metered data the facility has and whether that data may be available for this evaluation.

Facilities of this type typically monitor their processes and keep records of monitored data, operational schedules and product throughput. The existence of these data and the willingness of the program participant to share these data with us will ultimately determine the M&V approach. The requested data will include:

- Operational schedule of the proposed system
- Grinder technical information
- Baseline and proposed power and current draw of motors

From our assessment of the project file and our experience with similar measures, we know that monitoring the motors with loggers that record current, power factor, and voltage would be useful. All three motors will be monitored with true power loggers if trend data are not available.

Our on-site verification will assess the overall quality of the monitoring installation and attempt to verify that the measurements are taken at the correct physical locations. We will attempt to verify the accuracy of the power measurements with redundant spot measurements.

Formulae and Approach

The ex post savings calculation will use basic electrical conversions, annual operating hours, and the difference in pre and post retrofit motor energy consumption. Metered data is essential to calculate the proposed annual energy consumption. An hourly motor profile will be created from the data for each day of the week. Since all days are relatively similar, the final hourly profile was an average of all days. The metered energy consumption will be extrapolated to represent a full year based on reported seasonality and operational schedule. The baseline kW data will be collected from the application data with measurements before the installation of the proposed equipment. The annual baseline energy usage is the average power consumption of the motors multiplied by the annual operating hours.

We will use the following equations to determine pre and post installation energy consumption.

$$P_{pre\ retrofit} = (\text{motor hp}) \times 0.7457 \times \text{L.F.}/(\text{motor efficiency})$$
$$P_{post\ retrofit} = \text{monitored power from the data logger}$$

Where,

$P_{pre\ retrofit}$ = pre retrofitted motor power (kW)
$P_{post\ retrofit}$ = post retrofitted motor power (kW)
L.F. = Load Factor

$$P_{reduced} = P_{pre\ retrofit} - P_{post\ retrofit}$$

The annual savings then become:

$$\text{Annual kWh Savings} = P_{reduced} * \text{Annual Hours}$$

As the equations show, a key factor in the savings calculation is the annual operating hours and those will be calculated from the metered data. The greatest uncertainties in the ex ante savings estimate are associated with the estimate of motor load factor and annual operating hours. The ex ante calculation appeared to generate a single estimate of load factor based on pre retrofitted load estimate. This could easily have produced a 10 to15% error in the savings estimate.

Uncertainty in the savings estimate for the grinder motors can be more fully understood by setting projected ranges on the primary variables.

$P_{post\ retrofit}$ = motor power consumption (kW) (±5%)
minimum 191.6 kW; expected 201.7 kW; maximum 211.78 kW

Hr = annual operating hours (±10%)
minimum 6,501 hrs/yr; expected 7,224 hrs/yr; maximum 7,946 hrs/yr

LF = Load factor (-15% to +20%)
minimum 39.6% , expected 46.7%, maximum 56.4%

Accuracy and Equipment

A clamp on power meter, the LEM 2060 Analyst from Fluke, will be used to take spot measurements of the grinder motors. These instantaneous kW measurements will be compared with the collected trend kW data. This power meter has the capability of measuring RMS voltage, current, power factor, true power and total harmonic distortion.

In addition, Dent Instruments Elite pro loggers with three current transformers will be installed on each of the three motors for a period of at least three weeks. These loggers can sample at intervals up to 3 seconds. Their accuracy is better than 1% of the reading. Also, the accuracy of the current transformers is approximately ±1%.

These data then can be downloaded to the PC for further analysis. All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 5, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the two grinder motors and one pre-grinder motor and by interviewing the facility representative. Three Elite Pro energy loggers were installed on all three incented motors for a period of three weeks in the month of September 2007.

Installation Verification

The evaluation team physically verified the installation of two 200 hp grinder motors and one 150 hp pre-grinder motor. The facility representative also stated that the installation was completed on March 2005.

These are the only measures in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 6.

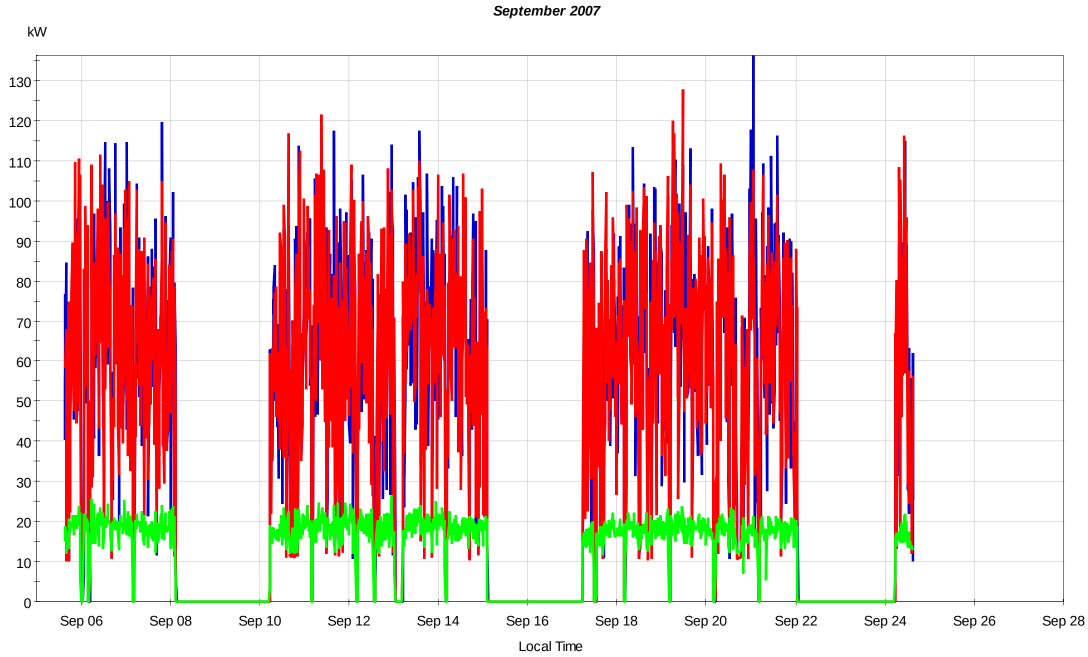
Scope of the Impact Assessment

The impact assessment scope is for the “Other” end use category in the SPC application covering premium efficiency motor retrofits. These are the only measures in this application.

Summary of Results

Three Elite Pro data loggers from Dent Instruments were installed on all three incented motors to measure the power consumption as well as the operating hours. It was found that the motors were operating 24 hours a day and 5 days a week and three hours on Saturdays. The facility representative stated that the 21-day period had been representative of normal facility operation. Figure 1 shows the power profile of all three motors for the monitoring period.

Figure 1: Power Profile of all Three Grinder motors (Grinder #1-Blue, Grinder #2-Red and Pre-Grinder- Green)



According to the facility personnel, by replacing the older inefficient system with a high-efficiency system, the facility has not only saved energy but also increased their productivity substantially. He also stated that the new system saves 40 minutes per day in production hours and eliminates a ten-hour weekly maintenance period. Table 1 shows annual hours saved by the new system.

Table 1: Annual Hours Saved By the New System

Annual production weekdays	252	Days
Annual production weekend	52	Days
Hours of production in weekdays	24	hrs/ day
Hours of production in weekend	3	hrs/ day
Total number of production hours	6,204	hrs/yr
Production gain	40	mins/day
Maintenance gain	10	hrs/week
Total hours gained	723	hrs/yr
Percentage gained	11.6%	
Production gain factor	1.116	

The post-retrofit energy consumption was calculated using the monitored kW data and operating schedule, taking into consideration eight holidays a year and no seasonal variation in the motor schedule.

As the installation of the new system not only saved energy but also increased productivity. This is captured in the measure data. No production figures were able to be gathered for this period.

The ex-post savings calculations were performed by comparing pre retrofit and actual post retrofit energy consumption.

The ex post impacts are calculated as follows:

- Pre-retrofit peak demand was 588.5 kW
- Pre-retrofit average demand was 441.8 kW
- Hours of use were 6,204 hrs/yr
- Annual kWh usage was 2,740,927 kWh/yr
- Based on energy logger data
  Estimated post-retrofitted peak demand: 173.3 kW
  Actual post-retrofit energy usage: 793,586 kWh/ yr

- The resulting annual kWh savings is 2,740,927 kWh/yr – 793,586 kWh/yr = 1,947,341 kWh/yr.

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit weekday 2 pm to 5 pm connected load.

- Peak kW savings is 588.5 kW – 173.3 = 415.2 kW.

The engineering realization rate for this application is 1.43 for demand kW reduction and 1.12 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 5.

Table 2 summarizes the baseline end use energy, the ex ante savings and the ex post calculation results. Total energy use was not available for this facility.

Table 2: Ex Ante, Ex Post Results

	Peak Demand (kW)	Annual kWh
Total Meter	Not Available	Not Available
Baseline End Use	588.5	2,740,927
Ex Ante Savings	290.7	1,735,928
Ex Post Savings	415.2	1,947,341

Table 3 is a summary of the percent of energy savings for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results were 49.4% of motor end use kW, and 63.3% of motor end use kWh. The ex post results were 70.6 % of motor end use kW and 71.0% of motor end use kWh.

Table 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/ kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	NA	NA	NA	NA
Baseline End Use %	49.4%	63.3%	70.6%	71.0%

6. Additional Evaluation Findings

The ex post energy savings and demand savings are higher than the ex ante energy savings because it was found that the new motors operate at an average load factor of 39% during the monitoring period, whereas the ex ante calculation was conducted using a higher load factor of 46.7%. It was also found that the installation of the new equipment has increased the productivity of the facility substantially by eliminating the weekly ten hour maintenance periods and production loss time of 40 minutes a day associated with the old inefficient system.

The evaluation team physically verified the premium efficiency motors, and used metered data to verify operating hours and motor load. The evaluation team is satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

The costs seem realistic for the grinders and pre grinder motors based on industry experience.

The project increased energy awareness in the company. The customer also stated that they are always looking for energy efficiency opportunities.

With a cost of $284,890 and a $138,874 incentive, the project had a 0.65 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 0.58 years. A summary of the economic parameters for the project is shown in Table 4.

The effective useful life of the high efficiency grinders is 15 years. Table 7 shows projected annual ex ante and ex post energy savings for multiple years 2004 through 2023.

7. Impact Results

Table 4: *Economic Information*

Description	Date	Project Cost, $	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, Therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ Incentive, yrs	Simple Payback w/o Incentive, yrs
Installation Approved Amount (Ex Ante)	7/19/2005	236,000	$284,890	290.7	1,735,928		225,671	138,874	0.65	1.26
SPC Program Review (Ex Post)	9/24/2007	236,000	$284,890	415.2	1,947,341		253,154	138,874	0.58	1.13

Table 5: Realization Rate Summary

	kW	kWh
SPC Tracking System	290.7	1,735,928
SPC Installation Report(Ex-ante)	290.7	1,735,928
Impact Evaluation(ex-post)	415.2	1,947,341
Engineering Realization Rate	1.43	1.12

Table 6: Installation Verification Summary

Measure Description	End-use category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Other	O			Install Efficient Grinders and Pre-Grinder	3	Two 200 hp P.E. Grinder Motors and One 150 hp P.E. Pre-Grinder Motor	Physically Verified the Grinders and Pre-Grinder	1.0

Table 7: Projected Multi Year Ex Ante and Ex Post Savings

Program Name:		SPC 04-05 Evaluation Site A098					
Year	Calendar Year	Ex-ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	0	0	0	0		
2	2005	289,321	324,557	0	0		
3	2006	1,735,928	1,947,341	290.7	415.2		
4	2007	1,735,928	1,947,341	290.7	415.2		
5	2008	1,735,928	1,947,341	290.7	415.2		
6	2009	1,735,928	1,947,341	290.7	415.2		
7	2010	1,735,928	1,947,341	290.7	415.2		
8	2011	1,735,928	1,947,341	290.7	415.2		
9	2012	1,735,928	1,947,341	290.7	415.2		
10	2013	1,735,928	1,947,341	290.7	415.2		
11	2014	1,735,928	1,947,341	290.7	415.2		
12	2015	1,735,928	1,947,341	290.7	415.2		
13	2016	1,735,928	1,947,341	290.7	415.2		
14	2017	1,735,928	1,947,341	290.7	415.2		
15	2018	1,735,928	1,947,341	290.7	415.2		
16	2019	1,735,928	1,947,341	290.7	415.2		
17	2020	1,446,607	1,622,784	290.7	415.2		
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	**26,038,920**	**29,210,119**				

SITE A099 (05-xxxx) Kim IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 2 END USE: Other

Measure	Install VSD Controls on a 700 hp Pulper Motor
Site Description	Paper Manufacturing Facility

1. Measure Description

Install a variable speed drive (VSD) on a pulping motor used to drive a mixer in a 15,000 gallon mixing tank used in the manufacture of tissue paper. A blade rotor is housed in the bottom of the tank and is used to process recycled dry bales of wood fiber pulp and water into pulp slurry. The pulping cycle is performed in batches.

2. Summary of the Ex Ante Calculations

The installation of the VSD is a calculated measure. The energy savings are a result of reducing the motor speed. The ex ante calculations show an estimated annual savings of 2,257,500 kWh due to the VSD. An incentive of $180,600 was calculated on a per kilo-watt hour of energy savings basis. However, the rebate was limited to $118,000 due to the 50% capital cost limitation. The program verification consisted of verifying the VSD installation, collecting power data on the motor, and verifying the operational schedule. The operational schedule was characterized by facility personnel, who estimated that the pulper tank completes, on average, 625 batches per month. Each batch takes approximately 45-60 minutes, depending on the grade of pulp. There are 3 different grades. Between batches, the pulper motor is inactive for roughly 5 minutes while the slurry pulp is unloaded and a new group of ingredients (water and wood fiber pulp) is added.

The ex ante baseline and estimated post retrofit energy usages were as follows:

- Baseline energy usage: 3,547,500 kWh/ yr
- Proposed post-installation energy usage: 1,290,000 kWh/ yr

The ex ante impacts were calculated as follows:

- Savings of 301 kWh/cycle
  Operating 625 cycles/month
  Energy savings were:

301 kWh/cycle x 625 cycles/month x 12 months/yr = 2,257,500 kWh/yr

The incentive was calculated as follows:

- $0.08 per kWh
  Incentive was $0.08 / kWh x 2,257,500 kWh = $180,600
- Measure cost adjustment was $62,600

- Incentive is calculated as $180,600 - $62,600 = $118,000

3. Comments on the Ex Ante Calculations

The ex-ante savings and incentive amount were based on the difference of baseline energy consumption and proposed energy consumption. The motor is a Toshiba 700 hp, 870 RPM motor driven by a 4160 volt starter. A 4160 volt Rockwell Power Flex variable frequency drive was installed on the pulper motor. The process is an open-loop system controlled by a Honeywell programmable logic controller (PLC).

The baseline energy consumption was calculated from five minute data and annual run-time data, which was measured in 2004. These measurements were provided by the applicant. Prior to the retrofit, the pulper motor ran at full speed for the length of the batch. To maintain consistency, the batch must be “whipped” with the pulper motor immediately before the next step in the process. If the pulp motor stops, the batch would settle to an unusable consistency. The downstream process is inconsistent, and the pulping step can not be executed “just in time” as the exact timing of when the next step could accommodate the batch of pulp is not predictable. The facility had attempted to save energy by turning off the pulper motor until just before it was needed, but the starts under heavy load caused premature motor failure. To maximize production and minimize motor failure, the motor ran at full speed until the next step was ready for the batch.

The proposed energy consumption of the pulper motor was calculated by multiplying a VSD energy savings control factor by the baseline power consumption. The as-built motor was assumed to use 64% less electrical energy per batch. For the purposes of the ex ante calculations, the VSD controlled motor was assumed to be operating at 73% of the full-load speed for the first 25 minutes of each 60 minute batch period. For the remaining 35 minutes, the pulper was assumed to operate at “slow beat”. Operation during the “slow beat” mode requires that the motor operate at 12.5% of full-load speed. Table 1 shows the baseline and proposed kW measurements for a batch run at 5-minute intervals.

Table 1: Ex Ante Baseline & Proposed kW Interval Measurement

Time (minutes)	Baseline kW	Proposed kW	kW Savings	kWh Savings
0	0	0	0	0
5	0	0	0	0
10	604	441	163	14
15	545	398	148	12
20	545	398	148	12
25	545	398	148	12
30	534	67	467	39
35	534	67	467	39
40	534	67	467	39
45	534	67	467	39
50	528	66	462	39
55	504	63	441	37
60	270	34	236	20
				301

The program file does not contain details concerning the assumptions made for the proposed energy consumption calculations. There is no explanation why 73% and 12.5% of full-load speed were assumed for the full speed and slow beat portions of each batch. The ex ante calculations also did not explicitly consider all grades of pulp being processed by the pulper motor. In addition, the ex ante calculations assumed the batch time was always 60 minutes, even though facility personnel reported that it varies between 45 and 60 minutes. Not only do the batch times vary, but the amount of operating time that the motor is full speed fluctuates from 60-70% of total batch time. Depending on how often each grade is processed and whether one is predominate over the other two, this could alter the energy savings significantly.

The Installation Report Review identifies these ex ante savings as 2,257,500 kWh and 0 kW; this agrees with the utility tracking system.

4. Measurement & Verification Plan

The facility where the measure was implemented is a 2,000,000 square foot paper manufacturing facility that consumed 4,943,304 kWh from January 2004 to January 2005. This measure reduces electricity usage by reducing motor speed throughout the entire batch cycle. The fundamental premise in development of the measurement and verification plan was that the amount of electrical energy that the process would use if the motor had not been controlled by a VSD should be determined and compared to present motor operation. The M&V plan was implemented in three basic steps, as follows:

1. Determine available data from site contact via telephone (operating schedule, etc.).

2. Verify motor data onsite (model number, efficiency, horsepower, speed, etc.) including motor quantity. Monitor the real-time motor power draw onsite. Take spot watt measurements of the motor.
3. Calculate the reduction in annual electricity consumption.

The initial contact by phone with the client was an essential first step in the development of this plan and helped further define the monitoring scope. During the phone call, attempts were made to definitively verify the schedule of the pulper and establish what metered data that the facility possessed (and whether the data were available for this evaluation).

Facilities of this type typically monitor their processes and keep records of monitored data, operational schedules and product throughput. The existence of these data and the willingness of the program participant to share these data with us ultimately determined the M&V approach. The requested data included:

- Operational schedules of the motor
- Baseline and proposed power and current draw of motor
- Motor name plate information (model number, manufacturer, efficiency, etc.)

Through discussions with the facility, it was determined that the facility has been performing constant metering since the VSD installation and that data was provided.

The facility's monitoring system consists of an Allen Bradley PLC, which is connected to a "PIE" software drive. This drive collects the energy consumption of the motor at five minute intervals. When the drive fills up with data, it is removed and downloaded to a computer. These data points at five minute intervals were provided to us and were used to inform the proposed energy consumption calculations. The baseline energy consumption was reported in the project file and calculated based on 5 minute interval data.

On-site verification determined the overall quality of the monitoring installation and attempted to verify that the measurements were taken at the correct physical locations.

The evaluation calculation for savings used annual operating hours and the difference in baseline and as-built power draw. For further detail on the evaluation calculations, see the "Summary of Results" section below.

The facility under consideration is large industrial facility with a 15 megawatt cogeneration system. Although the facility purchases electricity from the utility, the billing data represent a small amount of the energy consumed at the site. This single process constitutes a small fraction of total plant load, therefore, no billing analysis can be performed for this measure.

Formulae

According to the project file, pre-retrofit meter data was used to calculate the baseline load and power consumption. Facility operational data was used to calculate post-retrofit energy consumption. First, an hourly motor profile was created from the data for each day of the week. If all days are similar, the hourly profile represents an average of all days. There are no seasonal variations in the facility's schedule; therefore, the annual energy consumption was a simple extrapolation of the metered data. The following equations were used to determine pre and post installation power draw.

$$kW_{reduced} = kW_{baseline} - kW_{proposed}$$

The annual savings then become:

$$\text{Annual kWh Savings} = kW_{reduced} * \text{Annual Hours}$$

Note that the kW reduced is the average kW reduction for the measure. The operation of the motor is neither weather nor time dependent. Therefore, for the purposes of peak demand calculation, average kW reduction is the same for any period of time.

In accordance with the formula for kWh savings above, the average kW is used as $kW_{reduced}$ with the total operating hours.

As the equations show, a key factor in the energy savings calculation is the annual operating hours. These are to be calculated from the metered data. The evaluation team developed an appropriate annual savings calculation strategy according to field findings.

Uncertainty of the savings estimate for the VSD pulper can be more fully understood by setting projected ranges on the primary variables.

- $kW_{post\ retrofit}$
  160 kW expected, 150 kW minimum, 170 kW maximum (+6 %, -6 %)
- $kWpre_{preretrofit}$
  320 kW expected, 300 kW minimum, 340 kW maximum (+6 %, -6 %)
- Annual Hours
  8,760 expected, 8,000 minimum, 8,760 maximum (+0 %, -10 %)

There may be even larger variations in kW values, especially considering that kW is averaged even when batches are being loaded)

Accuracy and Equipment

The facility uses an Allen Bradley PLC 5/60 system to program the VSD. The PLC controller has the capability to control the speed set point of the motor and monitor the power draw at 5-minute interval. A user interface software called PIE is used to record the power draw from the PLC every five minutes. The monitored data is then stored in a computer. The supplied kW readings from the system have a five digit kW resolution; the readings are given in increments, e.g. 310, 315, 320. This implies a measurement precision of +/- 2.5 kW.

All data collected were reviewed to ensure it conformed to realistic values and was also verified with other data collected to identify any anomalies. No outliers and other suspicious data were found in the collected data.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 4, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the pulper motor and by interviewing the facility representative. Five-minute kW interval data, along with the motor speed for the VSD retrofitted pulper, were collected from the facility monitoring system for the month of August 2007.

Installation Verification

The evaluation team physically verified the installation of the VSD on the 700 hp pulper motor. It was apparent from the inspection that the Toshiba 700 hp pulper motor was retrofit with an Allen Bradley variable frequency drive.

This is the only measure in this application. The verification realization rate for this project is 1.0.

Scope of the Impact Assessment

The impact assessment scope for this application is for the motor end use measure in the SPC application covering the motor controls retrofit. This is the only measure in this application.

Summary of Results

One month of collected kW interval data from the facility monitoring system is shown below in Figure 1. The maintenance period, similar to the reported period, can be seen clearly in the graph. In Figure 2, two days of raw data, selected at random, are displayed to show the variation in load and runtime in the process. These data agree with the facility representative’s reported process description.

Figure 1: Pulper Motor Raw Meter data for One Selected Ex Post Month

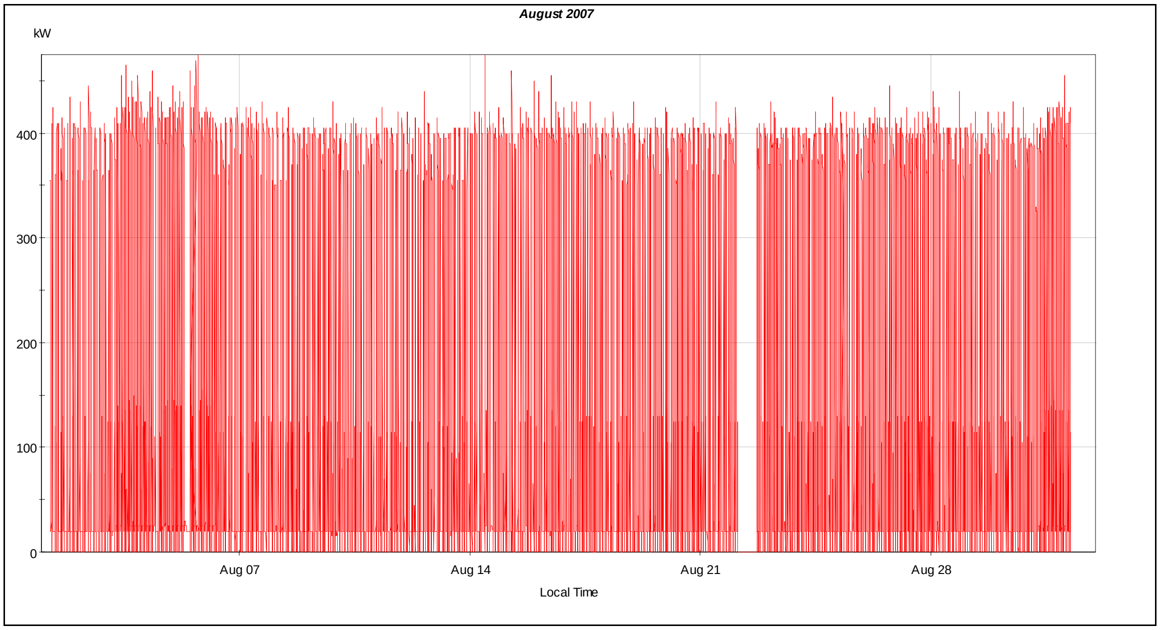


Figure 2: Motor Raw Data for Two Selected Ex Post Days

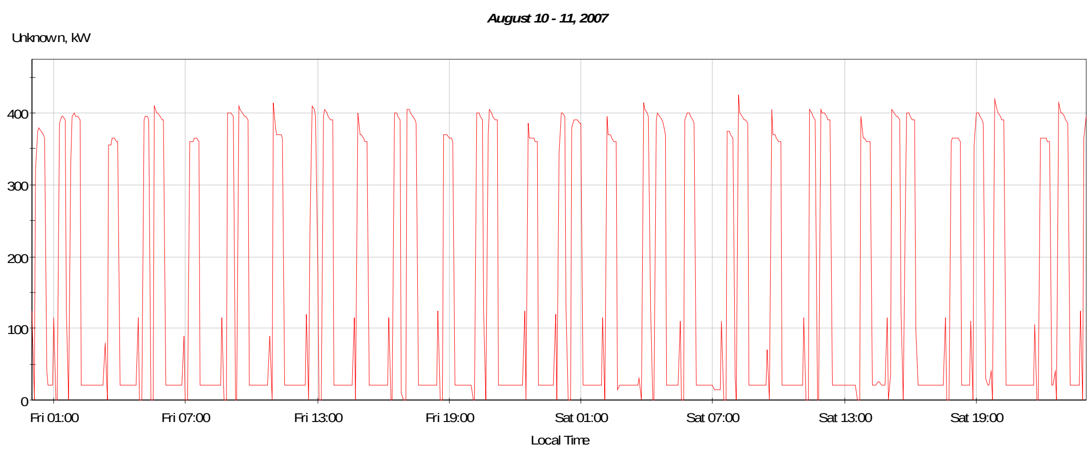
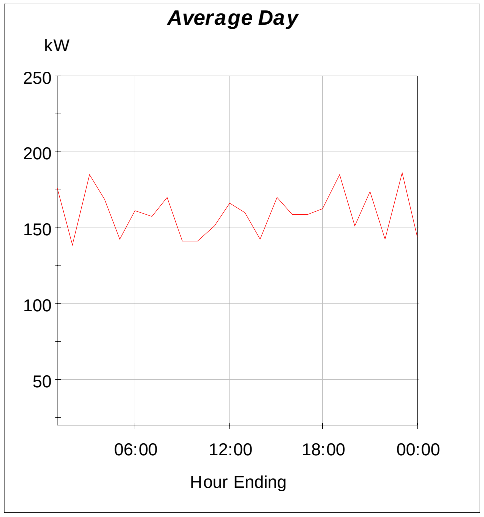


Figure 3 shows the average day power profile for the metering period. The metered data shows the pulper process operates 24 hours a day, seven days a week, except for approximately ten hours of shut down each month for preventive maintenance. According to the plant personnel, the pulper motor has the same schedule throughout the year and there is no seasonal variation.

Figure 3: Pulper Motor Average Day Profile



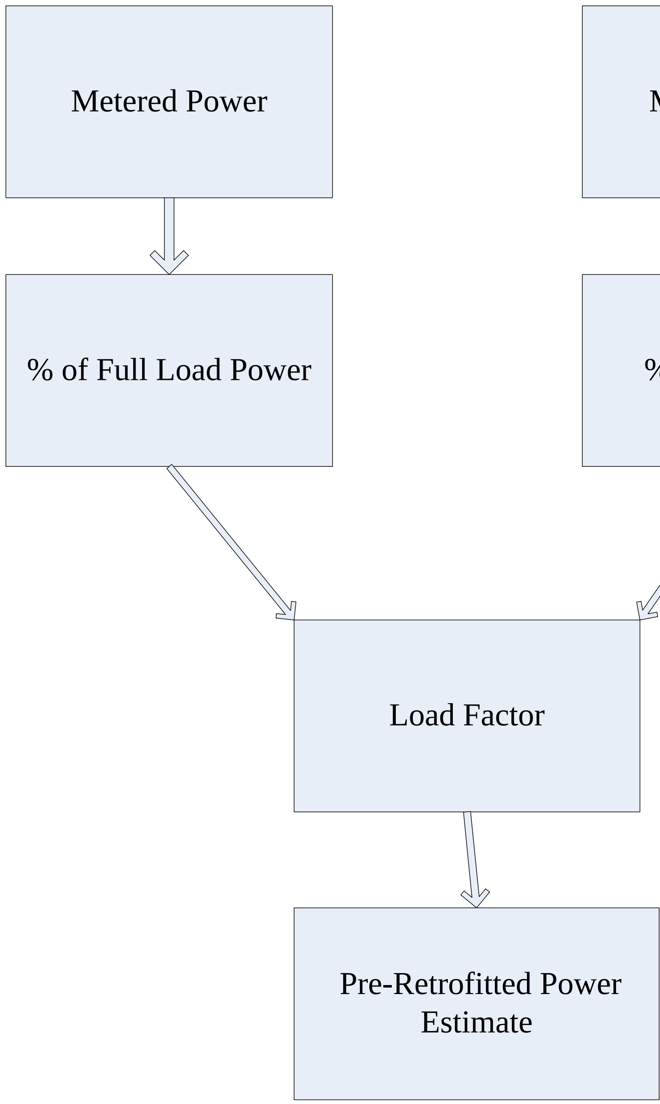
The ex- post calculations were performed using motor kW data obtained onsite. These data were plotted against the corresponding motor speed for the month of August. It was found that the power draw for a given speed had a high degree of variability. The batches of pulp varied in viscosity and therefore the resistance to the motor varies considerably. Furthermore, in most, but not all, batches, the power draw decreases during the process (even though the motor speed is constant). This effect is due to the pulp losing viscosity during the course of the process.

The challenge for the evaluation team was to create a pre-retrofit or baseline power draw that would approximate the power draw of the pulper motor before the VSD retrofit. The site contact reported that the batch times were the same as the pre-retrofit conditions and the motor was uncontrolled, "riding the curve" of the load.

With this information, an algorithm was created based upon the assumption that motor loading, as a percentage of full load power, would be similar for pre-retrofit and post retrofit conditions at or near full power at the beginning of the batch run. It was also assumed that the power draw of the pre-retrofit motor would decrease slightly over the course of batch run.

A specific approach was developed to estimate the pre-retrofit energy usage of the pulper motor. Load variations, motor speed, and load factor were the key parameters used to estimate the pre-retrofit energy usage. The overall concept of this method is shown in Figure 4.

Figure 4: Estimated Pre-retrofit Power Calculation Sequence



Each metered power reading was divided by rated full load power to determine % of full load power. Next the % of power reduced from reducing motor speed, speed factor, was made from taking the metered speed and the standard EPRI motor speed to load reduction relationship. Next, the motor load factor, LF, was calculated as follows:

$$LF = Power_{metered}/(\text{Full Load Power} * \text{Speed Factor})$$

Then the pre-retrofit power for the specific interval was estimated as full load power times the above calculated load factor. This value was used to create the pre-retrofit power profile at “full speed” conditions. When the motor went into “slow beat” mode, the pre-retrofit was assumed to remain at full speed with a 1% reduction in power draw every five minute interval to account for the decrement of viscosity. When the actual power draw was zero, the pre-retrofit power draw was also assumed to be zero.

Table 2: Example Point Calculations

Date/Time	Speed(RPM)	% VFD Power	% Speed	Speed Factor	Load Factor	Pre kW	Metered kW	Savings kW
8/1/07 15:00	**836**	**74.7%**	96.1%	88.7%	78.6%	373.6	355	18.6
8/1/07 15:05	**833**	**87.4%**	95.7%	87.8%	91.6%	435.2	415	20.2
8/1/07 15:10	**833**	**85.3%**	95.7%	87.8%	89.5%	425.2	405	20.2
8/1/07 15:15	**833**	**84.2%**	95.7%	87.8%	88.5%	420.2	400	20.2
8/1/07 15:20	**833**	**84.2%**	95.7%	87.8%	88.5%	420.2	400	20.2
8/1/07 15:25	**833**	**83.2%**	95.7%	87.8%	87.4%	415.2	395	20.2
8/1/07 15:30	**284**	**4.2%**	32.6%	3.5%	71.6%	411.0	20	391.0
8/1/07 15:35	**284**	**4.2%**	32.6%	3.5%	71.6%	406.9	20	386.9
8/1/07 15:40	**285**	**4.2%**	32.8%	3.5%	71.5%	402.9	20	382.9
8/1/07 15:45	**285**	**4.2%**	32.8%	3.5%	71.5%	398.8	20	378.8
8/1/07 15:50	**284**	**4.2%**	32.6%	3.5%	71.6%	394.9	20	374.9
8/1/07 15:55	**284**	**4.2%**	32.6%	3.5%	71.6%	390.9	20	370.9
8/1/07 16:00	**285**	**4.2%**	32.8%	3.5%	71.5%	387.0	20	367.0
8/1/07 16:05	**285**	**4.2%**	32.8%	3.5%	71.5%	383.1	20	363.1
8/1/07 16:10	**566**	**27.4%**	65.1%	27.5%	62.3%	296.0	130	166.0
8/1/07 16:15	**0**	**0.0%**	0.0%	0.0%	100.0%	0.0	0	0.0
8/1/07 16:20	**0**	**0.0%**	0.0%	0.0%	100.0%	0.0	0	0.0

Figure 5: Comparison of Actual Post Retrofitted kW Data with Estimated Pre-Retrofit Power Draw (in Blue)

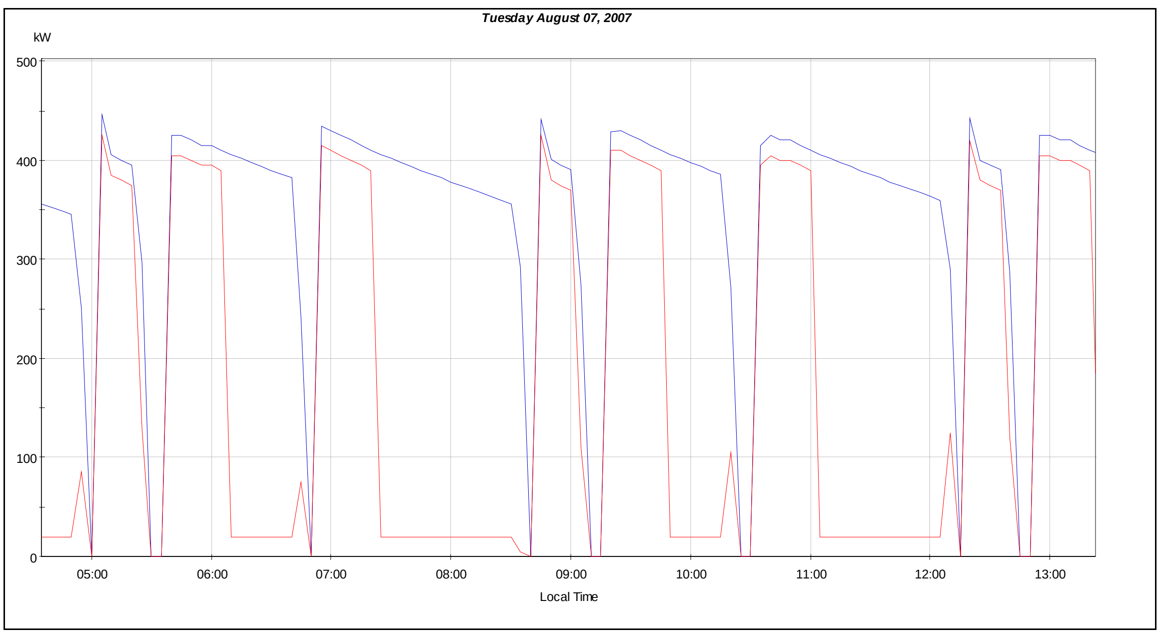
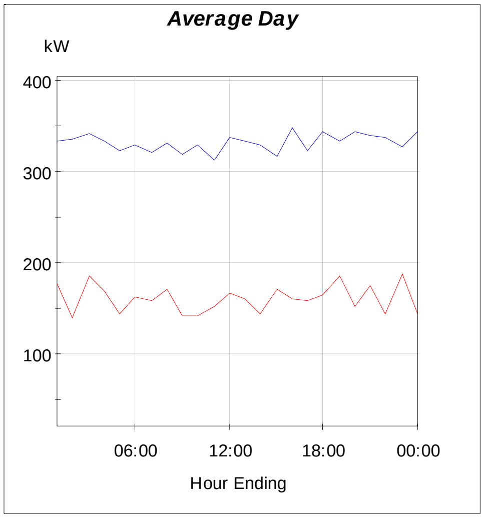


Figure 6 below shows a comparison between average day baseline (in blue) and ex-post power profile (in red).

Figure 6: Comparison between Estimated Pre-retrofit and Post-Retrofit Average Day Power Profile



The ex-post savings were calculated using the operating schedule and comparing the power draw of the pre-retrofit and installed pulper, taking into consideration there is no seasonal variation in the pulper motor schedule.

The ex post impacts are calculated as follows:

- Estimated pre-retrofit demand: 331.596 kW
- Estimated pre-retrofit energy usage: 331.6 kW * 8,760 hrs/yr = 2,904,781 kWh/ yr
- Post-retrofit demand: 159.89 kW
- Post-retrofit energy usage: 159.89 kW * 8,760 hrs/yr = 1,400,643 kWh/ yr
- The resulting annual kWh savings are

  2,904,781 kWh/ yr – 1,400,643 kWh/yr

  = 1,504,138 kWh/yr

The pulper application is a non-weather dependent load and process does not vary for weekday to weekend. Since the average day power profiles are representative of any given day, they are used to estimate coincident peak savings. We examined delta for both peak and average kW saving for the pulper to see if there is any significant difference between them and concluded the average demand is a better indicator for this project.

Average impacts were estimated by subtracting post-retrofit average demand from estimated pre-retrofit average demand.

- Average kW savings is 331.6 kW – 159.9 = 171.7 kW.

The engineering realization rate for this application is 0.67 for energy savings (kWh). The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown below in Table 6.

Utility billing data for the site was reviewed. In the 12-month period from February 2003 to January 2004 (pre-retrofit), the facility consumed 4,943,304 kWh. Table 3 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 4 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 45.7 % decrease in total meter kWh, and a 77.8 % decrease in pulper motor end use kWh. The ex post results showed a 20.5 % decrease in total meter kW, a 51.8 % decrease in pulper motor end use kW, a 30.4 % decrease in total meter kWh, and a 51.8 % decrease in pulper motor end use kWh.

Table 3: Total Meter, Ex Ante, and Ex Post Results

	Peak Demand (kW)	Annual kWh
Total Meter	838.1	4,943,304
Baseline End Use	331.6	2,904,781
Ex Ante Savings	NA	2,257,500
Ex Post Savings	171.7	1,504,137

Table 4: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	NA	45.7%	20.5%	30.4%
Baseline End Use %	NA	77.7%	51.8%	51.8%

6. Additional Evaluation Findings

The ex post energy savings are less than the ex ante energy savings. The data showed that the variable frequency drive retrofitted pulper saves less energy at the full speed portion of the process than anticipated. At the highest normal operating level of the pulper motor, the drive typically saves about 4% to 6% of the energy used, instead of the 27% predicted in the ex ante estimates. The ex ante estimate assume that the motor would be operating at 73% of rated motor speed during the “full speed” portion of the process , while the actual data show that the motor operates at 96% of rated motor speed during this portion of the process.

The evaluation team physically verified the VSD retrofit and the pulper motor, and used plant data to verify operating hours. The evaluation team is satisfied that the pre retrofit parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

Although, the evaluation team is confident in the ex post findings, being supplied with actual pre-retrofit data could have improved the impact analysis. Instead, the evaluation depended upon the memory of plant personnel, and needed to make certain assumptions to create a pre-retrofit profile of post retrofit operating conditions.

The installation costs appear reasonable for this retrofit based upon experience with installations of this type.

With a cost of $236,000 and an $118,000 incentive, the project had a 0. 40 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated ex post simple payback is 0.60 years. A summary of the economic parameters for the project is shown below.

7. Impact Results

Table 5: Economic Information

Description	Date	Project Cost, $	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, Therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ Incentive, yrs	Simple Payback w/o Incentive, yrs
Installation Approved Amount (Ex Ante)	12/1/2005	236,000	0	2,257,500	0	293,475	118,000	0.40	0.80
SPC Program Review (Ex Post)	9/4/2007	236,000	171.7	1,504,137	0	195,538	118,000	0.60	1.21

Table 6: Realization Rate Summary

	kW	kWh
SPC Tracking System	0	2,257,500
SPC Installation Report(Ex-ante)	0	2,257,500
Impact Evaluation(ex-post)	171.7	1,504,137
Engineering Realization Rate	NA	0.67

Table 7:Installation Verification Summary

Measure Description	End-use category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Other	O			Install VSD on a Pulper Motor	1	700 hp Pulper Mixer Motor	Physically Verified VSD and the pulper	1.0

Table 8: Multi Year Reporting Table

Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	376,250	250,690	0.0			
3	2006	2,257,500	1,504,137	0.0	171.7		
4	2007	2,257,500	1,504,137	0.0	171.7		
5	2008	2,257,500	1,504,137	0.0	171.7		
6	2009	2,257,500	1,504,137	0.0	171.7		
7	2010	2,257,500	1,504,137	0.0	171.7		
8	2011	2,257,500	1,504,137	0.0	171.7		
9	2012	2,257,500	1,504,137	0.0	171.7		
10	2013	2,257,500	1,504,137	0.0	171.7		
11	2014	2,257,500	1,504,137	0.0	171.7		
12	2015	2,257,500	1,504,137	0.0	171.7		
13	2016	2,257,500	1,504,137	0.0	171.7		
14	2017	2,257,500	1,504,137	0.0	171.7		
15	2018	2,257,500	1,504,137	0.0	171.7		
16	2019	2,257,500	1,504,137	0.0	171.7		
17	2020	1,881,250	1,253,448	0.0	171.7		
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	33,862,500	22,562,059				

SITE A100 (05-xxxx) McDo IMPACT EVALUATION
SAMPLE CELL: Original TIER: 5 END USE: Other

Measure	Install Energy Management System (EMS) for Lighting, Fans and Refrigeration
Site Description	Restaurant

1. Measure Description

The measure is for the installation of an energy management system (EMS) which controls the lighting, HVAC, and refrigeration systems. With the EMS installed, energy consuming systems will better match actual restaurant operational needs. The measure assumes that the EMS reduces the annual hours of operation for each of the systems from 2% to 25%. The facility is a fast food restaurant with a dining area, food preparation area, kitchen, and refrigerated space. The savings comes from this reduction in operating hours for each of the systems as compared to the manually controlled preexisting system.

2. Summary of the Ex-ante Calculations

The ex-ante savings were calculated using a load calculation spreadsheet. The kWh savings were estimated using the rated wattage of the systems and an anticipated annual operating hour reduction. The energy savings are a direct result of reducing the annual hours of operation. Savings were given based upon the kWh reduction at a rate of $0.05 per kWh for lighting measures and $0.08 per kWh for other measures. The ex-ante calculations estimate an annual savings of 14,389 kWh. An incentive of $1,087 was calculated based on these savings estimates. No demand savings were estimated; all savings were expected to be realized during off hours.

The SPC Program internal verification was completed remotely using the EMS system. The program verification consisted of verifying the annual hours of operation for the interior lighting and HVAC fans. No verification was completed for the refrigeration savings or exterior lighting.

The ex-ante impacts were as follows:

- Annual Energy Savings: 14,389 kWh/ yr

The incentive for the measure was calculated as follows:

Areas	**kWh Savings**	**Kwh Incentive**	**Total Incentive**
Lighting - Outdoor	556	$0.05	$27.80
Lighting -Indoor	1,565	$0.05	$78.25
HVAC Fans	7,086	$0.08	$566.88
Refrigeration System	5,182	$0.08	$414.56
Total	**14,389**		**$1,087.49**

The total incentive was as follows:

- Total incentive: $1,087

3. Comments on the Ex-ante Calculations

The ex ante savings agree with the savings from the utility tracking system.

The savings estimates were revised after the verification was completed. The savings spreadsheet from the initial estimation pre-verification was included in the project file. Additional measures were included in the initial spreadsheet that were not included the final savings calculations. There was no spreadsheet showing the finalized savings calculations after the verification occurred.

Verification consisted of remote examination of the EMS system to obtain operating schedules for the affected HVAC fans and the interior lighting. There was a pre-retrofit inspection of lighting fixture counts and wattages and inspection of the HVAC and refrigeration systems. No verification of the refrigeration measure or exterior lighting was performed.

The ex-ante savings and incentive were based on the difference of baseline annual hours and proposed annual hours. Exterior lighting savings were a result of a 2.5% reduction in annual operating hours due to the EMS system. All interior lighting used a percentage reduction of 2%, except for the lobby lighting hours which had a reduction of 4%. The exterior lighting operated approximately 2,912 hours after the installation of the EMS system. The annual operating hours for the interior lighting were approximately 7,889 hours. Two HVAC fans were included in the measure, the kitchen fan and the dining room fan. The baseline for both fans was constant operation, or 8,760 hours per year, while the verified hours were found to be 7,889 and 6,575 hours, respectively. The refrigeration measure consisted of a reduction in operation hours for compressors in both the walk-in freezer and walk-in cooler. The refrigeration savings were unverified; the baseline hours were 7,665 hours per year and the proposed hours were 6,935 hours per year.

The greatest contributor to uncertainty was the annual hours and to a lesser extent wattage estimation. Since the hours were verified using the EMS remotely, there is uncertainty as to how the lighting occupancy types were grouped together and how the rated wattages were allocated. However, the baseline for these measures is given as a percentage over the measured hours, which once again leaves much uncertainty as to their accuracy. The project file indicates that the facility has no seasonal variation, although this will need to be confirmed once onsite.

4. Measurement & Verification Plan

The restaurant is a 3,500 sf single story structure approximately 20 years old.

This measure reduces electricity usage by reducing the annual hours of the lighting, HVAC fans, and refrigeration equipment. The fundamental premise in development of the measurement and verification plan is to determine the actual post implementation annual hours and wattages. The M&V plan will be implemented in three basic steps:

1. On-site verification of EMS installation, lighting fixtures (fixture counts and wattages), fan installation, and refrigeration equipment installation. On-site monitoring of annual operating hours for the lighting, HVAC fans and refrigeration equipment.

2. Collect trend data for all three systems.

3. Request data, including:
    - Operational post-retrofit schedules of the lighting, HVAC, and refrigeration systems
    - Pre-retrofit lighting, HVAC, and refrigeration schedules
    - Any seasonal variation in operating schedules

If no data are available, the evaluation team will use the schedules included in the project file.

On-site verification will strive to determine the overall quality of the monitoring installation and attempt to verify that the measurements are taken at the correct physical locations. We will attempt to verify accuracy of operational schedule of all three systems. For lighting, light loggers may be installed on the lights. When suitable, amp loggers may also be installed at the lighting breaker panel to determine when banks of rooms on a common electric feeder are using their lights. The refrigeration system may be monitored by installing an amp logger on the refrigeration compressor.

Formulae and Approach

Energy savings at the facility will be calculated after the installation of EMS system using the following equation:

$$E_{savings} = P_{kWR} * (HR_{bl} - HR_{post})$$

Where,

$E_{savings}$ = annual energy savings, kWh/yr
P_{kWR} = rated power consumption of the system, kW
HR_{bl} = annual baseline operating hours, hr/yr
HR_{post} = annual post implementation operating hours, hr/yr

As the equations indicate, a key factor affecting the energy savings is the difference between the pre-implementation and post-implementation annual operating hours, which will be calculated from the metered data when available. The most appropriate annual savings calculation strategy will be developed depending on field findings.

Uncertainty for the savings estimate for the lighting retrofit lie primarily in the annual operating hours.

Annual operating hours (+/- 5%)

Interior Lighting: expected 7,889 hrs/yr; maximum 8,283 hrs/yr ; minimum 7,494 hrs/yr
Outside Lighting: expected 2,912 hrs/yr; maximum 3,057 hrs/yr; minimum 2,766 hrs/yr
HVAC Fans: expected 7,889 hrs/yr; maximum 8,283 hrs/yr; minimum 7,494 hrs/yr
Refrigeration System: expected 7,665 hrs/yr; maximum 8,048 hrs/yr; minimum 7,281 hrs/yr

Controlled wattages: +/- 5% for all systems

Accuracy and Equipment

HOBO on/off data loggers will be used to measure time-of-use of the lighting systems. The lighting meters have an adjustable light sensitivity threshold and record data at one second intervals. The Hobo dataloggers have an accuracy of +/- 1%.

An ACR OWL 400 data logger will be used to measure the amperage for the HVAC fans and refrigeration compressors. The logger can record data at five second intervals. The logger accuracy is +/-1% of full scale. The voltage will be used in conjunction with the rated amperage, voltage, and an estimated power factor to derive the power consumption. Also, the voltage logger will serve as a time-of-use logger to monitor the schedule of the equipment.

Once the data are recorded, they can be downloaded to the PC for further analysis. This will prevent data transfer errors.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex-post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 4, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the EMS and by interviewing the facility representative. Four lighting loggers were installed throughout the facility and two current loggers were installed on each of the refrigeration system compressors.

Installation Verification

The facility representative verified that there were no controls on the lighting, HVAC fans, or refrigeration system prior to installation of the EMS. We physically verified the existence of the EMS. We also verified that the fixture counts presented in the ex-ante calculations matched what was actually installed onsite. The verification rate is 1.0.

Scope of the Impact Assessment

There is only one measure in this application, the EMS installation, which contributes to savings in lighting, AC&R, and the “Other” category, covering controls and refrigeration end use measures in the SPC application covering reduced runtime.

Summary of Results

Four HOBO On/Off data loggers were installed in the facility for 21 days (from September 4, 2007- September, 25, 2007) to measure the operating hours of a representative sample of the indoor retrofit lighting fixtures. The outdoor lighting was not logged. The facility representative stated that the 21 day period had been representative of normal facility operation. It was found that, on average, the interior lighting systems were on 78.6% of the time compared to the 83.1% assumed in the ex-ante calculations.

The average measured hourly lighting profiles are shown in Figure 1for weekdays and weekends. Since this facility operates 7 days per week, variations in lighting schedules between the weekdays and weekends were not expected.. At the summer peak hour, between 2 pm and 5 pm on weekdays, the lights were measured to be on an average 96.9%.

Neither the outdoor lighting nor the HVAC fans could be logged. However, the estimates of operating hours were deemed reasonable.

Owl 400 amp loggers were installed on both the Mac 6 compressors for a period of three weeks. It was found that the compressor for the walk-in freezers operates continuously whereas the ex-ante estimate was calculated based upon a runtime of 6,935 hours per year. The walk-in cooler operates 7,616 hours a year, which was greater than the ex-ante assumption of 6,935 hours a year. Figure 2 shows the raw meter data for both the Mac6 compressors. Thus, the refrigeration system savings was estimated to be 0 kWh per year.

Figure 1: Average Measured Hourly Lighting Profiles

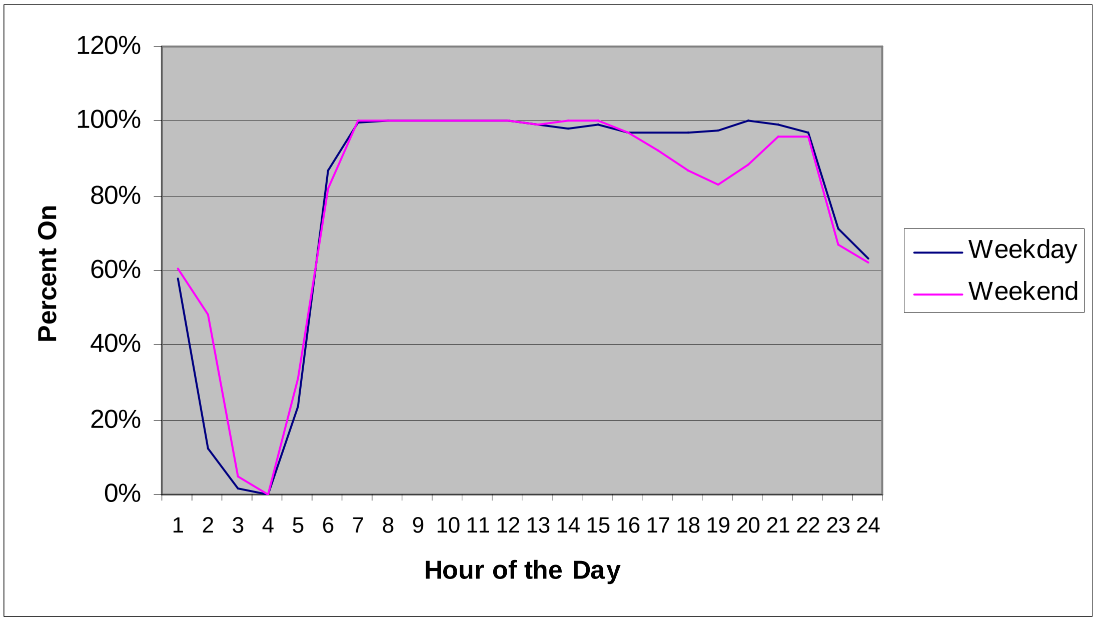
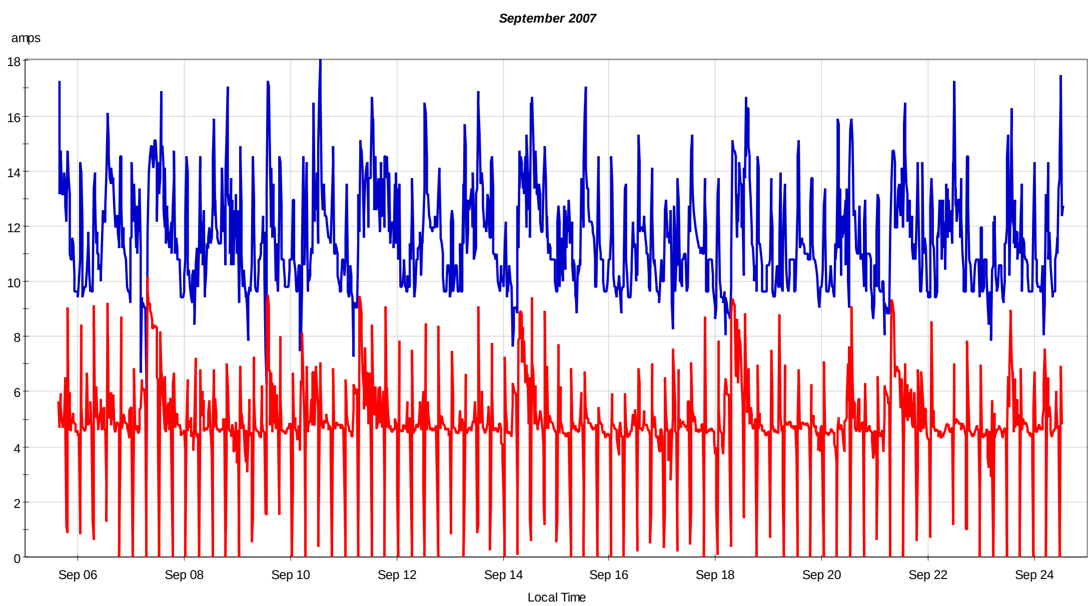


Figure 2: Raw Meter Data (amps) for Both Mac6 Compressors (Blue-Freezer, Red- Cooler)



The ex-post calculations were performed using the verified operating schedule and lighting fixture installed wattage. Table 1 shows a summary of the ex-post lighting logger data by area and day type. There were two main functional use areas in the facility: kitchen and dining room. Each area represented roughly 50% of the total installed wattage.

The ex-post impacts for interior lighting are calculated as follows:

- Pre retrofit annual kWh is 62,229 kWh /yr
- Post retrofit annual kWh is 52,543 kWh /yr
- Ex-post savings are calculated as 9,686 kWh/yr

Table 1 shows the ex-post savings summary for interior lighting.

Table 1: Summary of Ex-Post Interior Lighting Savings

Sl. No	Type of Fixture	Area	Unit Watts	No of Fixtures	Total Watts	Pre retrofit Hr/yr	Pre Retrofit kWh/yr	Post Retrofit. Hr/yr	Post Retrofit kWh/yr	Savings kWh/yr
1	Troffer T8 4x4 dining/counter	Lobby Lights	158	17	2,686	8,048	21,617	6,419	17,241	4375
2	Fixture Floods in Cans	Lobby Cans	75	3	225	8,048	1,811	6,419	1,444	367
3	Troffers T8's 4x4	Kitchen	158	23	3,634	8,231	29,911	7,409	26,924	2987
4	LF HO lamps & Ballasts	Counter Menu	1,080	1	1,080	8,231	8,889	6,419	6,933	1957
Total							**62,229**		**52,543**	**9,686**

The ex-post impacts for outside lighting are calculated as follows:

- Pre retrofit annual kWh is 24,541 kWh /yr
- Post retrofit annual kWh is 23,928 kWh /yr
- Ex-post savings are calculated as 614 kWh/yr

Table 2 shows the ex-post savings summary for outside lighting.

Table 2: Summary of Ex-Post Outside Lighting Savings

Sl. No	Type of Fixture	Area	Unit Watts	No of Fixtures	Total Watts	Pre Retrofit Hr/yr	Pre Retrofit kWh/yr	Post Retrofit. Hr/yr	Post Retrofit kWh/yr	Savings kWh/yr
1	Flourscent HO F41EHS &F8	Roof Beams	192	7	1,344	3,058	4,110	2,982	4,007	103
2	Flood Light	Softfit Light	75	9	675	3,203	2,162	3,123	2,108	54
3	Fluorscent HO/Neon	MCD Direction Sign	140	3	420	3,203	1,345	3,123	1,312	34
4	LF HO lamps & Ballasts	MCD M Sign	200	1	200	3,203	641	3,123	625	16
5	LF HO lamps & Ballasts	MCD Road Sign	550	1	550	3,203	1,762	3,123	1,718	44
6	LF HO lamps & Ballasts	MCD Facia Sign	1,080	2	2,160	3,058	6,605	2,982	6,440	165
7	Flood Light	Drive Through Light	75	1	75	3,058	229	2,982	224	6
8	Fluorscent HO/Neon	MCD Direction Sign	140	3	420	3,203	1,345	3,123	1,312	34
9	Mercury Vapor MV 175	Wall Pack Lights	205	6	1,230	3,203	3,940	3,123	3,841	98
10	LF HO lamps & Ballasts	Menu Board	750	1	750	3,203	2,402	3,123	2,342	60
Total							**24,541**		**23,928**	**614**

The ex-post impacts for HVAC fans are calculated as follows:

- Pre retrofit annual kWh is 47,488 kWh /yr
- Post retrofit annual kWh is 40,402 kWh /yr
- Ex-post savings are calculated as 7,086 kWh/yr

Table 3 shows the ex-post savings summary for HVAC fans.

Table 3: Summary of Ex-post HVAC Fan Savings

Sl. No	Type of Equipment	Area	Unit Watts	No of Fixtures	Total Watts	Pre retrofit Hr/yr	Pre Retrofit kWh/yr	Post Retrofit. Hr/yr	Post Retrofit kWh/yr	Savings kWh/yr
1	Kitchen unit Fan	Kitchen	3,622	1	3,622	8,760	31,729	7,889	28,574	3,155
2	Lobby HVAC Fan	Lobby	1,799	1	1,799	8,760	15,759	6,575	11,828	3930.815
Total							**47,488**		**40,402**	**7,086**

The ex-post impacts for the refrigeration system are calculated as follows:

- Pre retrofit annual kWh is 59,026 kWh /yr
- Post retrofit annual kWh is 59,026 kWh /yr
- Ex-post savings are calculated as 0 kWh/yr

Table 4 shows the ex-post savings summary for the refrigeration system.

Table 4: Summary of Ex-post Refrigeration Savings

Sl. No	Type of Equipment	Area	Unit Watts	No of Fixtures	Total Watts	Pre retrofit Hr/yr	Pre Retrofit kWh/yr	Post Retrofit. Hr/yr	Post Retrofit kWh/yr	Savings kWh/yr
1	Mac 6 Compressor	Walkin Freezer	4,342	1	4,342	8,760	38,036	8,760	38,036	-
2	Mac 6 Compressor	Walkin Cooler	2,756	1	2,756	7,616	20,990	7,616	20,990	-
Total							**59,026**		**59,026**	**-**

Since the savings for this measures are realized during unoccupied periods, there no coincident peak saving associated with the measure.

Utility billing data for the site was reviewed. In the 12 month period from January 2003 - December 2003 (pre-retrofit), the facility consumed 558.484 kWh. Table 5 summarizes total meter use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 6 is a summary of the percent of energy savings for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 2.6 % decrease in total meter use, a 7.4% decrease in all end user kWh. The ex post results showed a 3.1 % decrease in total meter use, a 9.0% decrease in end use kWh.

Table 5: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	na	558,484
Baseline End Use	na	167,545
Ex ante Savings	na	7,086
Ex Post Savings	na	7,086

Baseline use represents only the subsystems of the lighting, AC&R, and HVAC fan systems retrofit.

Table 6: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	na	1.3%	na	1.3%
Baseline End Use %	na	4.2%	na	4.2%

6. Additional Evaluation Findings

Since the measure was small and the fans were unable to be monitored, all end use savings for this measure were evaluated and reported.

Fixture counts and wattages of outdoor lighting were collected onsite. The only difference found from the ex-ante calculations was the presence of one additional 175 watt mercury vapor wall pack fixture. The lighting panel was sealed, and therefore was not able to be monitored. However, the ex ante estimates of operating hours were appeared to be reasonable. Therefore the reduction in outdoor lighting hours were assumed to be equal to the ex ante estimates.

The engineering realization rate for the HAVC system control is 1.0 for energy savings kWh. Due to lower ex ante annual operating hours, the realization rate for the indoor lighting savings portion was 6.19.

No savings were realized for the refrigeration system. Ex-post monitored hours of the refrigeration compressors were higher than both than pre and post annual hours assumed for the ex ante calculations. Additionally, the project file contained no explanation of the how the EMS saves refrigeration energy. Calls to the implementation contractor did not provide an explanation of why refrigeration energy is being saved. Since refrigeration load is not a function of occupancy, the evaluation team agreed that there are no refrigeration savings associated with this measure A summary of the realization rate is shown in Table 8.

The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program has not encouraged them to perform any other energy efficiency projects; however, they do believe it has increased their awareness of energy efficiency issues.

Costs for this small EMS seem to be reasonable, based upon industry experience.
No additional benefits beyond energy efficiency were noted for this measure.

With a cost of $16,950 and an incentive of $557, the project had a 6.99 year simple payback based on the ex-ante calculations. A summary of the economic parameters for the project is shown in Table 7.

The effective useful life of the EMS system is 15 years. Table 10 shows projected annual ex ante and ex post energy savings for multiple years 2005 through 2021.

7. Impact Results

Table 7: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	11/15/2005	$7,000	-	7,086	0	$921	$557	6.99	7.60
SPC Program Review (Ex Post)	8/9/2007	$7,000	-	7,086	0	$921	$557	6.99	7.60

Project cost of $7,000 and incentive of $557 represents fraction attributed to HVAC fan control.

Table 8: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	-	7,086	-
SPC Installation Report (ex ante)	-	7,086	-
Impact Evaluation (ex post)	-	7,086	-
Engineering Realization Rate	NA	1.00	NA

1. Tracking System values used for realization rate calculations.

Table 9: Installation Verification Summary

Measure Description	End-use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
EMS	O	EMS Control on HVAC Fans	EMS Control on Exterior and Interior Lighting	EMS Control on Refrigeration System	1	EMS	Physically Verified the Installation of EMS System on HVAC, Lighting and Refrigeration System	1.0

Table 10: Projected Multi Year Ex Ante and Ex Post Savings of the EMS System

Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	1,181	1,181				
3	2006	7,086	7,086				
4	2007	7,086	7,086				
5	2008	7,086	7,086				
6	2009	7,086	7,086				
7	2010	7,086	7,086				
8	2011	7,086	7,086				
9	2012	7,086	7,086				
10	2013	7,086	7,086				
11	2014	7,086	7,086				
12	2015	7,086	7,086				
13	2016	7,086	7,086				
14	2017	7,086	7,086				
15	2018	7,086	7,086				
16	2019	7,086	7,086				
17	2020	5,905	5,905				
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	106,290	106,290				

Energy Management System with 15 year life.

Table 11: Percent On by Day Type for Two Main FUAs

Dining Room		
Hour	Weekdays	Weekends
1	23.8%	25.0%
2	1.1%	4.2%
3	0.0%	0.0%
4	0.0%	0.0%
5	0.0%	0.0%
6	82.5%	74.4%
7	100.0%	100.0%
8	100.0%	100.0%
9	100.0%	100.0%
10	100.0%	100.0%
11	100.0%	100.0%
12	100.0%	100.0%
13	100.0%	100.0%
14	100.0%	100.0%
15	100.0%	100.0%
16	100.0%	100.0%
17	100.0%	100.0%
18	100.0%	100.0%
19	100.0%	94.2%
20	100.0%	89.0%
21	100.0%	91.7%
22	94.0%	91.7%
23	44.6%	40.6%
24	29.9%	27.7%

Kitchen		
Hour	Weekdays	Weekends
1	95.4%	100.0%
2	25.1%	96.8%
3	3.8%	9.6%
4	0.0%	0.0%
5	49.4%	65.2%
6	91.0%	90.2%
7	98.8%	100.0%
8	100.0%	100.0%
9	100.0%	100.0%
10	100.0%	100.0%
11	100.0%	100.0%
12	100.0%	100.0%
13	98.3%	98.5%
14	95.9%	100.0%
15	97.7%	100.0%
16	93.3%	93.6%
17	93.3%	83.3%
18	93.3%	72.2%
19	94.7%	70.7%
20	100.0%	87.7%
21	97.9%	100.0%
22	100.0%	100.0%
23	100.0%	95.7%
24	100.0%	100.0%

FINAL SITE REPORT

SITE A101 (04-xxxx) Waln **IMPACT EVALUATION**
SAMPLE CELL: ORIGINAL **TIER: 4** **END USE: Other**

Measure	Install Variable Speed Drives (VSDs) on two of the 200 HP pump motors
Site Description	Pumping Station

1. Measure Description

Variable Speed Drives (VSDs) were installed on two (2) of the 200 HP pump motors located at the pumping station. Because the old 200 HP motors would not accommodate the new VSDs, two new 200 HP motors were installed to replace two of the old 200 HP motors.

2. Summary of the Ex Ante Calculations

A custom calculation spreadsheet was used to determine the annual savings. For the two (2) 200 HP motors, the savings are based on the retrofit of the controls to VSDs from on/off controls. The custom calculations determine the kW for each control scheme at 10% speed intervals using typical unloading curves. The kWh savings is then determined by summing the kW savings at each interval multiplied by the hours at each interval.

Custom Energy Savings Calculations:

Baseline Usage	1,227,891 kWh
Proposed Usage	822,573 kWh
Annual Savings	405,318 kWh

3. Comments on the Ex Ante Calculations

A custom calculation spreadsheet was used to determine the annual savings to convert two (2) 200 HP motors to VSDs from on/off controls. Within these calculations it is evident that a billed energy usage is used for the base case to determine the savings. However, when the billed energy usage is used, in conjunction with the 149.2 kW full load input power for the motor, the motor would need to be running 8,230 hours per year. Per the same calculation sheet, the motor in the pre-retrofit condition only operated for 5,767 on-hours per year to produce the required flow. If the reduced hours of operation are used, the savings are reduced as shown below.

Adjusted Custom Energy Savings Calculations:

Baseline Usage	860,436 kWh
Proposed Usage	822,573 kWh
Peak Summer Impact & Annual Savings	37,863 kWh

This savings value is less than 10% of the original submitted savings based on reduced hours of operation due to the on/off control.

4. Measurement & Verification Plan

This site consists of a pumping station that delivers domestic water to the city water system at a pressure of 65 to 75 psi, pre-retrofit and 67 psi post-retrofit. The pumping station sits on top of a reservoir located next to a park. The pumping station consists of five (5) pumps: three (3) 200 HP, one (1) 150 HP, and one (1) 100 HP. Two of the 200 HP motors were replaced and the new replacement 200 HP motors were fitted with VSDs. The peak water consumption times are typically early morning, late afternoon, and evening periods. The pumps are staged as needed. Typically, the lead pump is one of the 200 HP pumps.

The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction due to the installation of the VSDs on the two (2) 200 HP pump motors.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. The usage of the pumps is not expected to remain consistent enough for single point measurements to be representative of the average usage. Seasonal variation is expected to occur and two weeks may be adequate to yield reliable seasonal estimates; however, a longer period would more fully capture actual variations during different seasons and the persistence of savings. Interval data on a 15-minute or less basis, preferably during the summer months of June to September, would be needed to accurately determine utility peak period demand savings.

Pre-retrofit and post-retrofit calculations of booster pump demand and energy use will be calculated using the following formulae:

<u>Post-installation</u>

Peak kW = kW at maximum flow rate condition for VFD at post-retrofit head pressure

$$\text{kWh} = \frac{\text{metered kWh x weeks per year x seasonal adjustment factor}}{\text{metered weeks}}$$

The seasonal adjustment factor is to account for seasonal water consumption differences, and will be determined from historical billing data.

<u>Pre-installation</u>

Peak kW = kW at maximum flow rate condition and peak pre-retrofit head pressure

kWh = pre-installation hours of operation x kW for max expected flow at average pre-retrofit head pressure

The most significant variables to be quantified are the pre-retrofit and post-retrofit hours of operation and the pre and post retrofit kW demand profiles of the pumps. Pre-retrofit hours will be confirmed with the site personnel to verify that the running hours listed in the application (8,238 hours per year) were valid. If required, appropriate modifications for the savings calculations will be made to the pre-retrofit usage figures, possibly based on post-retrofit monitoring, in order to establish a realistic baseline for energy use.

The installation of the two (2) VSDs will be physically verified during the onsite visit.

The post-retrofit energy consumption will be verified by installing Hobo FlexSmart data loggers with WattNode WNA-3D-480-P watt-hour transducers and Magnalab SCT-1250-200 current transformers on the power supplied to the VFD. The energy consumption of the pumps will be logged with a sampling delay of no greater than 2 minutes, for a minimum of 14 days to verify the post-retrofit energy consumption.

The greatest uncertainty in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit hours of operation.

Uncertainty for the savings estimate for the pump VSD retrofit can be more fully understood by setting projected ranges on the primary variables.

<u>For the Pre-Retrofit 200 HP pump motors</u>

- 200 HP pump motors average total kW of 162 kW, maximum of 202.5 kW, minimum of 121.5 kW (±25%, based on judgment of deviation from typical throttled condition pump unloading curve in the SPC calculator, deviation from judgment of pump brake horse power input to SPC calculator, and deviation from judgment of throttled flow rate)
- 200 HP pump motors average hours of operation of 8,238 running hours expected, maximum of 8,760 running hours, minimum of 4,943 running hours (+6.3%, -40%, based on judgment of deviation based on discussions with customer representative and typical operating conditions for similar facilities)

<u>For the Post-Retrofit 200 HP pump motors with VSDs</u>

- VSD controlled 200 HP pump motors average total kW of 170 kW, maximum of 255 kW, minimum of 128 kW (+50%, -25% based on judgment of deviation from typical VFD pump unloading curve in the SPC calculator, deviation from judgment of pump brake horse power input to SPC calculator, and deviation from judgment of throttled flow rate)
- VFD controlled 200 HP pump motors average hours of operation of 8,238 running hours expected, maximum of 8,760 running hours, minimum of 6,179 running hours (+6.3%, -25%, based on judgment of deviation based on discussions with customer representative and typical operating conditions for similar facilities)

<u>For the 200 HP pump motors with VSD Retrofit</u>

- 405,318 kWh expected savings, minimum 0 kWh, maximum 550,267 kWh (-100%, +35.7%, based on pre-retrofit and post-retrofit pump operation above)
- No kW savings expected due to decreased system efficiency at 100% flow condition due to less than 100% efficiency of VSD.

Accuracy and Equipment

The Hobo FlexSmart loggers have a resolution of ±10 seconds. The WattNode watt-hour transducers have an accuracy of ±0.50%, and the Magnelab SCT-1250-200 current transformers have an accuracy of ±1.5%.

Annualizing the data based on the reporting period is estimated to result in possible inaccuracies of +/- 20%.

The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to Microsoft Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 5, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the post-retrofit VFDs and pumps. Two VFDs were found to be installed on turbine pumps for the city water system.

5.1. Installation Verification

For the pump motor VFD installation project, the facility representative verified that prior to the installation of the VFDs the motors operated at constant speed. The installation of the two 200 HP pump VFDs was physically verified during the on-site process.

The facility representative stated that the retrofit was completed approximately March of 2005.

A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
OTHER-PUMP VFD	O			VFD INSTALLATION ON TWO PUMPS	2	200HP VFD	PHYSICALLY VERIFIED INSTALLATION OF PUMP VFDS	1.00

5.2. Scope of the Impact Assessment:

The impact assessment scope is for the Other-VFD end use measure in the SPC application. This was the only measure in this application.

5.3. Summary of Results:

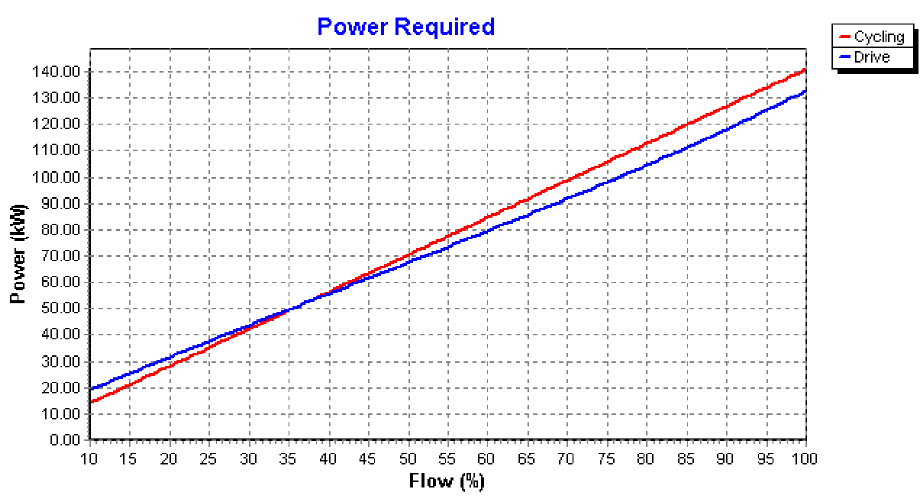
Two Hobo energy loggers with 200A CTs were installed on the input power wiring to the VFDs for a period of seven (7) days (from September 5, 2007-September 11, 2007) to record the operating hours and energy consumption of the two pump motors with VFDs.

The customer representative stated that the pump station is operational for 24 hours per day, 365 days per year. In addition, the customer representative stated that there are five (5) pumps to meet the pumping requirements at this facility. For any given condition, the required number of pumps are base-loaded, with one pump running in variable speed mode to meet the flow requirements. The discharge system pressure is set for 65.2 psi with the new system.

The customer representative also verified that the pre-retrofit pump motors cycled on/off based on the system pressure. The system pressure would vary from 65 to 75 psi. With the new VFD system the system pressure is set for 65.2 psi and does not vary significantly.

For the kW and kWh savings, curves were developed using the metered kW values as well as pressure reduction information collected through discussion with the customer. The peak kW reduction was then determined to be the kW reduction at 100% full load. The kWh reduction is the summation of the kW reduction at each percent load condition multiplied by the hours at that load condition.

Figure 1: Pre-Retrofit and Post-Retrofit kW per Percent of Full Load



The facility representative stated that this facility operates typically 24 hours per day, seven days per week. Occupancy at this facility is very light, with generally no people expected to be at the facility.

The pump motors and VFDs are expected to operate 8,760 hours per year, each one approximately half of the time. Therefore, at the summer peak hour, between 3 pm and 4 pm on weekdays, one pump motor is expected to be in operation.

The ex post impacts are calculated in Table 2 below:

Table 2: Energy and Demand Formulae

Pre-Retrofit Demand kW_{peak} = 100% Full Load Pre-Retrofit kW
= 141.1 kW

Post-Retrofit Demand kW_{peak} = 100% Full Load Pos-Retrofit kW
= 132.9 kW

Peak kW Savings = Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak}
= 141.1 kW – 132.9 kW
= 8.2 kW

Pre-Retrofit kWh = Pre-Retrofit Peak kW x Full Load Hours +
Pre-Retrofit kW at 90% Flow x Hours at 90% Flow +
Pre-Retrofit kW at 80% Flow x Hours at 80% Flow +
Pre-Retrofit kW at 70% Flow x Hours at 70% Flow +
Pre-Retrofit kW at 60% Flow x Hours at 60% Flow +
Pre-Retrofit kW at 50% Flow x Hours at 50% Flow +
Pre-Retrofit kW at 40% Flow x Hours at 40% Flow +
Pre-Retrofit kW at 30% Flow x Hours at 30% Flow +
Pre-Retrofit kW at 0% Flow x Hours at 0% Flow
= 141.1 kW x 1056 hrs + 126.9 kW x 493 hrs + 112.8 kW x 493 hrs + 98.8 kW x 1267 hrs + 84.7 kW x 774 hrs + 70.6 kW x 985 hrs + 56.4 kW x 1619 hrs + 42.3 kW x 352 hrs + 0 kW x 1,724 hrs
= 633,626 kWh

Post-Retrofit kWh = Post-Retrofit Peak kW x Full Load Hours +
Post-Retrofit kW at 90% Flow x Hours at 90% Flow +
Post-Retrofit kW at 80% Flow x Hours at 80% Flow +
Post-Retrofit kW at 70% Flow x Hours at 70% Flow +
Post-Retrofit kW at 60% Flow x Hours at 60% Flow +
Post-Retrofit kW at 50% Flow x Hours at 50% Flow +
Post-Retrofit kW at 40% Flow x Hours at 40% Flow +
Post-Retrofit kW at 30% Flow x Hours at 30% Flow +
Post-Retrofit kW at 0% Flow x Hours at 0% Flow
= 132.9 kW x 1056 hrs + 118.1 kW x 493 hrs + 104.5 kW x 493 hrs + 91.8 kW x 1267 hrs + 79.6 kW x 774 hrs + 67.6 kW x 985 hrs + 55.7 kW x 1619 hrs + 43.7 kW x 352 hrs + 0 kW x 1,724 hrs
= 600,231 kWh

$$\begin{aligned} \text{kWh Savings} &= \text{Pre-Retrofit Demand kW}_{peak} - \text{Post-Retrofit kW}_{peak} \\ &= 633{,}626 \text{ kWh/yr} - 600{,}231 \text{ kWh/yr} \\ &= 33{,}395 \text{ kWh/yr} \end{aligned}$$

The ex post energy reduction is less than the ex ante estimate. A preliminary analysis was submitted to the utility, which predicted as savings of approximately 40,000 kWh per year. This is not significantly different than the savings determined in the ex post analysis. The original analysis was abandoned, however, in favor of the results determined by two additional analysis methods. One compared the expected energy consumption of the pumps with VFDs to the metered data for the entire facility. The other used the SPC calculator, which did not account for the high static pressure load in the system. As a coincidence, the two analyses produced similar results for energy savings.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the invoices for the work performed for the project. The costs included for this project only include one of the two VFDs and motors because only one of the two VFDs will be in operation at any time. The customer did not give any drawbacks associated with the equipment. A non-energy benefit for the new equipment is better pressure control for the city water system. Also, the customer did not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer stated that it is likely that participation in the 2004/2005 SPC program did encourage them to complete this and other retrofit projects. Specifically, they have completed similar projects at other pumping stations, all of which received utility incentives.

We were unable to physically verify the pre-retrofit pump operating characteristics and hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

7. Impact Results

Based on the ex ante savings of 0 kW and 405,318 kWh the engineering realization rate for this application is 0.08 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 3.

Table 3: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	-	405,318	-
SPC Installation Report (ex ante)	-	405,318	-
Impact Evaluation (ex post)	8.2	33,395	-
Engineering Realization Rate	N/A	0.08	N/A

Utility billing data for the site was reviewed. In the 12-month period from January 2005 - December 2005 (post-retrofit), the facility consumed 793,720 kWh. Peak demand was 618.2 kW in July 2005. Table 4 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 4: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	618.2	793,720
Baseline End Use	141.1	793,720
Ex ante Savings	0.0	405,318
Ex Post Savings	8.2	33,395

Table 5 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 0.0% decrease in total meter kW, a 0.0% decrease in the end use kW, a 51.1% decrease in total meter kWh, and a 51.1% decrease in the end use kWh. The ex post results showed a 1.3% decrease in total meter kW, a 5.8% decrease in the end use kW, a 4.2% decrease in total meter kWh, and a 4.2% decrease the end use kWh.

Table 5: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	0.0%	51.1%	1.3%	4.2%
Baseline End Use %	0.0%	51.1%	5.8%	4.2%

With a cost of $105,000 and a $32,425 incentive, the project had a 1.38 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 16.72 years. A summary of the economic parameters for the project is shown in Table 6.

Table 6: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), ($1.10/therm) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	1/17/2004	$105,000	-	405,318	-	$52,691	$32,425	1.38	1.99
SPC Program Review (Ex Post)	9/26/2007	$105,000	8.2	33,395	-	$4,341	$32,425	16.72	24.19

It was determined that the pump VFD project was defined as a Miscellaneous Measure-Variable Frequency Drive project in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the VFD system was assumed to have a useful life of fifteen (15) years.

A summary of the multi-year reporting requirements is given in Table 7.

Table 7: Multi-Year Reporting Requirements

Program Name:		SPC 04-05 Evaluation Appl A101					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	-	-	-	-	-	-
2	2005	405,318	33,395	-	8.2	-	-
3	2006	405,318	33,395	-	8.2	-	-
4	2007	405,318	33,395	-	8.2	-	-
5	2008	405,318	33,395	-	8.2	-	-
6	2009	405,318	33,395	-	8.2	-	-
7	2010	405,318	33,395	-	8.2	-	-
8	2011	405,318	33,395	-	8.2	-	-
9	2012	405,318	33,395	-	8.2	-	-
10	2013	405,318	33,395	-	8.2	-	-
11	2014	405,318	33,395	-	8.2	-	-
12	2015	405,318	33,395	-	8.2	-	-
13	2016	405,318	33,395	-	8.2	-	-
14	2017	405,318	33,395	-	8.2	-	-
15	2018	405,318	33,395	-	8.2	-	-
16	2019	405,318	33,395	-	8.2	-	-
17	2020			-	-	-	-
18	2021	-	-	-	-	-	-
19	2022	-	-	-	-	-	-
20	2023	-	-	-	-	-	-
TOTAL	**2004-2023**	6,079,770	500,925			-	-

FINAL REPORT

SITE A102 (xxxx-04) Metr IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 1 END USE: Other

Measure	Replace existing open piping system with new closed piping system at a pumping station
Site Description	Municipal Pumping Station

1. Measure Description

The customer implemented one measure to reduce the pump energy usage required to transfer potable water.

The measure requires the installation of a new 66-inch diameter transfer pipe directly to the pumping station suction header bypassing the open tank suction reservoir. This modification allows 146 feet of head pressure in the transfer pipe to be used to reduce the total pumping head on the transfer pumps. As part of this project, VFDs were required to be installed on the pumps to control the pressure downstream of the station.

2. Summary of the Ex Ante Calculations

The ex ante calculations used the standard pump formula to determine the reduced pumping annual savings.

The standard pump formula used to determine Bhp is:

$$\text{Pump Bhp} = (\text{Flow}_{gpm} \times \text{Head}_{'\ H2O}) / (3{,}960 \times \text{Pump Efficiency}_{\%})$$

Where, from submitted calculations:
1. 3,960 is a conversion constant
2. Pump Efficiency was assumed to be 85%
3. Expected average flow was 31,550 gpm
4.Head Pressure: Existing – 245 ft
Proposed – 99 ft
5. Pump Bhp is pump brake horsepower

Energy and Demand savings were determined using the following formula:

$$\text{Demand Savings} = (\text{Pump Bhp}_{existing} - \text{Pump Bhp}_{proposed}) \times 0.746 \text{ kW/Hp}$$

$$\text{Energy Savings} = \text{Demand Reduction}_{kW} \times 8{,}760 \text{ Hrs/yr}$$

The ex ante pump savings results are:

Measure - Piping Modifications:		
Base Usage (2,296 Bhp)	1,712 kW	14,997,120 kWh
Proposed Usage (928 Bhp)	692 kW	6,061,920 kWh
Pumping Savings	1,020 kW	8,935,200 kWh

The pumping station used a water turbine driven electrical generator to capture a portion of the energy of the incoming water stream to produce electricity for on-site use. The amount of electricity generated that will no longer be realized is 3,738,455 kWh per year (amount provided by the owner). Subtracting this amount from the Pumping Savings yields the following reported savings:

Annual Savings -	629 kW	5,196,745 kWh

No calculation was presented to support the utility reported demand savings of 692 kW. However, 629 kW is the expected demand for the post-retrofit system.

3. Comments on the Ex Ante Calculations

The installation report review did not change the amount of reported savings and found that the modifications were installed as expected. These savings agree with the utility tracking system.

The rebate for the pumping modification was determined using the standard theoretical pump formula resulting in 629.0 kW demand savings and 5,196,745 kWh energy savings and an estimated total incentive of $415,739.60.

The following paragraphs highlight notable concerns or deficiencies that resulted in adjustments of the ex ante calculations for this site.

Both the existing and proposed demand savings were based on the Bhp of the pumps. However, this approach does not take into consideration the additional losses in the system due to motor and drive losses. The corrected formula to account for these losses is:

$$\text{Demand Savings} = (\text{Pump Bhp}_{existing} - \text{Pumps Bhp}_{proposed}) \times 0.746\ \text{kW/Hp} / (\text{Motor Efficiency}_{\%} \times \text{VFD Efficiency}_{\%})$$

The post inspection report indicated the pump motors are all the same at 1,200 hp each. Recent CEE updated motor efficiency tables indicate that, for motors greater than 500 hp, a typical pre-EPACT full load nominal efficiency of 95% would be representative. Also, since the pump motor loading will remain greater than 75% (928/1200) the motor efficiency should be constant across the expected operating range. Therefore a factor of 1/0.95 should have been included in the original calculation to represent the motor efficiency.

Variable Speed Drives have losses that are dependent on speed. Information from the Office of Information Technology has data on VFD efficiency obtained from equipment manufacturers. This data was graphed and, using a curve fit program, a formula developed to calculate the efficiency based on motor speed. The formula for larger motors is:

$$\text{Efficiency} = 2.3005*\text{Percent Speed}^3 - 5.3936*\text{Percent Speed}^2 + 4.2135*\text{Percent Speed} - 0.142$$

Percent speed is determined as the cube root of the percent load. Assuming the pre retrofit system required two pumps, the percent load on each was 96% (2,296 bhp/2,400 bhp) yielding a 98% speed with a calculated 97% VFD efficiency. The new condition has one pump operating at 77% load, 92% speed, with a VFD efficiency of 96%. The respective VFD efficiency factors are 1/0.97 for the existing system and 1/0.96 for the new conditions.

The corrected energy savings based on the ex ante analysis are:

Base Usage (2,296 Bhp)	1,859 kW	16,285,419 kWh
Proposed Usage (928 Bhp)	759 kW	6,249,187 kWh
Pumping Savings	1,100 kW	9,636,232 kWh

Less the generated electricity amount, the adjusted savings are:

5,897,776 kWh.

The reported demand savings of 629 kW was not supported with calculations. If the reported amount of on-site generated electricity is produced throughout the year, then the average purchased demand reduction seen would have been 427 kW (3,738,455 kWh/8,760 hrs/yr). Reducing the calculated demand savings by this amount, the reported demand savings should have been:

673 kW (1,100 kW – 427 kW)

4. Measurement & Verification Plan

The site consists of a water pumping station which pumps the incoming water up to the required head pressure, lifting the water over a hill south of this location. An existing building holds the four 1,200 hp pumps.

The piping system before the project was an open system, where the incoming water was diverted to an underground atmospheric reservoir. When the water was dumped into this reservoir, it lost all the head pressure which existed in the incoming pipe flow. Water was then pumped from the reservoir to the necessary flow and head needed to deliver the water over the hill and into the water system as described above.

The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction due to the installation of the new piping and discharge pressure regulator (surge tank) over the useful life of these measures.

Formulae and Approach

For this application, we propose to use IPMVP Option C (Billing Analysis). Water flow is the main variable for this facility that is regularly metered and recorded at the facility. The facility's pumps use almost all electricity consumed at the site with the usage being dependent on total water flow and pumping efficiency. Any modification which results in changes to pumping efficiency or in the amount of water pumped, will be visible in the metered energy use.

Measurement of the site energy usage relative to water flow will provide the necessary information for comparison of the new piping arrangement's actual operation to the predicted operation used in the ex ante calculation. Water flow is routinely measured at the pumping station and the actual measured volume for 12 months preceding implementation and for twelve months post installation will be used for the ex post energy calculations. A water flow profile with peak measured flow rates will be obtained from the owner based on recent historical records.

Pre-retrofit and post-retrofit calculations of demand and energy savings will be calculated using the following formulae:

Post-installation

Pump Peak kW = kW at Maximum Water Flow Rate

Measured site power (kW) with corresponding water flow (gpm) will be used to create a site input power curve unique to this facility. An input power formula as a function of water flow will be developed using a curve fit function. The formula will then be used in a spreadsheet water flow bin calculator. The basic calculation is the summation of:

$$\text{Pump kWh}_{\text{(flow rate)}} = \text{Calculated kW}_{\text{(flow rate)}} \times \text{hours/yr}_{\text{(flow rate)}}$$

The installation of the piping modifications will be physically verified during the onsite visit.

Pre-installation

Pre-installation usage calculations will require the site purchased energy usage (on-site generated power will not be included) for the 12 months preceding installation. A site purchased power formula, as a function of water flow, will be determined. This formula will be developed using the same methodology as in the post-installation discussion. The normalized pre-installation power requirement will be:

Pump Peak kW = kW at Maximum Post-Installation Water Flow Rate

The formula can be used in a spreadsheet water flow bin calculator. The basic calculation is the summation of:

$$\text{Pump kWh}_{\text{(post install flow rate)}} = \text{Calculated kW}_{\text{(post install flow rate)}} \times \text{hours/yr}_{\text{(flow rate)}}$$

Uncertainty for the savings estimate for the piping modification project can be more fully understood by setting projected ranges on the primary variables.

For the Piping Retrofit

- 673 kW expected savings, maximum 841 kW, minimum 505 kW (±25%, based on expected deviation of savings resulting from variations in flow, head pressure, pump operation, and electricity generation capability)
- 8,935,200 kWh expected savings, maximum 11,169,000 kWh, minimum 6,701,400 kWh (±25%, based on expected deviation of savings resulting in

variations in flow, head pressure, pump operation, and electricity generation capability)

Accuracy

The kW and kWh data collected is from utility interval and billing data and is expected to have an accuracy of ± 0.5%. Water flow data is taken from customer's EMS system and is expected to have an accuracy of at least ±5% or better.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 23, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the post-retrofit piping as well as pre-retrofit piping remnants. The current piping system at this facility is a closed system and does not include a reservoir or turbine system.

5.1. Installation Verification

The facility representative verified that prior to the installation of the piping retrofit, the piping was an open system. Prior to implementation, the piping into the facility was split from one-66" dia. pipeline to two-42" dia. pipelines. These were then throttled and run through a turbine generator. After the turbine, the water was dumped into an open reservoir, then re-pumped from this reservoir to a second reservoir. The installation of the closed system piping for the pump station was physically verified during the on-site process.

The facility representative stated that the retrofit was completed in approximately January of 2005.

A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
OTHER-PROCESS CHANGE	O			SYSTEM REPIPING TO INCLUDE CLOSED SYSTEM	1	PIPING	PHYSICALLY VERIFIED INSTALLATION OF CLOSED SYSTEM PIPING	1.00

5.2. Scope of the Impact Assessment

The impact assessment scope is for the Other end use category in the SPC application. This was the only measure in this application.

5.3. Summary of Results

The pumping system was observed with the new closed-system piping installed and in operation. It was observed that the reservoir and turbine system were not in operation. It was verified that each pump matched the submitted information.

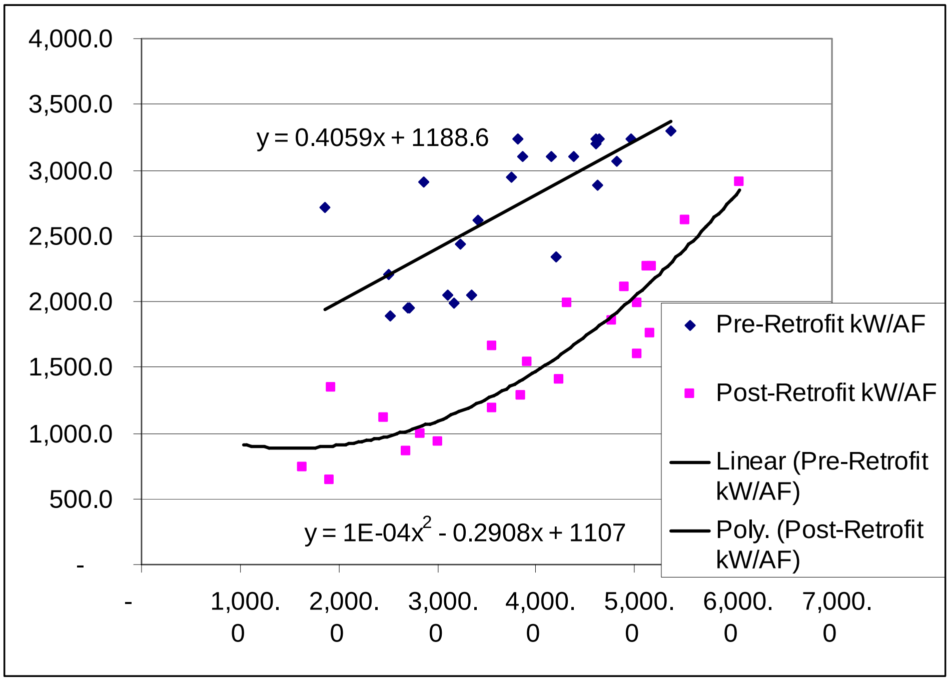
The customer was able to provide historical data for the pumping station for the years of 1995 through 2006. The data for years 1995 through 2001 was not included in the analysis because the level of water pumped at this station differed significantly during this time. Acre Feet was used as the volume of water pumped, representing a depth of one foot of water over an acre of water, in conformance with customer information. For the years of 2002-2003 (pre-retrofit) and 2005-2006 (post-retrofit), average annual kWh/AF (acre-ft) figures were developed. The pre-retrofit and post-retrofit kWh/AF values were then applied to the 2006 year data to determine the expected annual kWh savings. This information is presented in Table 2 below.

Table 2: Pre-Retrofit and Post Retrofit kWh/AF Values

Month	2002	2003	2005	2006
January	413.4	381.4	Excluded	158.4
February	409.6	456.9	144.7	173.9
March	91.9	382.2	152.8	159.5
April	348.4	385.3	168.1	160.2
May	297.9	389.9	176.7	168.9
June	373.9	390.8	183.6	194.2
July	333.8	389.2	205.3	222.7
August	444.2	415.8	215.7	231.2
September	430.8	388.9	237.6	240.6
October	407.0	390.1	186.3	187.2
November	474.2	404.6	178.8	171.7
December	521.5	320.9	163.5	153.4
Weighted Average	**377.5**	**389.7**	**195.4**	**192.6**

For the kW savings, curves were developed using the monthly kW values compared to monthly AF pumped. These curves were then used, along with the maximum monthly pumped AF for 2006, to determine the kW savings.

Figure 1: Pre-Retrofit and Post-Retrofit Peak kW/AF



The facility representative stated that this facility operates typically 24 hours per day, seven days per week. Occupancy at this facility is very light, with only a few people expected to be at the facility sporadically throughout the week.

The pump motor and piping retrofit is expected to operate 8,760 hours per year, therefore, at the summer peak hour, between 3 pm and 4 pm on weekdays, the closed system piping is expected to be in operation.

The ex post impacts are calculated in Table 3 below.

Table 3: Energy and Demand Formulae

Pre-Retrofit Demand kW_{peak}	= C1 x Post-Retrofit Peak Flow + C2 - $kW_{turbine}$ = 0.4059 kW/AF x 5,546.2 AF + 1,188.6 – 426.8 kW = 3,013.0 kW
Post-Retrofit Demand kW_{peak}	= C1 x Post-Retrofit Peak Flow^2 + C2 z Post Retrofit Peak Flow + C3 = 0.00095 kW/AF^2 x (5,546.2 AF)^2 + 0.2908 kW/AF x 5,546.2 AF + 1,107 = 2,416.3 kW
Peak kW Savings	= Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak} = 3,013.0 kW – 2,416.3 kW = 596.7 kW
Pre-Retrofit kWh	= Pre-Retrofit kWh /AF x Post-Retrofit AF –$kWh_{turbine}$ = 388.424 kWh/AF x 45,375 AF – 3,738,455 kWh = 13,886,281 kWh
Post-Retrofit kWh	= Post-Retrofit kWh /AF x Post-Retrofit AF = 193.985 kWh/AF x 45,375 AF = 8,802,053 kWh
kWh Savings	= Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak} = 13,886,281 kWh/yr – 8,802,053 kWh/yr = 5,084,228 kWh/yr

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. The customer did not give any drawbacks or any non-energy benefits associated with the new equipment. Also, the customer did not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer stated that it is likely that participation in the 2004/2005 SPC program did encourage them to complete this and other retrofit projects. Specifically, they have completed lighting and VFD installation projects, all of which received utility incentives.

We were unable to physically verify the pre-retrofit pump operating characteristics and hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

7. Impact Results

Based on the ex ante savings of 629 kW and 5,196,745 kWh the engineering realization rate for this application 0.95 for kW reduction and 0.98 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 4.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	629.0	5,196,745	-
SPC Installation Report (ex ante)	629.0	5,196,745	-
Impact Evaluation (ex post)	596.7	5,084,228	-
Engineering Realization Rate	0.95	0.98	N/A

Utility billing data for the site was reviewed. In the 12-month period from January 2003 - December 2003 (pre-retrofit), the facility consumed 17,030,344 kWh. Peak demand was 3,264.0 kW in August 2003. Table 5 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 5: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	3,264.0	17,030,344
Baseline End Use	2,586.3	13,886,281
Ex ante Savings	629.0	5,196,745
Ex Post Savings	596.7	5,084,228

Table 6 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 19.3% decrease in total meter kW, a 24.3% decrease in the pumping end use kW, a 30.5% decrease in total meter kWh, and a 37.4% decrease in the pumping end use kWh. The ex post results showed a 18.3% decrease in total meter kW, a 23.1% decrease in the pumping end use kW, a 29.9% decrease in total meter kWh, and a 36.6% decrease the pumping end use kWh.

Table 6: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	19.3%	30.5%	18.3%	29.9%
Baseline End Use %	24.3%	37.4%	23.1%	36.6%

With a cost of $12,000,000 and a $415,740 incentive, the project had a 17.15 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is slightly less than the ex ante, and the estimated simple payback is 17.53 years. A summary of the economic parameters for the project is shown in Table 7.

Table 7: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), ($1.10/therm) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	2/11/2004	$12,000,000	629.0	5,196,745	-	$675,577	$415,740	17.15	17.76
SPC Program Review (Ex Post)	9/25/2007	$12,000,000	596.7	5,084,228	-	$660,950	$415,740	17.53	18.16

It was determined that the repiping project was defined as a Custom Measure-SPC project in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the repiped system was assumed to have a useful life of fifteen (15) years.

A summary of the multi-year reporting requirements is given in Table 8. Because this measure was installed in approximately December 2004 to January of 2005, the energy savings in year #1 (2004) are assumed to be 0% of the expected annual savings for this measure. In addition, no peak savings are assumed to occur.

Table 8: Multi-Year Reporting Requirements

Program ID:		**001 Application # A104**					
Program Name:		**SPC 04-05 Evaluation**					
Year	**Calendar Year**	**Ex-ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004	-	-	-	-	-	-
2	2005	5,196,745	5,084,228	629.0	596.7	-	-
3	2006	5,196,745	5,084,228	629.0	596.7	-	-
4	2007	5,196,745	5,084,228	629.0	596.7	-	-
5	2008	5,196,745	5,084,228	629.0	596.7	-	-
6	2009	5,196,745	5,084,228	629.0	596.7	-	-
7	2010	5,196,745	5,084,228	629.0	596.7	-	-
8	2011	5,196,745	5,084,228	629.0	596.7	-	-
9	2012	5,196,745	5,084,228	629.0	596.7	-	-
10	2013	5,196,745	5,084,228	629.0	596.7	-	-
11	2014	5,196,745	5,084,228	629.0	596.7	-	-
12	2015	5,196,745	5,084,228	629.0	596.7	-	-
13	2016	5,196,745	5,084,228	629.0	596.7	-	-
14	2017	5,196,745	5,084,228	629.0	596.7	-	-
15	2018	5,196,745	5,084,228	629.0	596.7	-	-
16	2019	5,196,745	5,084,228	629.0	596.7	-	-
17	2020	-	-	-	-	-	-
18	2021	-	-	-	-	-	-
19	2022	-	-	-	-	-	-
20	2023	-	-	-	-	-	-
TOTAL	**2004-2023**	77,951,175	76,263,415			-	-

FINAL SITE REPORT

SITE A103 (2005 - xxx) CSU IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: AC&R

Measure	Replace existing 230-ton centrifugal chiller with one (1) 400-ton Multistack centrifugal chiller driven by a variable speed drive (VSD)
Site Description	Office Building

1. Measure Description

The measure involves the installation of one (1) 400-ton centrifugal chiller with a VSD to replace one (1) 230-ton centrifugal chiller. Prior to the installation, one (1) 230-ton chiller was out of service for approximately one year and one (1) additional 230-ton chiller was handling all the cooling. The replacement of the one (1) operational 230-ton chiller was incented. This is the only measure evaluated for this application. The other measure in the application involved variable speed drives on chiller plant pumps and fans, which are classified in the "Other" category. This measure was, however, mislabeled in the utility tracking system.

2. Summary of the Ex Ante Calculations

The SPC Calculator for Early Retirement- AC&R (chiller module) was used to determine the energy savings. This program calculated the annual demand and energy savings of 0.0 kW and 55,294 kWh.

The ex ante results are:

Annual Savings -	55,294 kWh
Savings for remainder of 12-year useful life	663,528 kWh

In the original analysis the savings for the 12-year useful life for the chiller was used as the annual savings value, which resulted in a reported savings of 663,528 kWh for the chiller retrofit.

3. Comments on the Ex Ante Calculations

The energy savings for the chiller was determined using the Early Retirement- AC&R program within the SPC Calculator. Within the SPC Calculator, chillers are treated as a calculated measure, resulting in 0.0 kW demand savings and 55,294 kWh energy savings. The SPC calculator uses simplified bin analysis based on typical chiller operation and local climate data.

In addition to calculating annual savings the Early Retirement- AC&R program within the SPC Calculator calculates a savings for the remaining expected useful life of the pre-retrofit chiller. Based on a 12 year expected life and an annual savings of 55,294 kWh the total expected savings for this measure is 663,528 kWh. However, the savings for the 12 year expected life were then reported as the ex ante savings, which resulted in an over-reporting of annual energy savings by 608,234 kWh. This error also affected the incentive paid for the project.

The customer is installing a 400-ton chiller to replace a 230-ton chiller. In the original analysis, in order to account for the reduced load attributed to the chiller, the new chiller was entered as a 230-ton unit as well.

4. Measurement & Verification Plan

The facility has 11-stories with a total floor area of 212,000 sq. ft. and is occupied continuously with periods of peak occupancy occurring weekdays from 8:00 am to 5:00 pm. The post-installation system includes the installation of a new 400-ton centrifugal chiller with VFD.

The goal of the M&V plan is to estimate the actual kWh reduction due to the installation of a new VFD driven chiller over the useful life of the measure.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. Seasonal variation is expected to be variable; however, to obtain the range of outside air temperatures expected, one week should be a sufficiently long enough measurement period to calibrate an energy savings model. Interval data collected on a 15-minute or less basis, preferably during the summer months of June to September, could be helpful in accurately determining coincident peak period demand savings.

Measurement of the chiller input power relative to outdoor air temperature will provide the necessary information for comparison of the new chiller's actual operation to the predicted operation forecast by the SPC Calculator.

Pre-retrofit and post-retrofit calculations of demand and energy loads will be calculated using the following formulae:

<u>Post-installation</u>

Chiller Peak kW = kW at maximum Outdoor Air Temperature (either measured or predicted if the max OAT does not occur during the measurement period)

Chiller measured input power (kW) with corresponding outdoor air temperature will be used to create a chiller input power curve unique to this facility. An input power formula as a function of outdoor air temperature will be developed using a curve fit function. The resulting equations will be used in a spreadsheet bin calculator. The basic calculation is the summation of:

$$\text{Chiller kWh}_{\text{(bin temp)}} = \text{Calculated kW}_{\text{(bin temp)}} \times \text{hours/yr}_{\text{(bin temp)}}$$

Pre-installation

Pre-installation calculations are dependent on the actual cooling load. Cooling load can be determined by:

Cooling Load $_{\text{(bin temp)}}$ = New Chiller kW $_{\text{(bin temp)}}$ / New Chiller Effectiveness $_{\text{(bin temp)}}$ (kW/ton from manufacturers supplied data)

Peak kW = (kW/ton $_{\text{(chiller)}}$ x Tons $_{\text{(chiller)}}$)

Energy Savings is the summation of

kWh $_{\text{(bin temp)}}$ = (kW/ton $_{\text{(chiller)}}$ x Tons $_{\text{(chiller)}}$)$_{\text{(bin temp)}}$ x hours/yr $_{\text{(bin temp)}}$

The most significant variables to be quantified are the pre-retrofit and post-retrofit hours of operation and the pre and post retrofit kW demand profiles of the chiller. Pre-retrofit hours will be confirmed with the site personnel to verify that the hours listed in the application are valid. If required, appropriate modifications for the savings calculations will be made to the pre-retrofit usage figures, possibly based on post-retrofit monitoring, in order to establish a more accurate baseline for energy use.

The installation of the 400-ton centrifugal chiller will be physically verified during the onsite visit. The unit will be verified to be consistent with the unit proposed in the application. In addition, the post-installation energy consumption will be verified by utilizing the customer's on-site EMS software to compile the kW and kWh of the unit for a minimum of 7 days.

If the demand and energy consumption is not available from the EMS software, we will verify post-installation energy consumption of the chiller by installing Hobo FlexSmart data loggers with WattNode WNA-3D-480-P watt-hour transducers and Magnalab SCT-2000-600 current transformers. The energy consumption will be logged with a sampling delay of no greater than 1 minute, for a minimum of 7 days to verify the post-installation energy consumption.

The outdoor air temperature and relative humidity at the facility will be monitored using no less than one (1) Hobo H8 logger. The logged kWh will then be used in conjunction with temperature effects to determine the annual usage.

The greatest uncertainty in the ex ante savings estimate are associated with the pre-installation and post-installation utilization factors for the chiller. The utilization factor is a function of the load profile and the performance curve throughout the course of the entire year. For the chiller analysis, the SPC calculator utilizes a standard load profile based on the type of facility, hours of operation, and building area as well as a typical performance curve based on chiller type. In addition, the SPC calculator assumes a typical kW/ton for the baseline chiller; the actual baseline chiller kW/ton value was not used to calculate the savings in this program.

Uncertainty for the savings estimate for the chiller retrofit project can be more fully understood by setting projected ranges on the primary variables.

For the Pre-Installation Chiller

- 4,693 facility hours of operation expected, maximum of 5,162 hours, minimum of 4,224 hours (±10%, based on customers description of hours of operation and typical deviation in hours of similar facilities)
- 155.4 kW expected for the chiller, maximum of 170.9 kW, minimum of 113.6 kW (+10%, -27%, based on judgment of deviation from expected typical efficiency in SPC calculator and maximum load condition in SPC calculator)
- 605,521 kWh expected for the chiller, maximum of 710,400 kWh, minimum of 421,359 (+17%, -30%, based on judgment of deviation from expected typical efficiency in SPC calculator, typical utilization factor in SPC calculator, maximum load condition in SPC calculator, and hours of operation)

For the Post-Installation Chiller

- 4,693 facility hours of operation expected, maximum of 5,162 hours, minimum of 4,224 hours (±10%, based on customers description of hours of operation and typical deviation in hours of similar facilities)
- 157.3 kW expected for the chiller, maximum of 165.2 kW, minimum of 117.2 kW (+5%, -25%, based on judgment of deviation from expected typical efficiency in SPC calculator and maximum load condition in SPC calculator)
- 550,227 kWh expected for the chiller, maximum of 632,761 kWh, minimum of 385,159 (+15%, -30%, based on judgment of deviation from expected typical efficiency in SPC calculator, typical utilization factor in SPC calculator, maximum load condition in SPC calculator, and hours of operation)

Accuracy

The Hobo FlexSmart loggers have a time accuracy of ±10 seconds. The WattNode Watt-Hour transducers have an accuracy of ±0.45%+0.05%FS, and the Magnelab current transformers have an accuracy of ±1.5%. The Hobo H8 temperature and relative humidity loggers have an accuracy of ±1.3F (within the range of –4F to 104F) for temperature and ±5% for relative humidity.

The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to Microsoft Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 13, 2007. Information on the retrofit equipment and operating conditions was collected by interviewing the facility representative. The equipment installation was verified; however, during the equipment inspection process, the customer representative decided they were no longer willing to cooperate with the onsite process, willing to have data loggers installed on the equipment, and did not provide data for analysis.

Installation Verification

For the chiller retrofit project, the facility representative verified that one (1) 230-ton centrifugal chiller served the facility prior to the installation of the new chiller.

A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	AC&R Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
400 TON CHILLER TO REPLACE EXISTING 230 TON CHILLER	A	400 TON CHILLER TO REPLACE EXISTING 230 TON CHILLER	1	400 TON CHILLER	PHYSICALLY VERIFIED INSTALLATION OF CHILLER	1.00

Scope of the Impact Assessment

The impact assessment scope is for the AC&R end use measure in the SPC application. These were the only measures in this end use category.

Summary of Results

At the time of the on-site visit, the customer no longer was willing to allow data loggers to be attached to the equipment. Data points were collected during the post-installation verification. Per discussion with the customer representative, the operation had not changed from the period in which data was collected.

The chiller is expected to operate Monday through Friday, 7:00 AM to 10:00 PM, therefore, at the summer peak hour, between 2 pm and 5 pm on the hottest weekdays, the operating chiller is expected to be in operation.

The ex post impacts are calculated in Table 2 below:

Table 2: Energy and Demand Formulae

Pre-Retrofit Demand kW_{peak}	= Ex Ante Pre-Retrofit kW_{peak} = 155.4 kW
Post-Retrofit Demand kW_{peak}	= Post-Retrofit Demand kW_{peak} = 157.3 kW
Peak kW Savings	= Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak} = 155.4 kW – 157.3 kW = -1.9 kW
Pre-Retrofit kWh	= Ex Ante Pre-Retrofit kWh = 605,521 kWh/yr
Post-Retrofit kWh	= Ex Ante Post-Retrofit kWh = 550,227 kWh/yr
kWh Savings	= Pre-Retrofit kWh – Post-Retrofit kWh = 605,521 kWh/yr – 550,227 kWh/yr = 55,294 kWh/yr
Pre retrofit energy use reasonable for this application; ex ante savings of 55,294 kWh determined to be reasonable and accepted as ex post savings. Post retrofit use derived from these figures. Usage and savings may be 30 to 50 % higher than actual.	

An ex post kW demand reduction of –1.9 kW is expected. No credit or penalty was taken for a demand reduction in the ex ante calculations. The ex post energy savings are significantly lower than the ex ante energy savings. This is due to the ex ante calculations attributing 12 years worth of energy savings as the annual energy reduction.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. The cost appears to be high based on the chiller size.

The customer did not give any non-energy benefits or drawbacks associated with the new equipment. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future.

We were unable to physically verify the pre-retrofit fixture type or hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site must be enhanced to more accurately determine the impacts of the installed measures. However, the ex ante savings, though likely on the high side, are accepted. The very low realization rate results from the use of multi year savings for the annual kWh savings.

7. Impact Results

Based on the ex ante savings of 0 kW and 663,528 kWh, the engineering realization rate for this application was 0.08 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 3.

Table 3: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	-	663,528	-
SPC Installation Report (ex ante)	-	663,528	-
Impact Evaluation (ex post) First Year Savings	(1.9)	55,294	-
Engineering Realization Rate (First Year)	N/A	0.08	N/A
Impact Evaluation (ex post) Average Savings	(6.9)	35,917	
Engineering Realization Rate (Average)	N/A	0.05	N/A

Utility billing data for the site was reviewed. In the 12-month period from January 2003 - December 2003 (pre-retrofit), the facility consumed 3,131,264 kWh. Peak demand was 564.5 kW in April 2003. Table 4 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 4: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	564.5	3,131,264
Baseline End Use	155.4	605,521
Ex ante Savings	0.0	663,528
Ex Post Savings	-1.9	55,294

Table 5 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 0.0% decrease in total meter kW, a 0.0% decrease in AC&R end use kW, a 21.2% decrease in total meter kWh, and a 109.6% decrease in AC&R end use kWh. The ex post results showed a -0.3% decrease in total meter kW, a -1.2% decrease in AC&R end use kW, a 1.8% decrease in total meter kWh, and a 9.1% decrease in AC&R end use kWh.

Table 5: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	0.0%	21.2%	-0.3%	1.8%
Baseline End Use %	0.0%	109.6%	-1.2%	9.1%

With a cost of $415,000 and a $92,894 incentive, the project had a 3.73 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 44.81 years. A summary of the economic parameters for the project is shown in Table 6.

Table 6: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), ($1.10/therm) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	8/5/2004	$415,000	-	663,528	-	$86,259	$92,894	3.73	4.81
SPC Program Review (Ex Post)	9/28/2007	$415,000	(1.9)	55,294	-	$7,188	$92,894	44.81	57.73

It was determined that the chiller retrofit project was defined as an HVAC Chiller-High Efficiency project in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the chillers were assumed to have a useful life of twenty (20) years.

A summary of the multi-year reporting requirements is given in Table 7. Because this measure was installed approximately July of 2004 the energy savings in year #1 (2005) are assumed to be 1/2 of the expected annual savings for this measure.

Table 7: Multi-Year Reporting Requirements

Program Name:		SPC 04-05 Evaluation (Site 103)					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	331,211	27,601	-	-	-	-
2	2005	663,528	55,294	-	(1.9)	-	-
3	2006	663,528	55,294	-	(1.9)	-	-
4	2007	663,528	55,294	-	(1.9)	-	-
5	2008	663,528	55,294	-	(1.9)	-	-
6	2009	663,528	55,294	-	(1.9)	-	-
7	2010	663,528	55,294	-	(1.9)	-	-
8	2011	663,528	55,294	-	(1.9)	-	-
9	2012	663,528	55,294	-	(1.9)	-	-
10	2013	663,528	55,294	-	(1.9)	-	-
11	2014	663,528	55,294	-	(1.9)	-	-
12	2015	663,528	55,294	-	(1.9)	-	-
13	2016	335,737	31,113	-	(1.9)	-	-
14	2017	6,852	6,852	-	(14.3)	-	-
15	2018	6,852	6,852	-	(14.3)	-	-
16	2019	6,852	6,852	-	(14.3)	-	-
17	2020	6,852	6,852	-	(14.3)	-	-
18	2021	6,852	6,852	-	(14.3)	-	-
19	2022	6,852	6,852	-	(14.3)	-	-
20	2023	6,852	6,852	-	(14.3)	-	-
TOTAL	**2004-2023**	8,013,720	714,912			-	-

Note: If the multi year ex ante savings of 663,528 kWh are replaced with first year savings of 55,294 kWh in the realization rate calculations, the kWh realization rate is increased from 0.08 to 1.00 (8% to 105%). The kW realization rate is not affected.

FINAL REPORT

SITE A104 (xxxx-04) CalSt **IMPACT EVALUATION**
SAMPLE CELL: ORIGINAL TIER: 2 END USE: Other

Measure	Install Variable Frequency Drive (VFD) on a 1,500HP pump motor.
Site Description	Steel Mill - Manufacturing

1. Measure Description

A Variable Frequency Drive (VFD) was installed on one (1) 1,500HP descaling pump motor. As part of the VFD retrofit, the pump motor was replaced with a higher efficiency motor.

2. Summary of the Ex Ante Calculations

A custom calculation was used to determine the annual savings resulting from the motor retrofit and VFD installation project. For the one (1) 1,500 HP descaling pump motor, the savings are based on the retrofit from a throttled control system (opening and closing spray nozzles) as well as the installation of a 94.5% efficient motor to replace a 92.0% efficient motor. The calculation used the determination of the kW for loaded and unloaded times during both the pre and post VFD installation periods. The kWh savings is then determined by the difference between energy consumption in the pre- and post-VFD installation periods.

The ex ante results determined by the customer supplied calculations were:

For the One (1) 1,500HP descaling pump VFD:		
Pre-Replacement Usage	1222.0 kW	6,621,480 kWh
Post-Replacement Usage	1241.0 kW	2,254,756 kWh
Peak Summer Impact & Annual Savings	-19.0 kW	4,366,724 kWh

The incentive was listed as $240,909 in the Installation Report Review (IRR); the utility tracking system notes an incentive of $235,882. It is not apparent why this discrepancy exists.

3. Comments on the Ex Ante Calculations

The savings of 4,366,724 kWh/year and -19.0.kW were determined using custom calculation. The customer provided data used for calculations.

Table 1: Original calculated pre-retrofit demand and usage values using RMS method

	min./cycle	hrs./yr.	Motor Load (hp)	Line Load (hp)	Line Power (kW)	Annual kWh
Loaded Power	0.24		1,509	1,640	1,222 kW	
Unloaded Power	3.13		1,061	1,153	860 kW	
Production Total		6,296			890 kW	5,603,440
Roll Change Delay		73	1,061	1,153	860 kW	62,753
Production Delay		1,111	1,061	1,153	860 kW	955,088
Total						6,621,480

Note that there were many minor numerical discrepancies in the data presented in the application.

Table 2: Original calculated post-retrofit demand and usage values using RMS method

	min./cycle	hrs./yr.	Motor Load (hp)	Line Load (hp)	Line Power (kW)	Annual kWh
Loaded Power	0.24		1,509	1,597	1,241	
Unloaded Power	2.90		41	43	33	
Accel/Decel Power	0.22				465	
Production Total		6,296			352	2,215,305
Roll Change Delay		73				2,432
Production Delay		1,111				37,019
Total						2,254,756

In both the pre-retrofit condition without the VFD and the post-retrofit condition with the VFD, the operating kW was determined using a RMS method. This method used the equation below to determine the kW.

$$OpRMSPower = \sqrt{(\%CycleLoaded) * (LoadedPower)^2 + (\%CycleUnloaded) * (UnloadedPower)^2}$$

The operating RMS power kW is then multiplied by the hours to determine the annual energy usage. It was unclear why this method was used. It appears that this method over-weights the loaded power condition and results in an over-estimated value for the annual energy usage.

A more appropriate method of calculating the energy usage during the production time period uses a weighted average demand value.

$$AvePower = (\%CycleLoaded) * (LoadedPower) + (\%CycleUnloaded) * (UnloadedPower)$$

Table 3: Corrected calculated pre-retrofit demand and usage values using average method

	min./cycle	hrs./yr.	Motor Load (hp)	Line Load (hp)	Line Power (kW)	Annual kWh
Loaded Power	0.24	448	1509	1640	1,222	547,978
Unloaded Power	3.13	5,848	1061	1153	860	5,026,778
Production Total		**6,296**			**886**	**5,574,756**
Roll Change Delay		73	1061	1153	860	62,753
Production Delay		1,111	1061	1153	860	955,047
Total						**6,592,556**

Table 4: Corrected calculated post-retrofit demand and usage values using average method

	min./cycle	hrs./yr.	Motor Load (hp)	Line Load (hp)	Line Power (kW)	Annual kWh
Loaded Power	0.24	450	1509	1597	1,242	557,979
Unloaded Power	2.90	5,434	41	43	33	179,324
Accel/Decel Power	0.22	412				191,691
Production Total		6,296			147.6	928,993
Roll Change Delay		73				2,409
Production Delay		1,111				36,663
Total						**968,065**

The corrected ex ante results determined by the customer supplied calculations:

For the One (1) 1,500HP descaling pump VFD:		
Pre-Replacement Usage	1,223.0 kW	6,592,556 kWh
Post-Replacement Usage	1,241.6 kW	968,065 kWh
Peak Summer Impact & Annual Savings	-19.6 kW	5,624,491 kWh

When the two methods are compared is can be shown that the RMS method overestimates usage in both the pre-retrofit and post-retrofit condition. This results in savings being underestimated by 1,257,767 kWh per year.

4. Measurement & Verification Plan

The facility is a 450-acre steel plant with a 115-acre building. This facility's processes include hot strip rolling, hot strip finishing, continuous pickling, cold reduction milling, hot-dip galvanizing, cold rolling, annealing, and tempering. This facility also includes electric resistance pipe welding.

According to the application, before the retrofit, the descaling water was pumped by one 1,500 HP motor. The pump operated at constant speed; however, during unloaded periods, some of the piping is bypassed, drastically decreasing the head pressure required compared to loaded operation. After the retrofit, the pump speed was modulated through the use of a VFD. Production is expected to occur 148 hours per week throughout the year, with an additional 10 days extended downtime.

The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction due to the installation of the VFD on the 1,500 HP descaling pump, over the useful life of the VSD.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. The usage of the pumps is not expected to remain consistent enough for single point measurements to be representative of the average usage. Seasonal variation is expected to occur and two weeks may be useful to predict reliable seasonal estimates; however, a longer period would more fully capture actual variations during different seasons and the persistence of savings. Interval data on a 15-minute or less basis, preferably during the summer months of June to September, would be needed to accurately determine utility peak period demand savings.

Pre-retrofit and post-retrofit calculations of descaling pump motor instantaneous peak demand and annual energy use will be calculated using the following formulae:

Peak kW = 2,350 V x Measured Amperage at Loaded Condition x Power Factor x Sqrt(3)

> where the power factor is determined from typical power factor curves for large motors and the measured current value.

$kWh_{\text{(load level)}}$ = Calculated $kW_{\text{(load level)}}$ x $hours/yr_{\text{(load level)}}$

Alternatively, this formula could be expressed as

kWh = Peak kW x Utilization factor x Hours of operation

> where the utilization factor is the average percent motor load.

The most significant variables to be quantified are the pre-retrofit and post-retrofit hours of operation and the pre and post retrofit kW demand profile of the pump. Pre-retrofit hours will be confirmed with the site personnel to verify that the running hours listed in the application (7,480 hours per year) were valid. If required, appropriate modifications for the savings calculations will be made to the pre-retrofit usage figures, possibly based on post-retrofit monitoring, in order to establish a realistic baseline for energy use.

The installation of the VFD will be physically verified during the onsite visit.

The post-retrofit energy consumption will be verified through the use of the customer's amperage output data due to the high voltage of the equipment and accompanying safety considerations. The current output will be tracked, along with the cycle times per load condition, to develop a demand and energy profile per production cycle. This production cycle demand and energy profile will then be utilized along with the customer's annual production data, to determine annual demand and energy usage.

The greatest uncertainty in the ex ante energy savings estimate is associated with the pre-retrofit and post-retrofit demand utilization factor. This utilization factor is dependant on the time per cycle spent at each loading condition. In addition, the demand and energy levels at the various loading conditions are dramatically different, amplifying the potential error in calculated savings resulting from any potentially incorrect time assignment.

Uncertainty for the savings estimate for the pump VFD retrofit can be more fully understood by setting projected ranges on the primary variables.

<u>For the Pre-Retrofit Descaling Pump Motor</u>

- Pre-retrofit descaling pump motor instantaneous peak kW of 1,222.1 kW, maximum of 1,527.7 kW, minimum of 916.6 kW (±25%, based on judgment of deviation from observed amperage values and power factor deviation)
- Pre-retrofit descaling pump motor total kWh of 6,592,556 kWh, maximum of 8,581,935 kWh, minimum of 4,603,178 kWh (±30.2 based on judgment of deviation from observed amperage values, power factor deviation, production time variances, and hours of operation)

<u>For the Post-Retrofit Descaling Pump Motor</u>

- Post-retrofit descaling pump motor instantaneous peak kW of 1,241.7 kW, maximum of 1,551.9 kW, minimum of 931.6 kW (±25%, based on judgment of deviation from observed amperage values and power factor deviation)
- Post-retrofit descaling pump motor 7,480 total hours of operation expected, maximum of 8,228 running hours, minimum of 6,732 running hours (±10%, based on judgment of deviation based on discussions with customer and typical operating conditions for similar facilities)
- Post-retrofit descaling pump motor total kWh of 968,065 kWh, maximum of 1,717,804 kWh, minimum of 218,327 kWh (±77.4 based on judgment of deviation from observed amperage values, power factor deviation, production time variances, and hours of operation)

<u>For the Descaling Pump Motor Retrofit Savings</u>

- -19.6 instantaneous peak kW savings expected, maximum 415.8 kW, minimum – 455.0 (±2,220%, based on pre-retrofit and post-retrofit pump operation conditions above)
- 5,624,491 kWh expected savings, minimum 3,498,524 kWh, maximum 7,750,458 kWh (±37.8%, based on pre-retrofit and post-retrofit pump operation conditions above)

Accuracy

The current data collected is from customers monitoring system and is expected to have accuracies of ±3%. Annualizing the data based on the reporting period is estimated to result in possible inaccuracies of +/- 5%.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 6, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the VFD and by interviewing the facility representative. One (1) 1,500-hp VFD was found to be installed at this facility.

Installation Verification

For facility representative verified that prior to the installation of the VFD, the descaling pump motor operated at a constant speed. A bypass was utilized to reduce the brake horsepower of the pump during periods where the descaling spray was not needed. The installation of the VFD on the 1,500 hp descaling pump motor was physically verified during the on-site process.

The facility representative stated that the retrofit was completed approximately December of 2004.

A verification summary is shown in Table 5 below.

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
OTHER-PROCESS VFD	O			VFD ON 1,500 HP DESCALING PUMP MOTOR	1	VFD ON 1,500 HP PUMP MOTOR	PHYSICALLY VERIFIED INSTALLATION OF VFD	1.00

Scope of the Impact Assessment

The impact assessment scope is for the Other-Process VFD end use measure in the SPC application. This was the only measure in this application.

Summary of Results

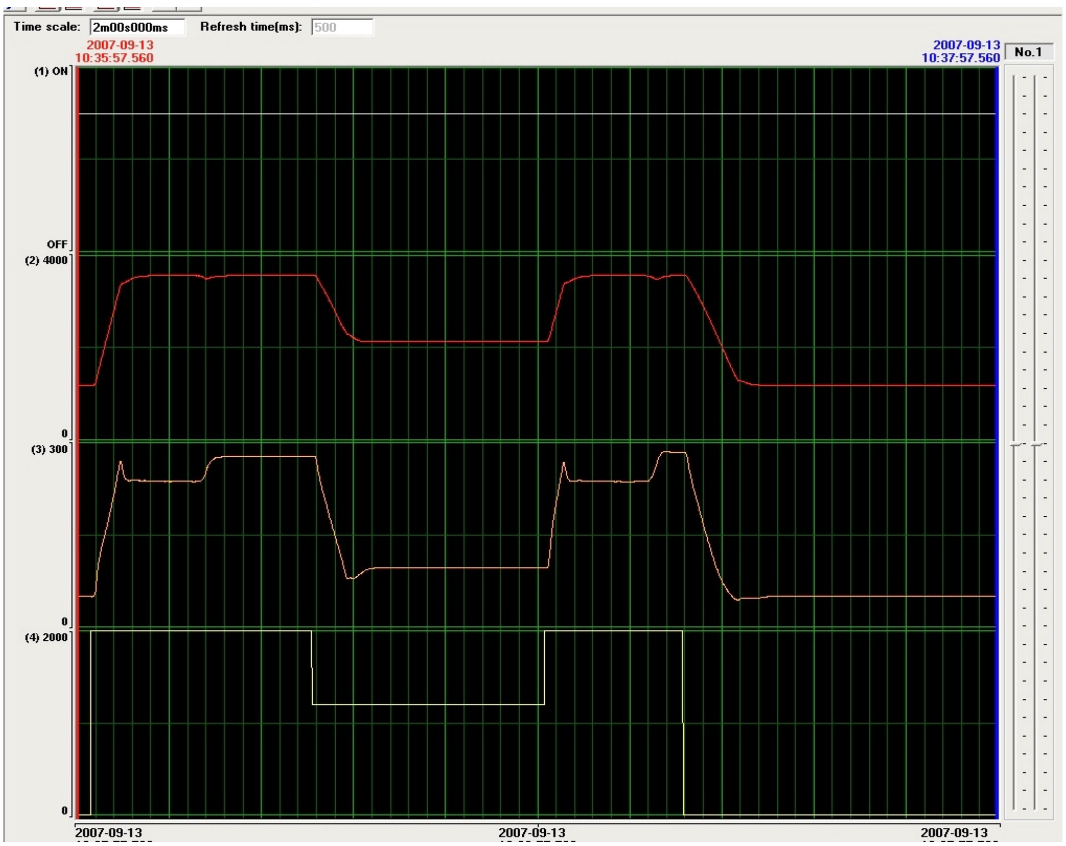
At the time of the site visit, the equipment in question was not operational due to unexpected maintenance. However, another identical line was in operation and was observed.

The identical system was observed for several cycles. It was observed that the peak demand as recorded by the VFD system was 1,049 kW. In addition, it was observed that the cycle times varied from approximately 3 minutes to 4 minutes long.

The customer was able to provide recorded data for the motor speed and torque during two different product runs for the post-retrofit system once it was repaired. It was determined that the length of the cycle was approximately proportional to the length of the product running in the line. Within each cycle, the loaded period of time remained similar at approximately 36 seconds, with the unloaded period longer for the longer product lengths. The loaded portion of one cycle is presented in Figure 1 below.

The facility representative stated that this facility operates typically 24 hours per day, seven days per week. The weekday shifts are the largest shift with an expected occupancy of around 100 workers for this area of the facility. During the weekend shifts the occupancy is much lower, at approximately 30 workers. The facility representative stated that the observed and recorded periods had been representative of normal facility operation.

Figure 1: Graph of Motor Torque and Speed



By multiplying the torque (third graph from the top) by the speed (second graph from the top), the motor power can be determined at any point during the production period. Using this method it was determined that during the loaded portion of the cycle the average demand was 860 kW. Using this average production loaded demand, the observed unloaded production demand, and the site representatives description of hours of operation the ex ante demand and energy usage could be calculated for both the pre-retrofit and post-retrofit operating conditions. This information is presented in Table 6 and Table 7 below.

Table 6: Ex Post Post-Retrofit Demand and Energy Usage

	hrs./yr.	Line Power (kW)
Peak Loaded Power	N/A	1,049
Average Loaded Prod.	572	629
Unloaded Production	4,771	34
Roll Change Delay	62	34
Production Delay	943	34
Total		

Table 7: Ex Post Pre-Retrofit Demand and Energy Usage

	hrs./yr.	Line Power (kW)
Loaded Power	572	1,222
Unloaded Power	4,771	860
Roll Change Delay	62	860
Production Delay	943	860
Total		

The descaling pump motor is expected to operate approximately 6,400 hours per year, therefore, at the summer peak hour, between 2 pm and 5 pm on the hottest weekdays, the descaling pump motor is expected to be in operation.

The ex post impacts are calculated in Figure 2 below.

Figure 2: Energy and Demand Formulae for VFD Installation

Pre-Retrofit Demand kW_{peak} = Pre Retrofit Loaded Power
= 1,222 kW

Post-Retrofit Demand kW_{peak} = Post Retrofit Loaded Power
= 1,049 kW

Peak kW Savings = Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak}
= 1,222 kW – 1,049 kW
= 173 kW

Pre-Retrofit kWh = Pre-Retrofit Loaded Power x Pre-retrofit loaded Hours + Pre-Retrofit Unloaded Power x (Post Retrofit Unloaded Production Time + Production Delay Hours + Roll Change Hours)
= (1,222 kW x 572 hours + 860 kW x (4, 771 hours + 62 hours + 943 hours))
= 5,672,120 kWh

Post-Retrofit kWh = Post Retrofit Average Loaded Power x Post-retrofit Loaded Hours + Post Retrofit Unloaded Power x (Post Retrofit Unloaded Production Time + Production Delay Hours + Roll Change Hours)
= (629 x 572 hours + 34 kW x (4,771 hours + 62 hours + 943 hours)
= 556,172 kWh

kWh Savings = Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak}
= 5,672,120 kWh/yr – 556,172 kWh/yr
= 5,115,948 kWh/yr

The ex post calculated energy savings is greater than the ex ante value. This is due to the improper application of a RMS formula to determine the average production demand, which was then multiplied by hours of operation to determine the energy consumption. However, the ex post energy savings are less than the energy savings projected by the corrected ex ante calculations due to a reduction in the hours of operation used in the ex ante calculations.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. In addition to saving energy in this project, the installation of the VFDs encouraged the implementation of a partitioned spray header project. The partitioned spray header project allows additional energy savings by reducing the descaling pump flow if narrow steel pieces are treated. The customer is attempting to complete this project at a future date. The customer did not give any drawbacks associated with the new equipment. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer stated that it is likely that participation in the 2004/2005 SPC program did encourage them to complete this and other retrofit projects. Specifically, it helped the payback period, which is a main consideration in the determination of which projects get selected for implementation on a competitive basis.

We were unable to physically verify the pre-retrofit pump motor type, operating characteristics, and hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

7. Impact Results

Based on the ex ante savings of –19.0 kW and 4,366,724 kWh the engineering realization rate for this application is –9.1 for kW reduction and 1.17 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 8.

Table 8: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	-	4,366,724	-
SPC Installation Report (ex ante)	(19.0)	4,366,724	-
Impact Evaluation (ex post)	173.0	5,115,948	-
Engineering Realization Rate	(9.11)	1.17	N/A

Utility billing data for the site was reviewed. In the 12-month period from January 2003 - December 2003 (pre-retrofit), the facility consumed 330,979,565 kWh. Peak demand was 73,728.0 kW in October 2003. Table 9 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 9: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	73,728.0	330,979,565
Baseline End Use	1222.0	6,621,480
Ex Ante Savings	-19.0	4,366,724
Ex Post Savings	173.0	5,115,948

Table 10 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 0.0% decrease in total meter kW, a –1.6% decrease in the descaling pump end use kW, a 1.3% decrease in total meter kWh, and a 65.9% decrease in the descaling pump end use kWh. The ex post results showed a 0.2% decrease in total meter kW, a 14.2% decrease in the descaling pump end use kW, a 1.5% decrease in total meter kWh, and a 77.3% decrease the descaling pump end use kWh.

Table 10: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	0.0%	1.3%	0.2%	1.5%
Baseline End Use %	-1.6%	65.9%	14.2%	77.3%

With a cost of $471,763 and a $240,909 incentive, the project had a 0.41 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is greater than the ex ante, and the estimated simple payback is 0.35 years. A summary of the economic parameters for the project is shown in Table 11.

Table 11: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), ($1.10/therm) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	5/6/2005	$471,763	(19.0)	4,366,724	-	$567,674	$240,909	0.41	0.83
SPC Program Review (Ex Post)	9/18/2007	$471,763	173.0	5,115,948	-	$665,073	$240,909	0.35	0.71

It was determined that the descaling pump motor VFD installation project was defined as a Miscellaneous Measure-Variable Frequency Drive project in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the variable frequency drive was assumed to have a useful life of fifteen (15) years.

A summary of the multi-year reporting requirements is given in Table 12. Because this measure was installed approximately December of 2004, the energy savings in year #1 (2004) are assumed to be 1/12 of the expected annual savings for this measure. In addition, no peak savings are assumed to occur.

Table 12: Multi-Year Reporting Requirements

	Program Name:	SPC 04-05 Evaluation, Site A104					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	363,894	426,329	-	-	-	-
2	2005	4,366,724	5,115,948	(19.0)	173.0	-	-
3	2006	4,366,724	5,115,948	(19.0)	173.0	-	-
4	2007	4,366,724	5,115,948	(19.0)	173.0	-	-
5	2008	4,366,724	5,115,948	(19.0)	173.0	-	-
6	2009	4,366,724	5,115,948	(19.0)	173.0	-	-
7	2010	4,366,724	5,115,948	(19.0)	173.0	-	-
8	2011	4,366,724	5,115,948	(19.0)	173.0	-	-
9	2012	4,366,724	5,115,948	(19.0)	173.0	-	-
10	2013	4,366,724	5,115,948	(19.0)	173.0	-	-
11	2014	4,366,724	5,115,948	(19.0)	173.0	-	-
12	2015	4,366,724	5,115,948	(19.0)	173.0	-	-
13	2016	4,366,724	5,115,948	(19.0)	173.0	-	-
14	2017	4,366,724	5,115,948	(19.0)	173.0	-	-
15	2018	4,366,724	5,115,948	(19.0)	173.0	-	-
16	2019	4,002,830	4,689,619	(19.0)	173.0	-	-
17	2020	-	-	-	-	-	-
18	2021	-	-	-	-	-	-
19	2022	-	-	-	-	-	-
20	2023	-	-	-	-	-	-
TOTAL	**2004-2023**	65,500,860	76,739,220			-	-

FINAL SITE REPORT

SITE A105 (xxx-04) P&OL IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: AC&R

Measure	Install a More Efficient Evaporative Condenser
Site Description	Refrigerated Warehouse

1. Measure Description

The customer is replacing an evaporative condenser for their refrigerated warehouse with a more efficient 850-ton evaporative condenser with VSD.

2. Summary of the Ex Ante Calculations

The installation of the 850 ton efficient evaporative condenser is an itemized measure in the SPC Program. The installation report indicates an annual demand and energy savings of 102 kW and 797,300 kWh for this measure.

3. Comments on the Ex Ante Calculations

The impact for the 850-ton evaporative condenser was determined using the itemized approach. The savings indicate that the itemized approach estimates this measure's impacts to be, 0.12 kW/ton (102 kW) demand savings and 938 kWh/ton (797,300 kWh) annual energy savings. The incentive is $75/ton ($63,750).

The estimated savings values of 0.12 kW/ton and 938 kWh/ton includes the effects of floating head pressure controls, which must be included on the post-retrofit equipment. The vast majority of the savings for this project are not savings from the use of this piece of equipment, but instead are savings realized at the refrigeration compressors. These typical energy savings values, used in the itemized measure calculations, were determined using detailed computer simulations based on the DOE-2.2 energy analysis program. For the analysis the following data and assumptions as well as base case were used.

Data and Assumptions

The study is based on a prototypical building based on a typical supermarket design of 32,000 square feet, and operating eighteen hours per day. The market contains a total of 11 display case line-ups, and 5 walk-in boxes. The display fixtures are assumed to be of mid-90's vintage, and encompass the types and range of temperatures commonly found in supermarkets. Most of the low-temperature fixtures include doors, but some are open tubs. The remainder of the display cases is meat, dairy, deli, beverage, and produce cases.

Base case

Each display case and walk-in cooler is served by its own compressor, for a total of 16 compressors in 16 separate refrigeration systems. The low-temperature systems use R-502, and the medium temperature systems use R-12. The systems share a single multi-circuit condenser whose fans are staged directly on outdoor dry bulb temperature. A discharge-air thermostat in each fixture cycles the compressor as required to meet the load.

The “typical” system used in this analysis is vastly different from the system under analysis. Energy usage differences from this “typical” system may dramatically affect the savings.

In addition, from the information provided for the new installed evaporative condenser, an Evapco Model 850 condenser was selected. The Model 850, at standard conditions, has a nominal rating of 603-tons, much smaller than the basis used to determine the incentive and savings. Using the standard rating of 603-tons, the demand and energy savings should have been 72.4 kW and 565,614 kWh.

Two required qualifications for the Itemized R-S2 rebate are that the new condenser must have a variable speed fan drive and that controls be installed to implement floating head pressure compressor operation. No evidence was included in the application documents to verify that these two requirements were met. The condenser also must be capable of operating at 18 ºF TD above ambient wet bulb.

Another qualification for the new condensers is that it must have a minimum EER value of 240 Btu/hr/watt. The manufacturer specifications are 603 tons (7,236,000 Btu/hr) and the unit has two 15 hp fans (24.5 kW at full load with a 91% motor efficiency). Assuming a VFD drive efficiency of 96%, the calculated EER of this model is 265 Btu/hr/watt.

4. Measurement & Verification Plan

The facility is a single story warehouse that was constructed in 1988. The facility has 4,401,954 cu. ft. of refrigerated storage space. The warehouse portion of this facility has few windows and no skylights. The facility is in continuous operation throughout the year.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. Seasonal variation is expected to be predictable and two weeks should be a sufficiently long enough measurement period to calibrate an energy savings model for both measures. Interval data collected on a 15-minute or less basis, preferably during the summer months of June to September, could be helpful in determining coincident peak period demand savings.

Pre-retrofit and post-retrofit calculations of evaporative condenser load and energy use will be calculated using the following formulae:

Post-installation

Condenser Peak kW = kW at maximum Outdoor Air WB Temperature (either measured or predicted if the max OAT does not occur during the measurement period)

Condenser measured input power (kW) with corresponding outdoor air WB temperature will be used to create a condenser input power curve unique to this facility. An input power formula as a function of outdoor air WB temperature will be developed using a curve fit function. The formula can then be used in a spreadsheet bin calculator. The basic calculation is the summation of:

$$\text{Condenser kWh}_{\text{(bin temp)}} = \text{Calculated kW}_{\text{(bin temp)}} \times \text{hours/yr}_{\text{(bin temp)}}$$

Pre-installation

kW = condenser full load efficiency x condenser capacity x peak usage factor

kWh = kW x hours of operation x average kW utilization factor

> Where the peak usage factor is a facility specific variable that is dependant on the facility load, schedule, and outdoor air temperature. Based on a peak usage factor of 100%, this kW could also be calculated:

kW = motor qty x motor HP x load factor x 0.7457 / (motor efficiency x VFD efficiency)

In addition to the actual demand and energy usage of the evaporative condenser, the effects on the refrigeration compressors must also be included. Pre-retrofit and post-retrofit calculations of compressor load and energy use will be calculated using the following formulae:

Compressor Peak kW = kW at maximum Outdoor Air WB

$$\text{Compressor kWh}_{\text{(bin temp)}} = \text{Calculated kW}_{\text{(bin temp)}} \times \text{hours/yr}_{\text{(bin temp)}}$$

> Where the compressor demand curve is developed from the facility's refrigeration equipment, head pressure controls, and customer described load profiles along with the annual outdoor air DB and WB profiles.

This will result in a compressor input power curve unique to this facility.

The most significant variables to be quantified for the evaporative condenser are the pre-retrofit and post-retrofit average kW load factor values. Site personnel will be interviewed to more accurately determine the operating loads of the evaporative condenser. In addition, if possible, the full load efficiency of the pre-retrofit evaporative condenser will be determined from manufacturer's information. Appropriate modifications for the savings calculations will be made to the pre-retrofit usage figures if required, in order to establish a more accurate baseline for energy use.

We will physically verify the installation of the 603-ton evaporative condenser during the onsite visit. We will verify that the installed evaporative condenser is modulated by a VFD. We will verify the floating head pressure controls. We will verify the post-retrofit energy consumption of the evaporative condenser by installing Hobo FlexSmart data loggers with WattNode WNA-3D-480-P Watt-hour transducers and Magnalab SCT-750-020 current transformers on the power supplied to the VFD for each fan motor. The energy consumption of the condenser will be logged with a sampling delay of no greater than 1 minute, for a minimum of 7 days to verify the post-retrofit energy consumption. In addition, the refrigeration system of the facility will be examined and diagramed, with significant equipment data recorded, to better determine the floating head pressure effects. In addition, the customer will be interviewed to determine how the refrigeration configuration of the warehouse fluctuates over the course of a typical year.

The outdoor air temperature and relative humidity at the facility will be monitored using no less than one (1) Hobo H8 logger. The logged kWh and refrigeration system information will then be used in conjunction with temperature and wet bulb data to determine the annual usage.

Uncertainty for the savings estimate for the evaporative condenser replacement can be more fully understood by setting projected ranges on the primary variables.

<u>For the Evaporative Condenser Retrofit</u>

- 72.4 kW expected savings (102 kW in the workpapers), minimum 4.5 kW, maximum 181.25 kW (-93.8%, +150.0%, based on pre-retrofit and post-retrofit evaporative condenser operation above, and expected deviation from typical floating head pressure control savings)

- 7,337 running hours expected, maximum of 8,760 running hours, minimum of 6,236 running hours (+19%, -15%, based on judgment of deviation of hour of operation from discussions with customer representative and typical operating conditions for similar facilities)

- 565,614 kWh annual expected savings (797,300 in the workpapers), minimum 10,032 kWh, maximum 1,432,425 kWh (-98.2%, +153.3%, based on pre-retrofit and post-retrofit condenser operation and floating head pressure controls installation and operation)

Accuracy

The Hobo FlexSmart loggers have a time accuracy of ±10 seconds. The WattNode Watt-Hour transducers have an accuracy of ±0.45%+0.05%FS, and the Magnelab SCT-750-020 current transformers have an accuracy of ±1.5%. The Hobo H8 temperature and relative humidity loggers have an accuracy of ±1.3 ºF (within the range of –4 ºF to 104 ºF) for temperature and ±5% for relative humidity.

The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to Microsoft Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 11, 2007. Information on the replacement equipment and operating conditions was collected by inspection of the evaporative condenser and by interviewing the facility representative. System condensing temperatures and outdoor air conditions were collected from the customer's EMS data logging system. A Fluke digital multimeter was used to determine the power draw of the refrigeration compressor motors.

Installation Verification

The facility representative verified that the pre-retrofit evaporative condenser fan had a constant speed cycling control scheme. The representative noted that floating head pressure controls were added before the replacement of the evaporative condenser. The installation of the post-retrofit oversized evaporative condenser was physically verified. Variable speed fan control for the evaporative condenser was also verified.

This is the only measure for this application. The verification realization rate for each of the projects verified is 1.0. A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
AC&R	H	Oversized Evaporative Condenser			1	Oversized Evaporative Condenser	PHYSICALLY VERIFIED EQUIPMENT QUANTITY AND TYPE	1.00

Scope of the Impact Assessment

The impact assessment scope is for the installation of an oversized evaporative condenser with a VFD. This was the only measure in this application.

Summary of Results

The post-retrofit oversized evaporative condenser was observed operating with variable speed fan control. The condenser fans were verified to be operating at a reduced speed.

The evaporative condenser rejects the heat from five refrigeration compressors. There are three Mycom 160LUD screw compressors, one Mycom 160VLD screw compressor, and one Mycom F6WA reciprocating compressor installed. The total installed capacity of the refrigeration compressors is approximately 300 tons. The matches closely with the capacity of the evaporative condenser at peak design conditions.

A Fluke digital multimeter was used to measure the amps, volts, and power factor of each of the operating refrigeration compressors. At the time of the site visit there were two compressors operating. A 150 HP Mycom screw compressor, model number 160VLD, was operating at –18 ºF saturated suction pressure and 73 ºF saturated condensing temperature. Also, a 50 HP Mycom reciprocating compressor, model number F6WA, was operating at 20 ºF saturated suction temperature and 77 ºF saturated condensing temperature. The measured power consumption of the compressors is presented below in Table 2.

Table 2: Measured Refrigeration Compressor Power

Compressor	FW6A	160VLD
Volts	469	468
Amps	41	61.4
Power Factor	0.64	0.86
kW	21.3	42.8

The refrigeration compressor specifications (tons and brake horsepower) were obtained from the manufacturer's website. The specifications were only available at standard rating conditions (10 ºF saturated suction temperature and 95 ºF saturated condensing temperature). The capacity and power ratings of similar sized compressors from FES (the manufacturer of Mycom compressors) were used to determine the specifications of the compressors at actual operating conditions. The ratio of tons and BHP at actual operating conditions to tons and BHP at standard rating conditions for the FES compressors was used to scale the Mycom compressor ratings accordingly. The capacity and power required for the Mycom compressors operating at the observed conditions during the site visit are presented in Table 3 below.

Table 3: Compressor Ratings at Observed Operating Conditions

Compressor	FW6A	160VLD
suction T	20	-18
condensing T	77	73
Tons	48.4	62.1
BHP	42.4	120.3

The load observed during the site visit was back calculated by converting the measured kW for each compressor into BHP. The percent power was then determined by dividing the operating BHP by the rated BHP at the operating conditions. The percent load was then determined by using percent power versus percent load curves. The operating tonnage was determined by multiplying the percent load by the full load capacity at the observed operating conditions. These results are presented in Table 4 below.

Table 4: Compressor Operating Load and Power

Compressor	FW6A	160VLD
operating BHP	26.6	54.5
% power	63%	45%
% load	63%	35%
tons	30.3	41.6

The heat rejection load as seen by the condenser was then calculated using the calculated tonnage and brake horsepower. The facility representative indicated that the system load is relatively constant throughout the year.

The pre-retrofit and post-retrofit condenser specifications (capacities and motor horsepower) were obtained from manufacturer literature. Bin temperature data were used as an approximation for the outdoor weather at the facility. Data from the facility's EMS system was used to determine the condensing temperature relative to the outdoor air wet bulb temperature. In analyzing the data, it appears that the new evaporative condenser maintains an approximate approach temperature of 9.5 ºF. The pre-retrofit evaporative condenser was estimated to have the same approach temperature because sufficient capacity for the load observed at the time of the site visit.

Curve fits for the evaporative condenser, which take into account the outdoor air wet bulb and condensing temperature, were used to determine the capacity of the condenser at each temperature bin. The curve fits were developed using data from a major evaporative condenser manufacturer. The percent load on the evaporative condensers was then calculated. The fan energy usage was calculated for the pre-retrofit (single speed cycling fan) and post-retrofit (variable speed fan) condenser.

The ex post energy savings are only from the evaporative condenser fans.   Floating head pressure was already installed on this system, so no refrigeration compressor savings resulted from the measure.

The facility representative stated that the facility operates typically 18 hours per day, five days per week. In addition, the facility operates on Saturdays for seven hours. Both shifts during the week have an expected occupancy of around 29 workers. During the weekend the occupancy is much lower (about 5 workers).

The refrigeration system is expected to operate 8,760 hours per year, therefore, at the summer peak hour, between 2 pm and 5 pm on the hottest weekdays, the refrigeration system is expected to be in operation.

The ex post impacts are calculated in Table 5 below.

Table 5: Energy and Demand Formulae

Pre-Retrofit Demand kW_{peak}	= Σ(Pre-Retrofit Fan Motor HP x 0.7457 / Motor Efficiency) = 30 HP x 0.7457 kW/HP / 0.924 + 7.5 HP x 0.7457 kW/HP / 0.885 = 30.52 kW
Condenser $Load_{peak}$	= Compressor $Tons_{peak}$ x 12 MBH/Ton + Compressor Brake $Horsepower_{peak}$ x 2.545 MBH/HP = 71.9 Tons x 12 MBH/Ton + 80.9 HP x 2.545 MBH/HP = 827 MBH
Post-retrofit Percent $Load_{peak}$	= Condenser $Load_{peak}$ / Condenser $Capacity_{peak}$ = 827 MBH / 3,616 MBH = 0.23
Fan Percent $Speed_{peak}$	= (Condenser Percent $Load_{peak}$)^(1/0.72) = (0.23)^(1/0.72) = 0.13 = 0.15 [minimum fan speed is set at 15%]
Post-Retrofit Demand kW_{peak}	= Post-Retrofit Fan Motor HP x 0.7457 x (% Fan $Speed_{peak}$)^3 / (Motor Efficiency x VFD $Efficiency_{@speed}$) = 30 HP x 0.7457 kW/HP x (0.15)^3 / (0.91 x 0.14) = 0.60 kW
Peak kW Savings	= Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak} = 30.52 kW – 0.60 kW = 29.93 kW
Pre-retrofit Percent $Load_{peak}$	= Condenser $Load_{peak}$ / Condenser $Capacity_{peak}$ = 827 MBH / 1,434 MBH = 0.58
Pre-Retrofit kWh	= Σ(Pre-Retrofit Demand kW_{Bin} x Pre-retrofit $Hours_{Bin}$ x Pre-retrofit Percent $Load_{Bin}$) = (30.52 kW x 1 hour x 0.58 + 30.52 kW x 5 hours x 0.58 +…) = 153,346 kWh/yr
Post-Retrofit kWh	= Σ(Post-Retrofit Demand kW_{Bin} x Post-retrofit $Hours_{Bin}$) = (0.60 kW x 1 hour + 0.60 kW x 5 hours +…) = 4,612 kWh/yr
kWh Savings	= Pre-Retrofit kWh – Post-Retrofit kWh = 153,346 kWh/yr – 4,612 kWh/yr = 148,752 kWh/yr

The ex post kW demand reduction is less than the ex ante estimate for several reasons. First, in the ex ante calculations, the demand savings are calculated based on the total capacity of the evaporative condenser. In this system, the load seen by the condenser is much less than the capacity. In addition, the capacity of the condenser varies depending on the condensing temperature and outdoor air wet bulb. If the actual peak operating capacity was used (300 tons), the itemized savings would be much closer to the ex post kW demand reduction. Finally, the compressors already utilized floating head pressure control and no savings was attributed to the refrigeration compressors, drastically reducing savings.

The ex post energy savings are less than the ex ante energy savings due to the overestimation of demand reduction.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. The customer did not relay any drawbacks associated with the new equipment. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. However, the customer did indicate that they recently lost a large customer. This has reduced the load on their refrigeration system, which affected the ex post savings. There is no reason to believe that the refrigeration load will or will not be increasing in the future. The customer's participation in the 2004/2005 SPC Program has encouraged them to perform other energy efficiency projects for which they did not participate in an incentive program.

We were unable to physically verify the pre-retrofit refrigeration head pressures and refrigeration load. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

7. Impact Results

Based on the ex ante savings of 102.0 kW and 797,300 kWh the engineering realization rate for this application is 0.29 for kW reduction and 0.19 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 6.

Table 6: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	102.0	797,300	-
SPC Installation Report (ex ante)	102.0	797,300	-
Impact Evaluation (ex post)	29.9	148,752	-
Engineering Realization Rate	0.29	0.19	N/A

Utility billing data for the site was reviewed. In the 12-month period from January 2003 - December 2003 (pre-retrofit), the facility consumed 5,259,981 kWh. Peak demand was 962.9 kW in July 2003. Table 7 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 7: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	962.9	5,259,981
Baseline End Use	94.5	638,957
Ex ante Savings	102	797,300
Ex Post Savings	29.9	148,752

Table 8 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 10.6% decrease in total meter kW, a 108.0% decrease in evaporative condenser and compressor end use kW, a 15.2% decrease in total meter kWh, and a 124.8% decrease in evaporative condenser and compressor end use kWh. The ex post results showed a 3.1% decrease in total meter kW, a 31.7% decrease in evaporative condenser and compressor end use kW, a 2.8% decrease in total meter kWh, and a 23.3% decrease in evaporative condenser and compressor end use kWh.

Table 8: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	10.6%	15.2%	3.1%	2.8%
Baseline End Use %	108.0%	124.8%	31.7%	23.3%

With a cost of $155,000 and a $63,750 incentive, the project had a 0.88 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 4.72 years. A summary of the economic parameters for the project is shown in Table 9.

Table 9: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), ($1.10/therm) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	7/15/2004	$155,000	102.0	797,300	-	$103,649	$63,750	0.88	1.50
SPC Program Review (Ex Post)	9/27/2007	$155,000	29.9	148,752	-	$19,338	$63,750	4.72	8.02

It was determined that the oversized evaporative condenser project was defined as a cooling tower/evaporative condenser project in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the oversized evaporative condenser was assumed to have a useful life of fifteen (15) years.

A summary of the multi-year reporting requirements is given in Table 10. Because this measure was installed approximately October 2005, the energy savings in year #1 (2004) are assumed to be 0% of the expected annual savings for this measure and the energy savings in year #2 (2005) are assumed to be 1/4 of the expected annual savings for this measure. In addition, no peak savings are assumed to occur in year #1 or year #2.

Table 10: Multi-Year Reporting Requirements

Program ID:	001 Application # A105						
Program Name:	**SPC 04-05 Evaluation**						
Year	**Calendar Year**	**Ex-ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004	-	-	-	-	-	-
2	2005	199,325	37,188	-	-	-	-
3	2006	797,300	148,752	102.0	29.9	-	-
4	2007	797,300	148,752	102.0	29.9	-	-
5	2008	797,300	148,752	102.0	29.9	-	-
6	2009	797,300	148,752	102.0	29.9	-	-
7	2010	797,300	148,752	102.0	29.9	-	-
8	2011	797,300	148,752	102.0	29.9	-	-
9	2012	797,300	148,752	102.0	29.9	-	-
10	2013	797,300	148,752	102.0	29.9	-	-
11	2014	797,300	148,752	102.0	29.9	-	-
12	2015	797,300	148,752	102.0	29.9	-	-
13	2016	797,300	148,752	102.0	29.9	-	-
14	2017	797,300	148,752	102.0	29.9	-	-
15	2018	797,300	148,752	102.0	29.9	-	-
16	2019	797,300	148,752	102.0	29.9	-	-
17	2020	597,975	111,564	102.0	29.9	-	-
18	2021	-	-	-	-	-	-
19	2022	-	-	-	-	-	-
20	2023	-	-	-	-	-	-
TOTAL	**2004-2023**	11,959,500	2,231,273			-	-

FINAL REPORT

SITE A106 (xxxx-05) USx1 IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 1 END USE: AC&R

Measure	Install new chillers driven by variable frequency drives (VFDs) at three sites: 1. Install two new VFD driven chillers to replace existing constant speed chillers and direct expansion compressors at Site 1 2. Install two new VFD driven chillers to replace existing constant speed chillers and direct expansion compressors at Site 2 3. Install three new VFD driven chillers to replace existing constant speed chillers at Site 3
Site Description	Three (3) Processing / Distribution Centers

1. Measure Description

Overview - At Site 1 and Site 2, the original chillers were replaced with larger chillers on VFDs. The original chillers at Site 3 were replaced with equal size chillers with VFDs.

Site 1 - Modifications to the central plant include two (2) new variable frequency drive (VFD) centrifugal chillers. The chillers are 400 ton Carrier units (Model: 19XRV3737357CNH64).

Site 2 – Modifications to the central plant include two (2) new variable frequency drive centrifugal chillers. The chillers are 400 ton Carrier units (Model: 19XRV3737357CNH64).

Site 3 – Modifications to the central plant included three (3) new variable frequency drive centrifugal chillers. The chillers are 400 ton Carrier units (Model: 19XRV3737357CNH64).

For this report, only the measures included in the AC&R category will be verified. This category includes the chiller installations at the three sites. Variable frequency drive installations performed at the same time were not included in the end use category or scope for this evaluation. Two of the variable frequency drive measures for pumps and fans were incorrectly labeled in the AC&R category in the utility tracking system.

2. Summary of the Ex Ante Calculations

Chiller efficiency savings were determined using the following basic formula:

> Energy savings (at each OAT bin) = [{(Existing Bin Chiller Load x 3.516/Chiller COP) + (Existing Bin DX Load x 3.516/DX COP)} – (Total Bin Cooling Load x New Chiller Efficiency in kW/ton)] x Bin Hours

The new chiller efficiency was determined from the manufacturer's performance curve.

This calculation was completed for each temperature bin through the temperature range from 52 F to 107 F (5 F bin increments). The results from each OAT bin were summed to obtain the total savings.

> Demand savings (at the 107F OAT bin) = [{(Existing 107F Bin Chiller Load x 3.516/Chiller COP) + (Existing 107F Bin DX Load x 3.516/DX COP)} – (Total 107F Bin Cooling Load x New Chiller Efficiency in kW/ton)]

Site 1 –
A custom bin hour spreadsheet calculator was used to determine the cooling efficiency annual savings. The spreadsheet used a cooling load profile provided by the owner. This load profile is then used; along with a constant COP of 5.0 for the old chillers' efficiencies and a constant COP of 3.5 for the DX units cooling efficiencies, to determine the existing cooling energy usage. A part load performance curve (with formula) was provided by the owner for the new chillers to determine the peak and part load kW/ton as well as annual kWh usage for the new chiller units.

The original cooling efficiency results, determined by the custom spreadsheet calculation, are:

For the chiller installation:

Pre-Replacement Old Chiller Usage -	-----kW	446,141 kWh
Pre-Replacement Old DX Units Usage –	-----kW	733,560 kWh
Post-Replacement New Chillers Usage -	-----kW	477,845 kWh
Peak Summer Impact & Annual Savings -	117 kW	701,856 kWh

The demand values are left blank in the above table because the pre-replacement and post-replacement demand values used to determine the savings value of 117 kW could not be determined or duplicated from the supplied calculations.

Using the supplied information, the corrected ex-ante cooling energy and demand savings results are:

For the chiller installation:

Pre-Replacement Old Chiller Usage -	155 kW	446,141 kWh
Pre-Replacement Old DX Units Usage –	200 kW	733,560 kWh
Post-Replacement New Chillers Usage -	142 kW	477,845 kWh
Peak Summer Impact & Annual Savings -	213 kW	701,856 kWh

Site 2 –
A custom bin hour spreadsheet calculator was used to determine the cooling efficiency annual savings. The spreadsheet used a cooling load profile provided by the owner. This load profile is then used, along with a constant COP of 5.0 for the old chiller's efficiencies and a constant COP of 3.37 for the DX units' cooling efficiencies, to determine the existing cooling energy usage. A part load performance curve (with formula) was provided by the owner for the new chillers to determine the peak and part-load kW/ton as well as annual kWh usage for the new chiller units.

The original cooling efficiency results, as determined by the custom spreadsheet calculator, are:

For the chiller installation:

Pre-Replacement Old Chiller Usage -	543 kW	876,148 kWh
Pre-Replacement Old DX Units Usage –	88 kW	390,819 kWh
Post-Replacement New Chillers Usage -	227 kW	800,235 kWh
Peak Summer Impact & Annual Savings -	404 kW	466,732 kWh

Using the supplied energy savings calculations, the corrected ex-ante cooling energy and demand savings results are:

For the chiller installation:

Pre-Replacement Old Chiller Usage -	542 kW	1,601,862 kWh
Pre-Replacement Old DX Units Usage –	88 kW	390,819 kWh
Post-Replacement New Chillers Usage -	226 kW	800,235 kWh
Peak Summer Impact & Annual Savings -	404 kW	1,192,246 kWh

Site 3 –
A custom bin hour spreadsheet calculator, similar to what was used for the other two sites, was likely used to determine the annual energy and demand savings for the Site 3 Site. The spreadsheet uses a cooling load profile provided by the owner. This load profile is then used, along with a constant existing cooling system COP to determine the existing cooling demand and energy usage. For the proposed chiller, the manufacturer's part load performance curve and existing cooling load was used to determine the demand and energy usage for the new chiller units.

The original cooling efficiency results provided are:

For the chiller installation:

Pre-Replacement Old Chiller Usage -	-----kW	------------kWh
Post-Replacement New Chillers Usage -	-----kW	------------kWh
Peak Summer Impact & Annual Savings -	289 kW	2,537,971 kWh

The original cooling savings results could not be duplicated to recreate the combination of demand and energy savings presented using the installed tonnage, hours of operation, and new chiller efficiency as presented in the application.

For this report, only the measures included in the AC&R category will be verified. This category includes the chiller installations at the three sites.

3. Comments on the Ex Ante Calculations

The installation report review shows savings of 3,706,559 kWh/year and 811.1 kW. These figures agree with the utility tracking system figures.

Site 1 –
The following paragraphs highlight notable concerns or deficiencies that resulted in adjustments of the ex ante calculations for this site.

A combination of 220 tons of existing water chillers and 200 tons of existing DX cooling were removed and replaced with two (2) 400-ton chillers. The supplied calculations used an efficiency rating of COP = 3.5 for the existing DX units and COP = 5.0 for the existing chillers. These efficiency ratings (COP) were considered constant for both systems through all temperature bins and corresponding loads.

This assumption is reasonable for the chillers as long as the load remains above 40% of design chiller capacity. The chiller loading does stay in the near constant efficiency range with the exception of the lowest temperature bin, which accounts for 10% of the total hours of operation. The slight decrease in chiller efficiency, combined with the few hours of operation at these conditions, should have minimal impact on the overall results. Assuming a constant COP for the DX compressors seems reasonable.

Supporting documentation behind the baseline DX compressor and chiller COP values was not provided. COP values from the California Energy Commission's *2001 Energy Efficiency Standards for Residential and Nonresidential Buildings* for equipment efficiency, as of 10/29/2001, lists a baseline of an 11.0 EER (COP = 3.22) for the DX compressors and a 5.0 COP for the chillers. The values used in the original calculations are equal to or higher that the listed minimum values. The efficiency values used seem reasonable.

The peak demand savings listed for this site was 117 kW. The source of this value could not be verified from the calculation provided. Assuming the peak savings results from the warmest bin temperature and that the both DX compressors will be operating simultaneously, the savings should be the DX compressor demand plus the chiller demand less the new chiller demand. This method results in a demand savings of 213 kW. The assumption of both DX compressors operating simultaneously at the warmest bin temperature is reasonable as the DX cooling load (from the owner provided load profile) at this bin temperature matches the combined compressor capacity.

Site 2 –

The following paragraphs highlight notable concerns or deficiencies that resulted in adjustments of the ex ante calculations for this site.

A combination of 125 tons of existing water chillers and 520 tons of existing DX cooling were removed and replaced with two (2) 400-ton water-cooled chillers. The supplied calculations used an efficiency rating of COP = 3.37 for the existing DX units and COP = 5.0 for the existing chillers. These efficiency ratings (COP) were considered constant for both systems through all temperature bins and corresponding loads.

This assumption is reasonable for the chillers as long as the load remains above 40% of design chiller capacity. The chiller loading does stay above 40% of capacity throughout the loading profile. Assuming a constant COP for the DX compressors appears reasonable.

Supporting documentation behind the baseline DX compressor and chillers COP values was not provided. COP values from the 2001 Energy Efficiency Standards for equipment efficiency, as of 10/29/2001, lists 11.0 EER (COP = 3.22) for the DX compressors and a

5.0 COP for the chillers. The values used in the original calculations are equal to or higher that the listed minimum values. The efficiency values used seem reasonable.

The original energy savings calculation had an incorrect multiplier applied in the formula to determine the existing DX cooling energy consumption. The formula used changed below bin temperatures of 77F. At this bin, for the DX cooling load, it was determined that only one of the two compressors in each unit was needed to meet the load. The formula had a 50% multiplier applied for all temperature bins lower than 77F. While the number of required compressors at these bins may be at 50%, the COP (or kW/ton) does not change. The 50% multiplier should not have been applied. The savings calculation was adjusted by removing the multiplier and the modified results are shown in section 2.

The peak demand savings listed for this site was 404 kW. The peak demand savings is from the warmest bin temperature and it was assumed that all DX compressors will be operating simultaneously. The savings is the DX compressor demand plus the chiller demand less the new chiller demand. The assumption that all DX compressors would be operating simultaneously at the warmest bin temperature is suspect since the 425 ton load (from the owner provided load profile) at this bin temperature is less than the combined DX compressor capacity of 520 tons. It would be reasonable to assume that an equal percentage of compressors, 81.7%, would be operating on average. Applying this percentage to the DX compressor demand would reduce the demand savings from 404 kW to 305 kW.

Site 3 –
The following paragraphs highlight notable concerns or deficiencies that resulted in adjustments of the ex ante calculations for this site.

The original energy and demand savings calculations were not available. Attempts to re-create the reported savings could not be achieved. The combination of 2,537,971 kWh and 289.6 kW savings is not possible for combinations of chillers and/or DX systems similar to the other sites. In can be inferred that the replaced system already used chilled water (no AHU replacement was included in any of the descriptions for this site). The base system would need a COP of 3.65 with a design maximum cooling load of 1,200 ton (design capacity of the new chillers) to achieve the reported energy savings. Based on those assumptions, the demand reduction would have been much larger than reported, nearly 453 kW. Unless the scope of the air conditioning retrofits for this site is drastically different than described in the application, an incorrect assumption or assumptions may have been made in the original calculations.

4. Measurement & Verification Plan

The facilities are large, comprising a total of 1,096,162 sq ft (Site 1 – 312,017; Site 2 - 324,603; Site 3 – 459,542). The buildings are occupied continuously. According to the application, the AHU fans operated 24 hours per day, 7 days per week. The original cooling compressors and chillers operate for all hours above an outdoor air temperature of 52 F. After the retrofit, new chiller operation is limited to outdoor air temperatures above 57 F, due to better economizer controls on the AHUs.

Site 1 –
The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction due to the installation of the two 400 ton chillers w/ VFDs.

Measurement of the chiller input power relative to outdoor air temperature will provide the necessary information for comparison of the new chiller's actual operation to the predicted operation used for the ex ante calculations.

Site 2 –
The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction due to the installation of the two 400 ton chillers w/VFDs.

Measurement of the chiller input power relative to outdoor air temperature will provide the necessary information for comparison of the new chiller's actual operation to the predicted operation used for the ex ante calculations.

Site 3 –
The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction due to the installation of the three 400 ton chillers w/ VFDs.

Measurement of the chiller input power relative to outdoor air temperature will provide the necessary information for comparison of the new chiller's actual operation to the predicted operation used for the ex ante calculations.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation. The usage of the chillers is not expected to remain consistent enough for single point measurements to be representative of the average usage. Seasonal variation is expected to be somewhat variable and two weeks may be able to yield reliable seasonal estimates; however, a longer period would more fully capture actual variations during different seasons and the persistence of savings. Interval data on a 15-minute or less basis, preferably during the summer months of June to September, would be needed to accurately determine utility peak period demand savings.

Pre-retrofit and post-retrofit calculations of chiller loads and energy use will be calculated using the following formulae:

<u>Post-installation</u>

Chiller Peak kW = kW at maximum Outdoor Air Temperature (either measured or predicted if the max OAT does not occur during the measurement period)

Chiller measured input power (kW) with corresponding outdoor air temperature will be used to create a chiller input power curve unique to each facility. An input power formula as a function of outdoor air temperature will be developed. This formula will be used in a spreadsheet bin analysis similar to the original spreadsheet calculator. The basic calculation is the summation of:

Chiller kWh $_{\text{(bin temp)}}$ = Calculated kW $_{\text{(bin temp)}}$ x hours/yr $_{\text{(bin temp)}}$

Pre-installation

Pre-installation calculations are dependent on the actual cooling load. Cooling load can be determined by:

$\text{Cooling Load}_{(bin\ temp)} = \text{New Chiller kW}_{(bin\ temp)} / \text{New Chiller Effectiveness}_{(bin\ temp)}$ (kW/ton from manufacturer's supplied data)

For the Site 1 and Site 2 facilities, the demand and energy savings will be calculated using the cooling load as determined from the metered data. In addition, the portion of the cooling load attributed to the DX and the pre-retrofit chiller in the original calculations will be used to determine the demand and energy savings for each cooling method. Using the given pre-retrofit DX & chiller system COP (converted to kW/ton) values the peak demand savings (at 107 F) are:

$$\text{Peak kW} = (\text{kW/ton}_{(DX)} \times \text{Tons}_{(DX)}) + (\text{kW/ton}_{(chiller)} \times \text{Tons}_{(chiller)})_{(107F)}$$

Energy Savings is the summation of

$$\text{kWh}_{(bin\ temp)} = ((\text{kW/ton}_{(DX)} \times \text{Tons}_{(DX)}) + (\text{kW/ton}_{(chiller)} \times \text{Tons}_{(chiller)}) - (\text{kW/ton}_{(new\ chiller)} \times \text{Tons}_{(new\ chiller)}))_{(bin\ temp)} \times \text{hours/yr}_{(bin\ temp)}$$

The most significant variables to be quantified are the pre-retrofit and post-retrofit hours of operation and the pre and post retrofit kW demand profiles of the chillers. If required, appropriate modifications for the savings calculations will be made to the pre-retrofit usage figures, possibly based on post-retrofit monitoring, in order to establish a realistic baseline for energy use.

The installation of the chillers will be physically verified during the onsite visit.

If available, the post-retrofit energy consumption for the chillers will be verified by collecting no less than two weeks of collected data from the customer's EMS software package. The collected data from the EMS software will then be used in conjunction with local temperature data to determine annual usage.

If the customer's EMS data is unavailable or incomplete, the post-retrofit energy consumption for the chillers will be verified by installing Hobo FlexSmart data loggers with WattNode WNA-3D-480-D watt-hour transducers and Magnalab SCT 2000-600 current transformers on the power supplied to the chillers at the Site 1 and Site 2 facilities. The energy consumption of the chillers will be logged with a sampling delay of no greater than 2 minutes, for a minimum of 14 days to verify the post-retrofit energy consumption. In addition, the outdoor air temperature and relative humidity at each of the Site 1 and Site 2 facilities will be monitored using no less than one (1) Hobo H8 logger. The logged kWh per site will then be used in conjunction with temperature to determine the annual usage.

The power consumption at the Site 3 facility will be determined using the chiller operation information gathered at the other two facilities as well as by interviewing the customer representative to develop a reasonable operating schedule and profile.

Uncertainty for the savings estimate for the chiller projects can be more fully understood by setting projected ranges on the primary variables.

For the Site 1 Chiller Retrofit

- Chiller retrofit total peak kW savings of 213.5 kW, maximum of 242.5 kW, minimum of 175.0 kW (+13.6%, -18.0%, based on judgment of deviation from typical DX unit efficiency, typical older chiller efficiency, unit load factors, and part load utilization factors)
- Chiller retrofit annual hours of operation of 8,047 hours, maximum of 8760 hours, minimum of 6,834 hours (+8.9%, -15%, based on judgment of deviation from submitted hours of operation based on typical deviation of hours of operation of similar facilities and discussions with customer)
- Chiller retrofit total peak kWh savings of 701,996 kWh, maximum of 854,306 kWh, minimum of 507,604 kWh (+21.7%, -27.7%, based on judgment of deviation from typical DX unit efficiency, typical older chiller efficiency, unit load factors, part load utilization factors, and hours of operation)

For the Site 2 Chiller Retrofit

- Chiller retrofit total peak kW savings of 305.6 kW, maximum of 356.1 kW, minimum of 237.8 kW (+16.5%, -22.2%, based on judgment of deviation from typical DX unit efficiency, typical older chiller efficiency, unit load factors, and part load utilization factors)
- Chiller retrofit annual hours of operation of 8,205 hours, maximum of 8760 hours, minimum of 6,974 hours (+6.8%, -15%, based on judgment of deviation from submitted hours of operation based on typical deviation of hours of operation of similar facilities and discussions with customer)
- Chiller retrofit total peak kWh savings of 1,192,624 kWh, maximum of 1,464,182 kWh, minimum of 837,061 kWh (+22.8%, -29.8%, based on judgment of deviation from typical DX unit efficiency, typical older chiller efficiency, unit load factors, part load utilization factors, and hours of operation)

For the Site 3 Chiller Retrofit

- Chiller retrofit total peak kW savings of 453.0 kW, maximum of 588.3 kW, minimum of 320.3 kW (+29.9%, -29.3%, based on judgment of deviation from typical DX unit efficiency, typical older chiller efficiency, unit load factors, and part load utilization factors)
- Chiller retrofit annual hours of operation of 8,047 hours, maximum of 8760 hours, minimum of 6,834 hours (+8.9%, -15%, based on judgment of deviation from submitted hours of operation based on typical deviation of hours of operation of similar facilities and discussions with customer)
- Chiller retrofit total peak kWh savings of 2,538,526 kWh, maximum of 3,272,843 kWh, minimum of 1,622,934 kWh (+28.9%, -36.1%, based on judgment of deviation from typical older chiller efficiency, unit load factors, part load utilization factors, and hours of operation)

For the Chiller Retrofits Combined

- 4,433,146 kWh expected savings, minimum 3,431,593 kWh, maximum 5,231,111 kWh (-22.6%, +18.0%, based on pre-retrofit and post-retrofit operation above)
- 972.0 kW expected savings, minimum 777.6 kW, maximum 1,119.6 kW (-20.0%, +15.2%, based on pre-retrofit and post-retrofit operation above)

Accuracy and Equipment

The Hobo FlexSmart loggers have a resolution of ±10 seconds. The WattNode watt-hour transducers have an accuracy of ±0.50%, and the Magnelab current transformers have an accuracy of ±1.5%. The Hobo H8 temperature and relative humidity loggers have an accuracy of ±1% for temperature and ±3% for relative humidity.

Annualizing the data based on the reporting period is estimated to result in possible inaccuracies of +/- 20%.

The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to Microsoft Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 20, 2007. Information on the retrofit equipment and operating conditions was collected by inspection and by interviewing the facility representatives. Two (2) kW/kWh loggers were installed on the chillers at the Site 1 and Site 2 facilities (one logger per site) for the period of August 20 through September 11, 2007. One temperature/relative humidity logger was installed at the Site 1 facility for the same time period. One kW/kWh logger was placed on one of the air-handling units at the Site 1 facility for the period of September 12 to September 13, 2007.

5.1. Installation Verification

The facility representative verified that the pre-retrofit chillers were consistent with the units submitted in the application.

It was physically verified that the chillers and air handling unit fans had VFDs installed on them. The facility representative stated that the retrofit was completed by June 2005.

These three chiller replacements are the only AC&R measures in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Chiller Retrofit	A	Install Two(2) 400-ton chillers at Site 1, Install Two (2) 400-ton Chillers at Site 2, Install three (3) 400-ton chillers at Site 3	7	400 ton Chillers with VFDs	Physically verified installation of equipment at Site 1 and Site 2	1.00

5.2. Scope of the Impact Assessment

The impact assessment scope is for the replacement of the chillers at three facilities. At the Site 1 and Site 2 sites, the original chillers were replaced with larger chillers on VFDs. The original chillers at the Site 3 site were replaced with equal size chillers with VFDs.

As the selected sample, only the Site 1 and Site 2 facilities were included in the monitoring and verification. Results were extrapolated to Site 3.

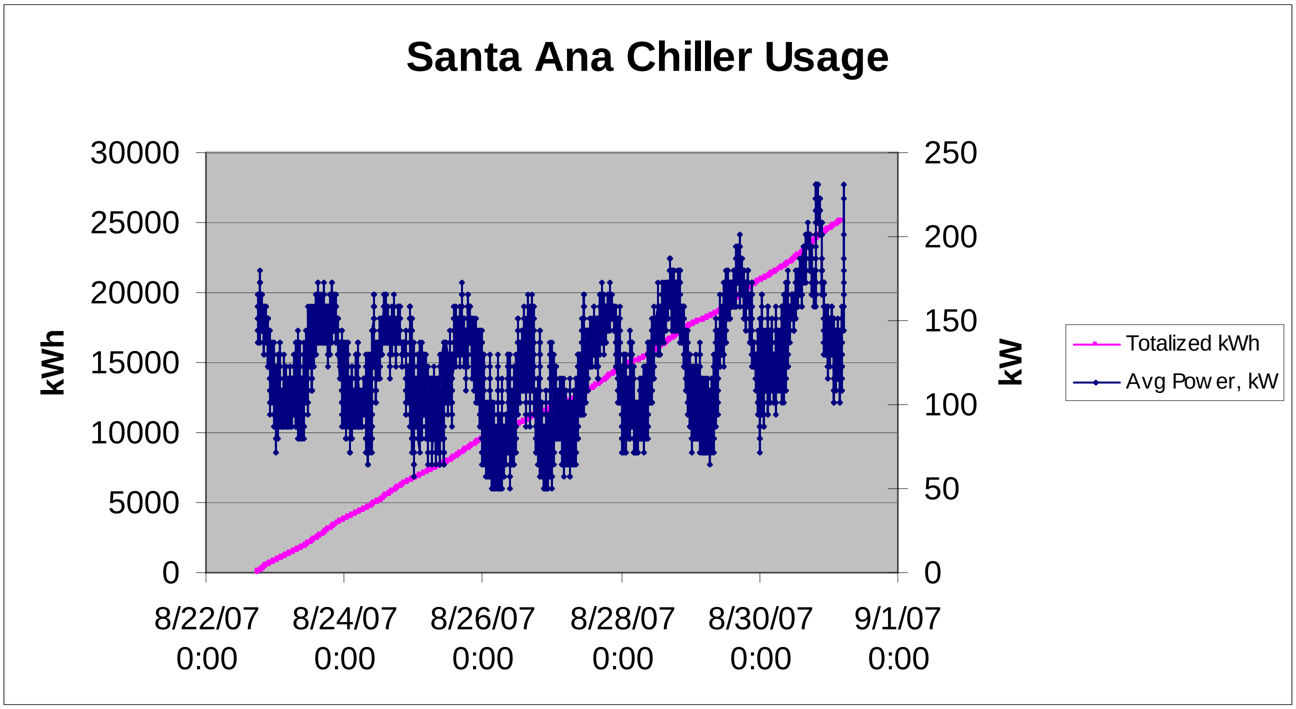
5.3. Summary of Results

Two (2) Hobo Wattnode kW/kWh loggers were installed on the chillers at the Site 1 and Site 2 facility from August 20, 2007 through September 11, 2007 to measure the operating hours and power consumption. One Hobo temperature/relative humidity logger was installed outdoors during this same time period at the Site 1 facility. The facility representatives stated that the monitoring periods had been representative of normal facility operation.

After installation of the monitoring device at the Site 2 facility, it appears that chilled water was provided only by the standby chiller for unknown reasons. No data were obtained for the Site 2 chiller.

The facilities are all in operation twenty-four hours per day, seven days per week. The equipment included in this project is in operation during these hours. A period of metered data for the chiller at the Site 1 facility is shown in Figure 1.

Figure 1: Non-Summer Metered Data



Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load.

The ex post impacts are calculated in Figure 2 below.

Figure 2: Energy and Demand Formulae

The following formulas include only the Site 1 chiller.

Pre-Retrofit Demand kW = Chiller kW from logged data (at each Bin temperature)

Post-Retrofit Demand kW = Chiller kW from logged data (at each Bin temperature)

Peak Demand Savings = Peak Pre-Retrofit Demand kW – Peak Post-Retrofit kW
= 388.55 kW – 264.28 kW
= 124.27 kW

Pre-Retrofit kWh = $\sum$ (Pre-Retrofit Demand kW_{bin} x Pre-retrofit $Hours_{bin}$)

Post-Retrofit kWh = $\sum$ (Post-Retrofit Demand kW_{bin} x Post-retrofit $Hours_{bin}$)

Energy Savings = Site 1 Chiller (Pre-Retrofit kWh – Post-Retrofit kWh)
= 1,537,759 kWh/yr – 745,734 kWh/yr
= 792,025 kWh/yr

Total Savings for All Sites Combined:

Note that the savings attributed to the chiller replacement for all three sites were changed by adjusting the load on the chiller systems for all each site, based on the logged power consumption of the Site 1 chiller.

Total Peak Demand Savings = 1,738.3 kW – 1,056.4 kW
= 681.9 kW

Total Energy Savings = 7,068,014 kWh/yr – 3,811,498 kWh/yr
= 3,256,516 kWh/yr

Note that for the equipment that was not monitored, the available pre-retrofit and post-retrofit equipment and conditions were reviewed for appropriateness.

The ex ante calculations overestimated the number of chillers operating at the Site 2 and Site 3 facilities. This overestimated the ex ante demand and energy savings. Additionally, the logged data indicated that the ex ante savings underestimated the power consumption of the new chiller at the Site 1 facility, which is attributed to estimated load being greater than what was used in the ex ante calculations. This underestimated both the pre and post retrofit energy consumption.

6. Additional Evaluation Findings

The facility representatives stated that the cost estimates provided in the application are from the vendor invoices for the work performed for the project and are an accurate reflection of the project costs. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program has not encouraged them to perform any other energy efficiency projects for which they did not participate in an incentive program.

We were unable to physically verify the pre-retrofit equipment or hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representatives. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measure at Site 1; greater evaluation effort would be helpful in extrapolating the results to Sites 2 and 3.

7. Impact Results

Based on the ex ante savings of 3,706,559 kWh and 811.1 kW, the engineering realization rate for this application is 0.88 for energy savings (kWh) and 0.84 for demand savings (kW). A summary of the realization rates is shown in Table 2.

Table 2: Realization Rate Summary

Savings	kW	kWh	Therm
SPC Tracking System	811.1	3,706,559	-
SPC Installation Report (ex ante)	811.1	3,706,559	-
Impact Evaluation (ex post)	681.9	3,256,516	-
Engineering Realization Rate	0.84	0.88	NA

The ex ante savings assumed that two chillers would be in operation at the Site 1 and Site 2 facilities, and that three chillers would be in operation at the Site 3 facility. Actual operation is only one chiller at each of the Site 1 and Site 2 facilities and a maximum of two chillers at the Site 3.

Utility billing data for the three sites were reviewed. Annual usage for all three sites prior to the retrofit was 24,585,549 kWh. Combined peak demand for all three sites was 3,829.3 kW. Table 3 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 3: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	3,829.3	24,585,549
Baseline End Use	1,738.3	7,068,014
Ex ante Savings	811.1	3,706,559
Ex Post Savings	681.9	3,256,516

Table 4 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations.

Table 4: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	21.2%	15.1%	17.8%	13.2%
Baseline End Use %	46.7%	52.4%	39.2%	46.1%

With a cost of $6,100,000 and a $518,918 incentive, the project had an 11.58 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 13.18 years. A summary of the economic parameters for the project is shown in Table 5.

Table 5: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	9/22/2005	$6,100,000	811.1	3,706,559	0	$481,853	$518,918	11.58	12.66
SPC Program Review (Ex Post)	9/30/2007	$6,100,000	681.9	3,256,516	0	$423,347	$518,918	13.18	14.41

It was determined that these projects were defined as HVAC-Water Cooled Chiller projects in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the project was assumed to have a useful life of twenty (20) years. A summary of the multi-year reporting requirements is given in Table 6. Because this measure was installed

June 2005, the energy savings in year #1 (2005) are assumed to be 50% of the expected annual savings for this measure.

Table 6: Multi-Year Reporting Requirements

Program ID:		**Application # 106**					
Program Name:		**SPC 04-05 Evaluation**					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004					0	0
2	2005	1,853,280	1,628,258	811.1	681.90	0	0
3	2006	3,706,559	3,256,516	811.1	681.90	0	0
4	2007	3,706,559	3,256,516	811.1	681.90	0	0
5	2008	3,706,559	3,256,516	811.1	681.90	0	0
6	2009	3,706,559	3,256,516	811.1	681.90	0	0
7	2010	3,706,559	3,256,516	811.1	681.90	0	0
8	2011	3,706,559	3,256,516	811.1	681.90	0	0
9	2012	3,706,559	3,256,516	811.1	681.90	0	0
10	2013	3,706,559	3,256,516	811.1	681.90	0	0
11	2014	3,706,559	3,256,516	811.1	681.90	0	0
12	2015	3,706,559	3,256,516	811.1	681.90	0	0
13	2016	3,706,559	3,256,516	811.1	681.90	0	0
14	2017	3,706,559	3,256,516	811.1	681.90	0	0
15	2018	3,706,559	3,256,516	811.1	681.90	0	0
16	2019	3,706,559	3,256,516	811.1	681.90	0	0
17	2020	3,706,559	3,256,516	811.1	681.90	0	0
18	2021	3,706,559	3,256,516	811.1	681.90	0	0
19	2022	3,706,559	3,256,516	811.1	681.90	0	0
20	2023	3,706,559	3,256,516	811.1	681.90	0	0
TOTAL	**2004-2023**	68,571,342	60,245,540				

FINAL SITE REPORT

SITE A107 (04-xxxx) Pla2 IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 2 END USE: Other

Measure	Replace three 700 HP pumps with one 1,750 HP pump
Site Description	Petroleum Product Production

1. Measure Description

This project involved the replacement of three 700 HP pumps with a single 1,750 HP pump at an oilfield.

2. Summary of the Ex Ante Calculations

During the reviewer's inspection, one 3,000 HP pump, one 950 HP pump, and three auxiliary 700 HP pumps were observed to be operating. The reviewer's baseline energy consumption is based on three auxiliary pumps being energized and fully loaded. The ex ante calculations are based on measurements of amps and voltage performed by the customer for the 950 HP and 700 HP pumps. The measurements were witnessed by the reviewer. The 3,000 and 1,750 HP pumps have permanently installed power monitoring equipment. The power readings were recorded by the reviewer. The reviewer estimated the power factor to be 0.88 and 0.95 for the 700 HP and 950 HP pumps, respectively, and calculated the pump kW. The savings calculations indicate that the pumps operate 8,736 hours annually.

Prior to the completion of the project, the customer replaced the impeller on the 3,000 HP pump. The impeller replacement significantly increased the output of the pump. The repair of the pump impeller was correctly classified by the IOU as maintenance, and the energy savings associated with the repair were excluded from the ex ante calculations. The repair of the 3,000 HP pump impeller, and the better than expected performance of the 1,750 HP pump, enabled the customer to turn off the 950 HP pump as well as the three 700 HP pumps.

The formulae used were:

kW= (amps x volts x power factor x sq. root of three)/(1,000 watts/kW)
kWh = kW x annual hours

The Installation Report states that the ex ante savings are 2,939,240 kWh annually and demand reduction is 336.5 kW. These values do not agree with the Tracking System, which lists savings of 2,406,450 kWh and 275.5 kW of savings.

3. Comments on the Ex Ante Calculations

The ex ante calculations are based on readings of permanently installed power monitoring equipment for the 3,000 HP and the 1,750 HP pumps and on measurements of amps and voltage performed by the customer and witnessed by the reviewer for the 700 HP and 950 HP pumps. The reviewer estimated the power factor to be 0.88 and 0.95 for the 700 HP and 950 HP pumps, respectively, and calculated the pump kW. The savings calculations indicate that the pumps operate 8,736 hours annually. The power factor estimate appears reasonable.

4. Measurement & Verification Plan

According to the application, prior to the retrofit there was one 3,000 HP pump, one 950 HP pump, and three auxiliary 700 HP pumps operating. Following the completion of the project, the installation report documents state that one 3,000 HP pump and one 1,750 HP were operating. As noted above, the customer was able to turn off the 950 HP and the three (3) 700 HP pumps.

The project saves energy by the installation of a more efficient 1,750 HP pump on a water flood system at an oilfield.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit hours of pump operation and the pump energy consumption.

The goal of the M&V plan is to verify the peak demand kW and annual kWh savings over the expected useful life of the equipment.

Formulae and Approach

The M&V plan is a modified version of IPMVP Option A.

The application contains measurements of amps and voltage performed by the customer and witnessed by the reviewer for the pumps. The reviewer estimated the power factor to be 0.88 and 0.90 for the 700 HP and 950 HP pumps, respectively. The savings calculations indicate that the pumps operate 8,736 hours annually. The power factor estimate appears reasonable. The 3,000 HP and 1,750 HP pumps have power monitoring equipment installed. All pumps are constant speed units that produce constant volumes (according to the relevant pump and system curves).

To determine pre-retrofit pump kW and kWh

The kW calculations performed by the reviewer will be used as the best available data. If nameplate data reveals lower power factor operation, the kW of the existing units will be adjusted. The hours of operation will be adjusted based on the results of discussions with the customer and from seven (7) days of monitoring data on the 3,000 HP and 1,750 HP pumps.

To determine post-retrofit pump kW and kWh

The customer measured (and reviewer witnessed) pump amps and voltage measurements for the 700 and 950 HP pumps will be used in the ex post calculations, as those units are no longer utilized. The reviewer estimated power factors for these pumps will also be used unless nameplate data indicate a lower power factor. During the site visit, the power monitor reading on the 3,000 HP and 1,750 HP pumps will be confirmed. Power and flow measurements on the operating pumps, for a minimum of 7 days, will be collected to verify the number of pumps operating and the average flow rate. Annual hours of operation will be verified with the customer. The seven day period results will be annualized, and adjusted for holidays if appropriate.

The formulae to be used are as follows:

kW for the 700 HP and 950 HP pumps:
kW= (amps x volts x power factor x sq. root of three)/(1,000 watts/kW)

kW and flow rate for the 3,000 HP and 1,750 HP pump will be read on the power monitoring equipment

kWh/yr = kW x hours/yr

The energy consumption of this measure is not greatly affected by the outside air temperature. To estimate peak demand kW reduction, the expected reduction in connected kW due to the reduced pumping energy during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in the week with the hottest weekday in June, July, August, September will be determined by calculating the average kW reduction from 2 pm to 5 pm, Monday to Friday in June, July, August, September.

Demand savings (kW) will be determined as described above. The average post retrofit kW will be subtracted from the pre retrofit kW and the peak demand reduction will be calculated.

Peak demand reduction kW= Average kW_{pre} – Average kW_{post}

Both the kW and kWh savings will be adjusted to account for the increased efficiency of the 3000 HP motor and the de-energization of the 950 HP motor. As part of this adjustment, the amount of time the 950 HP motor can be taken out of service will be considered.

Uncertainty for the savings estimate can be more fully understood by setting projected ranges on the primary variables.

Pump Replacement

- 3,800 kW pre-retrofit expected maximum demand, +/- 10% (3,420 kW to 4,180 kW)
- 3,500 kW post retrofit (+/- 15%) (2,975 kW to 4,025 kW)
- 8,736 hours pre retrofit expected, + 1%/- 5% (8,300 to8,760 hours)
- 6,500 GPM pre-retrofit expected, +/- 15% (5,525 to 7,475 GPM)

Accuracy and Equipment

The customer's volt and amp field measurements are expected to have a measurement error of less than 7%. According to the customer, the NuFlo Measurement Systems MC-II flow meters are industrial grade instrumentation, and are expected to have an accuracy of +/- 10%. Similarly, the instrumentation for the power measurement on the 3,000 and 1,750 HP pumps (Westinghouse IQ Data Plus II) as well as the current measurement on the 950 HP pump (Cutler Hammer) are industrial grade and are expected to have an accuracy of +/- 3%. Annualizing the seven day measurement period is estimated to be +/- 10% accurate.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 20, 2007. Information on the piping system retrofit and operating conditions was collected by inspection of the water flood pumping system and by interviewing the facility representative. Water flood pump make, model, quantities and hours of operation were verified.

Our interview with the customer revealed that production has increased significantly since the project documented in the application was completed. The water flood pumping system capacity has been increased to meet increased system flow requirements. In the current system, the 1,750 HP pump operates in parallel with the 3,000 HP and 950 HP pumps to serve the water flood piping distribution system. The 700 HP pumps remain as back ups and are only expected to be energized when one of the larger pumps is serviced or fails.

Data was collected for 8 days to document the current operating parameters of the water flood system. Power and flow readings were manually recorded once a day from instrumentation installed on the pumping system. The 3,000 HP and 1,750 HP pumps have power meters installed. The 950 HP pump instrumentation only measures pump current on each phase. Each pump has a flow meter installed at its discharge.

Input kW for the 950 HP pump was calculated as follows:
kW= (amps x volts x power factor x sq. root of three)/(1,000 watts/kW)

System voltage for the 950 HP pump was assumed to be equal to the 1,750 HP pump that operates on the same electrical supply. The power factor was assumed to be 0.95 which is similar to the readings from the 1,750 and 3,000 HP pumps.

The instantaneous flow rate for each of the pumps was also recorded, and the three readings were added together to determine the total system flow. We calculated the average kW/GPM for the 8 day period and compared this to the data collected by the reviewer before and after the retrofit documented in the application.

The customer confirmed that the water flood pumps operate continuously. Maximum occupancy is approximately 200 employees at any given time. The facility does not close for holidays.

Installation Verification

We verified the nameplate data on the 3,000 HP; 1,750 HP; and 950 HP pumps serving the water flood piping system. All three pumps were operating at the time of the site visit. There are seven 700 HP pumps. None of the 700 HP pumps was operating at the time of the site visit.

This is the only measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 6 below.

Scope of the Impact Assessment

The impact assessment scope is for the process/other end use measure in the SPC application covering the water flood piping retrofit. This is the only measure in this application.

Summary of Results

Based on data collected by the reviewer, before the retrofit the water flood system flow rate was 6,454 GPM and total pump power was 3,793 kW for a system efficiency of 0.588 kW/GPM. After the retrofit, the water flood system flow rate was 6,454 GPM and total pump power was 3,457 kW for a system efficiency of 0.536 kW/GPM. The average flow rate from data collected on 8 days in August and September 2007 was 8,536 GPM and average total pump power was 4,227 kW for a system efficiency of 0.495 kW/GPM. The customer also provided data collected for 14 days in November 2006. The average flow rate from this data was 7,936 GPM and average total pump power was 4,125 kW for a system efficiency of 0.520 kW/GPM.

Table 1 is a summary of the data collected before and after the retrofit documented in the application, data from November 2006 and data more recently collected in August and

September 2007. The data measured in August and September 2007 confirms that the system efficiency remains better than that documented in the post retrofit case. We therefore accept the ex ante impacts, as reportedly production increase and greater efficiencies in the ex post data will have effects that may cancel each other. Production data was unable to be obtained.

The energy consumption of this measure is not greatly affected by the outside air temperature. To estimate peak demand kW reduction, the expected reduction in connected kW due to the increased pumping efficiency during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday (in the week with the hottest weekday in June, July, August, September) was determined by calculating the average kW reduction measured pre and post retrofit.

Table 1: Summary of Data

Description	GPM	kW	kW/GPM
Baseline	6,454	3,793	0.588
Post retrofit	6,454	3,457	0.536
Data Collected November 2006	7,936	4,125	0.520
Data Collected Aug./Sept. 2007	8,536	4,227	0.495

- Pre and post retrofit hours of pump operation are 8,736 hours/year.
  (8,760 hours/year –24 hours/year for service= 8,736 hours/year
- Pre-retrofit demand is 3,793 kW.
- Annual pre-retrofit energy consumption is 33,135,648 kWh/hr.

  3,793 kW x 8,736 hours= 33,135,648 kWh/hr.
- Post-retrofit demand is 3,457 kW.
- Annual post-retrofit energy consumption is 30,200,352 kWh/hr.

  3,457 kW x 8,736 hours= 30,200,352 kWh/hr.
- The resulting annual kWh savings is 33,135,648 kWh/yr – 30,200,352 kWh/yr = 2,935,296 kWh/yr

Summer peak demand reduction impacts were estimated by subtracting the pre and post retrofit demand data. Average demand reduction is 336 kW.

- The demand reduction is 336 kW.
  3,793 kW – 3,457 kW = 336 kW.

The engineering realization rate for this application is 1.00 for demand kW reduction and 1.00 for energy savings kWh. A summary of the realization rate is shown in Table 5.

Utility billing data for the site was provided in the application. For the period January 2004 to December 2004, pre-retrofit annual consumption was 137,315,928 kWh. Peak demand was 16,704 kW. Table 2 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility provided numbers.

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 2.0% decrease in total meter kW, an 8.9% decrease in pumping end use kW, a 2.1% decrease in total meter kWh, and an 8.9% decrease in pumping end use kWh. The ex post results showed essentially the same reductions.

Table 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	16,704	137,315,928
Baseline End Use	3,793	33,135,648
Ex ante Savings	336	2,939,240
Ex Post Savings	336	2,935,296

Table 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	2.0%	2.1%	2.0%	2.1%
Baseline End Use %	8.9%	8.9%	8.9%	8.9%

6. Additional Evaluation Findings

The ex post kW demand reduction and annual kWh savings are essentially the same as the ex ante estimate. Although the operating conditions of the water flood pumping system have changed significantly since the installation of the measure documented in the application (i.e. increased flow with a different pumping arrangement), we determined that the system operating efficiency exceeds that documented in the application. Some of the increased system efficiency is due to projects that are documented SPC applications submitted after the completion of this project. Therefore, no additional ex post savings impacts are being credited to this project.

The facility representative stated that the cost estimate provided in the application ($550,000) is from the invoice for the work performed for the project and is an accurate reflection of the project cost. In addition to saving energy, the benefits of the project were a more reliable pumping system with better flow characteristics. Participation in the 2004/2005 SPC Program has not encouraged the customer to perform any other energy efficiency projects without participating in an incentive program.

Seven of the old 700 HP pumps remain on-site and the pre-retrofit pump type and quantities were physically verified. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measure.

With a cost of $550,000 and a $235,139 incentive, the project had a 0.82 year simple payback based on the ex ante calculations. The ex post savings estimate for the project are essentially the same, and the estimated simple payback is 0.83 years. A summary of the economic parameters for the project is shown in Table 4. The customer has continued to make changes to the water flood pumping system since the completion of the project documented in the application. Many of the changes to the water flood system have been documented in SPC applications submitted later. Our analysis has shown that the water flood pumping system efficiency has remained better than that documented in this application and therefore the multi-year impacts, shown in Table 7 below, are expected to remain constant over the life of the equipment.

7. Impact Results

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	5/16/2005	$550,000	336.5	2,939,240	0	$382,101	$235,139	0.82	1.44
SPC Program Review (Ex Post)	10/1/2007	$550,000	336.0	2,935,296	0	$381,588	$235,139	0.83	1.44

Table 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	336.5	2,939,240	-
SPC Installation Report (ex ante)	336.5	2,939,240	-
Impact Evaluation (ex post)	336.0	2,935,296	-
Engineering Realization Rate	1.00	1.00	NA

Table 6: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Process- OTHER	O			Replace three 700 HP pumps with one 1,750 HP pump	1	Sulzer 6x8x12.5, Serial # C9704132, 1,750 HP, 3,560 RPM, 212 amps @ 4,160 Volts, 60hz	Physically the installation of the verified new pump.	1.0

Table 7: Multi Year Reporting Table

Program ID	**SPC 2004 Application # A107**
Program Name	**2004-2005 SPC Application**

Year	Calendar Year	Ex-Ante Gross Program Projected kWh Savings	Ex post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program Projected Peak kW Reduction	Ex-Post Gross Evalaution Projected Peak kW Reduction	Ex-Ante Gross Program Projected Therm Savings	Ex post Gross Evaluation Confirmed Program Therm Savings
1	2004	0	0	0	0	0	0
2	2005	1,469,620	1,467,648	337	336	0	0
3	2006	2,939,240	2,935,296	337	336	0	0
4	2007	2,939,240	2,935,296	337	336	0	0
5	2008	2,939,240	2,935,296	337	336	0	0
6	2009	2,939,240	2,935,296	337	336	0	0
7	2010	2,939,240	2,935,296	337	336	0	0
8	2011	2,939,240	2,935,296	337	336	0	0
9	2012	2,939,240	2,935,296	337	336	0	0
10	2013	2,939,240	2,935,296	337	336	0	0
11	2014	2,939,240	2,935,296	337	336	0	0
12	2015	2,939,240	2,935,296	337	336	0	0
13	2016	2,939,240	2,935,296	337	336	0	0
14	2017	2,939,240	2,935,296	337	336	0	0
15	2018	2,939,240	2,935,296	337	336	0	0
16	2019	2,939,240	2,935,296	337	336	0	0
17	2020	2,939,240	2,935,296	337	336	0	0
18	2021	2,939,240	2,935,296	337	336	0	0
19	2022	2,939,240	2,935,296	337	336	0	0
20	2023	2,939,240	2,935,296	337	336	0	0
Totals	2004 - 23	54,375,940	54,302,976				

FINAL REPORT

SITE A108 (04-xxxx) Farm IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 5 END USE: AC&R

Measure	Replacement of two (2) 350-ton Chillers
Site Description	Large Office

1. Measure Description

Two (2) 350-ton Carrier model 19DH centrifugal chillers were replaced with two (2) 350-ton Carrier model 19XR water-cooled, centrifugal chillers. The pre-installation chillers were installed in 1982 and were never overhauled, so they were not eligible for early retirement. The post-installation chillers have an efficiency rating of 0.548 kW/ton. Both pre- and post-installation chillers include compressors that run with reduced hours due to the use of air-side economizers. The post-installation chillers were installed without VFDs. The chiller plant operates Monday through Friday from 5:30 AM to 5:30 PM and Saturdays from 5:30 AM to 12:00 PM.

2. Summary of the Ex Ante Calculations

The 2004 SPC Calculator (AC&R Cooling Units module) was used to determine the annual savings. The SPC AC&R Cooling Units calculator uses pre-defined building types along with building location, floor area, and hours of operation to determine a load profile for the chiller based on the ASHRAE simplified bin method. This load profile is then used, along with an industry standard performance curve for constant speed or VFD controlled chillers, to determine the peak and part-load kW as well as annual kWh usage for the units.

The ex ante results determined by the 2004 SPC calculator are:

For the chiller replacement:

Pre-Replacement Usage -	378.2 kW	454,656 kWh
Post-Replacement Usage -	359.5 kW	432,263 kWh
Peak Summer Impact & Annual Savings -	18.6 kW	22,393 kWh

The ex ante savings reported in the utility tracking system and in the Installation Report Review are 22,393 kWh and 0.0 kW. No credit is taken for the 18.6 kW demand reduction calculated by the SPC calculator.

3. Comments on the Ex Ante Calculations

The 2004 SPC Calculator (AC&R Cooling Units module) was used to determine the annual savings. The SPC calculator uses information on chiller type, building type, building area, and location to determine a building factor and an average to peak kW ratio, which are then used to determine peak load and annual energy usage.

The SPC calculator calculates the building factor based on the building type and area. For a large office area of 240,000 square feet, the building factor is about 0.937.

The hours of operation of the chiller and average to peak kW ratio are variables that would be determined based on site-specific information. The SPC calculator uses an ASHRAE simplified temperature bin analysis to determine a typical load profile, which is then coupled with a standard performance curve to determine full load and part load demand.

For these chillers, the SPC calculator assumes an average to peak kW ratio of approximately 0.348.

The annual peak demand and energy usage of the chiller can be approximated using the formulae:

kW = chiller full load efficiency x chiller capacity x building factor

kWh = kW x hours of operation x average to peak kW ratio

4. Measurement & Verification Plan

The facility is a 6 story, approximately 240,000 square foot office building. It was constructed in 1982. The building is expected to be occupied during regular office hours 5:30 AM to 5:30 PM Monday through Friday and 5:30 AM to 12 PM on Saturday. According to the application, before the installation, the facility utilized two 350-ton centrifugal chillers, which were original equipment and installed in 1982. Both chillers operated at near full capacity during regular office hours throughout the year. The new chillers will operate similarly, but at a slightly higher efficiency.

The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction due to replacement of the two (2) 350-ton centrifugal chillers with two (2) new centrifugal chillers with an efficiency of 0.548 kW/ton over the expected useful life of the new equipment.

Formulae and Approach

For this application, we propose to use a modified version of IPMVP Option A, Partially Measured Retrofit Isolation.

The usage of the chillers is not expected to remain consistent enough for single point measurements to be representative of the average usage. However, seasonal variation is expected to be somewhat predictable and two weeks should be sufficient to calibrate an energy savings model; a longer period would more fully capture actual variations and the persistence of savings. Interval data on a 15-minute or less basis, preferably during the summer months of June to September, would be needed to accurately determine coincident peak period demand savings.

Pre-installation and post-installation calculations of chiller load and energy use will be calculated using the following formulae:

Post-installation

> Chiller Peak kW = kW at Maximum Outdoor Air Temperature (either measured or predicted if the max OAT does not occur during the measurement period)

Chiller measured input power (kW) with corresponding outdoor air temperature (OAT) will be used to create a chiller input power curve unique to each facility. An input power formula as a function of outdoor air temperature will be developed. This formula will be used in a spreadsheet bin analysis similar to the spreadsheet calculator used in the SPC Calculator. The basic calculation is the summation of:

$$\text{Chiller kWh}_{\text{(bin temp)}} = \text{Calculated kW}_{\text{(bin temp)}} \times \text{hours/yr}_{\text{(bin temp)}}$$

Pre-installation

Pre-installation calculations are dependent on the actual cooling load. Cooling load can be determined by:

$$\text{Cooling Load}_{\text{(bin temp)}} = \text{New Chiller kW}_{\text{(bin temp)}} / \text{New Chiller Effectiveness}_{\text{(bin temp)}}$$

(kW/ton from manufacturers supplied data)

Using the given pre-retrofit system kW/ton values, the peak demand savings (at 107 F OAT) are:

$$\text{Peak kW} = (\text{kW/ton} \times \text{Tons})_{\text{(107F)}}$$

Energy Savings is the summation of

$$\text{kWh}_{\text{(bin temp)}} = ((\text{kW/ton}_{\text{(old chiller)}} - \text{kW/ton}_{\text{(new chiller)}}) \times \text{Tons}_{\text{(new chiller)}})_{\text{(bin temp)}} \times \text{hours/yr}_{\text{(bin temp)}}$$

The most significant variables to be quantified are the pre-retrofit and post-retrofit hours of operation and the pre and post retrofit kW demand profiles of the chillers. If required, appropriate modifications for the savings calculations will be made to the pre-retrofit usage figures, possibly based on post-retrofit monitoring, in order to establish a realistic baseline for energy use.

We will physically verify the installation of the two (2) 350-ton centrifugal chillers during the onsite visit. We will verify the post-installation energy consumption by utilizing the customer's on-site EMS software to log the kW and kWh of the units with a sampling delay of no greater than 2 minutes for a minimum of 14 days.

If the demand and energy consumption is not available from the EMS software, we will verify post-installation energy consumption by installing Hobo FlexSmart data loggers with WattNode WNA-3D-480-P Watt-hour transducers and Magnalab SCT-1250-200 current transformers. The energy consumption of the chillers will be logged with a sampling delay of no greater than 1 minute, for a minimum of 14 days to verify the post-installation energy consumption.

In addition, the outdoor air temperature and relative humidity at the facility will be monitored using no less than two (2) Hobo H8 loggers. If possible, the daily occupancy level for the logged period will be verified with the customer representative. The logged kWh per unit output will then be used in conjunction with temperature and occupancy effects to determine the annual usage.

The greatest uncertainty in the ex ante savings estimate are associated with the pre-installation and post-installation average kW load factor of the chillers. The average kW load factor is a representation of the chiller load profile and the performance curve throughout the course of the entire year. The SPC calculator utilizes a standard load profile based on the type of facility, hours of operation, and building area as well as a typical performance curve based on chiller type. In addition, the SPC calculator assumes a typical kW/ton for the baseline chiller, therefore, the actual baseline chiller kW/ton value was not used to calculate the savings in this program.

Uncertainty for the savings estimate for the chiller replacement can be more fully understood by setting projected ranges on the primary variables.

For the Pre-Installation Chillers

- 378.2 kW expected, maximum of 404.7 kW, minimum of 340.4 kW (+7%, -10%, based on judgment of deviation from typical efficiency in SPC calculator, maximum load condition in SPC calculator, and period codes for chiller operation and efficiency)
- 0.348 average to peak kW ratio expected, maximum of 0.47, minimum of 0.23 (±35%, based on judgment of deviation from typical load profile and chiller standard performance curve in SPC calculator)

For the Post-Installation Chillers

- 359.5 kW expected, maximum of 395.4 kW, minimum of 323.6 kW (±10%, based on judgment of deviation from typical chiller efficiency in SPC calculator, maximum load condition in SPC calculator, and period codes for chiller operation and efficiency)
- 0.348 average to peak kW ratio expected, maximum of 0.52, minimum of 0.23 (+50%, -35%, based on judgment of deviation from chiller standard performance curve in SPC calculator)

For the Chiller kWh Savings

- 22,393 kWh annual expected savings, minimum 9,762 kWh, maximum 35,024 kWh (±56%, based on pre-installation and post-installation chiller operation above)
- 3,458 running hours expected, maximum of 4,115 running hours, minimum of 2,939 running hours (+19%, -15%, based on judgment of deviation based on discussions with customer representative and typical operating conditions for similar facilities)

Accuracy

The Hobo FlexSmart loggers have a time accuracy of ±10 seconds. The WattNode Watt-Hour transducers have an accuracy of ± 0.45% + 0.05%FS, and the Magnelab SCT-1250-200 current transformers have an accuracy of ± 1.5%. The Hobo H8 temperature and relative humidity loggers have an accuracy of ± 1.3F (within the range of –4 F to 104 F) for temperature and ± 5% for relative humidity.

The Hobo logger uses a PC serial interface for data transfer, and all data will be exported to Microsoft Excel format.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 4, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the chillers and by interviewing the facility representative. The two chillers (Carrier model 02XR-322CH64) are installed, with one chiller covering the entire load and the other chiller installed for redundant backup.

Installation Verification

For the chiller retrofit project, the facility representative verified that prior to the installation of the two new chillers, two 19DH model Carrier 350 ton chillers were being used. The installation of the new chillers was physically verified during the on-site process. The facility representative stated that the retrofit was completed during the 2004 calendar year.

A verification summary is shown in Table 1 below.

Table 1: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
350 TON CHILLERS TO REPLACE EXISTING 350 TON CHILLERS	A	350 TON CHILLERS TO REPLACE EXISTING 350 TON CHILLERS			2	350 TON CHILLERS	PHYSICALLY VERIFIED INSTALLATION OF CHILLERS	1.00

Scope of the Impact Assessment

The impact assessment scope is for the chiller measure in the AC&R end use category in the SPC application. This was the only measure in this application.

Summary of Results

One Hobo temperature / relative humidity logger was installed outside the site to measure local weather conditions for 9 days (from September 4, 2007-September 12, 2007), and a kW logger was installed for the same period to measure the operation of the retrofit chiller. The kW logger malfunctioned and EMS data were not available for this measure, so analysis was conducted using customer billed data from one year prior to the installation and one year after the installation.

The facility representative stated that this office's open hours are typically from 5:30 AM to 5:30 PM, Monday through Friday and from 5:30 AM to 12:00 PM Saturday. The facility representative stated that the 9-day period had been representative of normal facility operation.

Hours of operation estimates employ the customer's description, as no data contradict this claim. The hours of operation are summarized in Table 2 below.

Table 2: Fixture Operating Hours

	Office
Number of Chillers	2
Number of Chillers On	1
Expected Annual Operating Hours	3,458

The chillers are expected to operate Monday through Friday, 5:30 AM to 5:30 PM, therefore, at the summer peak hours, between 2 pm and 5 pm on weekdays, the operating chiller is expected to be in operation.

The ex post impacts are calculated in Table 3 below.

Table 3: Energy and Demand Formulae for VFD Installation

Pre-Retrofit Demand kW_{peak}	= Pre-Retrofit Chiller Tons x Pre-Retrofit Chiller Qty x Building Factor x Pre-Retrofit Chiller Efficiency = 350 Tons/Chiller x 1 Chiller x 0.985 Building Factor x 0.576 kW/Ton = 198.6 kW
Post-Retrofit Demand kW_{peak}	= Post-Retrofit Chiller Tons x Post-retrofit Chiller Qty x Building Factor x Post-Retrofit Chiller Efficiency = 350 Tons/Chiller x 1 Chiller x 0.985 Building Factor x 0.548 kW/Ton = 188.9 kW
Peak kW Savings	= Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak} = 198.6 kW – 188.9 kW = 9.8 kW
Pre-Retrofit kWh	= Pre-Retrofit Demand kW_{peak} x Pre-retrofit Hours x Avg/Peak Load Factor = 198.6 kW x 3,458 hours/year x 0.233 Avg kW/Peak kW = 160,161 kWh/yr (allowing for rounding)
Post-Retrofit kWh	= Post-Retrofit Demand kW_{peak} x Post-retrofit Hours x Avg/Peak Load Factor = 188.9 kW x 3,458 hours/year x 0.233 Avg kW/Peak kW = 152,273 kWh/yr (allowing for rounding)
kWh Savings	= Pre-Retrofit Demand kW_{peak} – Post-Retrofit kW_{peak} = 160,161 kWh/yr – 152,273 kWh/yr = 7,888 kWh/yr

The ex post kW demand reduction is lower than the ex ante demand reduction. The post retrofit chiller type and quantity was found to be as expected, but the system has redundancy that was not originally modeled. Per the site representative, only one chiller is operated at any point in time. The ex post energy savings are correspondingly lower than the ex ante energy savings due to an additional lower usage factor than originally estimated.

6. Additional Evaluation Findings

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. The customer did not give any non-energy benefits or drawbacks associated with the new equipment. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. There did not seem to be any additional energy awareness or any other interest in installing energy efficiency measures due to program participation.

We were unable to physically verify the pre-retrofit chiller type or hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site to accurately determine the impacts of the installed measures could have been improved by monitoring the chillers.

7. Impact Results

Based on the ex ante savings of 0.0 kW and 22,393 kWh, the engineering realization rate for this application could not be developed for kW reduction, but was 0.35 for energy savings kWh. The values shown in the tracking system agree with those shown in the installation report for this application. A summary of the realization rate is shown in Table 4.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	-	22,393	-
SPC Installation Report (ex ante)	-	22,393	-
Impact Evaluation (ex post)	9.8	7,888	-
Engineering Realization Rate	N/A	0.35	-

Utility billing data for the site was reviewed. In the 12-month period from January 2003 - December 2003 (pre-retrofit), the facility consumed 2,746,362 kWh. Peak demand was 832.8 kW in July 2003. Table 5 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results.

Table 5: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	832.8	2,746,362
Baseline End Use	198.6	160,161
Ex ante Savings	0.0	22,393
Ex Post Savings	9.8	7,888

Table 6 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 0.0% decrease in total meter kW, a 0.0% decrease in chiller end use kW, a 0.8% decrease in total meter kWh, and a 14.0% decrease in lighting end use kWh. The ex post results showed a 1.2% decrease in total meter kW, a 4.9% decrease in chiller end use kW, a 0.3% decrease in total meter kWh, and a 4.9% decrease in lighting end use kWh.

Table 6: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	0.0%	0.8%	1.2%	0.3%
Baseline End Use %	0.0%	14.0%	4.9%	4.9%

With a cost of $222,271 and a $3,135 incentive, the project had a 75 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 214 years. A summary of the economic parameters for the project is shown in Table 7.

Table 7: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), ($1.10/therm) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	8/5/2004	$222,271	-	22,393	-	$2,911	$3,135	75.28	76.35
SPC Program Review (Ex Post)	9/28/2007	$222,271	9.8	7,888	-	$1,025	$3,135	213.69	216.75

It was determined that the chiller retrofit project was defined as an HVAC Chiller-High Efficiency project in the California Public Utilities Commission *Energy Efficiency Policy Manual.* Therefore, the chillers were assumed to have a useful life of twenty (20) years.

A summary of the multi-year reporting requirements is given in Table 8. Because this measure was installed by August 2004, the energy savings in year #1 (2004) are assumed to be 1/3 of the expected annual savings for this measure. In addition, no peak savings are assumed to occur in the first year.

Table 8: Multi-Year Reporting Requirements

Program ID:		SPC 0405 Evaluation - Application # A108					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004	7,464	2,629	-	-	-	-
2	2005	22,393	7,888	-	9.8	-	-
3	2006	22,393	7,888	-	9.8	-	-
4	2007	22,393	7,888	-	9.8	-	-
5	2008	22,393	7,888	-	9.8	-	-
6	2009	22,393	7,888	-	9.8	-	-
7	2010	22,393	7,888	-	9.8	-	-
8	2011	22,393	7,888	-	9.8	-	-
9	2012	22,393	7,888	-	9.8	-	-
10	2013	22,393	7,888	-	9.8	-	-
11	2014	22,393	7,888	-	9.8	-	-
12	2015	22,393	7,888	-	9.8	-	-
13	2016	22,393	7,888	-	9.8	-	-
14	2017	22,393	7,888	-	9.8	-	-
15	2018	22,393	7,888	-	9.8	-	-
16	2019	22,393	7,888	-	9.8	-	-
17	2020	22,393	7,888	-	9.8	-	-
18	2021	22,393	7,888	-	9.8	-	-
19	2022	22,393	7,888	-	9.8	-	-
20	2023	22,393	7,888	-	9.8	-	-
TOTAL	**2004-2023**	432,925	152,506			-	-

FINAL SITE REPORT

SITE A109 (04-xxxx) Lead **IMPACT EVALUATION**
SAMPLE CELL: ORIGINAL TIER: 3 END USE: Other

Measure	Air Compressor System Retrofit
Site Description	Manufacturing

1. Measure Description

This project involves the replacement of three (3) 150 HP inlet modulated rotary screw compressors with one 400 HP VSD rotary screw compressor.

2. Summary of the Ex Ante Calculations

The energy savings and incentive calculations, performed by an IOU engineer, used an average compressed air flow of 1,526 cfm and compressor demand of 373.5 kW for the facility baseline. The baseline CASE Index (explained below) is 245. The CASE Index methodology in conjunction with 5 days of monitored data was used to estimate the post retrofit energy consumption and incentive.

Compressed Air Supply Efficiency (CASE) Index

The CASE Index was based on a May 2004 California Energy Commission PIER Program Consultant Report 500-04-037 entitled: "Industrial Compressed Air Supply System Efficiency". This methodology of evaluating the overall efficiency of a compressed air system was used in the analysis. The CASE Index is defined as:

CASE Index = (Average cfm x 60)/(Average kW)

The CASE Index is a value from 0 to 300. Based on 1-week monitoring, the average flow at the facility was 1,526 cfm and the average compressor power was 373.5 kW, which resulted in a CASE Index for the baseline operation of 245. According to the research paper, on average, modern efficiently designed compressed air systems which operate properly should have a CASE Index of at least 250.

The ex ante calculations estimated that the post retrofit system demand would average 264.52 kW and that the compressed air plant would operate 8,600 hours annually.

The annual savings were calculated to be 937,228 kWh with a demand reduction of 109 kW as follows:

373.50 kW - 264.52 kW = 108.98 kW
108.98 kW x 8,600 kWh = 937,228 kWh

The Installation Report states that the ex ante savings are 937,228 kWh annually and demand reduction is 109 kW. These values agree with the tracking system data.

3. Comments on the Ex Ante Calculations

The ex ante calculations were performed using the CASE Index methodology. The documents state that the CASE Index inputs were developed using actual measurements of pre and post retrofit system airflow and compressor kW. A detailed summary of the post retrofit monitoring data is not included in the application documents.

4. Measurement & Verification Plan

Approximately 6 months after the completion of the project, the customer vacated the building where the 400 HP VSD air compressor was originally installed. The compressor has been moved to the customer's new location and the compressed air system at the new facility currently has two 150 HP inlet modulated rotary screw compressors and the 400 HP VSD rotary screw compressor. Air demand has increased at the new facility and all three compressors are required to meet peak air demand. The customer manually turns compressors on and off according to the expected plant loads based on plant production schedules.

When the application was approved, it was based on the new 400 HP VSD compressor meeting all of the plant demand. The operating conditions have changed significantly from what was anticipated in the original ex ante calculations. The 400 HP compressor that is documented in the application is still operating and we used its current operating load to estimate the impacts. Using the current air demand profile for the 400 HP VSD compressor, we compared the energy consumption of the 400 HP VSD compressor to the three 150 HP inlet modulated rotary screw compressors that were documented as the baseline in the application.

Energy savings are realized by the higher efficiency of the VSD unit at part-load conditions. Although the ex ante calculations were based on 8,600 annual hours of operation, the application stated that the compressed air plant operates continuously.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit hours of operation, air usage profile, and the compressor energy consumption.

The goal of the M&V plan is to verify the kW and kWh consumed, which can be derived from the air usage profile and pre-retrofit and post-retrofit hours of operation. Compressor unloading curves for the pre-retrofit and post-retrofit compressors will be used to estimate annual energy consumption and peak demand reduction from the air usage profiles over the useful life of the retrofits.

Formulae and Approach

The M&V plan is a modified version of IPMVP Option A.

For this application, the pre-retrofit compressor usage and characteristics will be verified with the facility representative.

Power monitoring equipment will be installed on the 400 HP VSD compressor for a minimum of 7 days, in order to verify the post retrofit hours of operation and power usage. Power will be measured in 2 minute intervals (or less) and averaged for each hour to determine average hourly kW.

Power measurements for the new compressor will be annualized to determine the annual kWh.

Using the measured average hourly kW, we will calculate the average hourly air usage profile of the new compressors for seven days using performance data for the VFD and load/unload compressors (% of compressor capacity vs. % full load power, based on data available from the manufacturer and / or from the DOE Compressed Air Challenge).

The pre-retrofit kW and kWh will be calculated based on performance data for the pre-retrofit compressors, which used inlet modulation control, utilizing the performance data (% of compressor capacity vs. % full load power) from the DOE Compressed Air Challenge.

The energy consumption of this measure is not greatly affected by the outside air temperature. To estimate peak demand kW reduction, the expected reduction in connected kW due to the increased compressor efficiency during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in the week with the hottest weekday in June, July, August, September will be determined by calculating the average kW reduction from 2 pm to 5 pm, Monday to Friday during the 7 day period.

If kW measurements cannot be taken, we will request that the customer log readings from the compressor control panels on an hourly basis showing the air flow and air compressor kW for a 24 hour period. We will then use this data to annualize compressor performance.

The formulae and methodology for the calculations are summarized as follows:

<u>To determine post-retrofit compressor kW and kWh</u>

Measure kW in 2 minute (or less) intervals.

Calculate average kW for each hour for 168 hours (7 days):
Average the kW readings over the one hour period.

Calculate the average kWh for each hour in the 168 hour period:
Hourly kWh = Average hourly kW x 1 hour

Calculate kWh for the 168 hour period:
Sum the 168 hourly results.

Estimate the annual kWh:
Multiply the 168 hour result x 52.14 weeks/year to obtain annual kWh (accounting for holidays if appropriate).

Calculate the average peak kW from the monitoring results between 2 p.m. to 5 p.m., Monday to Friday, during the monitoring period.

To determine pre-retrofit compressor kW and kWh

Obtain the maximum capacity of the new air compressors and maximum input power from the manufacturer's representative. Determine the average hourly acfm from VFD and load/unload compressor performance data (% capacity versus % power) and adjust for changes in equipment/production/schedules if necessary.

Utilizing performance data from the DOE Compressed Air Challenge (CAC) and manufacturer's data (maximum capacity of the old air compressors and maximum input power) stated in the application, determine the average hourly kW for 168 hours for the pre-retrofit compressors. This will be determined from CAC performance data and based on the hourly air usage profile developed above.

Calculate the average kWh for each hour in the 168 hour period:
Hourly kWh= Average hourly kW x 1 hour

Calculate kWh for the 168 hour period:
Sum the hourly results.

Estimate the annual kWh:
Multiply the 168 hour result x 52.14 weeks/year to obtain annual kWh (accounting for holidays if appropriate).

Calculate the average peak kW from the CAC performance data based on the hourly air usage profile developed above, between 2 p.m. to 5 p.m., Monday to Friday, during the monitoring period.

The average peak kW and the kWh figures from the post-retrofit analysis will be subtracted from the pre-retrofit analysis and the result will be the ex post impact (kW and kWh savings).

Uncertainty for the savings estimate can be more fully understood by setting projected ranges on the primary variables.

Air Compressor Retrofit

- 375 kW pre-retrofit expected average maximum demand, + / - 25% (285-465 kW)
- 8,760 operating hours pre retrofit expected, +0%/- 15% (7,446-8,760 hours)
- Air usage: 1,525 cfm average +/- 30% (1,068-1,980 cfm)

Accuracy and Equipment

The Dent Elite Pro power monitors have a measurement error of less than 1%. The accompanying current transducers (CTs) have a measurement error of 2 to 5 % depending on the size needed for the compressor and the CT manufacturer. The compressor performance data is estimated to be +/- 5% accurate. Annualizing the seven day measurement period is estimated to be +/- 10% accurate.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected at the site to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 16, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the air compressor system and by interviewing the facility representative. Air compressor make, model, quantities and hours of operation were verified. The customer's contractor had recently completed a compressed air system evaluation for the facility. We obtained the monitoring data for the 400 HP compressor from the contactor. Power consumption was measured on the new VFD driven air compressor in 15 second intervals over a 164.6 hour period beginning on Tuesday June 19, 2007 at 2 p.m. The customer stated that this period is an accurate representation of the facility operation. We used this data for the ex post analysis.

The building is occupied continuously and the compressed air system is always energized except during holidays. Maximum occupancy is approximately 60 employees at any given time. The facility is closed 5 holidays annually.

Installation Verification

The facility representative verified that there were three 150 HP Sullair LS20S-150H air compressors installed before the retrofit. Two of the compressors remain and are used as described above. The Sullair LS20S-150H is rated at 638 CFM at 125 psig and 140.7 kW. The new compressor is a Sullair TS32C-350H/W, rated at 1,702 CFM at 125 psig and 318.7 kW. The new compressor is oil cooled and VFD driven.

This is the only measure in this application. The verification realization rate for this project is 1.0. A verification summary is shown in Table 6 below.

Scope of the Impact Assessment

The impact assessment scope is for the process/other end use measure in the SPC application covering the air compressor retrofit. This is the only measure in this application.

Summary of Results

Power consumption for the 400 HP compressor was measured in 15 second intervals by the customer's contractor. Data was analyzed for 164 hours, beginning at 2 p.m. June 19, 2007. Input power ranged from zero to 360 kW, with an average of 230.6 kW. The new compressor operated for 156 hours out of the 164.6 hour period analyzed.

The facility representative stated that the period monitored was reflective of average operation and that the operation of the facility had not changed in any significant way since the new compressor was installed at the new facility. Therefore, there was no adjustment to the energy consumption due to an un-representative monitoring period.

Using the measured average hourly kW, we calculated the air usage profile of the new compressor for the 164.6 hour period using performance data for the VFD and inlet modulated compressors (% of compressor capacity vs. % full load power, based on data available from the manufacturer and from the DOE Compressed Air Challenge, shown in Table 1).

The pre-retrofit kW and kWh were calculated based on performance data for the pre-retrofit compressors, which used inlet modulation control, utilizing the performance data (% of compressor capacity vs. % full load power) from the DOE Compressed Air Challenge, as shown in Table 1.

The energy consumption of this measure is not greatly affected by the outside air temperature. To estimate peak demand kW reduction, the expected reduction in connected kW due to the increased compressor efficiency during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, in the week with the hottest weekday in June, July, August, September was determined by calculating the average kW reduction from 2 pm to 5 pm, Monday to Friday during the 7 day period.

Table 1: Air Compressor Control Comparison

% of Compressor Capacity	Modulation (Inlet Valve) % FL Power	Variable Frequency Drive % FL Power
100	100.0	100.0
95	98.5	95.2
90	97.0	90.4
85	95.5	85.6
80	94.0	80.8
75	92.5	76.0
70	91.0	71.2
65	89.5	66.4
60	88.0	61.6
55	86.5	56.8
50	85.0	52.0
45	83.5	47.2
40	82.0	42.4
35	80.5	37.6
30	79.0	32.8
25	77.5	28.0
20	76.0	23.2
15	74.5	18.4
10	73.0	13.6
5	71.5	8.8
0	70.0	4.0

Values from the Compressed Air Challenge Workshop
Sponsored by the US Department of Energy

Using this methodology for the 164.6 hour period, we determined that the pre-retrofit energy consumption was 50,747 kWh and the post retrofit energy consumption was 37,954 kWh. The new VFD driven compressor reduced energy consumption by 12,973 kWh for the 164.6 hour period beginning at 2 p.m. on June 19, 2007.

- Pre and post retrofit hours of compressor operation are 8,640/year.
  (365 days/year –5 holidays/year)x 24 hours/day= 8,640 hours/year
- Average pre-retrofit energy consumption is 308.3 kWh/hr.

  50,747 kWh /164.6 hrs = 308.3 kWh/hr.
- Annual pre-retrofit energy consumption is 2,663,712 kWh.

  308.3 kWh/hr. x 8,640 hrs = 2,663,712 kWh (allowing for rounding)
- Average post-retrofit energy consumption is 230.6 kWh/hr.

  37,954 kWh /164.6 hrs = 230.6 kWh/hr.
- Annual post-retrofit energy consumption is 1,992,384 kWh.

  230.6 kWh/hr x 8,640 hrs = 2,663,712 kWh (allowing for rounding)
- The resulting annual kWh savings is 2,663,712 kWh/yr – 1,992,384 kWh/yr = 671,328 kWh/yr

Summer peak demand reduction impacts were estimated by averaging the demand reduction for the time period 2 pm to 5 pm, Monday to Friday. Average demand reduction is 89.6 kW.

The engineering realization rate for this application is 0.82 for demand kW reduction and 0.72 for energy savings kWh. A summary of the realization rate is shown in Table 5.

Utility billing data for the site was provided in the application. For the period January 2004 to December 2004, pre-retrofit annual consumption was 3,879,840 kWh. Peak demand was 742 kW. Table 2 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results based on the utility provided numbers.

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 14.7% decrease in total meter kW, a 35.4% decrease in compressor end use kW, a 24.2% decrease in total meter kWh, and a 35.2% decrease in compressor end use kWh. The ex post results showed a 12.1% decrease in total meter kW, a 29.1% decrease in compressor end use kW, a 17.3% decrease in total meter kWh, and a 25.2% decrease in compressor end use kWh.

Table 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	742	3,879,840
Baseline End Use	308	2,663,712
Ex ante Savings	109	937,228
Ex Post Savings	89.6	671,328

Table 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	14.7%	24.2%	12.1%	17.3%
Baseline End Use %	35.4%	35.2%	29.1%	25.2%

6. Additional Evaluation Findings

The ex post kW demand reduction is less than the ex ante estimate. The pre and post retrofit demand are higher than that used in the ex ante savings. The ex ante analysis assumed that the 400 HP compressor would serve the entire plant load. The customer's air usage has increased significantly and the 400 HP compressor now acts as the trim compressor with two 150 HP compressors used for the base load. The 400 HP compressor operates at a higher capacity than anticipated in the ex ante calculations, reducing the benefits of the VFD. The ex post energy savings are less than the ex ante energy savings for the same reason.

The facility representative stated that the cost estimate provided in the application ($223,821) is from the invoice for the work performed for the project and is an accurate reflection of the project cost. In addition to saving energy, the benefits of the project are quieter compressor operation and a more constant pressure in the compressed air line. The customer is currently evaluating adding a 500 HP compressor to the system. The 400 HP VFD compressor is likely to continue being used as the trim compressor, but the impact on the energy savings and demand reduction cannot be estimated at this time. Participation in the 2004/2005 SPC Program has not encouraged the customer to perform any other energy efficiency projects without participating in an incentive program.

One of the old compressors remains on-site and the pre-retrofit compressor type and quantities were physically verified. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measure.

With a cost of $223,821 and a $74,978 incentive, the project had a 1.2 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 1.7 years. A summary of the economic parameters for the project is shown in Table 4. The customer stated that they are planning to add another 500 HP compressor to the system, but the 400 HP compressor will remain as the trim machine, therefore the multi-year impacts, shown in Table 7 below, are shown as constant over the life of the equipment, due to the lack of complete information on the exact usage and configuration of the new system.

7. Impact Results

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	9/13/2004	$223,821	109.0	937,228	0	$121,840	$74,978	1.22	1.84
SPC Program Review (Ex Post)	8/18/2007	$223,821	89.6	671,328	0	$87,273	$74,978	1.71	2.56

Table 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	109.0	937,228	-
SPC Installation Report (ex ante)	109.0	937,228	-
Impact Evaluation (ex post)	89.6	671,328	-
Engineering Realization Rate	0.82	0.72	NA

Table 6: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Process- OTHER	O			Replace three 150 HP rotary screw air compressors with VFD driven 400 HP rotary screw air compressor.	1	Sullair TS32-350H	Physically verified compressor quantity and model.	1.0

Table 7: Multi Year Reporting Table

Program ID	**SPC 2005 Application # A109**
Program Name	**2004-2005 SPC Application**

Year	Calendar Year	Ex-Ante Gross Program Projected kWh Savings	Ex post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program Projected Peak kW Reduction	Ex-Post Gross Evalaution Projected Peak kW Reduction	Ex-Ante Gross Program Projected Therm Savings	Ex post Gross Evaluation Confirmed Program Therm Savings
1	2004	234,307	167,832	0	0	0	0
2	2005	937,228	671,328	109	90	0	0
3	2006	937,228	671,328	109	90	0	0
4	2007	937,228	671,328	109	90	0	0
5	2008	937,228	671,328	109	90	0	0
6	2009	937,228	671,328	109	90	0	0
7	2010	937,228	671,328	109	90	0	0
8	2011	937,228	671,328	109	90	0	0
9	2012	937,228	671,328	109	90	0	0
10	2013	937,228	671,328	109	90	0	0
11	2014	937,228	671,328	109	90	0	0
12	2015	937,228	671,328	109	90	0	0
13	2016	937,228	671,328	109	90	0	0
14	2017	937,228	671,328	109	90	0	0
15	2018	937,228	671,328	109	90	0	0
16	2019	702,921	503,496	109	90	0	0
17	2020					0	0
18	2021					0	0
19	2022					0	0
20	2023					0	0
Totals	2004 - 23	14,058,420	10,069,920				

Final Report

SITE A110 JTI IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 5 END USE: Other

Measure	Replace Two Metalworking Lathes
Site Description	Manufacturing Facility

1. Measure Description

Replace two lathes with newer, more efficient lathes.

2. Summary of the Ex Ante Calculations

The ex ante savings for the measure are 56,432.63 kWh and 35.6 kW as identified in the Installation Report Review (IRR). The measure was submitted as a calculated measure using customized engineering calculations. The SPC Calculator was not used. The calculated savings were less than the 72,029 kWh that were originally approved in the SPC application, as actual measurements were used instead of the application estimates. The SPC incentive of $ 4,514.61 was based on the calculated savings in the IRR.

The calculation methodology may be valid for kWh savings, but does not adequately take account of increases in production efficiency. Savings may be significantly overstated.

3. Comments on the Ex Ante Calculations

The customer originally submitted an application for the replacement of two older metal fabrication lathes with two new, more efficient lathes. The lathes are primarily used to fabricate aluminum and stainless steel parts from metal blanks. The energy use and savings are based on baseline power measurements of the original lathes, estimates of energy savings with the installation of new lathes, and power measurements on the new lathes after they were installed and in operation.

The baseline energy use is based on assumptions about how long the lathes fabricate aluminum and stainless steel and the measured power values. Out of a total of 4,992 hours per year of milling time that the lathes are used, 40% (1,997 hours per year) was dedicated to aluminum milling and 60% (2,995 hours per year) was dedicated to the milling of stainless steel. For lathe #1, the average power consumption was 8.56 kW for aluminum milling and 7.08 for stainless steel milling. For lathe #2, the average power consumption was 15.02 kW for aluminum milling and 11.55 kW for stainless steel milling. The calculations figures were provided as follows:

Lathe#1
Aluminum: 8.56 kW x 1,997 hours/year = 17,096 kWh/year
Stainless Steel: 7.08 kW x 2,995 hours/year = 21,215 kWh/year

Total: 17,096 kWh/year + 21,215 kWh/year = 38,311 kWh/year

Lathe#2
Aluminum: 15.02 kW x 1,997 hours/year = 29,993 kWh/year
Stainless Steel: 11.55 kW x 2,995 hours/year = 34,591 kWh/year
Total: 29,993 kWh/year + 34,591 kWh/year = 64,584 kWh/year

These results give a total of 47,089 kWh/year for aluminum fabrication for both lathes and 55,806 kWh/year for stainless steel fabrication for both lathes. The total for both lathes is 102,895 kWh/yr

An electrical demand of 23.58 kW for aluminum milling and 18.63 kW for stainless steel milling was measured in the pre-retrofit inspection.

After the two new lathes were installed, power measurements were performed again. However, only the aluminum fabrication process could be monitored as the plant was not fabricating any stainless parts on the day of post installation inspection. From these measurements, the calculations were as follows:

Lathe#1
Aluminum: 7.035 kW x 1,997 hours/year = 14,049 kWh/year

Lathe#2
Aluminum: 12.865 kW x 1,997 hours/year = 25,691 kWh/year

These results combine to a total of 39,740 kWh/year.

The ratio of the production efficiencies in kW/kg of material milled was used to normalize energy consumption to production. This resulted in energy use for aluminum milling to be reduced to 21,232 kWh/yr. Unfortunately, the normalization variable of kg of material removed per cycle (or per piece) did not take account of the time required to complete each piece so it did not adequately represent changes in production (pre retrofit to post retrofit). The cycle length is not recorded for the pre-retrofit measurements so it is impossible to back-calculate the actual pre-retrofit production rate.

The production intensity ratio in kW/kg was calculated as approximately 55%. This ratio was applied to the stainless steel production as well.

The kWh use for stainless steel, calculated using the same methods, was 25,221 kWh/yr. The total post retrofit consumption (stainless steel and aluminum) is 46,453 kWh/yr for both lathes.

Energy savings of 56,433 kWh/yr result from these calculations. Actual energy savings will differ because of hours of use, hours dedicated to aluminum verses steel milling, and the intricacy of the pieces being milled.

It should be noted that there were a very limited number of test runs and the data collected was incomplete with cycle time missing for the pre-retrofit measurements, and kg of material removed missing from the measurements in the Installation Report Review. The relationship of production efficiency to energy use should be further quantified with additional readings and monitoring over longer periods to obtain more accurate results.

The ex ante savings in the Installation Report of 35.6 kW is incorrect. It results from the sum of the post-installation average kW demands for aluminum and stainless steel on the two machines. There are two errors here: 1) the weighted average of kW used during stainless steel production and aluminum production should have been used instead of the sum, and 2) the difference between pre and post-installation kW should have been used instead of just the post-installation kW. The correct kW savings are 3.22 kW.

The ex ante savings for the measure are 56,432.63 kWh and 35.6 kW as identified in the Installation Report Review. The utility tracking system lists savings as 56,433 kWh and 35.6 kW.

4. Measurement & Verification Plan

The site is an industrial facility that houses a number of metal fabrication machines. This measure is to replace two metal fabricating lathe machines with two newer, more efficient metal fabricating lathe machines that consume less energy. The lathe machines are in operation 24 hours per day, 6 days a week for a total of 7,488 hours per year. The lathes are producing parts for about 16 hours per day and are re-configured for about 8 hours per day.

According to the application, before the retrofit, lathe #1, a Hatiea Seki Industrial Lathe, was calculated (based on measurements) to consume 38,311 kWh/yr and lathe #2, a Cincinnati Milacron Lathe, was calculated to consume 64,583 kWh/yr. After the retrofit, a Mori- Seiki ZT1500Y replaced lathe #1 and a Mori-Seiki ZT2500, replaced lathe #2. Post-installation measurements and associated calculations revealed that the new lathe #1 consumed approximately 31,477 kWh/yr and the new lathe #2 consumed approximately 55, 321 kWh/yr. The project saves energy through the installation of two new lathes that accomplish the same fabrication tasks, but consume less energy to do it.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

IPMVP Option A approach will be used.

In order to estimate peak demand kW reduction from installing the new lathes, a data logger which records the electric demand should be used. This logger should record the electricity used during the manufacture of a number of parts. The recording time should consist of two time periods. The first period should be the time it takes for a technician to remove a previously made part and replace it with a new metal blank. During this time, the lathe is idling, but still consuming electricity. The second time period should consist of the actual time that it takes to machine the desired part.

It should also be noted whether the part that is being fabricated is aluminum or steel, since these are the two materials that are principally used in the lathes and they place different demands on the lathes. Different alloys milled should also be noted.

The uncut metal blank and the fabricated part should be weighed, so that the amount of material that is removed from the machined part can be determined.

Information may be available from operating logs and machine control panels / SCADA systems. This information will be obtained and utilized as possible.

To determine the actual energy used, the kW/kg – a surrogate for production energy intensity - was used in the ex ante calculations to normalize energy use to production. The difference in energy intensity was used to estimate savings based on assumptions of hours of use (16 hours per day) and ratios of stainless steel to aluminum part production (60%/40%). Energy use intensity for steel was assumed identical to aluminum since no steel was being produced in the post installation period. It was unclear how long post retrofit monitoring was in effect, and the cycle time for the machining of one piece was not recorded.

Steps in the M&V plan are as follows:

1) Obtain operating logs for operating hours for each machine – actual operating hours should be used. It will be determined if operating hours are exactly 16 hrs/day and 6 days per week, or if machines are shut off early, for lunch, etc. Operators will be interviewed concerning actual hours.

2) Consult management and production logs to determine the exact mix of aluminum and steel parts produced and which alloys are used. Determine for several years, if possible, on a weekly basis. Interview management for changes.

3) Monitor machines during steel production and aluminum production. Obtain kg production figures and cycle times.

4) Monitor each machine for at least one 24 hour period (up to 2 weeks). Obtain production during this period.

5) Peak kW readings should be obtained.

6) Pre machine operating data should also be obtained, if possible.

The two most significant variables to be quantified are the hours of operation and the energy demand required for machining and production. The hours will be confirmed by site personnel and interviews.

Uncertainty for the savings estimate for the retrofit can be more fully understood by setting projected ranges on the primary variables.

<u>For higher efficiency machines</u>

- Hours/yr expected: 7488 (+/- 20%)
- Aluminum Percentage: 40% expected, (+/- 20%)
- Demand: 10.0 kW expected (+/- 50%)

<u>For kW demand reduction</u>

- 3.22 kW reduction expected, (+/- 100 %, expected value based on calculated demand reduction not previously recorded correctly)

There may be a small potential source of error introduced since measurement will not be performed throughout the year. This error is estimated at a maximum of + /- 10%

Accuracy and Equipment

The kW loggers, if used, will be Dent Elite Pro dataloggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be +/- 2 % accurate where reviewed data is deemed reasonable.

Annualizing that data from a 1 to 14 day monitoring period is projected to result in a possible error in the final results of +/- 10 %.

Current or power meters may also be used. The current meter to be used, if this M&V technique is selected, would be an Amprobe ACD-41PQ, with an accuracy of +/- 2%.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 21, 2007. Information on installation and operating conditions was collected by interviewing the facility representative and by inspection of the machines. The model numbers on the machines were verified, and found to correspond to those in the Installation Report, except for one character on Lathe #2, which was reported as “4” but should have been “H”. These machines were relocated to a different manufacturing site owned by the same company after their initial installation. The site was located in the same utility service area. They were inspected at this new facility, a one story 21,000 square foot (sf) manufacturing facility. There was, in fact, a second machine of each type referenced in this application (4 machines in total.) Both of the ZT2500Y machines, (lathe #2 type), were machining aluminum at the time of the site visit. The ZT1500Y machine (lathe #1) referenced in the application was machining aluminum at the time of the site visit and the other ZT1500Y was machining stainless steel.

The interview with the floor manager revealed approximately 30% downtime for maintenance and setup on these machines. He also stated that the new machines run about 80% aluminum and 20% stainless steel or carbon steel. The new machines run parts with a flange 90% of the time. For this type of part, much more material is removed since the feedstock must have a diameter large enough to accommodate the flange. The parts without a flange are usually machined on the slower, smaller machines. The new machines are double spindle (one end of the material is machined and then the machine passes it over to the other spindle and the other end of the piece is machined). Therefore, one cycle produces a finished product in this machine, whereas it takes two passes (two cycles) in the older machines.

The facility is in operation 24 hours a day six days a week, and this was also the case with the old machines. They are soon planning to change to 24 hour operation seven days a week.

The pre retrofit lathe machines were very old at the time of the measure implementation. The machines were functional but with significant maintenance problems, which required substantial downtime. The machines provided poor and unacceptable performance at the time of replacement. The machines were not meeting the technical and performance needs of the facility. The old machines were computer numerical control lathes, whereas the new ones are double spindle, 7 to 8 axis, multitasking machines that lathe and also mill.

Installation Verification

It was physically verified that two (2) machines with serial numbers matching those in the Installation Report were installed in the facility. This is the only measure in this application. The verification realization rate for this project is 1.0 (2 / 2). A verification summary is shown in Table 8 below.

Scope of the Impact Assessment

The impact assessment scope is for the “Other” end use measure in the SPC application covering the calculated savings from the new lathe machines. This is the only measure in this application.

Summary of Results

The connected load of the two new Mori Seiki machines was measured over a 15 to 30 minute period while the machines were making aluminum parts. The monitoring period included 7 cycles for the ZT1500Y machine and 5 cycles for the ZT2500Y machine. The feedstock and the finished parts were weighed using a Pelouze scale (Model SP5) to determine the kg of material removed per part. The time required to machine a part was also recorded for each machine. The connected load of an additional machine was monitored because it was the same model (ZT1500Y), and was machining stainless steel parts. Only two cycles of this machine were monitored. The results of the measurements are summarized in Table 1.

Table 1: Measurements on Mori Seiki Integrated Machines at Site A110

	Material being machined	Machined piece has flange	feedstock diameter (inches)	Time per part (min.)	Average kW	Weight of feedstock (g)	Weight of finished piece (g)	Material removed (g)
ZT2500Y machine	aluminum	yes	2.5	8	7.04	236	35	201
ZT1500Y machine	stainless steel	no	0.75	6	8.60	103.3	27	76.3
additional ZT1500Y machine	aluminum	yes	1.25	4	12.06	88	11	77

The power measurements on the two machines are similar to the power measurements previously made on these two machines. There seems to be no correlation between power and type of material being processed on the new machines. The power used to process steel on the 2500 machine measured during the project review falls between the two power measurements when aluminum was being processed on the same machine. The power used to process steel on the 1500 machine measured during the evaluation is higher than the power measurements of aluminum milled on the same machine. Conversely, the power measurements when steel was processed on the old machines were lower than the measurements when aluminum was processed (see Table 2). Separate lines were included in the ex ante calculations for the hours that the machines processed steel and aluminum parts. However, it is not clear that this separation is necessary, and it may introduce additional error into the ex post calculations. The ex post calculations will not calculate separately the energy reductions in processing the two different metals.

Table 2: Summary of All Measurements at This Site

	Lathe #	Material machined	Measured by:	average kW	kg/ cycle	min/ cycle	cycles/ yr	kg/yr	g/ minute
2	aluminum	Inspection	12.865	0.424587	2	3.5	34234	14535	121
1	aluminum	Inspection	7.035	0.151944	1	3	39940	6069	51
2	steel	Review	9.1		2	15	7988		
1	aluminum	Review	8.95		1	3	39940		
2	aluminum	Evaluation	7.04	0.201	2	8	14978	3010	25
1	aluminum	Evaluation	8.60	0.076333	1	6	19970	1524	13
1	steel	Evaluation	12.06	0.077	1	4	29955	2307	19
			9.38						**46**
1	aluminum	Inspection	8.47	0.085	1	8	14978	1273	11
1	aluminum	Inspection	8.65	0.086	1	8	14978	1288	11
1	steel	Inspection	7.08	0.367	1	22	5446	1999	17
2	aluminum	Inspection	14.68	0.357	2	22	5446	1944	16
2	aluminum	Inspection	15.36	0.156	2	10	11982	1869	16
2	steel	Inspection	11.55	1.019	2	35	3423	3488	29
			10.97						**16**

* Figures in red are assumed based on conversations with facility representative about cycle times, those in black are measured.

Not all of the necessary data was collected during the previous site visits; in particular, the cycle time is missing. Conversations with the facility representative revealed that the integrated machines actually replace 6 operations on milling and lathe machines with manual loading between each of the 6 operations. The time needed to make a part on the integrated machine is 4 minutes, while the time to make a part on the old machines is 11 minutes including the loading time. The cycle times on the old machines are assumed such that the average material removal rate is 63% faster on the new machines – corresponding to the 7/11 (63%) reduction in time to make one part, according to the facility representative.

The facility is open 24 hours a day, six days a week, before and after replacement of the machines. This sums to 7,488 hours a year, accounting for 0 holidays. Pre-installation, the machines experienced 33% downtime for setup and maintenance, according to the pre-installation inspection report and unchanged in the post-installation inspection report. This results in 4,992 hours of operation a year. During the onsite evaluation, the facility representative interview revealed that, post-retrofit, the downtime was slightly reduced to 30% for setup and maintenance, resulting in 5,242 operational hours per year. The post-installation hours of operation are adjusted for production by decreasing the hours by 63%, the percent decrease in time required to make a part, as described by the facility representative.

The old equipment replaced through this rebate was at the end of its life. The facility representative indicated that the machines were "old", "barely running" and needed "lots" of non-scheduled maintenance. This equipment was being replaced with or without a rebate. In this case, the baseline for the energy savings is not the energy use of the old equipment, but the energy use of “industry standard” equipment. The SPC rebate program hopes to encourage the customer to upgrade to equipment that is more efficient than industry standard. In the interview, the facility representative stated that all the new machines are energy efficient. Phone conversations with the Mori Seiki sales representative confirmed that the NL series lathe machines are their best selling lathe machine. The Mori Seiki NL1500 and NL2500 will be used as the baseline for this project. The full load amps of the NL series are 25% and 32% of their ZT series counterparts for the 1500 and 2500 machines respectively. These ratios are applied to the measured power draw of the integrated machines to determine the power draw of the baseline NL series lathes, recognizing that this approach is more valid for kW demand savings than kWh savings and in each case does not take into account varying percentage loadings.

Each ZT series integrated machine replaces not only a lathe machine, but also a milling machine. The ZT series integrated machine is able to process two parts at one time, as the lathe and milling machine are combined. In order to make a fair comparison, the power draw of the lathe and milling machine combined must be compared to the power draw of the integrated machine. In the absence of any information about the milling machines used, it was assumed that the milling machine is a Denford VMC 1300 milling machine which draws 8 amps. The baseline power consumption is the sum of the power for the lathe and the milling machine. The kW used for the ex post calculations are the average of all post-installation measurements for each machine, as noted in Table 2. As previously mentioned, steel and aluminum milling are not separated because the data do not indicate that milling of the two materials require different input power to the equipment. (The facility representative did indicate that milling of steel takes more energy because the RPM of the machine must be set slower, resulting in less material removed per second; however, the pre-retrofit or post retrofit data do not confirm this increase in energy use). The results of the power and energy savings calculations are shown in Table 3.

Table 3: Ex Post Savings Calculations

	Hours	kW-1	kW-2	Total kW	Total kWh
Pre-installation (Hatiea Seiki and Cincinnati Milacron lathes)	4992	8.07	13.86	21.93	109,475
Baseline (Mori Seiki NL series lathe & milling machine)	4992	10.30	11.05	21.35	106,583
Post-Installation (unadjusted)	5242	9.16	9.67	18.83	98,705
Post-Installation (adjusted for production increase)	1888	9.16	9.67	18.83	35,551
Savings (baseline to post-installation adjusted for production)				**2.52**	**71,033**

The largest uncertainty in the kW and kWh savings are from the assumption of the kW draw of the milling machine (8 amps +/- 5 amps) and the reduction in time required to make one part (63% +/- 10%). The savings range is from 12.52 kW to -7.48 kW and 130,840 kWh to 11,259 kWh in the best and worst cases, respectively.
Table 4 summarizes the total metered use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers. These machines were relocated after their purchase to a new facility in the same IOU service territory. The billing data is from the new facility,

and is only available for 6 months prior to the retrofit. The total meter annual kWh use is the annualized equivalent of kWh use for the 6 months prior to the retrofit, and the total meter kW is the maximum demand over this same period. The baseline use for the ‘Other’ end use category is calculated as 80% of the total electricity use for the machine shop facility.

Table 5 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results show demand savings of 13.3% and 16.7%, and energy savings of 5.4 % to 6.8% for the total meter and baseline end use respectively. The predicted savings were a small portion of the total energy use and the baseline end use for this site. The ex post results for the machines show smaller demand savings of 0.9% to 1.2%, and larger energy savings of 6.8% to 8.5% for the total meter and baseline end use respectively.

Table 4: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	267	1,040,886
Baseline End Use	213.6	832,709
Ex Ante Savings	35.6	56,433
Ex Post Savings	2.5	71,033

Table 5: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	13.3%	5.4%	0.9%	6.8%
Baseline End Use %	16.7%	6.8%	1.2%	8.5%

6. Additional Evaluation Findings

Installation costs appear to be realistic.

It does not appear that participation in the SPC program stimulated involvement in other energy efficiency efforts or programs.

7. Impact Results

The pre-retrofit machine type was not able to be physically verified. However, the facility representative was very knowledgeable about the pre-existing machines, and was able to detail their characteristics sufficiently for the needed analysis. The level of M&V employed at this site is marginally sufficient to accurately determine the impacts of the installed measures with a high degree of certainty. Critical pieces of information, particularly the cycle times, were not detailed for the pre retrofit equipment.

With a cost of $460,000 and a $4,515 incentive, the project had a 62.09 year simple payback based on the ex ante calculations. The ex post energy savings estimate for the project is larger than the ex ante, and the estimated simple payback is 49.33 years. A summary of the economic parameters for the project is shown in Table 6.

Table 6: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	8/10/2005	$460,000	35.6	56,433	0	$7,336	$4,515	62.09	62.70
SPC Program Review (Ex Post)	9/21/2007	$460,000	2.5	71,033	0	$9,234	$4,515	49.33	49.81

The engineering realization rate for this application is 0.07 for demand savings and 1.26 for energy savings. According to the installation report, the ex ante savings are 56,433 kWh annually and demand reduction is 35.6 kW. A summary of the realization rate is shown in Table 7.

Table 7: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	35.6	56,433	-
SPC Installation Report (ex ante)	35.6	56,433	-
Impact Evaluation (ex post)	2.5	71,033	-
Engineering Realization Rate	0.07	1.26	NA

1. Tracking System values used for realization rate calculations.

The Installation Verification Summary is shown in Table 8.

The savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 9. A 15 year life for custom SPC measures was used.

Table 8: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
PROCESS	P			Replace existing Cincinnati Milacron and Hatiea Seki lathe machines with ZT 1500 and ZT 2500 Mori Seiki Integrated machines	2	ZT 1500 and ZT 2500 Mori Seiki Integrated Machines	Physically verified Mori Seiki machines, matching make, model and serial number to paperwork	1.00

Table 9: Multi Year Reporting Table

Program ID Program Name		SPC 2004 Application # A110 2004 – 2005 SPC Evaluation					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	18,811	23,678				
3	2006	56,433	71,033	35.6	2.5	0	0
4	2007	56,433	71,033	35.6	2.5	0	0
5	2008	56,433	71,033	35.6	2.5	0	0
6	2009	56,433	71,033	35.6	2.5	0	0
7	2010	56,433	71,033	35.6	2.5	0	0
8	2011	56,433	71,033	35.6	2.5	0	0
9	2012	56,433	71,033	35.6	2.5	0	0
10	2013	56,433	71,033	35.6	2.5	0	0
11	2014	56,433	71,033	35.6	2.5	0	0
12	2015	56,433	71,033	35.6	2.5	0	0
13	2016	56,433	71,033	35.6	2.5	0	0
14	2017	56,433	71,033	35.6	2.5	0	0
15	2018	56,433	71,033	35.6	2.5	0	0
16	2019	56,433	71,033	35.6	2.5	0	0
17	2020	37,622	47,355	35.6	2.5	0	0
18	2021					0	0
19	2022						
20	2023						
TOT	2004-2023	846,489	1,065,489				

Final Site Report

SITE A111 Calpor (2004-xxx) IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 2 END USE: Other

Measure	High Efficiency Classifiers
Site Description	Manufacturing

1. Measure Description

Replace two (2) classifiers using several large motors in the cement pulverization with higher efficiency units using smaller motors.

2. Summary of the Ex Ante Calculations

Customized calculations were submitted for the savings due to higher efficiency classifiers. The ex ante savings were identified in the Installation Report Review and the utility tracking system as 3,690,665 kWh/year and 126.00 kW.

The basis of the incentive payment was based on the incentive rate per kWh saved.

The ex ante calculations are based on production tons and production efficiencies derived from information supplied by the applicant (the customer) per the electrical submeter for the incented equipment and production records / estimates of the carrying capacity of the equipment . The baseline production used for the calculations is 205,631 tons. Production data was provided for the pre-retrofit and post-retrofit periods to verify the calculations.

3. Comments on the Ex Ante Calculations

The savings figures in the Installation Report Review (IRR) are identical to the utility tracking system savings figures (3,690,665 kWh/yr and 126.00 kW).

The savings were also calculated using the post installation data and the Operating Report savings (3,287,535 kWh/yr and 108.0 kW) are less than the savings reported in the Installation Report Review (IRR). These are used as the ex ante savings (which were never updated in the utility tracking system).

The ex-ante calculations used the post installation data ranging from June 2005 to July 2006. The ex-ante kWh savings were normalized for equivalent baseline production (205,631 tons).

Pre- retrofit and post-retrofit loads and energy use can be calculated using the following formulae:

$$\text{kWh savings} = \text{kW}_{pre} \times \text{energized hours}_{pre} - \text{kW}_{post} \times \text{energized hours}_{post}$$

Coincident peak demand period savings = $kW_{pre} - kW_{post}$

The check calculations were performed as follows:

Pre-retrofit calculations:

- Baseline Production (tons): 205,631 tons
  Pre-retrofit hours of operation: 6908.8 hours/year
  Pre-retrofit wattage (kW): 1968 kW
  Production-tons per hour: 29.8
  kWh/ton: 66.1
  Annual kWh usage: 1968 kW x 6908.8hrs/yr = 13,596,518 kWh/yr

Post-retrofit calculations:

- Baseline Production (tons): 205,631 tons
  Production-tons per hour: 36.5
  kWh/ton: 50.1
  Pre-retrofit wattage (kW): 1829.3 kW
  Pre-retrofit hours of operation: 5634.8 hours/year
  Annual kWh usage: 1829.3 kW x 5634.8 hrs/yr = 10,307,740 kWh/yr

  Annual usage based on production and kWh/ton is 10,302,113 kWh/yr (~0.05% lower)

- The resulting annual kWh savings: 3,288,778 kWh/yr

- The resulting kW savings:1968 kW -1829.3 kW = 138.7 kW

4. Measurement & Verification Plan

The process is located outside and the base equipment is approximately 40 years old. Use is continuous for 80% of the year dependent on market conditions.

According to the customer, the equipment grinds and classifies the material using large grinding balls. These balls have some course surfaces that wear over time, causing increased energy consumption. There is need for refurbishment after several months or years, depending on usage and feedstock conditions.

The ton / output of the old machine will be confirmed, the hours of operation of the old and new classifiers , and production data after the retrofit will be obtained to the extent possible, to show the persistence of savings. These will be regressed with production data if this approach will yield a more accurate result for the ex post savings.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction due to this measure, over the expected useful life of the measure (classified as 15 years as a custom SPC measure).

Formulae and Approach

A modified version of IPMVP Option A will be utilized.

Most recent production data will be used to estimate the energy savings. The data obtained will be used to determine the production (tons per hour) and kWh/ton.

Uncertainty for the savings estimate can be more fully understood by setting projected ranges on the primary variables.

<u>For retrofitting the classifiers:</u>

- 36.5 tons/hr expected, minimum 29 tons/hr, maximum 44 tons/hr (+/- 20%)
- 126 kW savings expected, minimum 100 kW, maximum 150 kW (includes +/- 20% for fixture wattage difference)
- kWh savings: 3,690,655 kWh expected, 3,000,000 kWh minimum ; 4,000,000 kWh maximum (+/- 10% for range of possible savings)

Accuracy and Equipment

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on August 16, 2007. Information on the retrofit and the operating hours were collected by inspecting the classifier and by interviewing the facility representatives.

Installation Verification

It was physically verified on the day of the on-site survey that all the new equipment has been installed. At the time the verification, it was reported that the plant was operating 50% of the time, as compared to the period before the retrofit. This is mainly due to the decrease in the market demand. The facility typically operates 8,760 hours per year. The most recent production data was collected from the facility. The measure submitted in the report was verified. The verification realization rate for this project is 1.00.

Scope of the Impact Assessments

The impact assessment scope is for the ‘Other’ end use category in the SPC application. This is the only measure in the application.

Summary of Results

The ex-post calculations were performed using the most recent post production data ranging from May 2006 to April 2007. The kW/ton, average kW usage and tons/hr production were determined using the data. The kWh calculations were normalized to equivalent baseline production. The results of the ex post impacts are shown below:

For the pre-retrofit calculations, the ex ante baseline is the best available information and is used as the ex post baseline.

Pre-retrofit calculations:

- Baseline Production (tons): 205,631 tons
  Pre-retrofit hours of operation: 6908.8 hours/year
  Pre-retrofit wattage (kW): 1968 kW
  Production-tons per hour: 29.8
  kWh/ton: 66.1
  Annual kWh usage: 1968 kW x 6908.8hrs/yr = 13,596,518 kWh/yr

Post-retrofit calculations:

- Baseline Production (tons): 205,631 tons
  Production-tons per hour: 33.9
  kWh/ton: 52.4
  Pre-retrofit wattage (kW): 1851 kW
  Pre-retrofit hours of operation: 6065.8 hours/year
  Annual kWh usage: 1851 kW x 6065.8 hrs/yr = 11,227,796 kWh/yr
- The resulting annual kWh savings: 2,367,427 kWh/yr
- The resulting kW savings:1968 kW -1851 kW = 117 kW

  Annual usage based on production and kWh/ton is

  52.4 kWh/ton x 205631 = 10,775,064 kWh/yr

Ex post savings based on this approach are 2,821,454 kWh/yr. The demand savings are 117 kW and are not weather dependent. This value is used as the coincident demand savings.

Table 1 summarizes the total metered energy use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and the additional data obtained from the customer. The baseline end use energy is the calculated energy use for the pre retrofit use for the specific equipment replaced.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	16128.0	184,538,802
Baseline End Use	1968.0	13,595,223
Ex Ante Savings	108.0	3,287,535
Ex Post Savings	117.0	2,821,454

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 0.7% decrease in total meter kW, a 5.5% decrease in baseline end use kW, a 1.8% decrease in total meter kWh, and a 24.2% decrease in baseline end use kWh. The ex post results showed a 0.7% decrease in total meter kW, a 5.9% decrease in baseline end use kW, a 1.5% decrease in total meter kWh, and a 20.8% decrease in lighting end use kWh.

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	0.7%	1.8%	0.7%	1.5%
Baseline End Use %	5.5%	24.2%	5.9%	20.8%

6. Additional Evaluation Findings

The ex post energy savings are less than the ex-ante energy savings. The calculations for ex-post savings used most recent production data. The drop in savings is due to the increase in the kWh/tons production. The ex post calculations were normalized to equivalent baseline tonnage similar to the ex-ante savings calculations.

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. Only one source was used. In addition to saving energy, the benefits of the project are better output and increased reliability. The customer anticipates changes to operation only based on market conditions; this will affect energy consumption in the foreseeable future. The customer's participation in the 2004/2005 SPC Program has increased the energy awareness of the facility. The customer has also installed high efficiency lighting and motors with rebates under a different program, has an energy management committee, and is considering wind generation.

We physically verified the post-installations of the facility. We obtained sufficient data from the facility to accurately asses and quantify the reported energy savings. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

However, as described above, the equipment grinds and classifies the material and components have course surfaces that wear over time, causing increased energy consumption. There is need for refurbishment after several months or years, depending on usage and feedstock conditions. Thus, analysis over a period of three to five years could yield a better estimate of the savings.

With a cost of $3,000,000 and $263,003 incentive, the project had a 6.40 years simple payback based on the ex ante calculations. The ex post savings estimate for the project is similar to that of the ex ante, and the estimated simple payback is 7.5 years. A summary of the economic parameters for the project is shown in Table 3.

7. Impact Results

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh		Estimated Annual Cost Savings ($0.13/kWh) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante from OR)	8/22/2006	$3,000,000	108.0	3,287,535	0	$427,380	$263,003	6.40	7.02
SPC Program Review (Ex Post)	4/20/2007	$3,000,000	117.0	2,821,454	0	$366,789	$263,003	7.46	8.18

The utility tracking data are the approved estimates of ex ante savings. The utility tracking savings were 126 kW and 3,690,665 kWh for the measure. The ex post savings are 117 kW and 2,821,454 kWh. The engineering realization rate is the ratio of the ex post results to the utility tracking data. The engineering realization rate for this application is 0.93 for demand kW reduction and 0.76 for energy savings kWh. A summary of the realization rate is shown in Table 4. The Installation Verification Summary for major measures is shown in Table 5 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 6.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	126.0	3,690,665	-
SPC Operating Report (ex ante)	108.0	3,287,535	-
Impact Evaluation (ex post)	117.0	2,821,454	-
Engineering Realization Rate	0.93	0.76	NA

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Other Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
Replace classifiers with higer efficiency units	Other			Higher efficiency classifer using small motors	1	Higher efficiency classifer using small motors	Physically verified	1.00

Table 6: Multi Year Reporting Table

Program Name:		SPC 04-05 Evaluation Site A111					
Year	Calendar Year	Ex-ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	1,643,768	1,410,727	108	117		
3	2006	3,287,535	2,821,454	108	117		
4	2007	3,287,535	2,821,454	108	117		
5	2008	3,287,535	2,821,454	108	117		
6	2009	3,287,535	2,821,454	108	117		
7	2010	3,287,535	2,821,454	108	117		
8	2011	3,287,535	2,821,454	108	117		
9	2012	3,287,535	2,821,454	108	117		
10	2013	3,287,535	2,821,454	108	117		
11	2014	3,287,535	2,821,454	108	117		
12	2015	3,287,535	2,821,454	108	117		
13	2016	3,287,535	2,821,454	108	117		
14	2017	3,287,535	2,821,454	108	117		
15	2018	3,287,535	2,821,454	108	117		
16	2019	3,287,535	2,821,454	108	117		
17	2020	1,643,768	1,410,727				
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	**49,313,025**	**42,321,810**				

Final Site Report

SITE A112 (2004-xxx) NOR IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: Lighting

Measure	T12 Lighting to T8 Lighting / Energy Management System (EMS) for Lighting Control
Site Description	Offices / Manufacturing Areas

1. Measure Description

Replace 2,300 T12 lamps in fluorescent fixtures with T8 lamps along with associated ballast changes. Install energy management system to reduce lighting hours of operation for retrofit fixtures.

2. Summary of the Ex Ante Calculations

The ex ante savings are identified in the Installation Report Review and in the Measure Savings Worksheet. Stipulated savings were used for the itemized measure (lamp replacement) and custom calculations were used to calculate the savings for the control of the lighting by the energy management system. Electrical kW and kWh savings are not consistent in the installation report review for the fluorescent fixture retrofit; savings of 172,447 kWh and 37.84 kW were not used in the final total savings figures of 421,419 kWh/year and 27.5 kW. The totals savings listed in the utility tracking system were 421,418 kWh/year and 26.75 kW.

The basis of the incentive payment was the itemized incentive list and the calculation of incentive based on the 50% cap on measure cost for the EMS connection for lighting control.

The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers. These workpapers (Measure E-L23) covers conversion from 4 foot fixtures (using T12 lamps and energy saving ballasts) to 4 foot fixtures (using T8 lamps and electronic ballasts). The average of the two lamp fixture and three lamp fixture savings is used as the basis of the per fixture savings of 0.009 kW. Coincident demand savings for the office market sector is 0.008 kW and annual kWh savings of 42 kWh per lamp, based upon 4,000 annual operating hours and a 0.81 coincident diversity factor.

The figures in the Measure Savings Worksheet do not match exactly with the savings calculated based on these numbers from the workpapers.

Additionally, the Measure Savings Worksheet identifies 3,440 lamps installed; the Installation Report Review indicates 2,500 lamps installed.

For the calculated measure, savings from the lighting control via the energy management system (EMS) was calculated based on an assumed fixture wattage, the number of lamps, and the lighting schedules, presumably from the EMS. The total number of lamps controlled was shown as 1,250 lamps. Pre retrofit conditions assumed the lights were energized continually. Post retrofit hours for each of 19 lighting control groups was identified separately.

The calculation correctly used the post retrofit kW, however the 600 fixtures in the mezzanine area were not retrofit but may also be controlled and this is not shown.

3. Comments on the Ex Ante Calculations

In general, the savings figures in the final Implementation Report (IR) are 421,419 kWh /yr and 26.75 kW, nearly identical to the utility tracking system savings figures (421,418 kWh/yr and 26.75 kW). It should also be noted that the sub-measures do not total to the reported amounts in the Installation Report Review.

For the lighting conversion from T12 lamps to T8 lamps, the values for kW savings (0.009 kW/lamp) in the lighting workpapers appear reasonable. The workpapers assume 4,000 hours of annual operation for the office market sector application; the ex ante kWh savings would be lower than actual kWh savings if all lighting was energized for longer periods.

The savings from the Measure Savings Worksheet for 3,440 fixtures were input into the Installation Report Review and used as a component in the ex ante savings; however, only 2,500 (or 2,300 fixtures) were installed.

The total savings incorporate the savings adjusted for the lower lamp quantities for the kW and kWh savings, however the 600 fixtures in the mezzanine area were not retrofit but may also be controlled; this was not incorporated in the custom calculations.

The expected effects for the actual installation are shown below.

Table 1: Expected Impact Effects

	#	kW each lamp	kW		hrs	kWh
Pre	2500	0.036	90.00		8760	788400
Post	2500	0.0285	71.25		8760	624150
Saved			**18.75**			**164250**
Pre	2500	0.0285	71.25		8760	624150
Post	2500	0.0285	71.25		4760	339150
Saved			**0.00**			**285000**
Total Saved			**18.75**			**449250**

The calculations were performed using simple pre-retrofit and post-retrofit equations containing fixture connected loads and energized hours of operation.

Pre- retrofit and post-retrofit lighting loads and energy use can be calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post}

The check calculations for the two main measures (involving conversion from HID fixtures and installation of the energy management system on these fixtures) were performed as follows:

- Pre-retrofit hours of operation: 8,760 hrs/yr
  Pre-retrofit wattage: 0.036 kW per lamp x 2,500 lamps = 90.0 kW
  Annual kWh usage: 90.0 kW x 8,760 hrs/yr = 788,400 kWh/yr
- Post-retrofit hours of operation: 4,760 hours/year
  Post-retrofit wattage: 0.0285 kW per lamp x 2,500 fixtures = 71.25 kW
  Annual kWh usage: 71.35 kW x 4,760 hrs/yr = 339,150 kWh/yr
- The resulting annual kWh savings: 788,400 kWh/yr – 339,150 kWh/yr = 449,250 kWh/yr

The kWh savings are significantly lower than reported in the Installation Report Review**.**

The table above shows the expected kWh and kW impacts of controlling new lighting, using an average reduction of 4,000 hours per year. The lighting control may apply to an additional 600 fixtures in the mezzanine area. These variables should be ascertained during the site visit.

The kWh savings are also dependent on the number of lamps; there are invoices in the application paperwork for 1,150 fixtures, equating to 2,300 lamps. These figures should also be confirmed by physical verification and discussions with the customer / sponsor.

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load.

Coincident peak demand reduction is calculated as follows:

- Reduction in connected kW load plus reduction in load due to motion sensor use: (90.0 kW – 71.25 kW) = 18.75 kW

This number is lower than the ex ante kW savings, most likely due to the larger number of fixtures in the Measure Savings Worksheet used to generate the kW savings.

4. Measurement & Verification Plan

The building is a two-level 2,600,700 manufacturing facility with offices. It is reported to be approximately 40 years old. The building area to be retrofit is primarily used for office and support functions and is occupied from approximately 5 am to 5 pm Monday through Friday. According to the application, before the retrofit there were 1250 fluorescent fixtures using T12 lamps; all fixtures were energized continuously. After the retrofit, there are 1,250 fluorescent fixtures using T8 lamp lamps. The post-retrofit fixtures were controlled according to occupancy schedules by a new connection to the energy management system.

The project saves energy through the installation of lighting fixtures with a lower connected wattage and through the control of the lighting fixtures with occupancy sensors to reduce the hours of operation.

The documentation in the application indicates that there are nineteen areas under different schedules. There are fixture counts for each of these areas. The areas include offices, halls, dining areas, kitchens, and open office areas.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the measures.

Formulae and Approach

A modified version of IPMVP Option A will be utilized.

The number of fixtures is believed to be relatively certain and will be field verified.

The pre retrofit hours of operation will be scrutinized by questioning of site personnel to ascertain that continuous operation was maintained year-round (including weekends, holidays, and other periods) in the areas affected by the retrofits.

Schedules for lighting energization for each section will be obtained from the EMS.

Pre-retrofit and new ballast information will be obtained, and the wattage of lamps previously in use (34 watt or 40 watt T12 lamps) will be determined to the degree possible.

Approximately 16 lighting loggers will be attempted to be placed in the largest eight of the nineteen areas to confirm deenergization. This may not be possible as site personnel indicated that the manufacturing and operations are sensitive and logging equipment is not allowed.

Lighting circuits may be able to be monitored if lighting circuits can be isolated, with spot measurements and electrical logging equipment.

As mentioned above, if possible, lighting loggers would be used to quantify hours of operation. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x ((energized $hours_{pre}$ - energized $hours_{post}$)) / energized $hours_{pre}$) during the hottest periods in the hours from 2 pm to 5 pm, Monday to Friday, in June, July, August, and September

The most significant variables to be quantified are the pre-retrofit and post-retrofit fixture hours of operation. Pre-retrofit hours will be confirmed with site personnel and interviews. The focus will be on verifying that, prior to the retrofit, the entire complement of fixtures was completely energized during the hours listed (8,760 hours/year) and that the listed hours/year were valid. Building or staff schedule logs for the pre-retrofit period could be examined if available.

Appropriate modifications for the savings calculations would be made to the pre-retrofit wattage or power usage figures if required, in order to establish a realistic baseline for energy use (for instance, to reflect 40 watt lamps if these were prevalent).

The use of fifteen sampling points is generally consistent with SPC program documentation from March 2001 (Appendix E, Sampling); this document suggests guidelines for determining sampling point requirements necessary to achieve an 80% confidence interval with 20% precision (using a coefficient of variation of 0.5). If possible, two loggers would be placed in each of the eight areas. A random sampling approach should be used for each area.

The light loggers would be placed so as to be unaffected by fixtures not on motion sensors or by ambient outside light.

If the light loggers cannot be placed in suitable locations, it was considered that, where the lighting circuits can be isolated and it can be determined that only lighting loads for a known number of lighting fixtures are controlled by that lighting circuit, a current or power meter could be used to track multiple fixtures. The total current / power would be determined by activating all fixtures and by confirming loads using the electrical drawings. Between three and six current/power meters are expected to be needed, to capture a representative sample of the lighting fixtures.

The lighting loggers or current sensors would be left in place for a period of 7 to 14 days. Attention will be given to the time period for monitoring, in order to avoid periods of irregular usage patterns (e.g., during holidays or breaks). While longer periods might be preferable, these periods are appropriate given the scope of the evaluation and reported usage characteristics.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture hours of operation. The lighting fixture quantities seem to be well established and the fixture counts were sampled and found to be accurate in post-installation inspection visits. The pre-retrofit and post-retrofit connected loads associated with various fixture types are also adequately quantified in the SPC lighting wattage tables.

Uncertainty for the savings estimate for the fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables.

For retrofit lamps (T12 to T8 conversion)

- 2500 lamps expected, minimum 2250, maximum 2750 (+/- 10%)
- 8,760 hours expected/reported, minimum 8000 hours, maximum 8,760 hours (-10%)
- 18.75 kW expected, minimum 20 kW, maximum 37 kW (includes + 100% for fixture wattage difference)

For EMS Control

- 2500 lamps expected, minimum 2250, maximum 2750 (+/- 10%)
- 4,760 hours post retrofit expected/reported, minimum 3000 hours, maximum 8,000 hours (-40%, + 80%)
- 71.25 kW expected, minimum 68 kW, maximum 74 kW (includes +/- 5 % for fixture wattage)

There may be a small potential source of error introduced since light logging is not planned for the smallest areas. This error is estimated at a maximum of + /- 2% and is not included in the analysis of uncertainty due to its size.

Accuracy and Equipment

The light loggers to be used are Dent TOU-L Lighting Smart*logger* dataloggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Annualizing that data from a 7 to 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

Current or power meters may also be used. The current loggers to be used, if this M&V technique is selected, would be HOBO U-12 loggers, with matched current transformers. The accuracy range is 3.4.5 %. The sensor would be calibrated to an Amprobe ACD-41PQ, with an accuracy of +/- 2%. An advantage of using current or power meters to monitor load is that the percent of time energized for an increased number of fixtures may be able to be captured.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on July 18, 2007. Information regarding the pre retrofit 2-lamp T12 fixtures being retrofit to 2-lampT8 fixtures with electronic ballast and the operational hours of the retrofitted fixtures with controls (EMS) was collected by interviewing the facility representative, from the site visit, and from the documents provided by the facility.

Installation Verification

The facility representative verified that there were 2300 T12 lamps before the retrofit and that they were operating continuously. It was verified that the 2-lamp T12 fixtures were retrofitted with 2-lampT8 fixtures with electronic ballast. It was not possible to physically verify all the retrofitted fixtures as access was not allowed into high security zones. Installation of lighting loggers was also not allowed. All post-retrofit fixtures are controlled by the Energy Management System (EMS). The EMS system is programmed to shut off during the non-operational hours.

These are the only measures in this application. The verification realization rate for the fluorescent fixture retrofit is 0.92 (2,500 fixtures were noted in the Installation Report Review). This verification rate is used for the entire project. The energy management system lighting control was achieved and has a realization rate of 1.0. A verification summary is shown in Table 7 below.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measures in the SPC application covering both lighting efficiency and controls retrofits. These are the only measures in this application.

Summary of Results

The Express Efficiency workpapers and the SPC itemized measure list was used as a guideline to determine the wattage for the pre-retrofit and post-retrofit fixtures. The operating hours are considered to be 8,760hrs/yr before the installation of the EMS.

Since, the lighting loggers were not allowed to be installed by the facility, the operating hours of the facility after the installation of EMS were determined based on the schedule provided by the facility and in the EMS. The operating hours after the installation of EMS awe determined to be 4,754 hrs/yr. Overall, the lights are on about 54.3% of the time and off 45.7% of the time.

The total savings are calculated in two parts. In the first part, calculations were performed to determine the savings due to retrofitting the 2-lamp T12 fixtures with 2-lamp T8 fixtures. The second part calculates the savings due the installation of EMS. The total savings due to both the measures are then calculated and summarized in table 2.

The ex post impacts for the retrofit are calculated as follows:

- Pre-retrofit hours of operation: 8,760 hrs/year.
  Pre-retrofit wattage: 0.036 per lamp x 2300 lamps = 82.8 kW
  Annual kWh usage: 82.8 kW x 8,760 hrs/yr = 725,328 kWh/yr
- Post-retrofit hours of operation (without EMS): 8,760 hrs/year
  Post-retrofit wattage: 0.029 per lamp x 2300 lamps = 66.7 kW
  Annual kWh usage is 66.7 kW x 8,760 hrs/yr = 584,292 kWh/yr
- The resulting annual kWh savings is 725,328 kwh/yr – 584,292 kwh/yr = 141,036 kWh/yr.

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load during the peak demand periods (2 pm – 5 pm weekdays).

Coincident peak demand reduction is calculated as follows:

- Reduction in connected kW load plus reduction in load due to retrofit: (82.8 kW – 66.7 kW) = 16.1 kW.

The ex post impacts for the EMS control are calculated as follows:

- Post-retrofit hours of operation without EMS: 8,760 hrs/yr.
  Post-retrofit wattage: 0.029 per lamp x 2300 lamps = 66.7 kW
  Annual kWh usage: 66.7 kW x 8,760 hrs/yr = 584,292 kWh/yr
- Based on the timing schedules provided by the facility, post-retrofit hours of operation with EMS: 4,754 hrs/year
  Post-retrofit wattage: 0.029 per lamp x 2300 lamps = 66.7 kW
  Annual kWh usage is 66.7 kW x 4,754 hrs/yr = 317,092 kWh/yr
- The resulting annual kWh savings due to EMS control is 584,292 kWh/yr – 317,092 kWh/yr = 267,200 kWh/yr
- Peak period kW savings: 0.0 kW (no demand limiting strategies were incorporated)

Table 2 below summarizes the ex-post results.

Table 2: Ex-post Savings Summary

	# of lamps	kW each lamp	kW	Operating hrs	kWh
Retrofit without EMS					
Pre	2300	0.036	82.8	8,760	725,328
Post	2300	0.029	66.7	8,760	584,292
Saved			**16.1**		**141,036**
Retrofit with EMS					
Pre	2300	0.029	66.7	8,736	584,292
Post	2300	0.029	66.7	4,754	317,092
Savings			**0.0**		**267,200**
Total Savings			**16.1**		**408,236**

Utility billing data for the site was reviewed. In the 12 month period from July 2003 - June 2004 (pre-retrofit), the facility consumed 43,008,984 kWh. Peak demand was 7776 kW in September 2003. Table 3 summarizes the total metered use, the baseline end use energy, the ex ante savings and the ex post calculation results. Baseline end use is for the entire lighting system and is estimated at 30% of the facility load.

Table 4 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 0.4% decrease in total meter kW, a 1.2% decrease in lighting end use kW, a 1.0% decrease in total meter kWh, and a 3.3% decrease in lighting end use kWh. The ex post results showed a 0.2% decrease in total meter kW, a 0.7% decrease in lighting end use kW, a 0.9% decrease in total meter kWh, and a 3.2% decrease in lighting end use kWh.

Table 3: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	7776.0	43,008,984
Baseline End Use	2332.8	12,902,695
Ex ante Savings	27.5	421,419
Ex Post Savings	16.1	408,236

Table 4: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	0.4%	1.0%	0.2%	0.9%
Baseline End Use %	1.2%	3.3%	0.7%	3.2%

6. Additional Evaluation Findings

The ex post energy savings are less than the ex ante energy savings. The difference in the savings may be due to overestimation of the operating hours or misapplication of the itemized measure calculation for the conversion to T8 lamps (along with a greater quantity of lamps in the ex ante savings). No justification was provided in the application to support the reported savings for the itemized measure. The EMS control measure ex post savings are approximately the same as the ex ante savings.

The facility representative stated that the cost estimate provided in the application is from the invoice for the work performed for the project and is an accurate reflection of the project cost. Three vendors were solicited for the work performed.

In addition to saving energy, the benefits of the project are better quality of lighting. The lighting system was approximately 18 years old, and was not satisfactory, requiring over 12 hours per week to maintain.

The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. However, due to the increased light levels, the facility is replacing some 32 watt T8 lamps on burnout with 25 watt lamps, increasing energy savings. No reliable estimate was provided and this was not factored into the ex post savings.

The customer’s participation in the 2004/2005 SPC Program increased energy awareness at the organization and encouraged the implementation of motor and VFD retrofits – it is believed that the organization did participate in an incentive program for these measures.

It was not possible to physically verify the pre-retrofit lighting fixture type, quantities and hours of operation for all areas as the facility had security concerns. However, these parameters have been accurately assessed and quantified based on our verification of accessible fixtures as a sample and discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $58,427 and a $15,495 incentive, the project had a 0.78 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 0.81 years. A summary of the economic parameters for the project is shown in Table 5.

7. Impact Results

Table 5: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh) $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	9/13/2005	$58,427	26.75	421,419	0	$54,784	$15,495	0.78	1.07
SPC Program Review (Ex Post)	7/18/2007	$58,427	16.1	408,236	0	$53,071	$15,495	0.81	1.10

The utility tracking system savings were 26.75 kW and 421,419 kWh. The ex post savings are 16.1 kW and 408,236 kWh. The engineering realization rate is the ratio of the ex post results to the utility tracking data. The engineering realization rate for this application is 1.08 for demand kW reduction and 0.97 for energy savings kWh. A summary of the realization rate is shown in Table 6. The Installation Verification Summary is shown in Table 7 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 8.

Table 6: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	26.75	421,419	-
SPC Installation Report (ex ante)	27.5	421,418	-
Impact Evaluation (ex post)	16.1	408,236	-
Engineering Realization Rate	0.60	0.97	NA

Table 7: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - T12 to T8 lamps	L		Replace 2500 2-lamp T12 fluorescent lamps with 2-lamp T8 fluorescent lamps		2,300	2 lamp T-8 fixtures with electronic ballast	Physically verified fixtures in few areas accessible and could not verify quantity.	0.92
LIGHTING - EMS for Lighting Control	L		Install EMS Control for 2300 fixtures		One EMS; 2310 lamps	Energy Management System (EMS)	Physically verified EMS; used EMS schedules to verify	1.00

Table 8: Multi Year Reporting Table

Program Name:		SPC 04-05 Evaluation Site A112					
Year	**Calendar Year**	**Ex-Ante Gross Program-Projected Program kWh Savings**	**Ex-Post Gross Evaluation Confirmed Program kWh Savings**	**Ex-Ante Gross Program-Projected Peak Program kW Savings**	**Ex-Post Gross Evaluation Projected Peak kW Savings**	**Ex-Ante Gross Program-Projected Program Therm Savings**	**Ex-Post Gross Evaluation Confirmed Program Therm Savings**
1	2004	175,591	170,098				
2	2005	421,418	408,236	26.75	16.1		
3	2006	421,418	408,236	26.75	16.1		
4	2007	421,418	408,236	26.75	16.1		
5	2008	421,418	408,236	26.75	16.1		
6	2009	421,418	408,236	26.75	16.1		
7	2010	421,418	408,236	26.75	16.1		
8	2011	421,418	408,236	26.75	16.1		
9	2012	421,418	408,236	26.75	16.1		
10	2013	421,418	408,236	26.75	16.1		
11	2014	421,418	408,236	26.75	16.1		
12	2015	421,418	408,236	26.75	16.1		
13	2016	421,418	408,236	26.75	16.1		
14	2017	421,418	408,236	26.75	16.1		
15	2018	421,418	408,236	26.75	16.1		
16	2019	421,418	408,236	26.75	16.1		
17	2020	245,827	238,138	26.75	16.1		
18	2021						
19	2022						
20	2023						
TOTAL	**2004-2023**	6,742,688	6,531,776				

Final Site Report

SITE A113 Para (2005-xxx) IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER: 4 END USE: Lighting

Measure	Occupancy Sensors/Photocells for High Bay T5 Lighting
Site Description	Food Processing Plant

1. Measure Description

Install 597 occupancy sensors with combined photocells for control of T-5 warehouse lighting.

2. Summary of the Ex Ante Calculations

The customer used the Itemized Measure Application Form; no kW or kWh savings were calculated in the Measure Savings Worksheet. The basis of the incentive payment was the Measure Savings worksheet. The measure was treated as an occupancy sensor retrofit only. The photocells are combined with the occupancy sensors.

The ex ante savings in the final Implementation Report were given as 853,068.23 kWh/yr and 182.085 kW for the SPC funded measure. These figures agree with the utility tracking system

The ex ante calculations for the itemized measures are typically based on the Express Efficiency workpapers.

For ceiling mounted occupancy sensors, the workpaper for ceiling / wall mounted occupancy sensors documents savings based on the control of eight (8) 4 foot 2 lamp fluorescent fixtures with 34 watt T-12 lamps, consuming 72 watts each including the ballast, in an office conference room. Savings are based on a reduction of usage from 2,210 hours/year to 1,040 hours/year (1,170 hours/year reduction). The workpaper reports a total of 789 kWh savings for all sectors (674 kWh/year plus a 17% office sector energy interactive effects factor). The non-coincident peak reduction of 0.305 kW was derived from the 0.576 kW controlled wattage and a 53% reduction in hours. Coincident peak reduction was reported at 0.381 kW, which includes a 1.25 average office sector Demand Interactive Effects factor.

3. Comments on the Ex Ante Calculations

The metal halide HID fixtures were retrofit to fluorescent fixtures using high output (HO) T5 lamps under the Summer Initiative program. These were noted to be four lamp fixtures and consume 170 watts; this was a calculated measure.

Pre retrofit hours of operation are given as 5,270 hours per year in the lighting tables for the Summer Initiative program. Pre retrofit schedules should be verified with previous operating logs and schedules, and possibly with light loggers on areas not retrofit with motion sensors.

The occupancy sensor operation should be confirmed. There is also photocell control, as well as occupancy sensing control enabled. The percent of fixtures for which daylight sensing is applicable should be determined. Hi – low and variable level lighting control is mentioned. Percent of savings are estimated by the vendor, but are not supported.

Note that the ex ante savings are itemized and based on the workpapers.

Using the 76% diversity factor for the “other” market end use sector in the workpapers and the kW of the controlled fixtures, the coincident peak demand (kW) savings associated with motion sensors on the new fixtures appears to be overstated. The wattage controlled by each motion sensor and the diversity factor in the workpapers do not accurately describe this installation. Also using the reported hours in the lighting tables, with the diversity factor as above, the ex ante kWh savings also appear to be overstated.

The calculations were developed using a simple pre-retrofit and post-retrofit algorithm with fixture connected loads and energized hours of operation.

Pre- retrofit and post-retrofit lighting loads and energy use were calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x (1 – diversity factor)

The calculations for the occupancy sensor measure, using a higher wattage of 234 watts per fixture, were performed as follows:

- Pre-retrofit hours of operation were 5,270 hrs/year.
  Pre-retrofit wattage was 0.234 kW per fixture x 597 fixtures = 139.7 kW.
  Annual kWh usage was 139.7 kW x 5,270 hrs/yr = 736,208 kWh/yr.
- Based on a 24% reduction in operating hours, post-retrofit hours of operation are 5,270 hours x (100% - 24%) = 4,005 hrs/year.
  Post-retrofit wattage is 0.234 kW per six-lamp fixture x 597 fixtures = 139.7 kW.
  Annual kWh usage is 178.78 kW x 4,005 hrs/yr = 425,234 kWh/yr.
- The resulting annual kWh savings is 736,208 kWh/yr – 425,234 kWh/yr = 310,974 kWh/yr.

Summer peak impacts were estimated by subtracting post-retrofit from pre-retrofit connected load and adding the diversity factor adjusted savings for occupancy sensor use.

Coincident peak demand reduction is calculated as follows:

- Reduction in connected kW load plus reduction in load due to motion sensor use is (139.7 kW x (100% - 76%)) = 33.5 kW.

These kW savings may be high due to high fixture wattages; the kWh savings will vary based on actual wattage and hourly reductions.

4. Measurement & Verification Plan

The building is a bi-level 400,000 sf food processing / packing plant. It is reported to be approximately 8 years old. The building has windows and skylights. Maximum occupancy is approximately 460 employees at any given time. According to the application, before the retrofit there were 597 four-lamp HO T-5 fluorescent fixtures without occupancy sensors or photocell control.

The project saves energy through controlling the lighting fixtures with occupancy sensors to reduce the hours of operation.

The goal of the M&V plan is to estimate the actual peak kW and annual kWh reduction over the expected useful lives of the measure.

Formulae and Approach

A modified version of IPMVP Option A can be utilized. Lighting loggers would be used to quantify hours of operation. Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Coincident verage peak demand period savings = kW_{pre} – kW_{post} + kW_{post} x % on according to loggers during the hours from 2 pm to 5 pm, Monday to Friday, in June, July, August, and September.

In this case, kW_{pre} = kW_{post}.

The most significant variable to be quantified is the fixture hours of operation, both pre-retrofit and post-retrofit. Pre-retrofit hours can be confirmed with site personnel and interviews. The focus would be on verifying that, prior to the retrofit, the entire complement of fixtures was completely energized during the hours listed (5,270 hours/year) and that the listed hours/year were valid (for example, building or staff schedule logs for the pre-retrofit period could be examined if available).

Appropriate modifications for the savings calculations would be made to the pre-retrofit usage figures if required, in order to establish a realistic baseline for energy use.

Monitoring with light loggers would be conducted on approximately 5% of the aisles and a center aisle where feasible. A minimum of two sensors for two aisles and one sensor per central aisle would be used in each of the three warehouses. Thus, a minimum of fifteen (15) sensors would be used; however, there could be significantly more sensors required, based on usage and traffic patterns. The customer confirmed that the three warehouses have similar usage patterns. The use of fifteen sampling points is generally consistent with SPC program documentation from March 2001 (Appendix E, Sampling), which suggests guidelines for determining sampling point requirements necessary to achieve an 80% confidence interval with 20% precision (using a coefficient of variation of 0.5).

A random sampling approach should be employed. The light loggers would be placed so as to be unaffected by fixtures not on motion sensors or by ambient outside light.

If the light loggers cannot be placed in proper locations, it was considered that, where the lighting circuits can be isolated and it can be determined that only lighting loads for the warehouse fixtures are controlled by that lighting circuit, a current or power meter could be used to track multiple fixtures. The total current / power would be determined by activating all fixtures and by confirming loads using the electrical drawings. Between three and six current/power meters are expected to be needed, to capture a representative sample of the lighting fixtures.

The lighting loggers or current sensors would be left in place for a period of 7 to 14 days. Attention will be given to the time period for monitoring, in order to avoid periods of irregular usage patterns (such as holidays or breaks). While longer periods might be preferable, these periods are appropriate given the scope of the evaluation and reported usage characteristics.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture hours of operation. The lighting fixture quantities are well established and were counted to within 5% in utility post-installation inspection visits and were supported by vendor invoices. The post-retrofit connected load associated with the new T5 fixtures are also adequately quantified by the vendor and are in fact lower than the figures in the SPC lighting wattage tables (presumably due to the use of low ballast factor ballasts to save more energy).

Uncertainty for the savings estimate for the warehouse fixture retrofit and for the motion sensors controlling these fixtures can be more fully understood by setting projected ranges on the primary variables:

<u>For motion sensors controlling the above fixtures</u>

- 597 fixtures expected, minimum 567, maximum 627 (+/- 5 %)
- 3,300 hours post retrofit expected/reported, minimum 1,650 hours, maximum 6,600 hours (- 50 % , +100 % based on judgment of use for site type; includes + / - 5% from annualizing estimates from short monitoring period)

Accuracy and Equipment

The light loggers to be used are Dent TOU-L Lighting Smart*logger* dataloggers. The Dent logger uses a PC serial interface for data transfer, and all data will be exported to a MS Excel format.

These loggers have a resolution of 1 second and for the purposes of the evaluation are considered to be 100% accurate where reviewed data is deemed reasonable.

Annualizing that data from a 7 to 14 day reporting period is projected to result in a possible error in the final results of +/- 5 %.

Current or power meters may also be used. The current loggers to be used, if this M&V technique is selected, would be HOBO U-12 loggers, with matched current transformers. The accuracy range is 4.5 %. The sensor would be calibrated to an Amprobe ACD-41PQ, with an accuracy of +/- 2%. An advantage of using current or power meters to monitor load is that the percent of time energized for an increased number of fixtures may be able to be captured.

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on July 19, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the occupancy sensors and the lights they control and by interviewing the facility representative. Sensor quantities and hours of operation were verified.

Installation Verification

The facility representative verified that 597 occupancy sensors were installed and each sensor controls one high bay fixture. It was physically verified that occupancy sensors were installed in the facility. The building representative stated that the fixtures that were existing before the retrofit were not on occupancy sensors or photocells that dimmed them to low power when the space was unoccupied or received sufficient daylight. The retrofit was completed by September 2005.

The installation of 597 occupancy sensors with combined photocells for control of warehouse lighting was the only measure in this application. The verification realization rate for this project is 1.00 (597/597). A verification summary is shown in Table 6 below.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measure covered by the SPC program. The motion sensor / photocell installation is the only measure in this program.

Summary of Results

The building schedule as given by the facility representative varies based on the season and in given in the table below. The facility is closed 5 holidays annually. The pre retrofit case assumes all lights are on when the building is occupied. It is assumed the lights are off during the unoccupied periods.

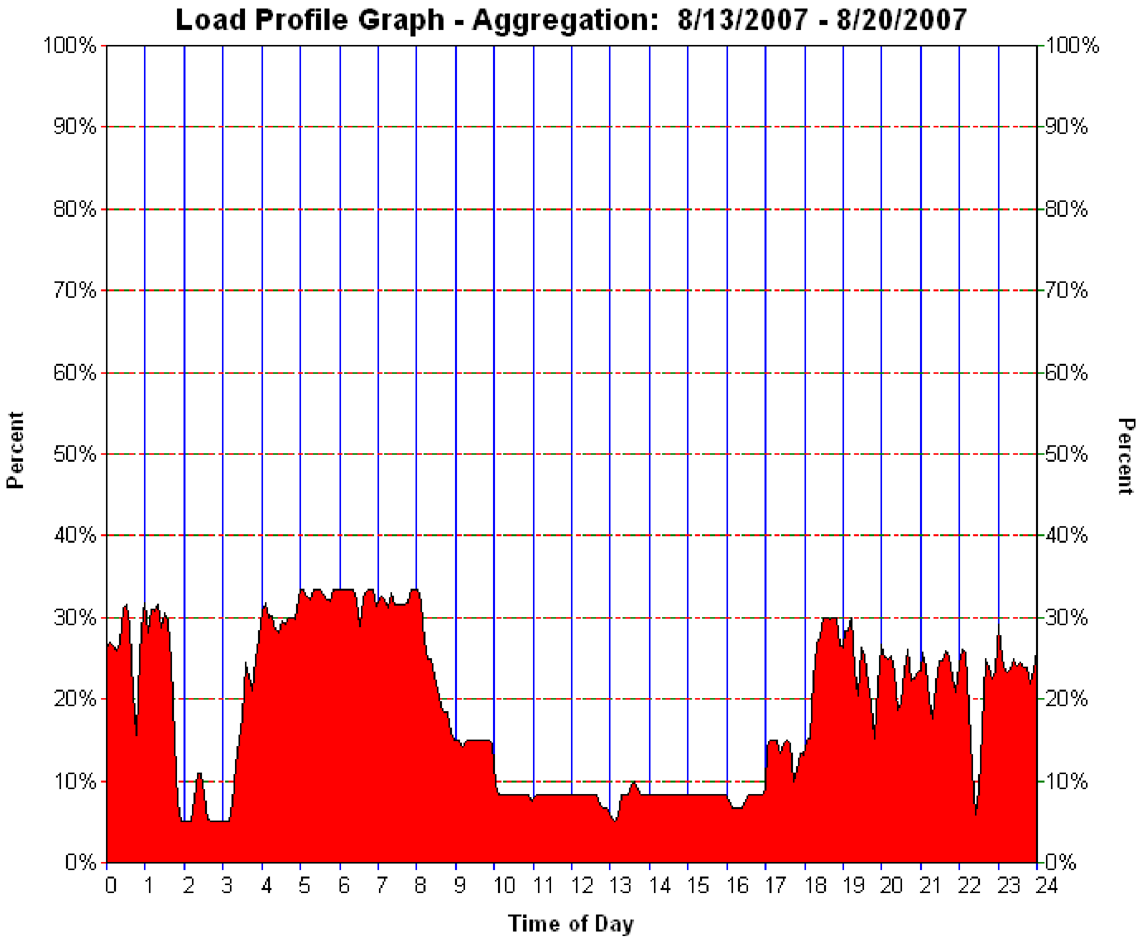
Table 1: Pre Retrofit Hours per Year

Months	Days/week	Hours/day	Wks/yr	Hours/yr
June to Sept.	4.5	13	17.3	1014
Oct. to Dec.	6	12	13.0	936
Jan. to May	6	16	21.7	2080
	Total hours/year			4030

Twelve light loggers were installed. The on-time of the fixtures was recorded for a seven day period between 1:13 PM on 8/13/07 and 1:13 PM on 8/20/07. The average percent on was 20% for eight of the twelve light loggers that had data recorded in this 7 day period (the other four loggers had sensitivity levels set too low and failed to record lighting changes). For the June to August annual period this data results in 585 hours, which is a 42.5% reduction in lighting hours when compared with the building occupancy schedule (table above) given by the facility representative (585 hours vs. 1014 hours). This percent reduction was applied to the total hours of operation based on the building occupancy schedule to represent the actual post retrofit hours. No change in building schedule was indicated by the facility representative and it is assumed that, for pre retrofit periods, all the lights were on during these hours and all were off outside of this time period.

During the expected coincident peak demand periods of 2 p.m. to 5 p.m. weekdays, the fixtures were measured to be on an average of 17.4% of the time. No special holidays or off days were included in this period. Figure 1 below shows a typical load profile.

Figure 1: Typical Load Profile



The main electricity end-uses at this facility are lighting and refrigeration. The facility representative confirmed that there was no change in the electricity use patterns before and after the retrofit other than the addition of the occupancy sensors.

The ex post savings associated with the occupancy sensors retrofit project is given below.

- Pre-retrofit hours of operation were 4,030 hrs/year based on building occupancy provided by facility representative.
- Pre-retrofit wattage for HO T-5 fixtures was 0.170 kW per fixture x 597 lamps = 101.5 kW.
- Annual kWh usage was 101.5 kW x 4,030 hrs/yr = 409,045 kWh/yr.
- Post-retrofit hours of operation are 4,030 hours x (100-42.5 %) = 2,317 hrs/year with the occupancy sensors.

- Post-retrofit wattage for HO T-5 fixtures was 0. 170 kW per fixture x 597 lamps = 101.5 kW.
- Annual kWh usage is 139.7 kW x   hrs/yr = 235,175 kWh/yr.
- The resulting annual kWh savings is 409,045 kWh/yr – 235,175 kWh/yr = 173,870 kWh/yr.

Summer peak impacts were estimated by subtracting post-retrofit load from pre-retrofit load, with an adjustment for the weekday 2 p.m. to 5 p.m. average measured post-retrofit percent on value of 17.38%

Summer peak demand reduction is calculated as follows:

- Percent off during peak x kW post-retrofit
- 82.6% x 101.5 kW= 83.8 kW

Billing data was analyzed for this site to see if it confirms the savings found in the engineering calculations, and it was found to be too variable to give an indication of energy reduction due to the lighting retrofit. The noise in the data is likely due to the large refrigeration load that is weather dependent.

Utility billing data for the site was obtained from the utility pre-retrofit annual consumption (for one year prior to retrofit) was 15,618,522 kWh. Peak demand was 636.7 kW. Baseline end use was assumed to be 30% of the total meter use. Table 2 summarizes the total metered use, the baseline end use energy, the revised ex ante savings and the ex post calculation results based on the utility billing data and evaluation site visit numbers.

Table 3 is a summary of the percent of energy savings for the total metered use and for the baseline end use, for both the ex ante and ex post savings calculations. The ex ante results showed a 28.6% decrease in total meter kW, a 95.3% decrease in lighting end use kW, a 5.5% decrease in total meter kWh, and a 18.2% decrease in lighting end use kWh. The ex post results showed a 13.2% decrease in total meter kW, a 43.9% decrease in lighting end use kW, a 1.1% decrease in total meter kWh, and a 3.7% decrease in lighting end use kWh.

The engineering realization rate for this application is 0.46 for demand kW reduction and 0.20 for energy savings kWh. According to the installation report, the ex ante savings are 853,068 kWh annually and demand reduction is 182.1 kW. A summary of the realization rate is shown in Table 4.

Table 2: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	636.7	15,618,522
Baseline End Use	191.0	4,685,557
Ex ante Savings	182.1	853,068
Ex Post Savings	83.8	173,870

Table 3: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	28.6%	5.5%	13.2%	1.1%
Baseline End Use %	95.3%	18.2%	43.9%	3.7%

6. Additional Evaluation Findings

It was found that the hours of operation were higher than those assumed in the Express Efficiency work papers and presumably used for the ex ante calculations. However, the wattages controlled are much lower than in the workpapers. Therefore, the ex post kWh reduction is much lower than the ex ante estimate.

In addition to saving energy, the benefits of the project are that the employees like the whiter light and the improved lighting levels. The customer does not anticipate any changes to operation that will affect energy consumption in the foreseeable future. Participation in the 2004/2005 SPC Program seems to have encouraged them to perform other energy efficiency projects, particularly motor replacements, some of which were replaced with incentive programs. They are also actively pursuing energy efficiency in other areas.

The capital costs were broken out from an invoice for fixtures and sensors. The unit costs appear to be reasonable.

7. Impact Results

The pre-retrofit lighting fixture type, quantities and hours of operation were unable to physically verify. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $61,146 and a $26,268 incentive, the project had a 0.55 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 2.71 years. A summary of the economic parameters for the project is shown in Table 4.

Table 4: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	9/16/2005	$61,146	182.09	853,068	0	$110,899	$26,268	0.31	0.55
SPC Program Review (Ex Post)	7/19/2007	$61,146	83.8	173,870	0	$22,603	$26,268	1.54	2.71

The realization rate of the peak kW demand is 0.46 and the realization rate of the energy savings is 0.20 as summarized in Table 5. The Installation Verification Summary is shown in Table 6 and the savings over the full life of the measure are shown in the Multi Year Reporting Table in Table 7.

Table 5: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	182.1	853,068	-
SPC Installation Report (ex ante)	182.1	853,068	-
Impact Evaluation (ex post)	83.8	173,870	-
Engineering Realization Rate	0.46	0.20	NA

Table 6: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		L-I3 High Bay Lighting Sensor		597	Each occupancy sensor / photocell controls on HO T-5 fixture	Physically verified occupancy sensor type and verified quantity from site and invoices	1.00

Table 7: Multi Year Reporting Table

Program ID:	Application # A113						
Program Name:	A0113 SPC 04-05 Evaluation						
Year	Calendar Year	Ex-ante Gross Program-Projected Program KWh Savings	Ex-Post Gross Evaluation Confirmed Program KWh Savings	Ex-Ante Gross Program-Projected Peak Program KW Savings	Ex-Post Evaluation Projected Peak KW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004					0	0
2	2005	284,356	57,957			0	0
3	2006	853,068	173,870	182.1	83.8	0	0
4	2007	853,068	173,870	182.1	83.8	0	0
5	2008	853,068	173,870	182.1	83.8	0	0
6	2009	853,068	173,870	182.1	83.8	0	0
7	2010	853,068	173,870	182.1	83.8	0	0
8	2011	853,068	173,870	182.1	83.8	0	0
9	2012	853,068	173,870	182.1	83.8	0	0
10	2013	853,068	173,870	182.1	83.8	0	0
11	2014	853,068	173,870	182.1	83.8	0	0
12	2015	853,068	173,870	182.1	83.8	0	0
13	2016	853,068	173,870	182.1	83.8	0	0
14	2017	853,068	173,870	182.1	83.8	0	0
15	2018	853,068	173,870	182.1	83.8	0	0
16	2019	853,068	173,870	182.1	83.8	0	0
17	2020	853,068	173,870	182.1	83.8	0	0
18	2021	568,712	115,913			0	0
19	2022						
20	2023						
TOTAL	**2004-2023**	13,649,088	2,781,912				

FINAL SITE REPORT

SITE A114 (04-xxxx) USN IMPACT EVALUATION
SAMPLE CELL: ORIGINAL TIER:2 END USE: Lighting

Measure	Lighting, HVAC and HVAC controls Retrofit
Site Description	Navel Base

1. Measure Description

The application documents numerous lighting measures including:

- 34,900 T-12 lamps and electronic ballasts retrofitted with new T8 lamps and electronic ballasts.
- 196 new VSDs for air handling units
- 163 new DDC thermostats
- 21 new economizers for existing package A/C units
- 20 new package A/C units replacing old A/C units

The evaluation covers only the lighting retrofit as the predominant end use category.

2. Summary of the Ex Ante Calculations

There are a total of thirteen sub-measures. Ten of the measures use a calculated approach and three of the measures are itemized. The lighting retrofit is one of the calculated measures.

This calculated measure uses a simple pre-retrofit and post-retrofit algorithm using fixture connected loads and hours of operation for the ex ante calculations. The calculations were originally performed by the energy efficiency service provider.

For the calculated measures, the ex ante baseline is the existing system connected load and hours of operation, and is in accordance with the SPC Program guidelines. Pre-retrofit and post-retrofit calculations of lighting loads and energy use were performed using the following formulae:

kW = Fixture watts / 1,000 w/kW x Fixture quantity
kWh = kW x hours

The ex ante calculations for the itemized measures are typically based on the Express Efficiency work papers.

According to the installation report, the total approved ex ante savings are 1,749,537 kWh and demand reduction is 383.9 kW, however the utility tracking data shows 1,749,520 kWh and 373.43 kW demand reduction.

The lighting retrofit is the primary measure, with 59% of the kWh annual savings and 97% of the annual demand savings was a retrofit to T-8 lamp and electronic ballast from T-12 lamp and electronic ballast. The ex ante impact for this measure is assumed to have been calculated for the 163 buildings with varying hours of operation using the following simple algorithms per building within a spreadsheet:

- Pre-retrofit and post retrofit hours of operation are the same and varied per building but on average were 4,557.27 hours/year
- Lamp wattage:
  Pre-retrofit – post-retrofit=11 watts/lamp
- Lighting demand reduction is :
  (0.011 kW) x 34,900 fixtures = 383.9 kW
- Lighting kWh savings are:
  383.9 kW x 4557.27 hours = 1,749,537 kWh
  This calculation agrees with the figure shown in the installation report.

The installation report data (1,749,537 kWh and demand reduction of 383.9 kW) will be used as the ex ante savings figures and the basis for the evaluation.

3. Comments on the Ex Ante Calculations

The ex ante calculations were performed according the SPC Program guidelines using the lighting fixture wattages from the SPC lighting wattage tables for the T-8 and T-12 fixtures/ballast/lamp combinations. An independent installation verification of the T-8 retrofit was conducted prior to this evaluation. Lamp, fixture and ballast quantities were verified. The savings appear to be realistic based on the quantity and type of retrofit.

4. Measurement & Verification Plan

There are numerous measures documented in the application. Approximately 59% of the total application ex ante energy savings and 97% of the total application demand reduction is associated with the retrofit of 34,900 T-12 lamp and ballast combinations with T-8 lamp and ballast combinations. Therefore, the evaluation will focus on this measure and the other measures will be verified to the extent possible.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting fixture and lamp quantities and hours of operation. The pre-retrofit and post-retrofit connected loads associated with various fixture types are adequately quantified in the SPC lighting wattage tables.

The goal of the M&V plan is to estimate the actual peak kW and actual annual kWh reduction over the expected useful lives of the primary measure, through quantifying hours of operation, lamp quantities, and lamp wattages.

Formulae and Approach

The M&V plan proposed is a modified version of IPMVP Option A.

For this application, the pre-retrofit fixture types, quantities and hours of operation will be verified with the facility representative. Variances due to burned out bulbs, maintenance, and/or schedules will be addressed to the extent possible. A portion of the post-retrofit lamp quantities and fixture types will be physically verified during the site visit. Several of the 163 buildings at this location - ideally buildings with different functions and a large number of retrofit lamps - will be physically verified. The spreadsheet from the independent evaluation will be used to cross reference hours of operation, room names, and lamp / fixture quantities.

No lighting loggers will be installed due to the large number (163) of buildings and the inability to determine a typical schedule among the many lighting schedules due to varying building uses.

Pre-retrofit and post-retrofit calculations of lighting loads and energy use will be calculated using the following formulae:

kWh savings = kW_{pre} x energized $hours_{pre}$ – kW_{post} x energized $hours_{post}$

Summer peak demand period savings = kW_{pre} – kW_{post} during the three contiguous hottest days between 2 pm to 5 pm, Monday to Friday, during the week with the hottest day in June, July, August, or September.

The greatest uncertainties in the ex ante savings estimate are associated with the pre-retrofit and post-retrofit lighting hours of operation and lamp quantity. The lighting lamp quantities seem to be well established and were counted to within 10% in utility post-installation inspection visits. The pre-retrofit and post-retrofit connected loads associated with various fixture types are also adequately quantified in the SPC lighting wattage tables.

Uncertainty for the savings estimate for the T-8 ballast and lamp retrofit can be more fully understood by establishing projected ranges on the primary variables, as follows:

- 34,900 lamps expected, minimum 31,410, maximum 38,390 (+/- 10%)
- 4,500 hours pre and post retrofit expected/reported, minimum 2925 hours, maximum 6075 hours (+/- 35%)

Accuracy and Equipment

All data collected will be reviewed to ensure it conforms to realistic values and will be cross-verified with other data collected to identify any anomalies. Data from outliers and other suspicious elements will be scrutinized and removed from the analysis if appropriate.

5. Summary of the Ex Post Evaluation, Installation Verification, and Scope of Impact Assessment

The on-site survey was conducted on September 20, 2007. Information on the retrofit equipment and operating conditions was collected by inspection of the lighting fixture and lamp quantities and by interviewing the facility representatives.

As this was a large facility with 163 buildings, and a number of the areas are hard to access due to security issues, a representative sample of three buildings with varying functions were chosen; the lighting in each was physically verified to the extent possible.

Installation Verification

The facility representative provided a spreadsheet from the lighting contractor which included the lighting contractor's count of replaced lamps as well as the count by an independent verifier. The two counts were within 1% of each other. The total number of lamps installed, according to the spreadsheet, is 38,597 lamps, close to the 38,659 lamps listed in the application paperwork. The number of lamps in the Installation Review was reduced to 34,900 with no explanation as to which lamps were not replaced.

We reviewed the complete list of lighting measures with the facility representative and verified that T8 lamps and ballasts had replaced T12 lamps and ballasts in 163 buildings. The facility representative verified that all lamps and ballasts were replaced on a one-for-one basis.

We physically verified that, for the three buildings sampled, there are 1,385 T-8 fluorescent fixtures and 5,570 lamps, or 79.7% of the fixtures noted on the contractor's spreadsheet for these buildings. The number of lamps associated with one building (building number 20000) in the contractor's spreadsheet was given as 3,504; we counted only 2,034 lamps in this building. All of the rooms in this building were surveyed, and all lamps counted. It is unlikely that one third of the lamps were missed. Furthermore, conversations with personnel on site indicated that some of the T8 lamps counted were installed in a retrofit that occurred in 2006, so they should not be included in the 2004 scope, but the exact number of lamps changed in the 2006 retrofit could not be determined. Investigation revealed errors on the contractor's spreadsheet, which, when corrected, showed 962 lamps replaced instead of 3,504. Due to the high uncertainty associated with the second retrofit at this building, the verification rate associated with this building was excluded from the total. The total number of lamps verified for the other buildings was compared with the figures from the independent inspection (prior to the evaluation site visit) to calculate a verification rate of 1.01.

Not all fixtures were able be verified due to restricted access. All fixtures were T-8 fixtures with a varying number of lamps per fixture. In two of the three buildings, very few burned out lamps were observed, however in building number 1403 (a medical building), a range of 25-100 percent of lamps per fixture was working: total of 138 burnt out lamps of the 1311 total lamps - 86.4% - are working. This is taken into account in the ex post calculations below.

We were unable to verify the quantities listed in the application for the remaining 160 buildings due to timing constraints. Applying the verification rate of the sample (1.01) to the entire retrofitted lamp population results in 35,370 total lamps. A verification summary is shown in Table 5 below.

Scope of the Impact Assessment

The impact assessment scope is for the lighting end use measure only in the SPC application covering both lighting efficiency and controls retrofits. The lighting measure is the only measure evaluated.

Summary of Results

The total lamp quantity physically verified was 3,536 in two buildings (not including the burned out lamps in one of the buildings #1403). This assumes that the inaccessible rooms contained the same number of fixtures and lamps as listed in the independent assessment.

The facility representative indicated the hours of operation for hanger 3 (building numbers 20000 and 20000A) to be Monday through Thursday 14 hours a day and Sundays 10 hours a day all year. Every other Friday is a day off, and the facility is also open on the 'typical closed days' for 10 hours 13 times a year for special occasions. The other buildings are assumed to be open an average of 10 hours a day from Monday to Friday from 7 a.m. to 5 p.m., as verified with the facility representative.

During the period between 2 p.m. to 5 p.m., Monday to Friday, the lamps were assumed to be on an average 100% of the time based on the schedules above.

The lamp number in building 1403 was adjusted to represent the actual percent of functioning lamps (86.4%) The other building was not adjusted to take this into account because few burned out lamps were observed.

The ex ante calculations were performed using the verified operating schedule and lighting fixture wattage from the SPC tables and data obtained from a lighting manufacturer for the T-8 fixtures.

The ex post impacts are calculated below for buildings 20000 and 20000A (hanger 3). . The same formula was used for the remaining buildings but input hours of operation (2,346.3 hours/year – 50 hrs/wk x 52.14 wks/yr x 0.9 for every other Friday off) and the number of lamps varied, resulting in 350.18 kW and 821,617 kWh savings. The same formula was used for buildings 1403 but the percent of working lamps (86.4%) was applied, resulting in 12.46 kW and 29,234 kWh savings.

- Pre and post retrofit hours of operation was 3,936 hrs/year.

Hanger (20000A)

hours operation/year	hrs/day	days/wk	wk/year	hr/yr
Monday - Thursday	14	4	52.14	2919.84
Flex Friday	14	0.5	52.14	364.98
Sunday	10	1	52.14	521.4
Special Occasions	10	1	13	130
			Total hours/year	3,936.22

- Wattage savings was 11 watts per lamp (assumed same as ex-ante) x 2,225 lamps = 24.475kW
- Annual kWh savings was 24.475 kW x 3,936.22 hrs/yr = 96,339 kWh/yr
- The resulting annual kWh savings is 96,339 kWh/yr + 821,617 kWh/yr + 29,234 kWh/yr = 947,190 kWh/yr.
- The resulting annual kW savings is 24.47 kW/yr + 350.18 kW/yr + 12.46kW/yr = 387.11 kW/yr.

The engineering realization rates based on the ex ante savings for this application are 1.0 for demand kW reduction and 0.5 for energy savings kWh, as shown below:

387.11 kW / 383.9 kW= 1.01

947,190 kWh / 1,749,537 kWh = 0.54

The values shown in the tracking system do not agree exactly with those shown in the installation report for this application. The values shown in the installation report are used as the basis of the evaluation. A summary of the realization rate is shown in Table 4.

Utility billing data for the site indicates that the total site annual energy use was 102,066,192 kWh and peak demand was 13,926 kW. The lighting baseline energy use is assumed to be 30% of the total site annual energy use. Table 1 summarizes the total metered use and the baseline end use energy, the ex ante savings and the ex post calculation results for the T-8 retrofit.

Table 2 is a summary of the percent of energy savings for the total metered use and for the baseline end use for the high bay lighting retrofit with occupancy sensors, for both the ex ante and ex post savings calculations. The ex ante results estimated a 2.8% decrease in total meter kW, a 9.2% decrease in lighting end use kW, a 1.7% decrease in total meter kWh, and a 5.7% decrease in lighting end use kWh. The ex post results showed a 2.8% decrease in total meter kW, a 9.3% decrease in lighting end use kW, a 0.9% decrease in total meter kWh, and a 3.1% decrease in lighting end use kWh.

Table 1: Total Meter, Ex Ante, Ex Post Results

	Peak Demand kW	Annual kWh
Total Meter	13,926.0	102,066,192
Baseline End Use	4,177.8	30,619,858
Ex Ante Savings	383.9	1,749,537
Ex Post Savings	387.1	947,190

Table 2: Percent Savings and Demand Reduction, Ex Ante, Ex Post

	Ex Ante		Ex Post	
kWh Savings/kW Demand Reduction	kW	kWh	kW	kWh
Total Meter %	2.8%	1.7%	2.8%	0.9%
Baseline End Use %	9.2%	5.7%	9.3%	3.1%

6. Additional Evaluation Findings

The ex post kW demand reduction is similar to the ex ante estimate; less lamps were verified than shown in the ex ante calculations. The ex post energy savings are less than the ex ante energy savings because the ex ante savings over estimated the amount of time the lights are on.

The facility representative had only been in his position for one year at the time of the site inspection and interview. No information had been left to him by his predecessor about the 2004 SPC retrofit so questions about the non-energy effects of the retrofit could not be answered. He did say that he plans to continue upgrading HVAC and lighting throughout the facility, and will take advantage of the SPC rebates if possible.

We were unable to physically verify the pre-retrofit lighting fixture type, quantities and hours of operation. However, we are satisfied that these parameters have been accurately assessed and quantified based on our discussions with the facility representative. The level of M&V employed at this site is sufficient to accurately determine the impacts of the installed measures.

With a cost of $687,746 and a $148,325 incentive, the project had a 2.37 year simple payback based on the ex ante calculations. The ex post savings estimate for the project is less than the ex ante, and the estimated simple payback is 4.38 years. A summary of the economic parameters for the project is shown in Table 3. A summary of the multi-year reporting requirements is given in Table 6.

7. Impact Results

Table 3: Economic Information

Description	Date	Project Cost	Estimated Demand Savings, kW	Estimated Energy Savings, kWh	Estimated Gas Savings, therms	Estimated Annual Cost Savings ($0.13/kWh), $	SPC Incentive, $	Simple Payback w/ incentive, yrs	Simple Payback w/o incentive, yrs
Installation Approved Amount (Ex Ante)	8/9/2005	$687,750	383.9	1,749,537	-	227,440	$148,325	2.37	3.02
SPC Program Review (Ex Post)	4/18/2007	$687,750	387.1	947,190	-	123,135	$148,325	4.38	5.59

All values are for the lighting retrofit only.

Table 4: Realization Rate Summary

	kW	kWh	Therm
SPC Tracking System	373.4	1,749,520	-
SPC Installation Report (ex ante)	383.9	1,749,537	-
Impact Evaluation (ex post)	387.1	947,190	-
Engineering Realization Rate	1.04	0.54	-

All values are for the lighting retrofit only.

Table 5: Installation Verification Summary

Measure Description	End-Use Category	HVAC Measure Description	Lighting Measure Description	Process Measure Description	Count	Equipment Description	Installation Verified (Explain)	Verification Realization Rate
LIGHTING - OTHER	L		T-8 L&E ballast 4-ft retrofit from T-12		35,370		Physically verified lamp type and quantity in 3 buildings & verified number of buildings from floor plan and documentation of previous inspectors.	1.01

Table 6: Multi Year Reporting Table

Program Name:		SPC 04-05 Evaluation Site A114					
Year	Calendar Year	Ex-Ante Gross Program-Projected Program kWh Savings	Ex-Post Gross Evaluation Confirmed Program kWh Savings	Ex-Ante Gross Program-Projected Peak Program kW Savings	Ex-Post Gross Evaluation Projected Peak kW Savings	Ex-Ante Gross Program-Projected Program Therm Savings	Ex-Post Gross Evaluation Confirmed Program Therm Savings
1	2004						
2	2005	1,749,537	947,190	383.9	387.1		
3	2006	1,749,537	947,190	383.9	387.1		
4	2007	1,749,537	947,190	383.9	387.1		
5	2008	1,749,537	947,190	383.9	387.1		
6	2009	1,749,537	947,190	383.9	387.1		
7	2010	1,749,537	947,190	383.9	387.1		
8	2011	1,749,537	947,190	383.9	387.1		
9	2012	1,749,537	947,190	383.9	387.1		
10	2013	1,749,537	947,190	383.9	387.1		
11	2014	1,749,537	947,190	383.9	387.1		
12	2015	1,749,537	947,190	383.9	387.1		
13	2016	1,749,537	947,190	383.9	387.1		
14	2017	1,749,537	947,190	383.9	387.1		
15	2018	1,749,537	947,190	383.9	387.1		
16	2019	1,749,537	947,190	383.9	387.1		
17	2020	1,749,537	947,190	383.9	387.1		
18	2021						
19	2022						
20	2023						
21	2024						
TOTAL	2004-2024	27,992,592	15,155,040				

C.

Appendix C: Survey Instruments

C.1

2004/2005 Nonresidential SPC Study
End-User Participant Survey

2004/2005 Nonresidential SPC Study
End-User Participant Survey

Prepared for SCE by
Itron

JUNE 13, 2007 - FINAL VERSION

Interview Tracking Information

Completion Date		**Survey Length (min.)**	

Customer Information

Company Name	
Contact Name	
Contact Title	
Phone	
Alt info (email, cell)	

Database Application Information

Application No. by Utility	PGE SCE SDGE		**SPC Prog. Year**	❑ 2004 ❑ 2005
Status of Applications	❑ All completed ❑ Implementation Stage ❑ Mixed ❑ Other:			
Sponsor Status	❑ EESP ❑ SELF ❑ BOTH Name of EESP:__________________________			
Site information	❑ Single Site ❑ Multi Site *Notes:*____________________________________			
Recent Audit Participant ?	❑ yes ❑ no	Date of Audit:_______________		
On-Site Completed ?	❑ yes ❑ no	**Assigned Application ID No:** _________________		

Impact Data Collection Information: (if Onsite completed)

Date of Onsite: ________________	**Onsite Interviewee:** _______________ **Title:** __________________
Onsite Surveyor: _______________	**Interviewee Contact: Phone:**_____________ **Email:**_____________
Projects/Measures reviewed:	
Installation status:	

Interviewer Notes:

____

____

END-USER PARTICIPANT INTERVIEW GUIDE – POSSIBLE LEAD IN MATERIAL

May I please speak with [CONTACT__________________]? [**Confirm this person is responsible for participation decision.]**

Hello, my name is ______ and I am calling about your participation in **[&UTILITY's]** Large Standard Performance Contract Program. I am with ITRON, we are an energy research firm hired to conduct a interviews on behalf of the California Public Utilities Commission and with the cooperation of **[&UTILITY's].**

We are interviewing firms that participated in the 2004 and 2005 Large Standard Performance Contract program to discuss a number of topics about the program. We **[have already visited/will also be visiting]** your site to get information on the measures installed. This call is to follow up to gain information on the decision making process. **[If available: One of our engineers spoke to [Onsite Interviewee Name] on [date of onsite]**.]

Your input to this research is extremely important. The interview will take ***approximately 30 minutes*** and any information that is provided will remain strictly confidential. We will not identify or attribute any of your comments or organization information. Is this a good time, or can we schedule a convenient time in the next couple of days to talk?

IF HESITANT: It is important that we speak with the same customers who participated in the first phase of the evaluation to be able to match the data collected onsite with the information we will request today. Your input to this survey is very important for ensuring the long-term success of these programs. Without input from the participants, we will have difficulty conducting a fair and complete evaluation of the program.

Thank you for taking part in this survey. The major purposes of this study are

(1) to obtain feedback on the design and administrative aspects of the program, and
(2) to understand the characteristics of participants in the program and the types of activity the program has generated. This interview is focused on experiences with the program to date.

[If they request a contact at their local utility, the following are the appropriate MAE representatives, not the program managers]

PGE	Rafael Friedmann	415-972-5799
SCE	Pierre Landry	626-812-7528
SDGE	Brenda Gettig	858-654-8755
CPUC	Peter Lai	213-576-7087

ESTABLISHMENT CHARACTERISTICS

[ONLY ASK IF HAVE NOT ALREADY BEEN ANSWERED IN AN ONSITE INTERVIEW.]
I'd like to ask you a few questions about your organization.

EC2. [IF SINGLE-SITE PARTICIPANT ASK]

Approximately how large is **your organization's** space in this facility?

[ELSE IF MULTI-SITE ASK] What is the average size of your organization's space among participating facilities? ___________sq. ft.
CODE 88 FOR DON'T KNOW; 99 FOR REFUSED, ROUGH ESTIMATE IS OK

EC3. How many employees are at this facility/ these participating sites?

Number of employees .... #___________
Don't Know 88
Refused 99

EC1. What is the primary business of the company/organization?

[CHECK APPROPRIATE CODE] __ Comm __ Ind __Inst __ Agric __ Other

EC1a. Description: [ENTER VERBATIM]_______________________________________

RESPONDENT INFORMATION

[ONLY ASK IF HAVE NOT ALREADY BEEN ANSWERED AT ONSITE INTERVIEW.]

RI1. First, I'd like to confirm the following information regarding your application.

RI1m. Could you please describe your role (regarding your firm's participation in the SPC Program)?

____

____

RI2. How many applications did you submit under the **&PROG_YEAR** SPC Program?
a.__________

b. Are any still active (in implementation stage, or waiting for final payments)?

Yes 1
No 2
Don't Know 88
Refused 99

c. If so, what stage are they in?__________________________________

RI3. Were any of your applications cancelled?

Yes 1
No 2
Don't Know 88
Refused 99

b. **If any cancelled probe reason(s)**

____

____

____

ASK IF SELF-SPONSOR ASK RI4, ELSE IF EESP SPONSORED ASK RI6,
(IF COMBO ASK SERIES)

RI4. According to our records, you are your own sponsor for your **&PROG_YEAR** SPC project(s). Is this information correct?

Yes .... 1 SKIP TO PE1a
No, information appears incorrect .... 2 ASK RI7
Don't Know 88
Refused 99

RI6. The energy services firm that sponsored your SPC program application is**:**
&SPONSOR/FIRM [FROM DATABASE]
Is this information correct?

Yes .... 1 SKIP TO EC1
No... 2
Don't Know **[END]** 88
Refused **[END]** 99

RI7. What is the correct name of your sponsor?:________________________

THIRD-PARTY FIRMS

[ONLY ASK IF HAVE NOT ALREADY BEEN ANSWERED IN AN ONSITE INTERVIEW.]
ASK IF SELF-SPONSOR; ELSE SKIP TO NEXT SECTION

PE1a. Have you received or are you receiving assistance from third party firms to plan and/or implement the **&PROG_YEAR** SPC project?

Yes 1
No...(SKIP TO NEXT SECTION)…2
Don't Know 88
Refused 99

PE1b. Could you please specify the Name of the firm(s)

Primary Firm 1______________________ Secondary Firm 2_____________________

PE1c. And what role did they play in your decision to implement the project? (how significant were they in your decision to do the project?) Did they provide… [select one]

Sponsorship of project application... 1
Significant decision-making assistance
(e.g. advice on design, specification)....................................... 2
Only limited assistance (e.g. only installation of equipment) 3
Don't Know 88
Refused 99

Notes: ____

____

____

PE2. For the SPC application that you self-sponsored, who prepared the energy savings calculations for your application?

You personally 1
Someone else in your organization (specify) __________ 2
The equipment vendor.......... 3
The energy efficiency services provider 4
An outside engineer or consultant 5
Someone else (specify) __________ 6
Combination of the above (explain) __________ 7
Don't Know 88
Refused 99

IF PE1c IS 1OR 2 ASK ALL THIRD PARTY RELATED QUESTIONS. ELSE IF EESP SPONSORED, ALSO ASK ALL THIRD PARTY RELATED QUESTIONS.

SPC PARTICIPATION - ID/CONFIRM MEASURES

DISCUSS WITH INTERVIEWEE THE MEASURES YOU ARE GOING TO ASK QUESTIONS ABOUT AS PER THE MEASURES INVESTIGATED FOR IMPACT EVALUATION. FIRST PRIORITY IS TO CONDUCT THE NET-TO-GROSS BATTERY FOCUSED ON THE END USE PROJECTS SELECTED AS "PRIMARY" FOR THE ON-SITE IMPACT EVALUATION.

[DETERMINE WHETHER THEY OR SOMEONE ELSE IS THE MORE APPROPRIATE PERSON TO ANSWER THE QUESTIONS. IF NECESSARY, CONDUCT ADDITIONAL INTERVIEWS WITH OTHERS TO ACCURATELY ANSWER THE QUESTIONS ON THE FOLLOWING PAGES.]

Sample Text: My understanding that you are doing [End Use/Measure X] and [End Use/Measure Y], is that correct?

List Measures by type, Describe as Necessary. Or attach and reference sheet with measures currently tracked in program database. [MEASURE DETAIL TO BE PROVIDED BY ON-SITE TEAM]
1.
2.
3.
4.

RI8a. Are any of the **&PROG_YEAR** SPC measures still waiting to be installed?

Yes 1
No... 2
Don't Know 88
Refused 99

RI8b. If any not yet installed, probe reason(s)

____

____

PROGRAM-RELATED DECISION MAKING SECTION - NET-TO-GROSS

[**INFORM THE INTERVIEWEE THAT THE FOLLOWING QUESTIONS PERTAIN TO <u>THE PRIMARY MEASURE OR END USE</u> FOR THE ENERGY EFFICIENCY EQUIPMENT INSTALLED AS PART OF THE 2004 or 2005 SPC PROGRAM. REMIND AS NEEDED WHICH MEASURE(S) YOU ARE ADDRESSING. <u>ASK IF THE RESPONSES VARY BY MEASURE OR END USE</u> TYPE [ENTER AS VERBATIM in PD1a1].**

PD1a Why did you decide to install **&MEASURE_PRIMARY ?** What other reasons? [DO NOT READ; check all that apply]

To replace old or outdated equipment 1
To allow remodeling, build-out, or expansion 2
To gain more control over how the equipment was used. 3
To improve measure performance... 4
To get a rebate from the program.. 5
To protect the environment... 6
To reduce energy costs 7
To reduce energy demand/likelihood of blackouts....................... 8
To respond to the energy crisis 9
To acquire the latest technology.. 10
Refused 88
Don't Know 99

PD1a1. Describe: ____

PD1b. How old was the equipment that was removed and replaced through the **&PROG_YEAR** SPC program?

Record Age... 66
No removed equipment – only added equipment 78
Don't Know 88
Refused 99

If PD1b=78 then go to PD2

PD1c Which of the following statements best describes the performance and operating condition of the equipment you replaced as part of the **&PROG_YEAR** program?

Existing equipment was fully functional 1
Existing equipment was fully functioning, but with significant problems.. 2
Or, existing equipment had failed or did not function.................... 3
Not applicable, ancillary equipment (VSD, EMS, controls, etc.)….4
Refused 88
Don't Know 99
Other. 77

PD1c1. Other - Describe:

____

____

PD2 If this is the FIRST TIME you're installing **&MEASURE_PRIMARY**, where did you first hear about it? [READ ONLY AS NEEDED]

Energy Audit from Utility .... 1 SKIP to PP1
Contractor.. 2 SKIP to PD2b
Architect / Engineer .... 3 SKIP to PD2b
Equipment Vendor.. 4 SKIP to PD2b
PG&E representative or program literature .... 5a SKIP to PP1
SCE representative or program literature .... 5b SKIP to PP1
SDG&E representative or program literature .... 5c SKIP to PP1
Other non-utility literature, including trade publications .... 6 SKIP to PP1
Self-knowledge / Education .... 7 SKIP to PP1
Business colleague / Professional association / Trade show........ 8 SKIP to PP1
From parent company .... 9 SKIP to PP1
Previous installation.. 10 SKIP to PP1
Energy Services Company,
often referred to as ESCOs (performance contract).............. 11 SKIP to PD2b
An unregulated company that provides electricity supply .... 12 SKIP to PP1
Energy Efficiency Program (non-utility) .... 13 SKIP to PP1
THIS WAS NOT THE FIRST TIME installing this measure…..14 SKIP to PP1
OTHER 77 PD2a
Refused .... 88 SKIP to PP1
Don't know.. 99 SKIP to PP1

PD2a. SPECIFY – OTHER [OK TO PUT COMPANY NAME]:

____

PD2b. Was this the same organization that sponsored your application, or the third party that provided assistance in preparing your application ?

Yes 1
No... 2
Refused 88
Don't know 99

PP1. Before participating in the **&PROG_YEAR** SPC program, had you ever purchased **&MEASURE_PRIMARY** or other high efficiency **&END_USE** measures for other buildings that you own or manage? (NOTE: SELECT 1 *and* 2 IF BOTH APPLY)

Yes, installed **&MEASURE_PRIMARY** previously 1
Yes, installed other **&END_USE** measures previously................. 2
No... 3 SKIP TO AD1
Refused .... 88 SKIP TO AD1
Don't know .... 99 SKIP TO AD1

PP3. Did you receive a rebate or financial incentive for this prior installation?

Yes, all installations were rebated 1
Yes, some installations were rebated.. 2
No... 3 SKIP TO PP7
Refused .... 88 SKIP TO PP7
Don't know .... 99 SKIP TO PP7

PP5. What company or organization provided the financial incentive(s)?

____

PP7. When did this installation occur? (NOTE: OK TO RECORD NUMBER OF YEARS AGO)

____

ASK AD1 IF THERE IS A RECORD OF PARTICIPANT HAVING A UTILITY ONSITE AUDIT; ELSE ASK AD10

AD1. Do you recall an **&UTILITY** representative visiting your facility and completing an energy survey on or about **&SURV_DATE**? [IF NEEDED: this survey involved an auditor coming to you facility and examining your equipment and asking questions about your energy use and your equipment. The auditor would have left energy saving information at the time of the audit and/or mailed you a **written report** with energy saving recommendations. Do you remember this on-site survey?]

Yes ....1 SKIP TO AD15
No... 2
Refused 88
Don't know 99

ASK IF WE HAVE NO RECORD OF AUDIT

AD10. Have you had an **&UTILITY** energy audit? This is where an auditor comes out to the facility, examines your equipment, and asks questions about your energy use and your equipment. The auditor would have left energy saving information at the time of the audit and/or mailed you a **written report** with energy saving recommendations.

Yes 1
No .... 2 SKIP TO PD3
Refused 88
Don't know 99

AD10a. In what year and month did your company have this **&UTILITY** Energy Audit? (If cannot recall month ask for season)

Record Year and Month________________________..... 77
Refused.......... 88
Don't Know 99

AD10b. (If necessary) Was this Energy Audit performed before or after you decided to install **&MEASURE_PRIMARY**?

Before 1
After 2
Refused 88
Don't Know 99

AD15. Was **&MEASURE_PRIMARY** one of the recommendations made on the **&SURV_TYPE** audit?

Yes 1
No 2
Refused 88
Don't know 99

ADN1. Regarding the **&MEASURE_PRIMARY** you installed, on a scale of 1-10, with 1 being *NOT* Influential and 10 being *VERY* Influential, how much did the **&SURV_TYPE** audit influence you to install this equipment?

Rating from 1 to 10: ________________________
Refused.......... 88
Don't Know 99

ADN3. If you had not had the **&SURV_TYPE** Audit, how likely is it your company would have installed the same **&MEASURE_PRIMARY?** Would you say…

Very likely 1
Somewhat Likely 2
Not at all likely 3
Refused 88
Don't know 99

ADN5 Consider the equipment you would likely have installed if you had not had the **&SURVTYPE** audit, would this equipment have been……

Less efficient than the equipment that was actually installed though the SPC Program.. 1
Standard efficiency equipment... 2
The same high efficiency equipment that was installed through the SPC Program.. 3
Not applicable for measure (e.g. VSD) 4
Refused 88
Don't know.. 99

ADN9 Did the **&SURVTYPE** audit affect the timing of your investment in **&MEASURE_PRIMARY**? That is, if you had not had **&SURVTYPE** audit would you have installed **&MEASURE_PRIMARY**…[READ OPTIONS]

At the same time.. 1
Within 1 Year, or.. 2
More than 1 year later?.. 3
Never….. 4
Refused….. 88
Don't Know …... 99

PD3 How did you first learn of the SPC Program? [DONT READ CHOICES; PROBE IF SAME SOURCE AS PD2] CIRCLE CLOSEST CATEGORY

Energy Audit from Utility ....1 SKIP to AL1
Contractor...2 SKIP to PD3b
Architect / Engineer ....3 SKIP to PD3b
Equipment Vendor..4 SKIP to PD3b
PG&E representative or program literature .... 5a SKIP to AL1
SCE representative or program literature .... 5b SKIP to AL1
SDG&E representative or program literature ....5c SKIP to AL1
Other non-utility literature, including trade publications .... 6 SKIP to AL1
Self-knowledge / Education .... 7 SKIP to AL1
Business colleague / Professional association / Trade show...... 8 SKIP to AL1
From parent company .... 9 SKIP to AL1
Previous installation.. 10 SKIP to AL1
Energy Services Company,
often referred to as ESCOs (performance contract)............. 11 SKIP to PD3b
An unregulated company that provides electricity supply .... 12 SKIP to AL1
Energy Efficiency Program (non-utility) .... 13 SKIP to AL1
OTHER 77 PD3a
Refused .... 88 SKIP to AL1
Don't know.. 99 SKIP to AL1

PD3a. SPECIFY – OTHER [OK TO PUT COMPANY NAME]:

____

PD3b. Was this the same organization that sponsored your application, or the third party that provided assistance in preparing your application ?

Yes 1
No... 2
Refused 88
Don't know 99

Ask if confirmed or self-report Audit participant (that is, AD1=yes or AD3a=yes or AD5=yes or AD10=yes) ELSE SKIP TO R6

AI1. Did the **&SURV_TYPE** Audit inform you of the SPC program?

Yes 1
No... 2
Refused 88
Don't know 99

R6. Did you hear about the financial assistance available from the SPC program **BEFORE** or **AFTER** you began to actually look at or collect information about the **&MEASURE_PRIMARY**? Was it …

BEFORE you first looked at installing the equipment 1
SAME TIME.. 2
AFTER had begun researching the equipment,
but before final decision... .3
AFTER had decided to install the equipment.............................. 4
Refused 88
Don't know... 99

PD4c. Overall, Which of the following best describes the process by which <u>you decided to install</u> the **&MEASURE_PRIMARY?**

Developed the idea ourselves and decided solely on our own to
pursue installation.. 1

Measure was previously identified in the **&SURV_TYPE** Audit,
but we were waiting for financial assistance to pursue it 2

Developed the idea on our own, but were convinced
by a third party to pursue installation 3

Received the idea from a third-party and were also
convinced by this party to pursue installation 4

Received the idea from a third-party but decided on
our own to pursue installation... 5

Other 77 PD4c1
Refused 88
Don't know... 99

PD4c1. Describe – Other / Record any Explanatory comments:

____

____

REMIND AS NEEDED WHICH MEASURE(S) YOU ARE ADDRESSING.
IF SELF-SPONSOR DOING ALL WORK IN_HOUSE (see Page 5), SKIP TO PD6c,

PD4d. Who initiated contact? Did &**SPONSOR/FIRM** approach you or did you approach them to discuss installing the ***&MEASURE_PRIMARY?***

Customer initiated contact 1
EESP / 3rd Party initiated contact.. 2
Other 77 PD4d1
Refused 88
Don't know 99

PD4d1. Other, Describe_____________________________________

[RECORD PD6a and PD6b BY MEASURE OR END USE IF NEEDED]

PD6a. How significant was the overall value of the services provided by **&SPONSOR/FIRM** in influencing your decision to install the **&MEASURE_PRIMARY (or end use)**? Would you say the value of their services was very significant, somewhat significant, somewhat insignificant or very insignificant?

Very Significant.. 1
Somewhat Significant 2
Somewhat Insignificant... 3
Very Insignificant 4
Refused 88
Don't know 99

PD6b. Please describe the specific ways in which &**SPONSOR/FIRM** contributed, if at all, to your decision to install the **&MEASURE PRIMARY (or end use)**?

____

____

PD6c. How significant was the SPC program and the financial incentive in influencing your decision to install the **&MEASURE_PRIMARY (or end use)**? Would you say the program's financial incentive was:

Very Significant.. 1
Somewhat Significant 2
Somewhat Insignificant... 3
Very Insignificant 4
Refused 88
Don't know 99

PD6d. [Please explain, include any payback information you have]

____

____

REMIND AS NEEDED WHICH MEASURE(S) YOU ARE ADDRESSING.

PD7. Without the SPC program, including the SPC incentive **and** [**READ NEXT CLAUSE FOR CUSTS WORKING WITH 3rd PARTY FIRMS**:] the contribution from **&SPONSOR/FIRM** how likely is it you would have installed the **MEASURE_PRIMARY**? Would you say…

Definitely would NOT have installed 1
Probably would NOT have installed.. 2
Probably would have installed 3
Definitely would have installed.. .4
Refused 88
Don't know.. 99

PD8 Without the SPC program, including the incentive [**READ NEXT CLAUSE FOR CUSTS WORKING WITH 3rd PARTY FIRMS**:] **and** the contribution from **&SPONSOR/FIRM**, how likely is it that the equipment you purchased would have been *as energy efficient* as the equipment you did install? Would you say . . .

Probably NOT as efficient..……………………………………….…..1
Probably as efficient……………………………………………..………2 Skip to PDQ
Not applicable for measure (e.g. VSD)……………………..………3 Skip to PD9b
Would not have installed any equipment…………………………4 Skip to PD9b
Refused 88
Don't know.. 99

ASK IF PD8=1

PD9 Without the SPC program, **[READ NEXT CLAUSE FOR CUSTS WORKING WITH 3rd PARTY FIRMS**:] including both the incentive **and** the contribution from **&SPONSOR/FIRM**, what type of equipment would you have most likely installed? Would you say.

Standard efficiency equipment.. 1
Equipment with above-standard efficiency but with lower efficiency than the equipment that was actually installed 2
Would not have installed anything…………………………………..3 SKIP TO PD9b
Refused 88
Don't know.. 99

ASK IF APPLICABLE [I.E. IF MEASURE COULD BE PHASED IN OR SCALED DOWN]

PDQ**.** Without the SPC program, how likely is it that you would have purchased fewer/ smaller / less of **&MEASURE_PRIMARY**? (e.g. fewer sites, fewer units, smaller capacity, etc.) Would you say. . .

Very likely.. 1
Somewhat Likely 2
Somewhat Unlikely ....3 SKIP TO PD9b
Very unlikely ....4 SKIP TO PD9b
Refused 88
Don't know.. 99

IF PDQ is a 1 or 2

PDQa. Can you please describe how the quantity of **&MEASURE_PRIMARY** might have been different if you had not participated in the SPC program?

____

____

PD9b. Would you have installed the **&MEASURE_PRIMARY** at a later date without the assistance of a sponsor or the SPC program incentive? (How many years later?) **[If over 1 year later, probe for best estimate of how many years later.]**

Same time/ within 6 months of when it actually was installed?..... 1
6 months to one year later?.. 2
within two years later?.. 3
within three years later? ….. 4
within four years later? ….. 5
within five years later? ….. 6
Other (# of years)______________________________.................. 7
Never….. 8
Refused 88
Don't know.. 99

ASK IF Audit participant

CMP1. Thinking about the different ways in which the Energy Audit and the SPC program may have influenced your equipment purchase decisions, which program would you say had more influence on your decision to install **&PRIMARY_MEASURE**, - the **&SURVTYPE** Audit Program or the SPC program? **[DO NOT READ]**

Audit 1
SPC 2
Both had equal influence 3
Neither had any influence ….. 4
Other Specify ____ 77
Refused 88
Don't know.. 99

SPILLOVER

Now I would like to ask you a few questions about other energy efficiency measures you may have installed since deciding to participate in the **&PROG_YEAR** SPC Program for the **[Measures].**

R1 Have you installed any other high efficiency equipment since you participated in the **&PROG_YEAR** SPC Program ? If so, was the new equipment part of an **&UTILITY** program or any other utility or government energy efficiency incentive program?

YES, we installed additional high efficiency equipment without seeking incentives.. 1 SKIP TO TO R5

YES, we installed additional high efficiency equipment, but we only applied for incentives for **SOME** projects……….2a

YES, we installed additional high efficiency equipment, and we applied for incentives for **ALL** projects…………2b

NO, we have further projects............................ 3 SKIP TO NS1
REFUSED... 88 SKIP TO NS1
DON'T KNOW.. 99 SKIP TO NS1

R1a For the additional high efficiency equipment you installed **WITH INCENTIVES**, to which program or organization did you apply for incentives ? (SPC, Express or other)

____

____

IF R1 = 2b SKIP to ASPO

[ASK IF R1 = 1 or 2a ELSE SKIP to ASPO] –

NOTE: Questions R5, R2 through R4a refers to additional EE measures that DID NOT receive any type of incentives

R5 For the additional high efficiency equipment you installed **WITHOUT** any type of program incentive, why wasn't this equipment purchase through a retrofit or incentive program?

____

____

____

R2 What type(s) of measures were added, and how many?

____

____

____

R3 [If unclear, ask.] Was this additional equipment you installed high efficiency? Was it more efficient than the standard efficiency of equipment available on the market ? (Probe as necessary to ensure equipment was high efficiency?)

YES, high efficiency	1	
NO, standard efficiency	2	SKIP TO NS1
REFUSED	88	SKIP TO NS1
DON'T KNOW	99	SKIP TO NS1

R4 How significant was your experience in the **&PROG_YEAR** SPC program in your decision to install the additional energy efficiency equipment (that did not receive incentives or was not part of the SPC or any other program)?

[**CLARIFY PROGRAM EXPERIENCE REFERS TO ALL FEATURES INCLUDING FORMER INCENTIVES, EXPERIENCE WITH EESPs THAT WOULD NOT HAVE OCCURRED OTHERWISE, ETC**.]

Very significant	1
Somewhat significant	2
Somewhat insignificant	3
Very insignificant	4
Refused	88
Don't know	99

R4a. And why is that? (Point here is to try to establish whether there is any causal relationship between experience in the program and installation of additional measures outside of programs.)

____

____

____

ASK IF Audit participant ELSE SKIP TO NS1

ASP0. Was/were the(se) measures among the recommendations made in the **&SURV_TYPE** Energy Audit?

Yes	1	
No	2	SKIP TO R5
Refused	88	SKIP TO R5
Don't Know	99	SKIP TO R5

ASP1. Regarding this additional equipment you installed outside the SPC program, on a scale of 1-10, with 1 being *NOT* Influential and 10 being *VERY* Influential, how much did the **&SURV_TYPE** Audit influence you to install this equipment?

Value from 1 to 10______________________________

Refused	88
Don't know	99

ASP3. If you had not had the **&SURVTYPE** Audit, how likely is it your company would have installed this equipment? Would you say…

Very likely.. 1
Somewhat Likely 2
Not at all likely ....3 SKIP to R5
Refused 88
Don't know.. 99

ASP5 Consider the equipment you would likely have installed if you had not had the **SURVTYPE** audit, would this equipment have been……

Less efficient (than the equipment that you did install). 1
Standard efficiency or the least expensive alternative available... 2
The same efficiency... 3
Not applicable for measure (e.g. VSD) ……………………………..4
Refused 88
Don't know.. 99

ASP9 If you had not had &**SURVTYPE** Audit would you have installed this new equipment…

At the same time...…1
Within 1 Year, or.. 2
More than 1 Year later?... .3
Refused 88
Don't know.. 99

NS1 Do you plan to implement any additional energy efficiency measures elsewhere at this facility or at other facilities of your organization ***in the future***? <u>If so, are these planned measures a result of your participation in the</u> **&PROG_YEAR** <u>SPC program</u>?

YES, plans more measures as a result of participation 1a

YES, plans more measures, ***partially*** a result of participation 1b

YES, plans more measures, but ***not*** as a result of participation.. 2

NO, no plans for more measures.. 3 SKIP TO NEB1
Refused .... 88 SKIP TO NEB1
Don't Know .... 99 SKIP TO NEB1

NS2 PROBE: How has SPC program participation affected your plans? Please describe which measures, how many, and why?

____

____

____

NS3 And how significant was your **&PROG_YEAR** SPC program experience in your plans to pursue additional energy efficiency measures? [**PROGRAM EXPERIENCE INCLUDES INCENTIVES, EXPERIENCE WITH EESPs / 3rd PARTY, THAT WOULD NOT HAVE OCCURRED OTHERWISE, ETC**.]

Very significant 1
Somewhat significant 2
Somewhat insignificant 3
Very insignificant 4
Refused 88
Don't know 99

NS4 Do you plan to apply for program incentives (SPC or Express or other) for assistance in installing this additional energy efficient equipment?

Yes, Already have 1
Yes, Probably 2
Undecided 3
No 4
Refused 88
Don't know 99

NON-ENERGY BENEFITS

Next, I'd like to discuss any changes resulting from the **&MEASURE_PRIMARY** from **&PROG_YEAR** that are not directly related to energy use.

NEB1. Has the new equipment affected the working environment for on-site personnel in positive or negative ways? (Examples: increased comfort with lighting levels or climate control, reduced occupational hazards, etc)

Project has had positive impacts on site Personnel 1
Project has had negative impacts on site Personnel 2
Project has had positive & negative impacts on site Personnel 3
Project has not affected site Personnel .... 4 SKIP TO NEB2
Refused .... 88 SKIP TO NEB2
Don't Know .... 99 SKIP TO NEB2

NEB1a. What were these impacts on site personnel? [DO NOT READ. RECORD VERBATIM AND RECORD CATEGORY IF APPLICABLE]

Comfort levels of personnel (e.g. temperatures, lighting) 1
Productivity of personnel 2
Intensity of operational tasks by site personnel 3
Intensity of maintenance tasks by site personnel 4
Refused 88
Don't Know 99

Record Response:

____

____

NEB2. Has the new equipment had any positive or negative effects on production processes at the project site? ? [DO NOT READ RESPONSES / QUESTION MAY BE N/A IF NEB1a=2]

Project has had positive impacts on production........................... 1
Project has had negative impacts on production 2
Project has had both positive & negative impacts on production.. 3
Project has not affected production ....4 SKIP TO NEB4
Refused ....88 SKIP TO NEB4
Don't Know ....99 SKIP TO NEB4

NEB2a. What were the specific impacts on production processes?

____

____

NEB4. Were there any other positive or negative changes resulting from this project that extend beyond changes affecting energy consumption, site personnel or production processes (e.g. increased security, higher quality services, etc.) ?

____

____

NEB5. Please consider all of the impacts of project NOT directly related to energy consumption. In terms of impacting your firms operations or bottom line, how significant were these non-energy project Impacts?

Very Significant 1
Somewhat significant.. 2
Somewhat insignificant... 3
Very insignificant 4
Refused 88
Don't Know 99

NEB6. Did you encounter any unforeseen project costs? – Were there unforeseen costs associated with project implementation or ongoing operations?

Unforeseen costs of project implementation................................ 1
Unforeseen ongoing operational costs 2
No unforeseen Costs...3 Skip to P2
Other unforeseen costs (Specify in NB5a) 77
Refused 88
Don't Know 99

NEB6a. Can you describe these unforeseen costs?

____

____

NEB6b. Can you provide any numerical estimate of what those costs might be ?

____

____

SPC PROCESS-RELATED EXPERIENCE

P2 What do you like about the **&PROG_YEAR** SPC program? (what do you view as the primary strengths?) [Note any differences mentioned across program years]

____

____

P3 What don't you like about the program? (what do you view as the primary features that need to be improved?)

____

____

P4 What do you think about the current incentive structure of the program? (Such as the payout schedule, end use incentive levels, cap on percent of project costs paid by incentives, incentive levels for measured vs. calculated savings)

____

____

P5a Please describe your experiences with the payment process for your SPC projects. Are payment procedures and timing of payments reasonable?

Yes 1
No 2
Refused 88
Don't know.. 99

P5b. Please explain: ____

____

____

P6 Did you use any of the program tools and supporting materials, such as the savings calculator or the website?

P6a. Used calculator?

Yes 1
No ....2Skip to P6e
Refused ....88 Skip to P6e
Don't Know ....99 Skip to P6e

P6b. Used website?

Yes 1
No ....2 Skip to P6e
Refused ....88 Skip to P6e
Don't Know 99 Skip to P6e

Ask if P6a or P6b =1 (yes)
P6c. Was/Were it/they helpful?

Yes, very helpful 1
Yes, Somewhat 2
No, did not help me 3
No, did not use 4
Refused 88
Don't Know 99

P6d. Please explain:

____

____

____

P6e. Did you receive assistance from **[&UTILITY**] staff with performing energy savings calculations?

Yes 1
No, but requested assistance 2
No, but did not request assistance 3
Refused 88
Don't know... 99

2004/2005 CALCULATED SAVINGS EXPERIENCE – 2 questions (MV2,3)

MV2 When you first decided to implement the projects included in the **&PROG_YEAR** SPC, how uncertain, if at all, would you say you were about the estimated ***energy*** savings for these projects? Would you say:

Extremely uncertain... 1
Somewhat uncertain... 2
Somewhat certain... 3
Extremely certain.. 4
Refused 88
Don't know... 99

MV2a Please elaborate:

[IF APPLICABLE – ALSO NOTE DIFFERENCES BY MEASURE OR ENDUSE]

____

____

ASK ONLY IF EESP SPONSORED, ELSE SKIP TO P6f

MV3 And did the fact that the **&UTILITY** SPC Program approved the EESP application increase your confidence in the EESP's estimates of savings?

Yes, greatly increased confidence.. 1
Yes, somewhat increased confidence 2
No, no effect on confidence.. 3
Refused 88
Don't know... 99

ASK IF SELF_SPONSOR

P6f. Did you receive assistance from **[&UTILITY]** staff with filling out SPC project applications?

Yes 1
No, but requested assistance 2
No, but did not request assistance 3
Refused 88
Don't know... 99

P7a. How would you say that the overall program experience with **[&UTILITY]** staff has been to date? Would you say…

Excellent 1
Good 2
Acceptable, about what expected 3
Somewhat poor 4
Very Poor 5
No contact with utility 6
Refused 88
Don't Know 99

P7b. Why do you say that? [RECORD VERBATIM]

____

____

P7c. What, if any other types of assistance that the **[&UTILITY]** staff could provide that would be useful to you? [What else could they have done?]

____

____

P8. Did you work directly with one of the **&UTILITYs'** technical support contractors during your project? (Clarify if necessary, the firms contracted with the utility to review applications, estimate savings, assist with M&V planning, and perform site visits. Nexant SBW Engineering or ASW Engineering (Subcontractors to Utility); SDG&E used internal staff only)

Yes 1
No 2
Refused 88
Don't Know 99

P9a. How would you say that your experience with the **[&UTILITY]** technical assistance contractor has been to date? Would you say…

Excellent 1
Good 2
Acceptable, about what expected 3
Somewhat poor 4
Very Poor 5
No contact with technical support contractor 6
Refused 88
Don't Know 99

P9b. Why do you say that? [RECORD VERBATIM]

____

____

P10a. If you have participated in the SPC program with more than one utility, did you notice any differences in how the program was designed or administered by those utilities?

Yes ....1 Ask P10b
No (no difference between utilities) ....2 SKIP TO P11
Only had experience with one utility ....3 SKIP TO P11
Refused ....88 SKIP TO P11
Don't Know ....99 SKIP TO P11

P10b. Please elaborate [make sure to specify what utilities are discussed and assign the comments correspondingly.]

____

____

P11. How would you rate your OVERALL satisfaction with the **&PROG_YEAR** SPC program? Would you say that you are:

Very Satisfied 1
Somewhat Satisfied.. 2
Neither Satisfied nor Dissatisfied.......................... 3
Somewhat Dissatisfied 4
Very Dissatisfied... 5
No contact with technical support contractor 6
Refused 88
Don't know.. 99

ENERGY-RELATED DECISION MAKING

Now I'd like to ask a final question about how your organization generally makes energy-related decisions.

DM3a As a result of your participation in the **&PROG_YEAR** SPC, have you made any changes in the ways in which your organization makes decisions about whether to implement energy-efficiency projects? [PROVIDE EXAMPLES such as mandatory EE specification policy, internal reward system for reducing energy costs, increased payback threshold, etc.]

Yes 1
No.. 2
Refused 88
Don't Know 99

DM3b Please Describe. **[RECORD VERBATIM]**

____

____

____

CLOSING

DM4 Are there any other positive or negative effects of your participation in the **&PROG_YEAR** SPC that you would like to mention that we have not asked about?

____

____

____

____

DM5 What suggestions do you have for improving the SPC program?

____

____

____

____

THANK YOU FOR YOUR PARTICIPATION IN THIS STUDY.

OTHER INTERVIEWER NOTES :

(Please briefly describe your overall impression of the customer's decision-making process. Include any comments on the net-to-gross story, program effects, other input, not clear in the structured questions):

____

____

____

C.2

Final PY2004-05 SPC Participant EESP Interview Guide

FINAL PY2004-05 SPC Participant EESP Interview Guide

NAME	PHONE:
TITLE	FAX
COMPANY	E-MAIL
STREET ADDRESS	
CITY	INTERVIEWER
STATE	CALL DATES
ZIP	COMPLETE DATE

Hello, my name is ________, with Itron, an energy research firm, and I am calling on behalf of the California Public Utilities Commission and the program evaluation staff at the California Investor-owned Utilities. May I please speak with ______________?

[AFTER REACHING CORRECT CONTACT] We are conducting an evaluation study on behalf of the California Public Utilities Commission. We are contacting energy service companies who participated in California's Standard Performance Contract (SPC) program in the 2004-2005 program years. Your input to this research would be very valuable and, if possible, we would like to interview you. The interview will provide you with an opportunity to provide feedback on your experience with the 2004-2005 SPC program. The interview will take about 20 minutes, and any information that is provided during the interview will remain strictly confidential. We will not identify or attribute any of your comments or company information. Is this a good time, or can we schedule a convenient time in the next couple of days to talk?

[IF HESITANT:] Your input to this survey is very important for ensuring the long-term success of these programs. Without input from industry representatives such as you, we cannot guarantee that the program will receive a fair and complete evaluation.

[IF RELUCTANT BECAUSE THEY WERE A SURVEY RESPONDENT IN PREVIOUS YEARS]: Thank you very much we appreciate your prior participation in an SPC evaluation interview. However, the program has changed significantly over the past few years, as has the market environment in California, and it is critical that we obtain up-to-date information from participating firms on the program as implemented in 2004-2005. Your input is critical to this process.

[IF SCHEDULED:] Callback date/time:
Thank you for taking part in this survey. The major purposes of this study are to provide feedback to the utilities and CPUC on the design and administrative aspects of the program. This interview is focused on experiences with the program to date.

Utility Reference Numbers for Interviewees Wanting to Confirm

PGE	Rafael Friedman	415-972-5799
SCE	Pierre Landry	626-302-8288
SDG&E	Brenda Gettig	858-654-8755

I. BACKGROUND INFORMATION (fill out before starting interview)

I'd like to start by reviewing some of the information we have received from the California utilities on your participation in the 2004-05 nonresidential standard performance contract programs.

(POPULATE FROM DATABASES AHEAD OF TIME and CONFIRM/UPDATE WITH INTERVIEWEE)

A. Our records show that your firm sponsored 2004-05 SPC applications for projects with following customers:

____
____
____

B. Our records show your firm participated in the SPC Program as a project sponsor for a total of X applications for Y customers with the following utilities:

	# of Projects	# of customers
PG&E…………………………………………………………	A	D
SCE…………………………………………………………	B	E
SDG&E………………………………………………………	C	F

C. Does that sound correct?

D. IF NO, how many applications did your firm sponsor? An estimate would be fine.(ENTER) _______ For how many customers? An estimate would be fine.((ENTER) _________

E. In addition to the applications you sponsored, did you also work on SPC projects for which the customer was the sponsor of record? If yes, about how many projects? ___________

F. Which approach do you prefer: sponsoring the application or having the customer sponsor the application? Why? (probe for differences across utilities, types of projects.)

G. Has your preference for sponsoring the application or having the customer sponsor the application changed over the years? In what way, and why?

H. Has your company worked on SPC projects in 2006 or 2007, either as the project sponsor or on customer-sponsored applications? IF YES, about how many projects? ______

I. Why have you not worked on any SPC projects since 2004-2005?

II. FIRMOGRAPHICS

Now I have a few questions on the general characteristics of your company.

A. What type of energy services firm is your firm? Would you say:

[IMPORTANT: NOTE ANY UNIQUE "SELF-CLASSIFICATION" TERMS.]

1. **"Traditional" ESCO** *(predominantly performance based contracts)*
2. **Energy Efficiency Services Company** *(EESP, mostly efficiency services)*
3. **Retail Energy Service Co. (RESCO)** *(selling both energy commodity and efficiency services)*
4. **Architecture / Engineering / Design Engineering**
5. **Building Maintenance and Operations**
6. **Equipment Vendor/Distributor**
7. **Other** *(please describe)*

What are the primary products and service provided by your firm: ______________________________

____

Which of the following best describes the geographic focus of your operations?

1. Local – What area? ______________________
2. Regional – What area? ______________________
3. Statewide (California)
4. National
5. International

B. About how many years has your company been providing energy efficiency services in California?

____

C. Approximately how many full-time equivalent employees (FTEs) do you employ, including all in-house contractors?

___ # FTEs in California?

III. SPC PROCESS-RELATED INFORMATION

Next I am going to ask you a few questions about your firm's experience with the 2004-2005 SPC program, including your perspective on program changes, opinions on how savings and incentives are determined, and your overall satisfaction with the program experience.

A. Do you recall what changes were made to the SPC program in 2004-2005 compared to previous years? (IF NO, prompt with: more funds, 2 year program, Itemized/Express Efficiency savings, early replacement for HVAC and motors)

B. Overall, how did the changes from 2003 to 2004-2005 affect your participation in the SPC program?

C. Thinking about all your 2004-2005 SPC projects, about what percentage of projects had savings attribution based on:

Itemized savings (Express Measures)	___%
Calculated Savings (using SPC calculator)	___%
Calculated Savings (no calculator)	___%
Measured Savings	___% [IF >0% Ask Q. F]

D. Please describe your perspective on the use of the itemized savings and calculated savings approaches. What are the advantages and/or drawbacks of each approach based on your experience?

____

____

[IF USING MEASURED SAVINGS METHOD ASK E; IF PARTICIPATED BEFORE 2003 (BETWEEN 1998 & 2002) ASK F; ELSE SKIP TO G]

E. If applicable, please describe your experiences with the "measured savings" process for your 2004-05 projects.

F. If applicable, please describe your experience with any measured savings reports associated with projects your firm was associated with for program years 1998 to 2003.

G. **(ALL)** Please describe your experiences with the installation requirements and payment process for your 2004-2005 SPC projects. Are installation requirements and payment processes reasonable? Please explain.

H. **(IF INVOLVED IN MULTIPLE TERRITORIES)** In your experience, were there any differences in how the 04-05 program was implemented by different utilities? Please explain.

I. What do you think about the incentive structure of the 2004-2005 SPC Program with regard to the following:

End use incentive levels
Payout schedule
Payments for itemized, calculated, and measured savings
Incentive caps per site/company
Limitations on lighting retrofits

J. Please describe any other aspects of the Program that you think were better or worse in 04-05 than in prior years.

K. How would you rate your OVERALL satisfaction with the <u>2004-2005</u> SPC program? Would you say that you are:

1. Very Satisfied
2. Somewhat Satisfied
3. Neither Satisfied nor Dissatisfied
4. Somewhat Dissatisfied
5. Very Dissatisfied
6. Don't Know / Not Applicable

And why is that?____

L. How would you say that your experience with the UTILITIES administering the program has been to date? Would you say…

Excellent 1
Good..2
Acceptable, about what expected...3
Somewhat poor 4
Very Poor..5
DON’T KNOW/NOT APPLICABLE 99

Why do you say that? ____________________________________

[IF MORE THAN 1 UTILITY: Would you rate your experience differently for different utilities? How and why?] ________________________________

M. Did you work directly with one of the utilities' technical support contractors during your project? (Clarify if necessary, whether the firms contracted with the utility to review applications, estimate savings, assist with measured savings plans, and perform site visits.)

Yes 1
No 2
Don't Know/Refused 99
[IF YES, ASK NEXT, ELSE SKIP]

N. How was your experience with the TECHNICAL ASSISTANCE CONTRACTORS in 2004-05? Would you say it was…

Excellent 1
Good...2
Acceptable, about what expected...3
Somewhat poor 4
Very Poor...5
No contact with technical support contractor 6
DON'T KNOW/NOT APPLICABLE 99

Why do you say that? ____________________________________

[IF MORE THAN 1 CONTRACTOR: Would you rate your experience differently for different contractors? How and why?] ________________________ ____________

O. Did you use any of the SPC program tools and supporting materials, such as the savings calculator or the website?

Did you use the calculator?

Yes 1
No 2
Don't Know/Refused 99

Was the calculator helpful?

Yes, very helpful 1
Yes, Somewhat 2
No, did not help me...3
No, did not use 4
Don't Know/Refused 99

Please explain: ____

Did you use the website?

Yes 1
No 2

Don’t Know/Refused 99

Was it helpful?

Yes, very helpful 1
Yes, Somewhat 2
No, did not help me..3
No, did not use 4
Don’t Know/Refused 99

Please explain:_______________________________________

IV. SPC-RELATED MARKET AND PROGRAM EFFECTS

Now I have a couple of questions about how the SPC program has affected your firm’s business, if at all.

A. Please describe how you use the incentive funds you've received from the 2004-05 SPC program. Are the funds passed through to the customer, retained completely, or shared between your firm and the customer?

Passed through to completely to customer..1
Retained completely..2
Shared 3

B. What effect, if any, has your participation in the 2004-05 SPC had on your business? For example, has it led to any improvements in your firms’ efficiency-related business development, marketing approaches, costs of serving customers, or product and service offerings?

____

____

C. How important was the 2004-05 SPC program to the energy efficiency portion of your California business? Would you say…

1. Very Important
2. Somewhat Important
3. Not very important
4. Don't Know / Not Applicable

And why is that?

____

D. (IF PARTICIPATED BEFORE) Compared to previous years, would you say the importance of the 2004-05 SPC program to your business:

1. Increased
2. Decreased
3. Remained about the same

4. Don't Know / Not Applicable

E. Based upon your experiences, what do you view as the primary strengths and weaknesses of the 2004-2005 program.

Strengths:____
____
____

Weaknesses:____
____
____

F. In light of the California goal of capturing all cost-effective energy efficiency opportunities, do you have any recommendations on how the SPC program could be modified to capture additional energy savings (without paying more for measures that would be installed anyway)? (Probe if useful: Are there specific measures or technologies you can think of that typically have paybacks in the 3-5 year range but are often not installed or influenced by the program? What might the program do to help move customers to adopt these types of projects?)
____
____

V. NTG AND OTHER ISSUES

Now I have just a few more questions before we wrap up.

A. Thinking about your sales efforts with customers in California, how do you promote participation in the SPC?

B. Thinking about your sales efforts with customers in California, in what percentage of your sales situations do you promote participation in the SPC? __________%

C. ***[IF >0% and <100%]*** What criteria do you use to decide whether to promote participation in the SPC program?_______________________

D. Of all your 2004-05 SPC projects**,** what percentage do you think you would have been able to sell without the SPC incentive payments?____________ (# or %) And why is that? (Note if project size would have been reduced or if changes by year)

____

E. (EESPs FOR SAMPLE CUSTOMERS ONLY) Thinking specifically about [PROJECT A] for [CUSTOMER A], what do you think that customer would have done if the SPC incentive payments had not been available?

1. Would have done the project anyway
2. Project would have been reduced in scope
3. Would not have done the project
4. Would have done the project, but in the future

   If so, in how many years? (range) _____________

F. Are you familiar with the utilities' nonresidential audit program? Yes ____No ____

Has your firm been involved in any SPC work that results from utility audits? If yes, please describe.
Do you have any suggestions for how to improve the audit programs or improve linkages with SPC and other incentive programs?

G. What other California utility programs did your firm participate in or sell through in 2004-05?

SPECIFY1: ______________________________

SPECIFY2: ______________________________

SPECIFY3: ______________________________

H. As part of our evaluation, we are also trying to identify and talk to companies who are in businesses like yours but who do not participate in the SPC program. Would you happen to know of any companies who are in the same market as yours but who did not work on SPC projects in 2004-2005?

____

VI. WRAP-UP

A. Finally, based on your experience with SPC or with other programs, do you have any other comments or suggestions for improving the SPC program?

____

That concludes the interview, thank you very, very much for your participation in this evaluation effort.

THE END

C.3

Telephone Survey – 2004/2005 SPC Study Nonparticipants

Final, July 16, 2007

Telephone Survey
2004/2005 SPC Study

Nonparticipants

Prepared for SCE

Prepared by
Itron Inc.

Interviewer ID ___ ___ ___

Survey Number ___ ___ ___ ___

CREATE VARIABLE UTILITY

SET VARIABLE UTILITY TO: PACIFIC GAS AND ELECTRIC COMPANY, SOUTHERN CALIFORNIA EDISON COMPANY, AND SAN DIEGO GAS AND ELECTRIC COMPANY, AS APPROPRIATE

REMINDER: **CHECK SAMPLE PULL AGAINST LIST OF SPC PROGRAM PARTICIPANTS, EXCLUDE PROGRAM PARTICIPANTS FROM SAMPLE**

INTRODUCTION

SCREEN1

[WHEN RECEPTIONIST ANSWERS]:

[LARGE COMPANY]: May I have Plant Engineering, please?

[SMALL COMPANY]: May I speak with the Facilities Manager, please?

[OTHER DEPARTMENTS TO ASK FOR]:

Maintenance	General Services
Operations (Manager)	Public Relations
Plant Services	Purchasing
Building Manager	Planning Department

LEAD IN

INTRO1

Hello, this is _______________________, calling from Itron on behalf of the California Public Utilities Commission and [UTILITY]. We are conducting a study on issues related to electricity and gas energy efficiency services in California. May I speak with the person in your organization who is responsible for energy-related decisions for your facilities, including the facility at [ADDRESS]?

[NOTE: INTERVIEWER SHOULD BE LOOKING FOR THE PERSON RESPONSIBLE FOR EQUIPMENT PURCHASES, ENERGY EFFICIENCY AND ENERGY SUPPLY AT **THIS** LOCATION. DO NOT RECORD INFORMATION FOR INDIVIDUAL AT SOME OTHER BUILDING OR LOCATION, EVEN IF BUILDING IS OWNED BY OFF-SITE MANAGER]

[IF NEEDED:] This is a fact-finding survey only – we are NOT interested in selling anything, and responses will not be connected with your firm in any way. The California Public Utilities Commission wants to better understand how businesses think about and manage their electricity and natural gas consumption. Your input is very important to the Commission.

1	Yes	INTRO2_2
2	Respondent not available now	CALL BACK
3	Respondent coming to phone	INTRO2_1
4	No such person	INTRO1A
88	Refused	INTRO1A

INTRO1A

[IF NO SUCH PERSON]: May I speak with the person in your organization who is responsible for decisions regarding construction, renovation, or operation of your physical facilities?

INTRO1B NAME OF CONTACT: ______________________________________

INTRO1C TITLE: ______________________________________

IF RESPONDENT IS NOT AVAILABLE, GET HIS/HER NAME AND TITLE; MAKE ARRANGEMENTS TO CALL LATER

INTRO2_1

WHEN RESPONDENT GETS ON THE LINE: Hello, this is _______________________, calling from Itron on behalf of the California Public Utilities Commission and [UTILITY]. We are conducting a study on issues related to energy services in California. Are you familiar with your organization's recent energy-related decisions such as those concerning equipment purchases, energy efficiency and energy supply?

1	Yes	INTRO3
2	No	INTRO2A

INTRO2_2

WHEN RESPONDENT GETS ON THE LINE: We are conducting a study on issues related to energy services in California. Are you familiar with your organization's recent energy-related decisions such as those concerning equipment purchases, energy efficiency and energy supply?

1	Yes	INTRO3
2	No	INTRO2A

INTRO2A

Who would be the best person in your organization to speak with about energy-related decisions for this facility? ____________________________________ ASK TO BE CONNECTED WITH THIS INDIVIDUAL.

INTRO2B

May I please speak with ___(insert from Intro2A)___________________

(IF CONTACT COMES TO PHONE, ASK INTRO2_1)

(IF CONTACT NOT AVAILABLE, SCHEDULE CALLBACK)

INTRO3

We are speaking with selected businesses and organizations to learn about their current energy practices and preferences. A group of energy policy makers will use information from this study to improve energy policies and programs for nonresidential customers. This interview should take about 15 minutes. Is this a good time for you or is there a better time I can call you back?

1	Yes	SC1

2	No, schedule callback	Call back
88	Refused	T&T

SC1. First, what is your job title? [DON'T READ] {1999, 2002}

1	Facilities Manager	EC1
2	Energy Manager	EC1
3	Other facilities management/maintenance position	EC1
4	Chief Financial Officer	EC1
5	Other financial/administrative position	EC1
6	Proprietor/Owner	EC1
7	President/CEO	EC1
SC1_8	Other (Specify)	EC1
88	Refused	EC1

FIRMOGRAPHIC CHARACTERISTICS

Now I'd like to ask a few quick questions about this facility. Unless otherwise stated, all questions pertain to THIS FACILITY [RESTATE FACILITY LOCATION IF NECESSARY].

EC1. What is the main activity performed at this location? {1999, 2002}
[FOCUS RESPONDENT ON SUCCINCT ANSWERS, E.G., MANUFACTURING, ADMINISTRATION, WAREHOUSING, RETAIL SALES, INDUSTRIAL PRODUCTION OF CHEMICALS, ETC.] [IF NECESSARY REFER TO ADDRESS OF FACILITY IN SAMPLE DATABASE]

1	Office	EC2
2	Retail (non-food)	EC2
3	College/university	EC2
4	School	EC2
5	Grocery store	EC2
6	Convenience store	EC2
7	Restaurant	EC2
8	Health care/hospital	EC2
9	Hotel or motel	EC2
10	Warehouse	EC2
11	Personal Service	EC2
12	Community Service/Church/Temple/Municipality	EC2

13	Industrial Electronic & Machinery	EC2
14	Industrial Mining, Metals, Stone, Glass, Concrete	EC2
15	Industrial Petroleum, Plastic, Rubber and Chemicals	EC2
16	Other Industrial	EC2
17	Agricultural	EC2
18	Condo Assoc/Apartment Mgmt	EC2
77	Other (SPECIFY)	EC2
88	Refused	EC2
99	Don't know	EC2

EC2. Approximately how many square feet does **your organization occupy in this facility?** {1999, 2002}

1	Less than 10,000 square feet	EC3
2	10,000 but less than 20,000 square feet	EC3
3	20,000 but less than 50,000 square feet	EC3
4	50,000 but less than 100,000 square feet	EC3
5	100,000 but less than 200,000 square feet	EC3
6	200,000 but less than 300,000 square feet	EC3
7	300,000 but less than 400,000 square feet	EC3
8	400,000 but less than 500,000 square feet	EC3
9	Over 500,000 square feet	EC3
10	Ag/Non-facility – Outdoors	EC3
88	Refused	EC3
99	Don't know	EC3

EC3. Does your organization..... {1999, 2002}

1	Own this space	EC5
2	Lease/Rent this space	EC4
3	Own a portion and lease the remainder	EC4
88	Refused	EC5
99	Don't know	EC5

EC4 Does your organization pay its own electric bill directly to [UTILITY] or is electricity provided under
your lease arrangement? {1999, 2002}

1	Pay own electric bill	EC5

2	Part of the lease arrangement	EC6
88	Refused	EC6
99	Don't know	EC6

EC5 What is your best estimate of your **AVERAGE MONTHLY** electric bill? {1999, 2002}

1	Less than 10,000 dollars	EC6
2	10,000 but less than 25,000 dollars	EC6
3	25,000 but less than 50,000 dollars	EC6
4	50,000 but less than 100,000 dollars	EC6
5	100,000 but less than 250,000 dollars	EC6
6	Over 250,000 dollars	EC6
88	Refused	EC6
99	Don't know	EC6

EC6. How many locations does your organization have? {1999, 2002}

1	1	EC7
2	2 to 4	EC7
3	5 to 10	EC7
4	11 to 25	EC7
5	Over 25	EC7
88	Refused	EC7
99	Don't know	EC7

EC7. What is the approximate number of full-time equivalent workers of all types employed by your organization at this facility? {1999, 2002}

1	1 to 10	IM3
2	11 to 50	IM3
3	51 to 100	IM3
4	100 to 250	IM3
5	251 to 500	IM3
7	501 to 1000	IM3
7	Or, over 1000	IM3
88	[Don't read] Refused	IM3
99	[Don't read] Don't know	IM3

EFFICIENCY-RELATED IMPROVEMENTS

Now I'd like to ask you a few questions about any energy-efficiency actions you may have taken recently.

IM3. In the past year, has your organization taken any specific actions to improve its energy efficiency or otherwise reduce energy consumption? {1999, 2002}

1	Yes	IM3a
2	No	IM8
88	Refused	IM8
99	Don't know	IM8

IM3a. Did these actions involve the installation of new equipment, or only changes in how you operate or use existing systems? {2002}

1	Installation of new efficient equipment	IM4
2	Changes in use and operation only	IM8
3	Both	IM4
88	Refused	IM8
99	Don't know	IM8

IM4. And in which of the following areas have you installed efficient equipment? [ACCEPT MULTIPLES, READ LIST.] {1999, 2002}

1	Installed efficient lighting equipment	IM4_1
2	Installed efficient HVAC or refrigeration equipment	IM4_1
3	Installed efficient motors or variable speed controls	IM4_1
4	Reengineered manufacturing or process systems to save energy	IM4_1
5	Installed energy management control systems or other controls	IM4_1
IM4_7	[Don't read] Other (specify)	IM4_1
88	[Don't read] Refused	IM4B
99	[Don't read] Don't know	IM4B

[**TEXT FOR EACH OF SIX CATEGORIES ABOVE THAT WERE SELECTED**:
CATEGORY FROM IM4 ABOVE, e.g., "LIGHTING"] {1999, 2002}

ASK IM4_1 FOR **EACH CATEGORY MENTIONED** IN IM4:

IM4_1. Let's take the [ANSWER FROM IM4].
Could you tell me what specific actions your organization took?
Record actions verbatim:______________________________

IM4b. And as a percentage of this facility's annual electricity consumption, by how much do you estimate these energy savings actions will reduce your annual consumption? {1999, 2002}

1	0 to 2 percent	IM8
2	3 to 5 percent	IM8
3	6 to 10 percent	IM8
4	10 to 15 percent	IM8
5	16 to 20 percent	IM8
6	More than 20 percent	IM8
88	Refused	IM8
99	Don't know	IM8

IM8. In the last year, were there any actions to improve energy efficiency or otherwise reduce energy consumption that were identified but not undertaken? {1999, 2002}

1	Yes	IM8A
2	No	CON1
88	Refused	CON1
99	Don't know	CON1

IM8a. And, overall, what were the most important reasons that you did not take these energy saving actions? [DO NOT READ. ACCEPT MULTIPLES. ALLOW VERBATIM RECORDING.] {1999, 2002}

IM8 A		CON1
1	Other priorities for capital spending	CON1
2	Amount of savings did not justify added investment costs	CON1
3	No funds available for investment	CON1
4	Energy savings were too uncertain	CON1
5	Could not obtain financing for investment	CON1
6	Needed more information to make decision or convince management	CON1
7	Not enough management time to oversee project	CON1
8	Would have taken too much time to get a convincing analysis	CON1
9	Uncertainty created by deregulation	CON1

10	Expectation that energy prices would decrease	CON1
11	Do not pay the electric or gas bill	CON1
12	Other (Specify)___**IM8A_OTH**	CON1
13	NONE	CON1
88	Refused	CON1
99	Don't Know	CON1

CONSERVATION ACTIONS TAKEN TO REDUCE/MANAGE ENERGY USE

Next, I'm going to ask you about conservation actions that your organization may have taken to reduce or manage its energy use. In contrast to the previous question, I want to focus now only on changes in how your organization uses its equipment, rather than any physical replacement of equipment.

CON1. Other than installing new equipment, is your organization taking any energy conservation actions to reduce your overall energy use, such as routinely turning off lights or adjusting air conditioning set points higher? {2002}

1	Yes	CON5
2	No	DR20
88	Refused	DR20
99	Don't know	DR20

CON5. What energy conservation actions is your organization taking? [SELECT ALL THAT APPLY] {2002}

1	Turn off office equipment such as PCs, monitors, printers and copiers when not in use, at night and during the weekend	CON7
2	Set thermostats lower when heating and higher when using the air conditioning	CON7
3	Schedule high electrical energy-use processes during off-peak periods where feasible.	CON7
4	Turn off any lights that are not being used, for example, unused offices and conference rooms	CON7
5	Turn down/dim the remaining lighting levels if you can	CON7
6	Set air conditioning thermostats to pre-cool spaces at off-peak times	CON7
7	Establish a system to alert employees of expected high demand days including, but not limited to E-mail, voice mail, or public address announcement to all employees	CON7
8	Reprogram EMS schedule	CON7

9	Run backup generator at times of peak demand	CON7
10	Decrease industrial production or consolidate shifts	CON7
11	Other (SPECIFY)	CON7

CON7. When did your organization start conserving energy in these ways? Would you say: {2002}

1	We've always tried to conserve energy in these ways	CON20
2	We started conserving a year or two ago	CON20
3	We just recently started conserving in the past few months	CON20
4	Since the 2001 energy crisis	CON20
77	Other (Specify)_________________	CON20
88	Refused	CON20
99	Don't Know	CON20

CON20. By roughly how much do you think the conservation actions you've taken have reduced your overall annual energy usage at this facility as compared to the usage of this facility prior to when you took such actions? {2002}

1	0 to 2 percent	CON25
2	3 to 5 percent	CON25
3	6 to 10 percent	CON25
4	10 to 15 percent	CON25
5	16 to 20 percent	CON25
6	More than 20 percent	CON25
88	Refused	CON25
99	Don't know	CON25

CON25. Of the things that you mentioned your organization is doing to conserve, do you think you are conserving more/less/or about the same as your organization did during the Summer of 2006? {2002}

1	More	CON30
2	Less	CON30
3	About the same	CON30
88	Refused	CON30
99	Don't know	CON30

CON30. What are the most important reasons that your organization continues to take energy

conservation actions to reduce its energy use? [ACCEPT MULTIPLES] {2002}

1	Lower energy bill	DR20
2	Reduce strain on grid/increase reliability	DR20
3	Be less vulnerable to outages / risk management	DR20
4	Avoid Blackouts	DR20
5	Civic Duty	DR20
6	Reduce greenhouse gases/mitigate climate change	DR20
7	Other (specify)	DR20
88	Refused	DR20
99	Don't Know	DR20

DR20. Next, I would like to ask you about actions that you would take or have taken this summer, specifically on power alert days when emergency warnings are issued because of extremely low electricity supplies. Are there additional actions you would take or have taken this summer on power alert days, such as shutting off non-critical equipment at midday, turning off more lights than usual, and setting the thermostat even higher than you normally would. {2002}

1	Yes	DR30
2	No	EP1
88	Refused	EP1
99	Don't know	EP1

IF DR20 = 1

DR30. What actions would you take or have you taken on days when power alerts are announced? {2002}

1	Turn off office equipment such as PCs, monitors, printers and copiers when not in use, at night and during the weekend	DR35
2	Set thermostats lower when heating and higher when using the air conditioning	DR35
3	Schedule high electrical energy-use processes during off-peak periods where feasible.	DR35
4	Turn off any lights that are not being used, for example, unused offices and conference rooms	DR35
5	Turn down/dim the remaining lighting levels if you can	DR35
6	Set air conditioning thermostats to pre-cool spaces at off-peak times	DR35
7	Establish a system to alert employees of expected high demand days	DR35

	including, but not limited to E-mail, voice mail, or public address announcement to all employees	
8	Reprogram EMS schedule	DR35
9	Run backup generator at times of peak demand	DR35
10	Decrease industrial production or consolidate shifts	DR35
11	Other (SPECIFY)	DR35
88	Refused	CC1
99	Don't know	CC1

IF DR30 NE 88 or 99

DR35. What is the primary reason you took or would take these actions?

1	Lower energy bill	CC1
2	Reduce strain on grid/increase reliability	CC1
3	Be less vulnerable to outages / risk management	CC1
4	Avoid Blackouts	CC1
5	Civic Duty	CC1
6	Reduce greenhouse gases/mitigate climate change	CC1
7	Other (specify)	CC1
88	Refused	CC1
99	Don't know	CC1

RESPONSE TO GREENHOUSE GAS MITIGATION POLICIES AND PROCEDURES

Now I'd like to ask you a few questions about your organization's response to current and future greenhouse gas mitigation rules and policies.

CC1. Is your organization currently subject to any rules or policies that seek voluntary or mandatory reductions in greenhouse gas emissions? (Examples of these are emissions reporting, emissions caps, emissions trading, and carbon offsets)

1	Yes	CC1a.
2	No	CC2
88	Refused	CC2
99	Don't know	CC2

CC1a Which rules or policies are you subject to? (Describe them) SKIP to CC3

CC2 Does your organization believe that it will be subject to rules or policies in the future that mandate greenhouse gas reductions, and if so, when do you think those will be implemented?

1	Yes, within the next year	CC3
2	Yes, between 1 and 2 years from now	CC3
3	Yes, more than 2 years from now	CC3
4	No, we do not believe these rules or procedures will be established	CC3
88	Refused	CC3
99	Don’t know	CC3

CC3 How, if at all, have concerns over current or future greenhouse gas mitigation rules or policies affected your organization’s interest or plans to make capital investments in energy efficiency-related projects? Would you say there has been an:

1	Increase in interest and increase in planned capital investment	ES1
2	Increase in interest but no increase in planned capital investment	ES1
3	No major change in interest or planned capital investment	ES1
88	Refused	ES1
99	Don’t know	ES1

ELECTRIC SUPPLY CHOICES

ES1. Some customers purchase the energy portion of their electricity service from a firm other than their local electric distribution company. Does this facility purchase electricity from a company other than [UTILITY]? {2002}

1	Yes	ES2
2	No	DM2a
88	Refused	DM2a
99	Don’t know	DM2a

ES2. From what company does this firm purchase its electric energy? {2002}

RECORD VERBATIM

Record name (ES2_OPN)____
Don’t know 88
Refused 99

CONTINUE WITH DM2a.

ENERGY-RELATED DECISION MAKING

Now I'd like to ask some questions about how your organization makes its energy-related decisions.

DM2a. Would you best characterize the PROCESS to approve major investments in energy efficiency projects in your organization as….[READ LIST] {1999, 2002}

1	Relatively simple and straightforward	DM3A
2	Somewhat complex, but manageable	DM3A
3	Complex and difficult to get through	DM3A
99	Don't know	DM3A

DM3A. Does your organization have any internal incentive or reward policies for business units or staff responsible for managing energy costs? {1999}

1	Yes	DM3B
2	No	DM4A
88	Refused	DM4A
99	Don't know	DM4A

DM3B. How do these incentive/reward structures work? {1999, 2002}

RECORD VERBATIM, CONTINUE

DM4A. And, what would you say are the main obstacles, if any, to approval of major energy efficiency investments at your organization? [DO NOT READ. ACCEPT MULTIPLES. ALLOW VERBATIM RECORDING] {1999, 2002}

1	Other priorities for capital spending	DM7
2	Amount of savings often do not justify added investment costs	DM7
3	No funds available for investment	DM7
4	Energy savings are usually too uncertain	DM7
5	Can not obtain financing for investments	DM7

7	Usually need more information than is available to make decision	DM7
7	Not enough management time to oversee project	DM7
8	Takes too much time to get a convincing analysis	DM7
9	Other (Specify**) DM4A_OTH**	DM7
10	No major obstacles to approval of efficiency projects	DM7
11	Internal conflicts between departments or decision makers	DM7
12	Do not pay the electric or gas bill	DM7
88	Refused	DM7
99	Don't Know	DM7

DM7. Has your organization assigned responsibility for controlling energy usage and costs to any of the following? [READ LIST] {1999, 2002}

1	An in-house staff person	DM9
2	A group of staff	DM9
3	An outside contractor	DM9
4	No	DM9
88	[Don't read] Refused	DM9
99	[Don't read] Don't know	DM9

DM9. Has your organization developed a specification policy for the selection of energy-efficient equipment? (EXAMPLES: REQUIREMENT THAT ALL NEW FLUORESCENT LIGHTING SYSTEMS USE ELECTRONIC BALLASTS, OR THAT ALL NEW MOTORS BE PREMIUM EFFICIENCY.) {1999, 2002}

1	Yes	DM12
2	No	DM12
88	Refused	DM12
99	Don't know	DM12

DM12. What investment criterion, if any, does your firm use when applying investment analysis to energy equipment selection? [ACCEPT ONLY ONE. PROMPT IF NECESSARY] {1999, 2002}

1	Payback period	DM12A
2	Internal rate of return	DM12A
3	Life-cycle cost analysis	DM12A
DM12_4	Other (specify)	DM12A
5	No criteria used	DM12A
88	[Don't read] Refused	DM12A
99	[Don't read] Don't know	DM12A

DM12A. Thinking in terms of project payback, what is the payback period that your organization typically requires to approve energy efficiency investments? {1999, 2002}

DM12A_	Enter number of years (if less than 1 yr then enter 77)	EO1
1	Don't have a payback period requirement	EO1
88	Refused	EO1
99	Don't know	EO1

EFFICIENCY OFFERS

Now I'd like to ask you a question about energy efficiency service offers you may have received.

EO1. In the past year, has your organization been approached by any companies offering to provide services to improve the efficiency of your facility's energy usage? {1999, 2002}

1	Yes	EO2
2	No	PC1
88	Refused	PC1
99	Don't know	PC1

EO2. And what specific types of services to improve the efficiency of your facility's energy usage were offered?

RECORD VERBATIM, CONTINUE

FAMILIARITY WITH AND USE OF PERFORMANCE CONTRACTING

Now I'd like to ask some questions about any experience your organization may have with a specific type of energy efficiency related contract.

PC1. How familiar is your organization with the concept of Energy Performance Contracting? Would you say: {1999, 2002}

1	Very familiar	PC3
2	Somewhat familiar	PC3
3	Unfamiliar	PC3
88	Refused	PC3

99	Don't know	PC3

PC3. And in the past year, has your organization been approached by any companies offering an Energy Performance Contract? {1999, 2002}

1	Yes	PC4B
2	No	SPO
88	Refused	SPO
99	Don't know	SPO

PC4B. Which of the following statements best describes how far you went in the decision making or project development process? [READ LIST] {1999, 2002}

1	Heard presentation but did not request proposal(s)	PC5
2	Asked for and received formal proposal(s) but did not enter contract negotiations	PC5
3	Tried to negotiate contract but failed to come to agreement	PC5
4	Negotiated and signed contract	PC7B
88	[Don't read] Refused	SPO
99	[Don't read] Don't know	SPO

PC5. What were the main reasons you did not enter into an Energy Performance Contract? [RECORD REASONS VERBATIM] {1999, 2002}

SKIP TO SP0

PC7B. What are the main reasons that you chose an Energy Performance Contract over other forms of project development? {1999, 2002}

[RECORD REASONS VERBATIM], THEN CONTINUE

AWARENESS AND ASSESSMENT OF SPECIFIC SERVICE PROVIDERS AND PROVIDER TYPES

SP0. Now I'd like to ask you how you would rate the credibility of different types of energy services providers.

SP4a_0. On a scale from 0 to 10 where 0 is not credible at all credible and 10 is extremely credible, please rate each of the following types of companies with respect to how credible you think they are as a source of energy-efficiency related information. {1999, 2002}

SP4A. ROTATE (1 – 5)

SP4A_1. Engineering / Architectural Design Firms
SP4A_2. Energy Equipment Contractors and Installers (e.g., lighting, HVAC)
SP4A_3. Energy Service Companies, often referred to as ESCOs
SP4A_3a. [UTILITY] Energy Audit Services
SP4A_4. Other [UTILITY] Sources
SP4A_5. Companies, besides your electric distribution company, that provide electricity supply, sometimes referred to as Energy Service Providers (ESPs)

CONTINUE WITH KN1.

KNOWLEDGE

Now I'd like to ask you a few questions about your organization's knowledge of energy savings opportunities.

KN1. First, what do you estimate is the maximum percentage by which your facility's total annual electricity consumption could be reduced by implementing all cost-effective energy-efficiency opportunities? [NOTE THAT THIS PERCENTAGE IS OF SAVINGS THAT COULD BE REALIZED BY DOING ALL POSSIBLE COST-EFFECTIVE ENERGY-RELATED PROJECTS BEYOND THOSE PREVIOUSLY IMPLEMENTED.] {1998, 2002}

KN1_1. Enter Percent........ 1
Don't know........ 98
Refused........ 99

KN2a. And using the same 1 to 10 scale, how would you rate your organization's knowledge of energy savings opportunities for lighting? {1998, 2002}

0 1 2 3 4 5 6 7 8 9 10

Don't know........ 98
Refused........ 99

KN2b. And using the same scale, how would you rate your organization's knowledge of energy savings opportunities for HVAC systems? {1998, 2002}

0 1 2 3 4 5 6 7 8 9 10

Don't know........ 98

Refused 99

KN2c. And how about for all of the other major energy-using systems in your facility? {1998, 2002}

0 1 2 3 4 5 6 7 8 9 10

Don't know 98
Refused 99

BARRIERS

And now, I have a few quick questions on two issues that may be barriers that your organization faces with respect to implementing cost-effective energy-efficiency opportunities.

BR1. A barrier to implementing energy efficiency projects often cited by organizations is uncertainty over the performance and savings of energy efficiency measures. There are a number of factors contributing to this uncertainty. On a scale from 0 to 10, where 0 is completely insignificant and 10 is very significant, how significant are each of the following two factors regarding potential energy efficiency measures?

BR1a. Uncertainty over whether new energy efficient equipment <u>will perform as well</u> as your existing equipment or new standard efficiency equipment {1999, 2002}

0 1 2 3 4 5 7 7 8 9 10

Refused 88
Don't know 99

BR1b. Uncertainty over whether <u>actual</u> energy savings <u>will be equal to or greater than estimated</u> savings {1999, 2002}

0 1 2 3 4 5 7 7 8 9 10

Refused 88
Don't know 99

BR3. Another barrier to implementing energy efficiency projects often cited by organizations is uncertainty about the firms providing the energy efficiency services. Again, on a scale from 0 to 10, where 0 is completely insignificant and 10 is very significant, how significant are each of the following factors regarding potential energy efficiency providers

BR3A. Uncertainty over the integrity or trustworthiness of the firm {1999, 2002}

0 1 2 3 4 5 7 7 8 9 10

Refused 88

Don't know 99

BR3C. Uncertainty over the long-term viability of the firm and their ability to provide ongoing support or guarantees for the project. {1999, 2002}

0 1 2 3 4 5 7 7 8 9 10

Refused 88
Don't know 99

PROGRAMS

PR1. Are you aware of other programs or resources that are designed to promote energy efficiency for businesses like yours? [IF YES] What types of programs can you recall? [RECORD ALL MENTIONS] [After each response prompt with "Can you recall any others?"]? {1999, 2002}

1	Rebates/incentives (include mentions of SPC and Express)	PR9
2	Business energy audits and feasibility studies	PR9
3	Energy Centers (Pacific Energy Center, SCE CTAC)	PR9
4	Seminars, classes, and workshops	PR9
77	Other programs [SPECIFY:]_________________	PR9
98	No, not aware of any programs	PR9
99	Don't Know	PR9

PR9. Did your firm participate in any energy efficiency programs offered by [UTILITY] or any government or third-party programs since January 2004? [RECORD ALL MENTIONS] {1999, 2002}

1	Yes, [UTILITY] Express Efficiency	PR10
2	Yes, [UTILITY] SPC/Standard Performance Contracting	PR10
3	Yes, [UTILITY] Business Energy Audits/Nonresidential Audit	PR10
4	Yes, other [UTILITY] [**SPECIFY**:] _______________________	PR10
5	Yes, other, Non-utility [**SPECIFY**:]_________________________	PR10
6	No, did NOT participate in other 2004-2005 programs	PR10
88	Refused	PR10
99	Don't Know	PR10

PR10. Did your firm participate in any demand reduction programs offered by [UTILITY] or any government, Independent System Operator, or third-party programs since January 2004? [RECORD ALL MENTIONS] {1999, 2002}

1	Yes, [**SPECIFY**:] _______________________	PR11

2	No, did NOT participate in any DR programs	PR11
88	Refused	PR11
99	Don't Know	PR11

PR11. And finally, do you have any other comments or suggestions regarding energy-efficient products and practices, or programs that support energy efficiency or peak load reduction? {1999, 2002}

[RECORD VERBATIM]

May I please record your name, simply for verification purposes – a supervisor will confirm a small percentage of the interviews I've done.

Thank you very much for your participation in this very important survey, you've been extremely helpful. I hope you found the process interesting and insightful. Thanks again, and have a great day.

C.4

SPC *2004/2005 Evaluation Project On-Site Data Collection Form*

SPC 2004/2005 EVALUATION PROJECT
ON-SITE DATA COLLECTION FORM – VERSION 2

I. INTERVIEW INFORMATION

Evaluator: ______________________________
Date of Site Visit: ______________________________
Company Name / App. No. : ______________________________
Street Address: ______________________________
Facility Representative(s): ______________________________
Phone / Email: ______________________________
Measure(s) Evaluated ______________________________

II. DESCRIPTION OF FACILITY

Primary Services or Products ______________________________
Total floor space of this facility ______________________________ ft^2
Conditioned floor space (this facility) ______________________________ ft^2

Day Type	**Pre-Retrofit Operating Hours**	**Closed All Day?**	**Open 24 hours?**	**Partial Occupancy %**	**Average # of Occupants?**
Weekdays	From _______ to _______	❑	❑		
Saturday	From _______ to _______	❑	❑		
Sunday	From _______ to _______	❑	❑		
Other	From _______ to _______	❑	❑		

Day Type	**Post-Retrofit Operating Hours**	**Closed All Day?**	**Open 24 hours?**	**Partial Occupancy %**	**Average # of Occupants?**
Weekdays	From _______ to _______	❑	❑		
Saturday	From _______ to _______	❑	❑		
Sunday	From _______ to _______	❑	❑		
Other	From _______ to _______	❑	❑		

Seasonal variations in the level of occupancy or use:
Number of annual holidays facility is closed:
Does evaluated measure(s) operate when facility is closed?

Interview Facility Representative.

1. Early retirement under the SPC 04-05 Evaluation requires calculation of energy savings using the existing equipment as the baseline for energy use (verses the current standards), but only for the remaining useful life of the equipment. This can apply to all measures, particularly lighting and equipment replacement. If the measure is an early retirement measure:

   a) At the time the equipment was replaced, how many years were left in its useful life (without major repairs which may have led to replacement)? ____________

   b) How old was the equipment that was removed and replaced? ________________

   c) Was the existing equipment fully functional, fully functioning but with significant problems, or non-functional? ____

   d) How often was major non-scheduled maintenance required and of what type?____

   e) How often had the equipment failed recently, and over what time period? ____

   f) How satisfactory was the performance of the old equipment? _________________

   g) How long would the old equipment have met the technical and performance needs of the facility? ____

2.) Does the customer have any reason to believe that there will be any changes in the operation of the primary measure?

a) Changes in hours ____

b) Changes in load ____

c) Impact on annual kWh savings ____

d) Impact on kW savings ____

3.) Document the source of the cost estimate for the primary end use measure evaluated.

a) Source ____

b) Multiple quotes from vendors or contractors / multiple ESCOs considered? ____

c) Type of financial analysis performed? ____

d) Full measure costs or incremental cost used? ____________________________________

e) Any opportunity costs (e.g., internal time/labor) factored into the calculations for the implementation costs? ____

4.) Any perceived non-energy benefits, e.g., increased production, increased comfort, new equipment, environmental branding, etc.? ____________________________________

5.) Did SPC program participation:

a) Promote increased energy awareness in your company? ______________________

b) Lead to installation of other efficiency measures? __________________________

c) If so, were these measures installed independently or under other programs? ____

Confirm that the measures were actually installed, the installation meets reasonable quality standards, measures are operating correctly, and measures can generate the predicted savings. ***To the maximum extent possible, verify installation of all measures in the SPC application (regardless of the end use).***

Description: ____

Quantity: ____

Make: ____

Model: ____

Serial Number: ____

Capacity (V,A, kW, MBH) ____

Operating? Y or N ____

____

Other Notes (Manufacturer Location/ Tel. No., Service Provider, etc.) ____
____
____

MONITORING PLANNING

Does the facility have an energy management system (EMS)? ______________________
Can data from the EMS be obtained? Can new monitoring points be added? ___________

Continuous Monitoring of:	Instruments	Measurements (or units)	% Sampled	Quantity Required		Voltage (120,210, 277, other)
				Logger Type	CTs Required	
kWh – Direct	kWh Meter	kW				
kWh – Indirect	EMS, Vibration Monitor, or Event Recorder	Status of Closure Points				
	Power or Ammeter	One-time kW reading (kW, A, V)				
Temperature	EMS, data logger	°F				n/a
Light Levels	EMS, data logger	On/Off (minutes)				n/a

Are there any restrictions or protocols required by the site to be followed for monitoring equipment installation? ____

Is a sample being conducted for items in an evaluated measure, or multiple measures, or multiple sites? If so, describe the sampling plan:

____

____

____

____

ADDITIONAL MEASURE SHEET

Description:	______________________
Quantity:	______________________
Make:	______________________
Model:	______________________
Serial Number:	______________________
Capacity:	______________________
Volts, Amps, kW, input mbtuh	______________________
Operating? Y or N	______________________
Other Notes (Manufacturer Location/ Tel. No., Service Provider, etc.)	______________________

Continuous Monitoring of:	Instruments	Measurements (or units)	% Sampled	Quantity Required		Voltage (120,210, 277, other)
				Logger Type	CTs Required	
kWh – Direct	kWh Meter	kW				
kWh – Indirect	EMS, Vibration Monitor, or Event Recorder	Status of Closure Points				
	Power or Ammeter	One-time kW reading (kW, A, V)				
Temperature	EMS, data logger	°F				n/a
Light Levels	EMS, data logger	On/Off (minutes)				n/a