San Diego Gas and Electric 2004-2005 RetroCommissioning Program

Final Report

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Portland Energy Conservation, Inc.

Submitted by:

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Executive Summary

The San Diego Gas and Electric 2004–05 RetroCommissioning Program funded projects at four sites. The implementer's scope included extensive pre-retrofit savings analysis, implementation support, sometimes direct implementation, and post-installation monitoring of the building energy management systems (EMSs) with follow-up support to maintain project persistence. PECI and their subcontractors regularly used the immediate post-implementation data to update savings estimates.

ERS performed direct energy measurement of much of the affected equipment and either independently calculated or re-visited earlier savings calculations. Evaluators used both this new measured data and previously unavailable post-installation trend data. The primary objective of this study was to estimate program gross impact and realization rates at the measure, site, and program level. In the course of this exercise ERS also collected information and have reported evaluation recommendations that could affect the net program impact.

Itron performed a PRISM style normalized annual consumption (NAC) billing analysis.[1] Both energy billing data and weather data were used to model the before and after energy consumption. The difference between the two periods provides a rough estimate of the resulting savings. This simple NAC analysis was conducted as further verification of the reported energy savings for each RCx program participant.

The implementation reports for the four RCx participants included 27 measures. Not every recommended measure was fully implemented and not every implemented measure has persisted through the M&V period. Table 1-1 summarizes the gross impact evaluation estimates and their associated realization rate by site and for the program.

[1] PRInceton Scorekeeping Method developed by Margaret F. Fels, Center for energy and Environmental Studies, Princeton University.

Table 1-1: Gross Impacts and Realization Rates by Site

Participant	Fuel	Ex Ante Savings	Ex Post Savings	EM&V Realization Rate
Participant A	Electricity (kWh)	1,470,615	1,423,508	97%
	Demand (kW)	33	127	387%
	Natural Gas (therms)	88,305	88,552	100%
Participant B	Electricity (kWh)	267,165	163,226	61%
	Demand (kW)	139	48	35%
	Natural Gas (therms)	0	n/a	n/a
Participant C	Electricity (kWh)	496,784	704,192	142%
	Demand (kW)	302	118	39%
	Natural Gas (therms)	0	n/a	n/a
Participant D	Electricity (kWh)	7,654,273	3,999,414	52%
	Demand (kW)	971	390	40%
	Natural Gas (therms)	177,558	75,366	42%
Total	Electricity (kWh)	9,888,837	6,290,340	64%
	Demand (kW)	1,445	683	47%
	Natural Gas (therms)	265,864	163,918	62%

Itron's NAC billing analysis verified ERS's findings to a significant degree, adding further confidence in the savings results.

In addition to the gross impact, ERS found that there is potentially significant participant spillover. The nature of the program in emphasizing O&M improvements over capital projects and incorporating persistence tracking makes this one of the key program strengths. The gross impact evaluators believe that participant on-site and off-site spillover is occurring in explicitly documentable and subtle hard-to-document actions. The report provides specific examples from each of the three participating firms but does not quantify a spillover factor.

There also was evidence of free ridership. Measure life and persistence are affected by the continual improvement nature of the program. Some measures still are in the process of being installed more than 18 months after implementation began.

ERS and Itron recommend that four steps be taken by the Implementer to increase the accuracy of future savings estimates and increase realization rates:

1. Ask field engineers to perform spot power measurement before and after implementation when RCx measures save pump or fan energy, especially when VFDs are involved
2. Provide the implementers with the CPUC-definition of peak demand period and ask that they estimate demand savings on this basis for each measure.

3. Continue the practice of involving implementation contractors that have long-term relationships with the participants.
4. Develop a whole facility baseline using historical energy billing, weather, and occupancy data.

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Introduction and Objectives

The Portland Energy Conservation, Inc (PECI) San Diego 2004–05 RetroCommissioning (RCx) Program funded projects at four sites. The implementer's scope included extensive pre-retrofit savings analysis, implementation support, sometimes direct implementation, and post-installation monitoring of the building energy management systems (EMSs) with follow-up support to maintain project persistence. PECI and their subcontractors regularly used the immediate post-implementation data to update savings estimates.

The program was subject to an earlier evaluation, during which Itron reviewed the computational approaches taken by the implementer, PECI, and their subcontractors. Generally the engineering approaches were found to be reasonable. This exercise was completed prior to the end of the persistence studies.

While the prior implementer work supported persistence evaluation and the prior engineering review validated the computational methodology, both largely omitted direct energy savings measurement.

In this scope of work, Itron and ERS each performed an independent look at the direct energy savings. ERS performed direct energy measurement of much of the affected equipment and either independently calculated or re-visited earlier savings calculations. ERS used both this new measured data and previously unavailable post-installation trend data. Itron performed a simple normalized annual consumption (NAC) billing analysis in an attempt to verify the electric and natural gas savings from a higher level than that performed by ERS.

The primary objective for ERS was to estimate program gross impact and realization rates at the measure level for as many of the 27 measures as cost-effectively possible. In the course of this exercise ERS also collected information and have reported evaluation recommendations that could affect the net program impact. For Itron, the primary objective was to weather normalize the pre and post RCx energy consumption and compare them to verify that the reported energy savings was observable.

3

Program Background

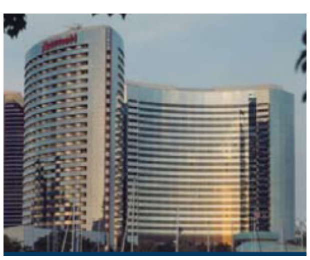
The PECI San Diego RetroCommissioning (RCx) Program is an ongoing program that provides incentives and training for commercial customers to achieve energy savings and improve comfort through building performance optimization. Most improvements are achieved from controls changes, as opposed to major equipment retrofits.[1] The scope of the service for the 2004-05 program included:

- A no-cost building screening study to determine if the building is a good candidate for RCx.
- Financial assistance for an in-depth RCx investigation that identifies specific O&M improvements and for implementing measures.
- Training building operators in maintaining improved building operations and utilizing updated system documentation.
- One year of follow-up measure tracking through remote monitoring of site EMS trend data to ensure measure persistence.

The implementation contractor added benchmarking to the scope for 2006-08. Buildings must have at least 100,000 square feet of conditioned space, a direct digital control (DDC) system in place, and central plant mechanical equipment in relatively good condition. Building management must be willing to commit at least 40-60 hours of senior building operations staff time to support the project.

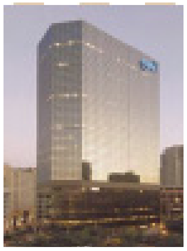
Savings potential was estimated or revised as many as four times for the projects: As part of the scoping study, in the in-depth investigation report, after measure installation, and later after post-installation trend monitoring.

This 2004-05 program gross impact evaluation focuses on project at four sites.

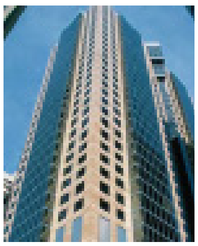


Participant A. This major conference hotel has two towers and 1.4 million square feet of conditioned space. Total electric and gas utility bills prior to project participation were about $2.4 million per year.

[1] Further description is available at the program Web site (http://www.sandiegorcx.com).



Participant B. This class "A" office building is 20 stories, has 428,000 gross conditioned square feet, and had utility bills of $660,000 in the year prior to participating in the program.



Participant C. This is a 34-story class "A" office building with 560,000 conditioned square feet including a restaurant, plus a 100,000-square foot garage. Total annual utility bills prior to the RCx service were about $1.3 million.

Participant D. This nine building, 800,000-square foot building pharmaceutical research campus spent almost $5 million per year in electricity and gas in the year preceding the RCx program participation.

Table 3-1 summarizes ERS's understanding of the program's implementation and evaluation chronology for these sites.

Table 3-1: Participant Chronology

Event	Completion Date by Project			
	#1001 Participant A	#1005 Participant B	#1006 Participant C	#1007 Participant D
Scoping Study	Oct 2004	Mar 2005	Apr 2005	Aug 2005
In-Depth Investigation Report	Sep 2005	May 2006	May 2006	
Post-Implementation Report	Sep 2006	Aug 2006	Aug 2006	Mar 2006
Performance Tracking Report (Quarterly)	Sep 2007 final	Oct 2007 3rd of 4	Oct 2007 3rd of 4	Dec 2007 final

The four implementation reports included 27 measures. Not every recommended measure was fully implemented and not every implemented measure has persisted through the M&V period. Two measures are scheduled to be but are not yet implemented and one is in the process of being implemented. In this latter case the problems identified in the measure (a nine-part recommendation) gradually have been addressed over two years and will continue to be addressed over the next two years.

4

Energy Efficiency Measures

Table 4-1 summarizes the status of all measures included in the four implementation reports. Status is as of March 20, 2008.

Table 4-1: Measures and Status

Site & Measure		Forecast Electricity Savings (kWh/yr)	Measure Status as of 3/20/08
#1001 Participant A			
M2	VFD on chilled water pump	54,000	Installed, not yet automated
M4	VFD on condenser water pump	129,000	Installed, not yet automated
M5	Reduce rear waterfall pumping	78,000	Implemented
M6	Reduce front water feature pumping	67,000	Implemented
M7	Turn off stream pump at night	120,000	Implemented
M8	Re-activate garage DCV fan control	476,000	Implemented
M12	Reduce simult. heating/cooling - repair AHU#5 VFD	146,000	In-process, multi-yr project
M12a	Reduce simult. heating/cooling all but repair AHU#5 VFD	281,000	
M14	Install VFD on S. Tower DHW pump	50,000	Implemented
M15	Install VFD on N. Tower DHW pump	70,000	Implemented
#1005 Participant B			
M1	Reduce summer night lobby cold deck fan operation	42,000	Implemented
M2	Reduce AHU cold deck static and temperature. Increase free cooling.	171,000	Partially implemented
M3	Condenser water reset for VFD chillers.	54,000	Not implemented
#1006 Participant C			
M1	Correct uneven cooling tower flow	94,000	Implemented
M2	Switch from parallel to series chiller sequencing	61,000	Unclear*
M3	Raise chilled water supply temperature	29,000	Implemented
M4	Reduce summer night fan operation	168,000	Implemented
M5	Reduce AHU1 cold deck static pressure & valve repair	25,000	Partially implemented
M6	AH2 and AH3 Repair static pressure sensor(s). Adjust AH2 chilled water valve. Add supply air temperature reset.	116,000	Partially implemented
M7	Reduce AHU4 supply air static pressure	4,000	Mostly implemented
#1007 Participant D			
M1	Reduce AHU cold deck static pressure setpoint to VAV boxes	569,000	Mostly implemented
M2	Reduced exhaust static pressure	192,000	Mostly implemented
M3	Reduce 100%OA cfm from 12 to 8 ACH in non-lab areas	1,745,000	Mostly implemented
M4	Increase thermostat deadband	410,000	Mostly implemented
M5	Reduce cfm when unoccupied	4,282,000	Implemented
M14	Increase night setback schedule	457,000	Implemented
TOTAL		**9,890,000**	

* Persistence report trend data on an example day indicates the measure was implemented but the facilities staff twice unequivocally stated it was not implemented as described, because it would interfere with the Hartman LOOP program logic, and they were unwilling to risk that. It may be that the Hartman LOOP optimization logic includes such sequencing under certain conditions, but such overriding instructions were not added.

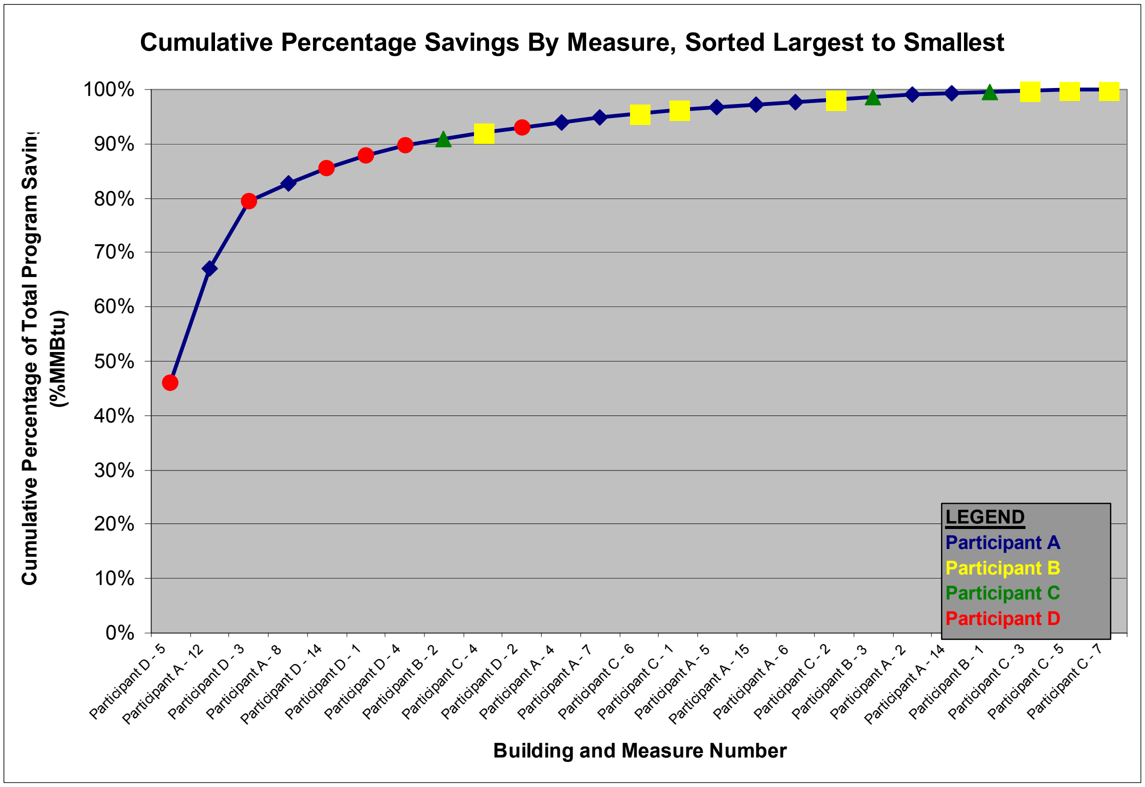
As noted previously the implementers have stayed involved with the site participants over several years and have regularly updated savings estimates. Table 4-2 shows the most recent savings estimates made available to ERS by the implementation contractor. ERS has used these as the *ex ante* savings estimates for the purposes of subsequently calculating measure realization rates. The table also shows the most recent known persistence estimates. The measure-by-measure impact results detailed in Appendix A show how the savings estimates have changed over time.

Table 4-2: *Ex* Ante Impact by Measure and Site

Site and Measure		Electric Energy Savings (kWh/yr)	Demand Savings (kW)	Gas Savings (therms/yr)
#1001 Participant A				
M2	VFD on chilled water pump	54,097	0	0
M4	VFD on condenser water pump	129,436	0	0
M5	Reduce rear waterfall pumping	78,079	11	0
M6	Reduce front water feature pumping	67,131	0	0
M7	Turn off stream pump at night	119,692	10	0
M8	Re-activate garage DCV fan control	475,931	0	0
M12	Reduce simult. heating/cooling - repair AHU#5 VFD	145,576	0	0
M12a	Reduce simult. heating/cooling all but repair AHU#5 VFD	280,523	0	88,305
M14	Install VFD on S. Tower DHW pump	50,380	6	0
M15	Install VFD on N. Tower DHW pump	69,770	6	0
Subtotal		**1,470,615**	**33**	**88,305**
#1005 Participant B				
M1	Reduce summer night lobby cold deck fan operation	41,956	0	0
M2	Reduce AHU cold deck static and temperature. Increase free cooling.	170,851	139	0
M3	Condenser water reset for VFD chillers.	54,358	0	0
Subtotal		**267,165**	**139**	**0**
#1006 Participant C				
M1	Correct uneven cooling tower flow	93,984	40	0
M2	Switch from parallel to series chiller sequencing	60,556	0	0
M3	Raise chilled water supply temperature	29,205	12	0
M4	Reduce summer night fan operation	168,010	0	0
M5	Reduce AHU1 cold deck static pressure & valve repair	25,410	1	0
M6	AH2 and AH3 Repair static pressure sensor(s). Adjust AH2 chilled water valve. Add supply air temperature reset.	115,731	208	0
M7	Reduce AHU4 supply air static pressure	3,888	41	0
Subtotal		**496,784**	**302**	**0**
#1007 Participant D				
M1	Reduce AHU cold deck static pressure setpoint to VAV boxes	569,402	70	0
M2	Reduced exhaust static pressure	192,127	22	0
M3	Reduce 100%OA cfm from 12 to 8 ACH in non-lab areas	1,744,673	705	44,694
M4	Increase thermostat deadband	409,608	174	568
M5	Reduce cfm when unoccupied	4,281,882	0	82,250
M14	Increase night setback schedule	456,581	0	50,047
Subtotal		**7,654,273**	**971**	**177,559**
TOTAL		**9,888,837**	**1,445**	**265,864**

To assist in the prioritization of evaluation resources at the beginning of the project, ERS sorted the measures by total annual energy savings and plotted cumulative savings. This is illustrated in Figure 4-1 and Table 4-3.

Figure 4-1: Ranked Measure Savings[1]



[1] The energy values underlying this plot differ from those in the prior figure in some cases, as this exercise was conducted at the beginning of the project. The *ex ante* impact table reflects best estimates as of the end of the project.

Table 4-3: Descriptions

Building and Measure No.	Description
Participant D - 5	Reduce supply air nights & weekends
Participant A - 12	Eliminate simultaneous heating and cooling and reduce AHU fan speeds
Participant D - 3	Reduced constant volume box CFM
Participant A - 8	Re-enable DCV for parking garage
Participant D - 14	Increasing setpoint during unoccupied times
Participant D - 1	Reduction SA AHU pressure setpoint to VAV boxes
Participant D - 4	Increase thermostat deadband
PARTICIPANT B - 2	Reduce cold deck static pressure setpoint and temperature setpoint. Modify changeover controls for free cooling.
Participant C - 4	Adjust thermostat schedule and optimize economizer operation.
Participant D - 2	Reduction SA AHU pressure setpoint to VAV boxes and EF pressure
Participant A - 4	Install VFD on one of three condenser pumps and modify control sequence
Participant A - 7	Turn off one stream pump at night
Participant C - 6	Repair static pressure sensor(s). Adjust AH2 chilled water valve. Add supply air temperature reset.
Participant C - 1	Rebalance water distribution system to achieve an even flow across the top of the tower.
Participant A - 5	Turn off one of the water fall pumps
Participant A - 15	Optimize North Tower domestic water booster pump
Participant A - 6	Turn off one of the front water feature pumps
Participant C - 2	Sequence chillers for serial operation, fully loading one chiller before bringing on the second chiller.
PARTICIPANT B - 3	Condenser water reset for VFD chillers.
Participant A - 2	Install VFD on one of three evaporator pumps
Participant A - 14	Optimize South Tower domestic water booster pump
PARTICIPANT B - 1	Place the cold deck fan on a stop-start schedule similar to the hot deck fan.
Participant C - 3	Increase the CHWS temperature.
Participant C - 5	Adjust control parameters to eliminate chilled water valve cycling
Participant C - 7	Supply air temperature reset.

5

Measurement and Evaluation Approach

This section describes the general approach applied to the evaluation process for Itron and ERS.

5.1 ERS

Talk with implementation contractor staff. ERS discussed the scope with Itron and PECI staff and subsequently with PECI's persistence assessment contractors AEC and Facility Dynamics. Due to the ongoing relationships inherent in the retrocommissioning project ERS and PECI team engineers subsequently worked together to resolve measure status and extract trend data from the participant sites EMS systems.

Scoping site visits. ERS met with representatives of each of the four sites to assess data available from the existing EMS, determine metering needs, and discuss persistence with site staff.

Site and Measure Selection. ERS originally proposed to evaluating savings at three of the four sites. Due to the nature of the savings distribution—the two smallest savers were run by the same management company—and the fact the sites all were in close geographic proximity, the plan was re-structured to evaluate all of the biggest savings measures at all four sites. The biggest savings site unexpectedly and at the last minute was unable to support additional on-site EM&V or provide their own trend data, so the plan was revised again. The savings at this site was too large to ignore, so ERS performed intensive engineering review of the original savings calculations for the biggest savings measures at this site and performed metering based evaluation for all measures at all three other sites where metering could enhance savings estimation over the *ex ante* estimate. Although this approach gives greater uncertainty to *ex post* impact estimation than would be ideal, it optimized use of evaluation resources for this small measure population. Otherwise, when prioritizing measure selection Participant C had the fewest measures evaluated. The four smallest measures there together added up to less than 2% of program savings and were not simple analysis. Thus they were excluded as low value measures for M&V.

Measurement and Evaluation (M&V) Plan. After the scoping visits, ERS developed M&V plans for each measure. The plan specified data to receive from the host site and ERS instrumentation. The former was largely flows and temperatures, the latter largely current and power.

Meter Installation and Removal. ERS completed on-site spot real power metering on 20 unique pieces of equipment representing about 30 total motors involved in the program during the week ending February 8, 2008. We installed logging meters at the motor control centers for all of those motors subject to variable load or uncertain schedule and that we did not have post-installation current or power data. Metering covered 3 of the 4 participating sites. The logging meters were removed in two trips, one ending March 7 and the other on March 24.

Other Data Collection. ERS received some trend data directly from PECI's team for two of the participant sites and remote access to the EMS to download available trend data for the other two sites.

Analysis. ERS followed the IPMVP Option "B" protocol as much as possible for all sites subject to short term metering. The exact approach varied by measure and is described in Appendix A. Any interactive effects with other measures or equipment were quantified. Building simulation modeling was not included.

5.2 Itron

Gather billing and weather data. Itron requested billing data for the program participants from SDG&E. Billing data was requested for all electric and gas accounts associated with the RCx projects. The date range requested was from January of 2004 through November of 2007.

Billing analysis methodology. The type of billing analysis Itron used is the PRInceton Scorekeeping Method (PRISM). PRISM was developed. The PRISM equation is specified as follows. First, the α, β and τ are estimated for the equation below:

$$f = \alpha + \beta(\tau - T_{out})_{+}$$

Where: f is the average daily energy usage
α is a constant to be estimated
β is a parameter to be estimated
T_{out} is the temperature outside the building
τ can be understood as temperature inside the building
$(\tau - T_{out})_{+} = \text{Max}(\tau - T_{out}, 0)$, is the heating degree-days

The model assumes that the energy used to keep the temperature inside the building different from outside the building is a linear function of the temperature difference. The parameters α, β and τ are the best fits to f and T_{out} of this linear model.

Second, the Normalized Annual Consumption (NAC) is calculated by plugging in the "normalized weather" data.

$$\text{NAC} = 365\alpha + \beta(\tau - T_{normal})+$$

Third, the pre and post period NAC are compared to estimate the normalized energy savings.

Data processing. Itron used billing data from the four participant sites, which included 25 separate accounts. This provided the electricity and natural gas usage from January 2004 to December 2007. The weather data Itron used was from the San Diego airport, Lindbergh Field. The available data was from December 18, 2002 to October 4, 2007. Itron used the weather data from January 1, 2004 to October 4, 2007 to construct HDDs and CDDs for the first step estimation, and the whole weather dataset to construct "normalized weather" data for the NAC calculation in the second step.

To get the usage for each site, Itron needed to sum the usages from several different accounts. In most cases, the bill dates and the bill days across accounts are very different. Therefore, we "calendarize" the billing data, so that each "bill" starts from the first day of the month and ends on the last day. Then, the total usage for each site is calculated by summing usages across accounts at each site.

Since Itron constructed the bills, it constructed the weather data for the bills similarly to make sure that the correct HDDs and CDDs. Itron first merged the weather data onto the billing data and let the weather data go through the same procedure of calendarization as the bills. Finally, the average monthly HDDs and CDDs were calculated across accounts for each site. For the regression modeling, the daily usage and daily HDDs and CDDs were used.

Model estimation. The first step in the billing analysis process was to estimate the daily energy usage as a function of weather. PRISM specifies that the base to be used in computing the HDD's and CDD's be optimized for each participant. To accomplish this, Itron regressed daily usage (electricity and natural gas separately) onto daily HDDs and CDDs, for the pre and post period of each site, separately.

$$use_{it} = \alpha + \beta_1 \text{HDD}^{\text{H}\tau}{}_{it} + \beta_2 \text{CDD}^{\text{C}\tau}{}_{it} + \varepsilon_{it}$$

Where: i indexes the 16 combinations of (site, pre/post period, electricity/gas)
$HDD^{H\tau}_{it}$ is the heating degree-days with respect to the temperature $H\tau$ for i at time t
$CDD^{C\tau}_{it}$ is the cooling degree-days with respect to the temperature $C\tau$ for i at time t
α, β_1 and β_2 are the parameters to estimate

$H\tau$ was permitted to range between 46°F and 90°F. $C\tau$ was permitted to range between 32°F to 85°F for each participant. This was done to put a limit on the number of HDD and CDD combinations to be estimated. It also puts some rational boundaries on what temperature values could be used. Overall, this produces 2,430 combinations of HDD and CDD. For each of the 16 i's, the regression above is run for 2,430 combinations of HDD and CDD, and α, β_1 and β_2 are obtained along with R^2 and adjusted R^2. Itron then chose the combination of $H\tau$ and $C\tau$ that provide the highest R^2 and the corresponding α, β_1 and β_2. For comparison purposes, Itron also computed HDD and CDD using the traditional base temperature of 65°F.

When constructing the normalized weather data, Itron calculated the HDDs and CDDs for each day of the whole weather sample, and then summarize the annual average HDDs and CDDs. The historical weather data used spanned from January, 1992 to October, 2007. For a base temperature of 65°F, the normalized HDD_{base65} equals 1133.9, and the normalized CDD_{base65} equals 519.7.

NAC simulation. Once the daily usage models were estimated, the second step in the billing analysis process was to simulate the energy use under weather normalized conditions. This produces a pre and post RCx consumption estimate under the same weather conditions. The simulated pre and post consumption estimates were then compared to verify if the reported savings were reasonable.

6

Findings

This section presents ERS *ex post* energy and demand impact estimates, the corresponding realization rates, and qualitative findings on persistence, spillover, and other factors that affect program net savings. It also presents Itron's billing analysis findings and reconciliation between ERS's findings and Itron's findings.

6.1 ERS Gross Impact Findings

Table 6-1 summarizes the M&V impact reported for each measure in Appendix A. Table 6-1 also includes engineering estimates of uncertainty. Table 6-2: Evaluation Gross Savings Realization Rate shows the gross savings realization rate calculated by dividing the Figure 4-2 values by those in Table 6-1. If the realization rate is "infinite," this is because the implementer claimed no impact but ERS believes that the measure did in fact result in impact. The basis of the impact and uncertainty estimates is included in Appendix A.

If the realization rate row is entirely blank, it corresponds with a measure that was not evaluated. Overall, ten of the twenty implemented and evaluated measures had rates over 100% for at least one parameter.

One reportedly unimplemented measure reduced the results for Participant B. Participant D's low realization rate on a few very large savings measures significantly dragged down the site and program overall realization rate.

As discussed previously, there were several measures ERS did not evaluate, either because their savings was too small to be of consequence or improving on the *ex ante* estimate was cost-prohibitive, or necessary data was not available. Realization rates are still needed for these measures to estimate program overall impact. ERS calculated the unweighted simple average realization rate by site and impact type to use to apply to measures not otherwise subject to measure evaluation for this purpose. They are illustrated in Table 6-3.

Table 6-1: Ex Post Measure Impact[1]

Site & Measure		Electric Energy Impact (kWh/yr)	Electric Demand Impact (kW)	Gas Impact (therms/yr)	Engineering Uncertainty Range		
#1001 Participant A							
M2	VFD on chilled water pump	48,203	0	0	-5%	to	20%
M4	VFD on condenser water pump	100,331	0	0	-5%	to	20%
M5	Reduce rear waterfall pumping	44,749	9	0	-10%	to	10%
M6	Reduce front water feature pumping	81,586	9	0	-3%	to	3%
M7	Turn off stream pump at night	33,316	5	0	-15%	to	15%
M8	Re-activate garage DCV fan control	502,688	84	0	-24%	to	2%
M12	Reduce simult. heating/cooling - repair AHU#5 VFD	158,464	0	247	-6%	to	11%
M12a	Reduce simult. heating/cooling all but repair AHU#5 VFD	*Not evaluated* --------------------------					
M14	Install VFD on S. Tower DHW pump	85,164	10	0	-16%	to	16%
M15	Install VFD on N. Tower DHW pump	92,009	10	0	-9%	to	9%
#1005 Participant B							
M1	Reduce summer night lobby cold deck fan operation	29,747	2	0	-11%	to	11%
M2	Reduce AHU cold deck static and temperature. Increase free cooling.	133,479	46	0	-23%	to	23%
M3	Condenser water reset for VFD chillers.	0	0	0	*Not applicable*		
#1006 Participant C							
M1	Correct uneven cooling tower flow	93,984	40	0	-20%	to	20%
M2	Switch from parallel to series chiller sequencing	*Not evaluated* --------------------------					
M3	Raise chilled water supply temperature	*Not evaluated* --------------------------					
M4	Reduce summer night fan operation	186,677	0	0	-15%	to	15%
M5	Reduce AHU1 cold deck static pressure & valve repair	*Not evaluated* --------------------------					
M6	AH2 and AH3 Repair static pressure sensor(s). Adjust AH2 chilled wate	252,993	52	0	-12%	to	12%
M7	Reduce AHU4 supply air static pressure	*kWh not eval.*	13	0			
#1007 Participant D							
M1	Reduce AHU cold deck static pressure setpoint to VAV boxes	368,554	46	0	-18%	to	27%
M2	Reduced exhaust static pressure	192,419	22	0	-10%	to	10%
M3	Reduce 100%OA cfm from 12 to 8 ACH in non-lab areas	926,204	255	17,485	-25%	to	25%
M4	Increase thermostat deadband	465,860	67	6,252	-30%	to	30%
M5	Reduce cfm when unoccupied	2,015,828	0	44,035	-25%	to	25%
M14	Increase night setback schedule	30,549	0	7,594	-25%	to	25%

[1] The intent of the uncertainty ranges is as follows: If a measure is estimated to save 100 kW and has -5% to +10% uncertainties, this means ERS is believes that the true savings is between 95 and 110 kW. The estimates are based on simple propagation of error calculations and may include statistically-based components associated with extrapolation from short to long term impact. When the latter is the case the range is associated with 90% statistical confidence, and when the engineer estimated likely value ranges based on professional judgment he did so in the spirit of 90% confidence. In general, however, the engineering uncertainty range does not represent statistically-based 90% confidence ranges. When meter manufacturers indicate full-scale accuracy, which we have included in the uncertainty calculations, they do not indicate associated confidence, for example,

Table 6-2: Evaluation Gross Savings Realization Rate

Site & Measure		Electric Energy Realization Rate	Electric Demand Realization Rate	Gas Realization Rate
#1001 Participant A				
M2	VFD on chilled water pump	89%		
M4	VFD on condenser water pump	78%		
M5	Reduce rear waterfall pumping	57%	82%	
M6	Reduce front water feature pumping	122%	*infinite*	
M7	Turn off stream pump at night	28%	50%	
M8	Re-activate garage DCV fan control	106%	*infinite*	
M12	Reduce simult. heating/cooling - repair AHU#5 VFD	109%		*infinite*
M12a	Reduce simult. heating/cooling all but repair AHU#5 VFD			
M14	Install VFD on S. Tower DHW pump	169%	173%	
M15	Install VFD on N. Tower DHW pump	132%	166%	
#1005 Participant B				
M1	Reduce summer night lobby cold deck fan operation	71%	*infinite*	
M2	Reduce AHU cold deck static and temperature. Increase free cooling.	78%	33%	
M3	Condenser water reset for VFD chillers.	0%		
#1006 Participant C				
M1	Correct uneven cooling tower flow	100%	100%	
M2	Switch from parallel to series chiller sequencing			
M3	Raise chilled water supply temperature			
M4	Reduce summer night fan operation	111%		
M5	Reduce AHU1 cold deck static pressure & valve repair			
M6	AH2 and AH3 Repair static pressure sensor(s). Adjust AH2 chilled wate	219%	25%	
M7	Reduce AHU4 supply air static pressure		32%	
#1007 Participant D				
M1	Reduce AHU cold deck static pressure setpoint to VAV boxes	65%	66%	
M2	Reduced exhaust static pressure	100%	100%	
M3	Reduce 100%OA cfm from 12 to 8 ACH in non-lab areas	53%	36%	39%
M4	Increase thermostat deadband	114%	39%	1101%
M5	Reduce cfm when unoccupied	47%		54%
M14	Increase night setback schedule	7%		15%
TOTAL		**62%**	**47%**	**43%**

Table 6-3: Evaluation Simple Average Realization Rate

Site & Measure	Electric Energy Realization Rate	Electric Demand Realization Rate	Gas Realization Rate
#1001 Participant A	99%	118%	na
#1005 Participant B	50%	33%	na
#1006 Participant C	143%	52%	na
#1007 Participant D	64%	60%	302%
TOTAL	89%	66%	302%

With this information in hand, ERS calculated the estimated impact by measure, participating site, and for the program overall shown in Table 6-4.

Table 6-4: Impact for All Measures, Sites Overall, and Program Overall and Realization Rates by Site

Site & Measure		Electric Energy Impact (kWh/yr)	Electric Demand Impact (kW)	Gas Impact (therms/yr)
#1001 Participant A				
M2	VFD on chilled water pump	48,203	0	0
M4	VFD on condenser water pump	100,331	0	0
M5	Reduce rear waterfall pumping	44,749	9	0
M6	Reduce front water feature pumping	81,586	9	0
M7	Turn off stream pump at night	33,316	5	0
M8	Re-activate garage DCV fan control	502,688	84	0
M12	Reduce simult. heating/cooling - repair AHU#5 VFD	158,464	0	247
M12a	Reduce simult. heating/cooling all but repair AHU#5 VFD	276,998	0	88,305
M14	Install VFD on S. Tower DHW pump	85,164	10	0
M15	Install VFD on N. Tower DHW pump	92,009	10	0
#1005 Participant B				
M1	Reduce summer night lobby cold deck fan operation	29,747	2	0
M2	Reduce AHU cold deck static and temperature. Increase free cooling.	133,479	46	0
M3	Condenser water reset for VFD chillers.	0	0	0
#1006 Participant C				
M1	Correct uneven cooling tower flow	93,984	40	0
M2	Switch from parallel to series chiller sequencing	86,739	0	0
M3	Raise chilled water supply temperature	41,833	12	0
M4	Reduce summer night fan operation	186,677	0	0
M5	Reduce AHU1 cold deck static pressure & valve repair	36,397	1	0
M6	AH2 and AH3 Repair static pressure sensor(s). Adjust AH2 chilled wate	252,993	52	0
M7	Reduce AHU4 supply air static pressure	5,569	13	0
#1007 Participant D				
M1	Reduce AHU cold deck static pressure setpoint to VAV boxes	368,554	46	0
M2	Reduced exhaust static pressure	192,419	22	0
M3	Reduce 100%OA cfm from 12 to 8 ACH in non-lab areas	926,204	255	17,485
M4	Increase thermostat deadband	465,860	67	6,252
M5	Reduce cfm when unoccupied	2,015,828	0	44,035
M14	Increase night setback schedule	30,549	0	7,594
TOTAL		**6,290,340**	**683**	**163,918**
#1001 Participant A		97%	387%	na
#1005 Participant B		61%	35%	na
#1006 Participant C		142%	39%	na
#1007 Participant D		52%	40%	42%
TOTAL		**64%**	**47%**	**62%**

6.2 Other ERS Findings

Spillover. In each project the implementation subcontractor either had a prior relationship with the site staff, has continued one after RCx conclusion or both. The nature of the program in emphasizing O&M improvements over capital projects and incorporating persistence tracking makes this one of the key program strengths. The gross impact evaluators believe that participant on-site and off-site spillover is occurring in explicitly documentable and subtle hard-to-document actions. Specific examples from each of the three participants include:

Participant A's gradual expansion of their internally–branded RetroCommissioning program from the Western Region to nationwide. This RCx program had existed prior to the project and had been first been created after successes at two other California hotels, but according to a conversation with Participant A's Western Region Energy Manager. Participant A's award-winning RCx project success inspired the Western Region manager to roll out the program more aggressively in California and then nationwide at their national facility managers' annual workshops.[2,3,4] Specifically, Participant A has contracted with the lead RCx engineer to work on additional RCx projects in the region.

Participant D's RCx funding was applied to four buildings of an eight-building campus. The four buildings share a common central HVAC plant and together their floor space combined met the program 100,000 square feet minimum size requirement. The other four buildings have about the same total floor space as the program buildings, but because they each have their own HVAC plant, were not eligible for program funding. Most of the RCx recommendations focused on air handling units (AHUs). These recommendations applied equally to all eight of the buildings on campus and the implementation subcontractor generally made the recommendations to the campus managers for campus-wide implementation. While not documented in the reported program savings tracking data for the four program buildings, the other buildings are realizing much of the same savings. This potentially introduces an on-site spillover multiplier of 2.0.

Participant B's and C's staff implemented a lower proportion of the measures than the other participants in part because they separately have been implementing Hartman Loop™ control upgrade projects across their portfolio of buildings.[5] These parallel projects are very much in the spirit of RCx. The client's satisfactory participation in the SDG&E RCx program encouraged and through improved facilities department cash flow partially funded other such

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2 See *APPROPRIATE USE OF THIRD PARTIES IN THE EXISTING BUILDING COMMISSIONING PROCESS – AN IN-HOUSE APPROACH TO RETROCOMMISSIONING*, World Energy Engineering Congress 2004, Tudi Haasl and David Sellers, Portland Energy Conservation, Inc.

3 Telephone call between J. Maxwell of ERS and Participant A, December 2007.

4 California Center for Sustainable Energy 2006 SANDEE Finalist.

5 The Hartman LOOP™ is a trademarked branding of one firm's packaged solution to all-variable all-primary chilled water plant controls. Through implementation, customers eliminate primary-secondary chilled water flow systems if they are present and add VFDs to the chilled water and condenser water pumps, the chiller(s), and cooling tower fans if they are not present. Then they use Hartman's proprietary control logic to minimize overall chilled water plant kW/ton and prevent conflicting feedback between the various VFDs.

projects not necessarily being implemented through SDG&E.[6] This represents potential on-site and off-site spillover.

Overall, a well-executed RCx process inherently and by design integrates good practices into daily facilities management decision-making and attitudes. While quantifying this factor was not in the scope of the study and rigorous questionnaires were not administered nor the analysis, ERS believes that the cultural and financial effects of on-site and off-site participant spillover in the range of 25% to 50% is likely for this program.

Persistence. The performance tracking report for Participant A assigned 0% cumulative persistence of savings for Measures 2 and 4. ERS recommends that this value not be generally applied to the measure across the entire equipment life for two reasons. The more minor reason is that Participant A did install the VFDs as recommended and informed us that while VFD operation was not initially automated they did make use of the VFDs manually for short periods during the performance tracking period. The major reason is that complete automation is being implemented, albeit on a delayed schedule due to a larger controls system migration and integration issue. At the time this report was written the measures were in test mode and actually operating as designed and recommended. Once the test period is over, the measure should have as full persistence as other implemented VFD-related measures.

Free Ridership. Two Participant C measures and one Participant B measure address chiller plant control. The facilities use Hartman LOOP logic to manage the plant settings and optimize overall chiller plant kW/ton with VFDs on all equipment. The Hartman LOOP is a proprietary system that reputedly employs expert system logic to decide what setpoints should be. Facilities staff virtually cannot adjust setpoints directly.[7] The client is highly satisfied with the system and has been gradually expanding its use at the participating sites coincident with the RCx process and also at other company-owned sites.[8] Each requires a service contract. That said, the controls system managers seem to have made some changes to the control sequences in response to the RCx recommendations. Evidence was contradictory and we could not entirely discern which changes were due to the RCx program

6 In-person interview between ERS and Participant B, December 20, 2007.

7 For example site staff cannot simply adjust the condenser water setpoint to increase tower energy use a little and save chiller energy use, with possible effects on the condenser water pump power as well. The Hartman LOOP theoretically monitors all three of these power points and determines the optimal condenser water setpoint as a function of load and outside wet bulb temperature or other variables without any explicit instruction. Forcing a specific setpoint with an external instruction is simply incompatible with the LOOP concept.

8 They reported total chiller plant efficiency including the chillers, pumps, and tower fans of less than 0.30 kW/ton under certain conditions. If true this is indeed exceptional performance.

and which were due to the Hartman LOOP's expert system optimization exercise and would have occurred anyway.

Measure Life. The PECI work papers submitted for this project cite an 8-year life and acknowledged that this long life assumption "is reasonable only with the aggressive persistence strategies that we are providing as part of our program."[9] The performance tracking component of the program clearly increased persistence during the tracking period. There were multiple instances (at least three known to evaluators) where the performance tracking monitors caught the regression of control settings or relay failures that returned retrofit conditions back to their pre-retrofit conditions. It is impossible to say for certain how long the inefficient operating mode would have continued without monitoring but it certainly would have been longer than without monitoring and in the worst case it could have signified the end of the measure life. In one case the failed condition was wasting over 200,000 kWh/yr.

If as we understand it program performance tracking stops after one year, it is reasonable to wonder how long the measures will persist. Having met with internal and third party engineering and controls contractors for three of the sites, the evaluators believe that awareness has been sufficiently raised that as such problems occur in the future they are more likely to be identified and repaired than not, but that not all will be caught.

ERS recommends that the EMS controls firms to program in alarms to alert staff any time the retrofit settings fail back to pre-retrofit model. This may have been done but it not obviously so.

On the other hand, certain of the changes made are likely to persist for more than eight years. Variable frequency drives were installed in response to two retrocommissioning recommendations. The DEER deemed measure life for this measure is 10 years. Further, we believe that this measure is likely to persist well beyond the life of the drive. An entire new skid of equipment (pump, motor, VFD, controls) was bought in order to implement the recommendation. We don't know of course but expect that the variable speed configuration will be retained after the drives fail.

In summary, we would use a savings declination curve that drops below 100% starting in year one, but that is above 0% beyond eight years.

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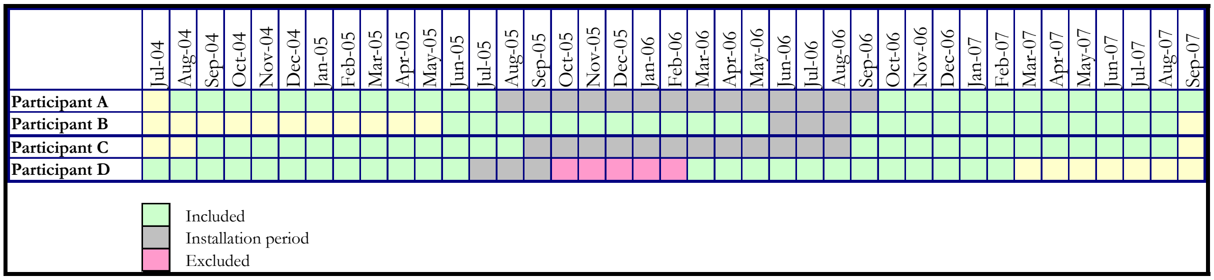
[9] SDGE BCRC Program PECI/AEC Work papers downloaded from http://www.californiaenergyefficiency.com/efficiency/SDGEWorkpapers/3rdParty/RCX_Retrocommisioning/PECI_AEC_Workpapers.doc. It is considered a long life assumption compared to the 2005 California Database of Energy Efficiency Resources (DEER) four-year life for retrocommissioning for refrigeration equipment, for example.

6.3 Itron Billing Analysis Findings

The date ranges of billing and weather data used in the analysis are summarized in Figure 6-1.

Figure 6-1: Summary of Pre, Post and Installation Period Data



Participant A and C had reportedly lengthy installation periods. Participant B, on the other hand, had a short installation period. For Participant D, there was a period immediately following the installation period that exhibited high electric usage. This period of time was excluded from the analysis as it appeared to be an irregular event.

The results of the PRISM billing analysis for each participant are summarized in Table 6-5.

Table 6-5: PRISM Billing Analysis Results by Participant

		Tao is calculated											
		Tao		Regression Results								Prediction	
		HDD (46 - 90)	CDD (32 - 85)	N Obs	R-Square	Intercept	t-statistic	HDD Coefficient	t-statistic	CDD Coefficient	t-statistic	NAC	Std Dev
Participant A	PrePeriod	87	75	12	0.9800	102,861	49.99	-1,560	-18.42	-30,317	-4.03	24,016,539	109,227
Electric	PostPeriod	63	63	11	0.9436	64,034	59.10	-553	-2.40	1,730	7.15	24,395,993	180,184
	Savings											**379,454**	
Participant A	PrePeriod	87	49	12	0.4613	15,488	2.47	-416	-2.46	-417	-2.47	21,644	2,821
Natural Gas	PostPeriod	47	61	11	0.6402	76	16.05	198	0.53	-4	-3.47	23,323	1,300
	Savings											**1,679**	
Participant B	PrePeriod	84	47	12	0.2290	165,280	1.69	-4,294	-1.58	-4,272	-1.58	3,968,535	25,774
Electric	PostPeriod	61	68	12	0.2401	10,312	64.37	-78	-1.38	26	0.23	3,734,531	35,643
	Savings											**(234,004)**	
Participant B	PrePeriod	53	63	12	0.8801	2,942	29.75	9,377	0.86	244	7.81	1,350,917	80,040
Natural Gas	PostPeriod	53	66	12	0.8998	2,876	40.26	-225	-0.80	284	8.23	1,159,412	19,741
(none reported)	Savings											**(191,506)**	
Participant C	PrePeriod	70	64	12	0.9724	27,406	24.07	-435	-3.50	1,138	5.62	9,702,578	91,345
Electric	PostPeriod	68	65	12	0.9891	26,978	83.31	-396	-10.64	826	9.83	9,542,676	41,182
	Savings											**(159,903)**	
Participant C	PrePeriod	86	69	12	0.5365	188	2.71	7	2.38	52	3.22	132,164	2,984
Natural Gas	PostPeriod	53	61	12	0.4950	472	20.74	69	1.06	-10	-2.27	160,225	5,692
(none reported)	Savings											**28,062**	
Participant D	PrePeriod	65	53	12	0.2014	140,405	3.92	-5,944	-1.37	-3,574	-1.51	31,739,952	1,586,637
Electric	PostPeriod	59	64	12	0.9838	71,663	69.59	-3,407	-6.47	3,123	15.91	27,471,010	230,430
	Savings											**(4,268,942)**	
Participant D	PrePeriod	76	52	12	0.9833	-3,212	-3.93	162	4.56	150	4.24	142,581	895
Natural Gas	PostPeriod	63	72	12	0.8862	296	27.92	16	6.33	-23	-1.83	119,424	2,512
	Savings											**(23,156)**	

The NAC savings is calculated by subtracting the post NAC from the pre NAC. A negative number signifies a reduction in energy use. Participant A does not show a reduction in either electric or natural gas use. Participant B shows both a reduction in electric and gas use, however, there was no reported natural gas savings for this participant. Participant C shows a reduction in electric use and an increase in natural gas use. As with Participant B, Participant C had no reported natural gas savings. Participant D shows a reduction in both electric and natural gas use.

As was mentioned earlier in Section 5, the HDD and CDD were also computed using a base temperature of 65 for comparison purposes. The results from these models are shown in Table 6-6.

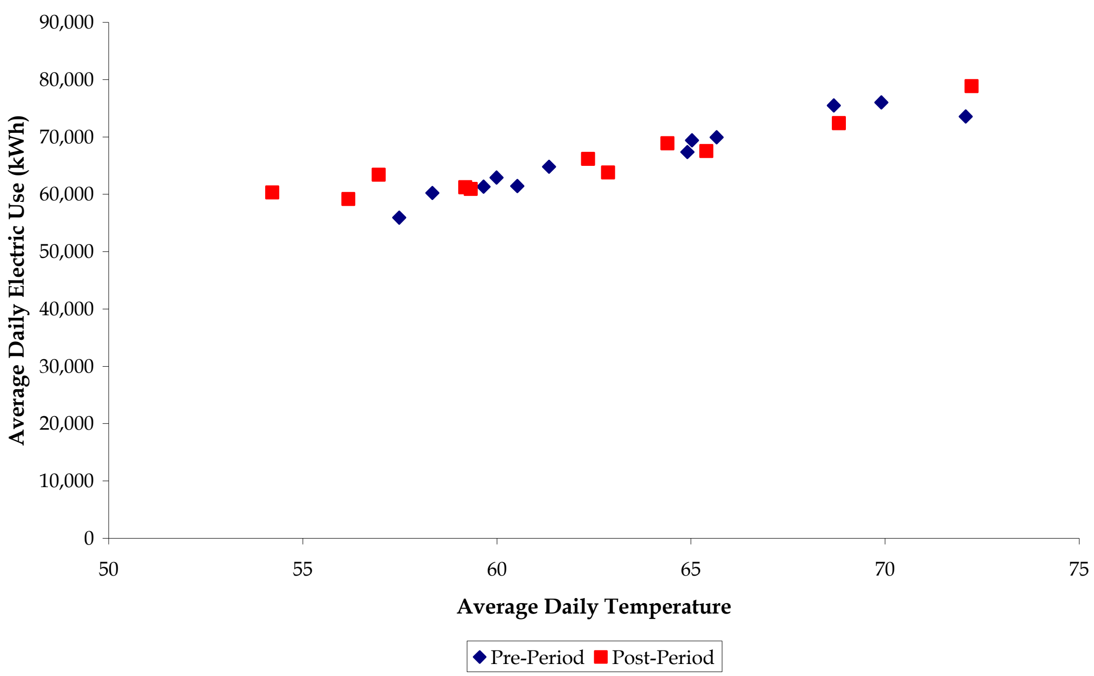
Table 6-6: Billing Analysis Results by Participant with Fixed HDD and CDD

		Tao = 65 for both HDD and CDD									
		Regression Results								Prediction	
		N Obs	R-Square	Intercept	t-statistic	HDD Coefficient	t-statistic	CDD Coefficient	t-statistic	NAC	Std Dev
Participant A	PrePeriod	12	0.9543	69,916	65.91	-1,792	-7.57	1,000	3.33	24,007,383	167,049
Electric	PostPeriod	11	0.9361	66,114	56.18	-682	-3.51	1,976	5.77	24,385,504	192,047
	Savings									**378,121**	
Participant A	PrePeriod	12	0.2633	61	4.30	-3	-0.78	-7	-1.74	16,013	2,374
Natural Gas	PostPeriod	11	0.5933	65	8.43	2	1.26	-4	-1.83	23,476	1,352
	Savings									**7,463**	
Participant B	PrePeriod	12	0.0328	10,935	60.21	-19	-0.52	-14	-0.21	3,962,582	30,595
Electric	PostPeriod	12	0.1942	10,352	42.52	-42	-1.03	4	0.05	3,732,394	36,603
	Savings									**(230,187)**	
Participant B	PrePeriod	12	0.8539	3,219	18.52	-35	-1.03	297	4.44	1,290,059	27,239
Natural Gas	PostPeriod	12	0.8947	2,783	20.87	8	0.38	250	6.45	1,155,141	19,256
(none reported)	Savings									**(134,918)**	
Participant C	PrePeriod	12	0.9623	26,051	39.41	-568	-3.82	1,556	8.52	9,672,906	107,478
Electric	PostPeriod	12	0.9881	26,076	99.93	-435	-10.15	997	13.09	9,543,454	43,016
	Savings									**(129,452)**	
Participant C	PrePeriod	12	0.3869	315	14.42	10	2.01	14	2.29	133,397	3,515
Natural Gas	PostPeriod	12	0.4003	438	11.98	6	1.05	-11	-1.04	161,371	6,048
(none reported)	Savings									**27,974**	
Participant D	PrePeriod	12	0.1908	99,436	9.55	-2,193	-0.96	-3,903	-1.46	31,778,417	1,595,367
Electric	PostPeriod	12	0.9799	74,924	52.85	-1,511	-6.30	3,094	11.13	27,241,337	249,633
	Savings									**(4,537,081)**	
Participant D	PrePeriod	12	0.9804	353	55.01	17	11.86	-6	-3.72	144,620	920
Natural Gas	PostPeriod	12	0.8631	289	18.34	13	4.96	-3	-0.88	119,014	2,685
	Savings									**(25,606)**	

These results do not differ all that significantly from those of the PRISM analysis, but in general the model fit statistics show the PRISM results to be slightly better.

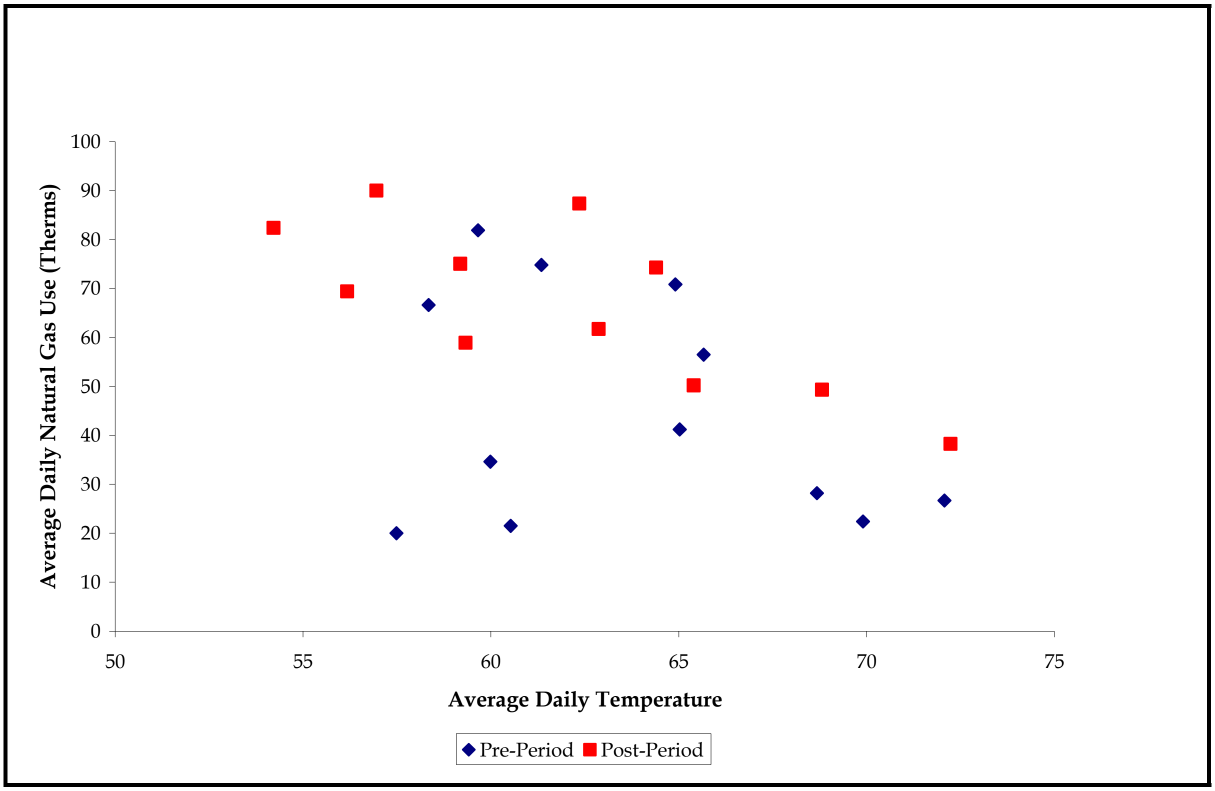
The calendarized billing and weather data were also graphed together to help understand the results. Each participant's average daily electric and natural gas use was plotted against the average daily temperature for each calendar month. The pre and post installation data are indicated in each graph. Participant A is shown in Figure 6-2 and Figure 6-3.

Figure 6-2: Participant A – Average Daily Electric Use versus Temperature



Participant A's electric use in both the pre and post periods exhibits an upward trend as the average daily temperature increases, as expected. However, there does not appear to have been any significant change in its usage pattern after the RCx installation period. This is consistent with the billing analysis results. Given that this is a hotel, any impact of the RCx could be masked by an increase in occupancy rates.

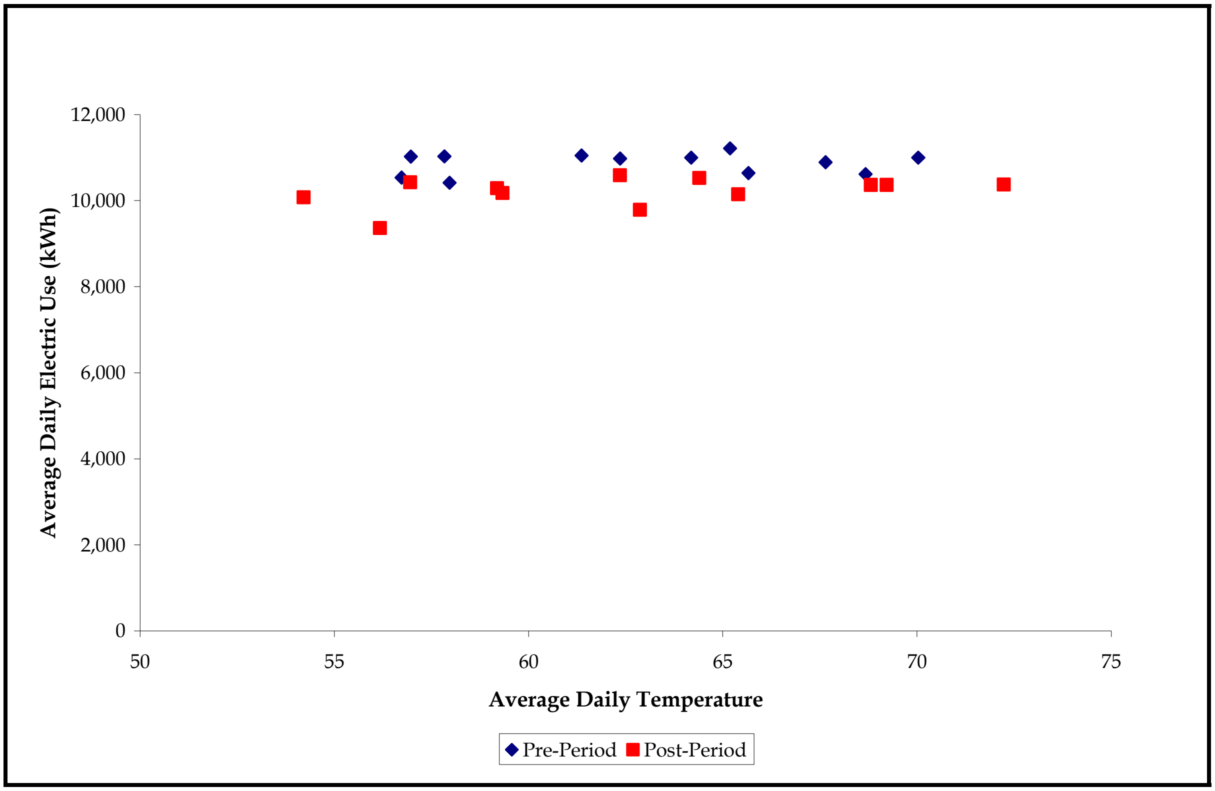
Figure 6-3: Participant A – Average Daily Gas Use versus Temperature



The gas use pattern for Participant A was very irregular in the pre RCx period. This supports the low R^2 of the pre period billing analysis regression model. The pattern of gas use in the post RCx period is much better behaved, but still the same general level if not higher than in the pre period. This too supports the billing analysis results. It is very difficult to determine what was the cause of either the irregular pre period pattern or the increased gas use in the post period given the type of facility involved and the absence of detailed occupancy rate information.

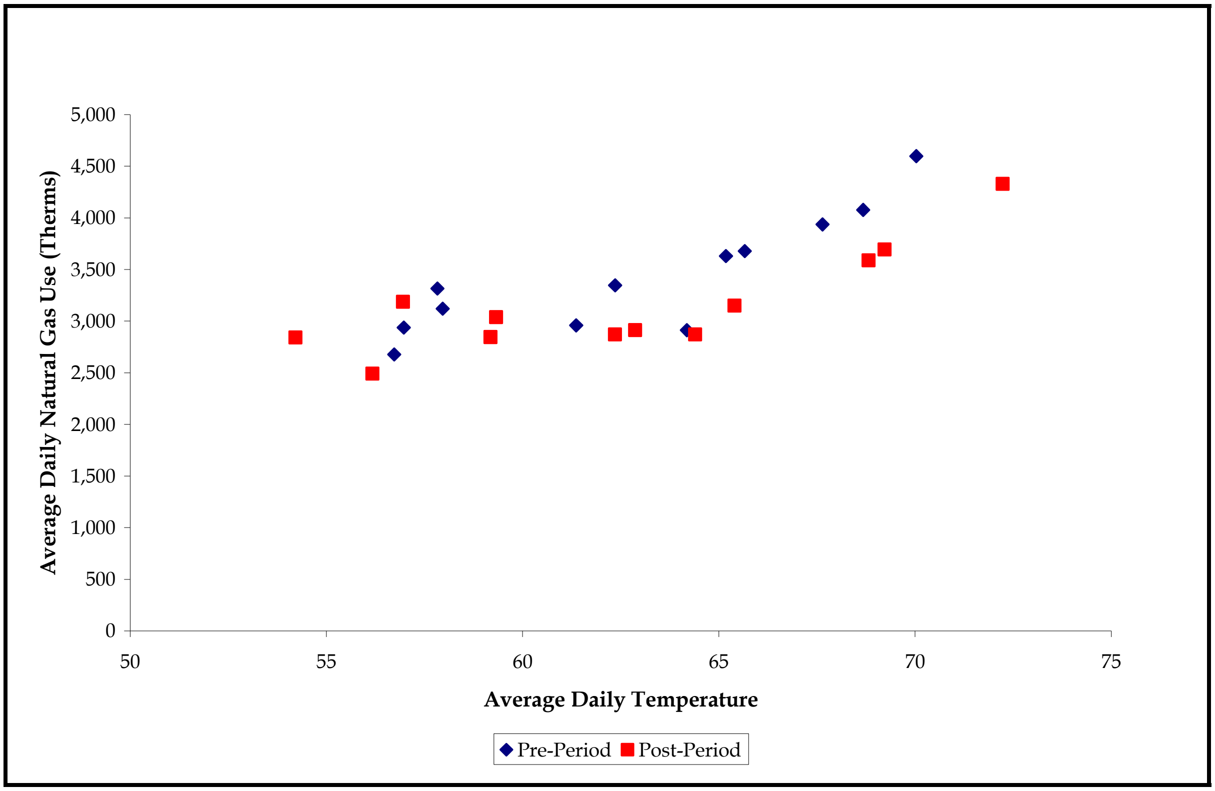
Participant B is shown in Figure 6-4 and Figure 6-5.

Figure 6-4: Participant B – Average Daily Electric Use versus Temperature



For Participant B, it is clearly visible that the post period electric use pattern is lower than in the pre period. This supports the billing analysis results.

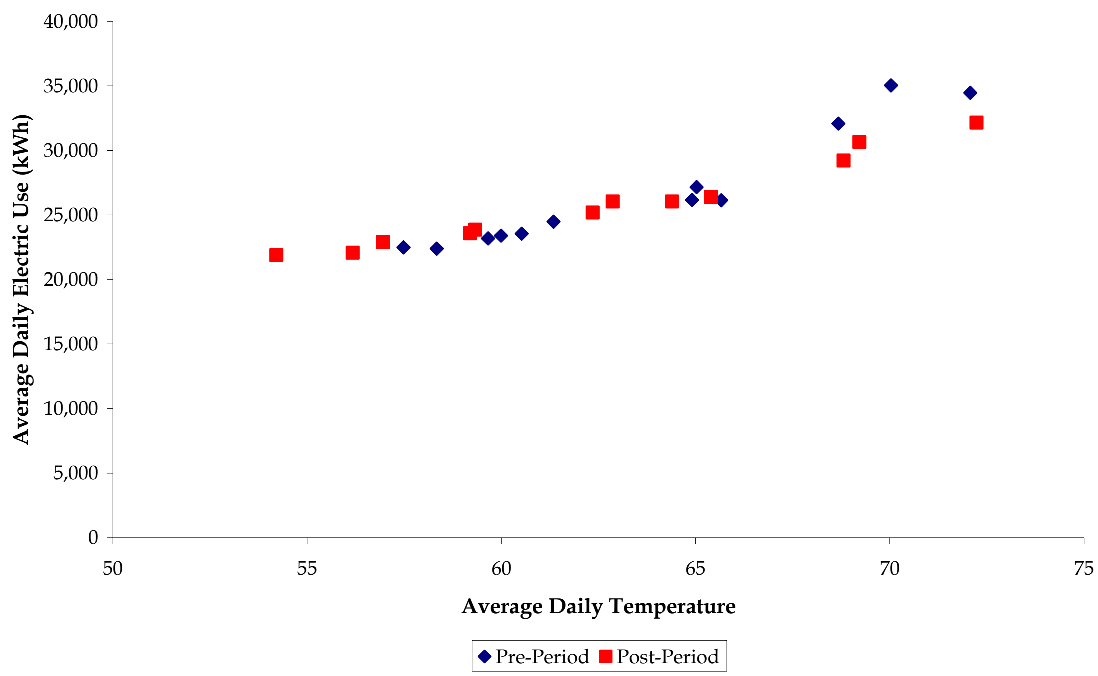
Figure 6-5: Participant B – Average Daily Gas Use versus Temperature



Participant B has an atypical nature gas usage pattern. It is not typical for natural gas use to increase as the temperature increases. One would expect the gas use to either stay the same or increase as temperatures decreased. Increasing gas use with increasing temperature is characteristic of a problem of cooling and heating air supplied to the conditioned spaces or some form of gas fired cooling. In any case, Participant B did not reportedly receive any gas saving RCx measures.

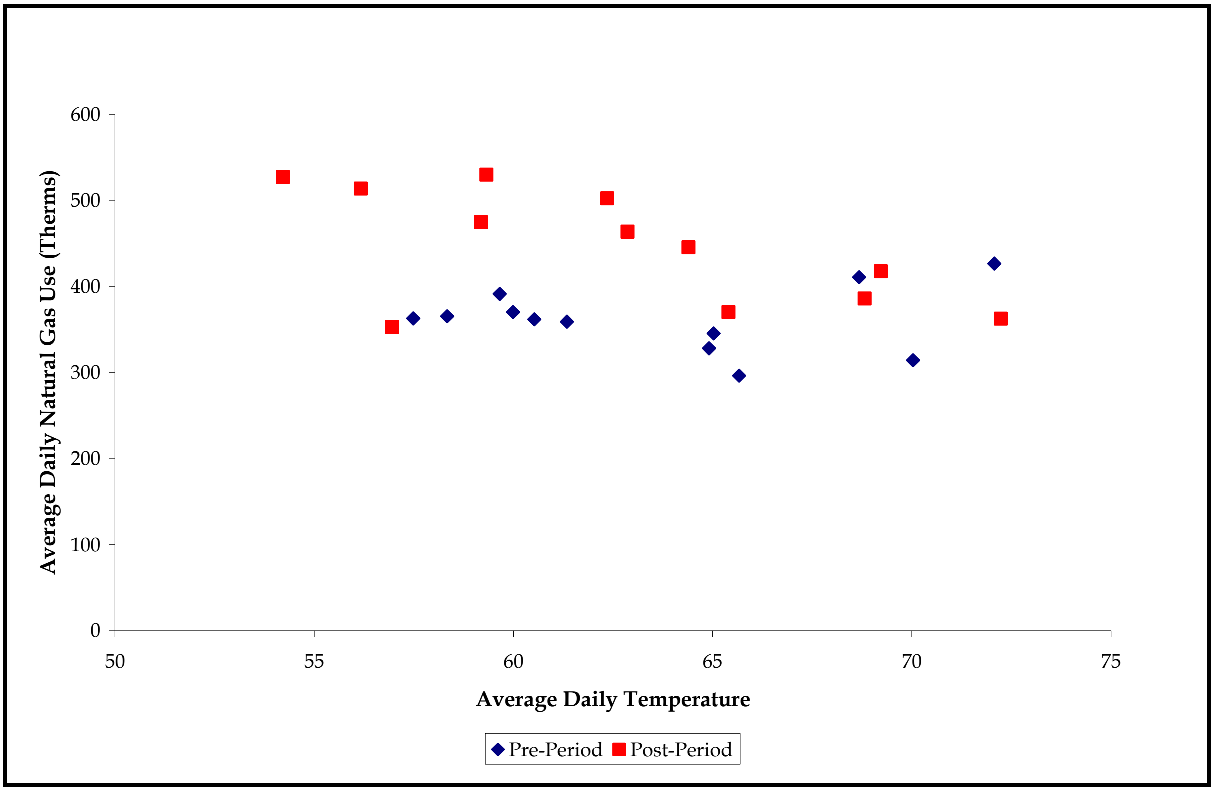
Participant C is shown Figure 6-6 and Figure 6-7.

Figure 6-6: Participant C – Average Daily Electric Use versus Temperature



Participant C shows a small lowering of its electric use in the post period as the average daily temperature begins to rise above 65°F relative to the pre period. This supports the results from the billing analysis.

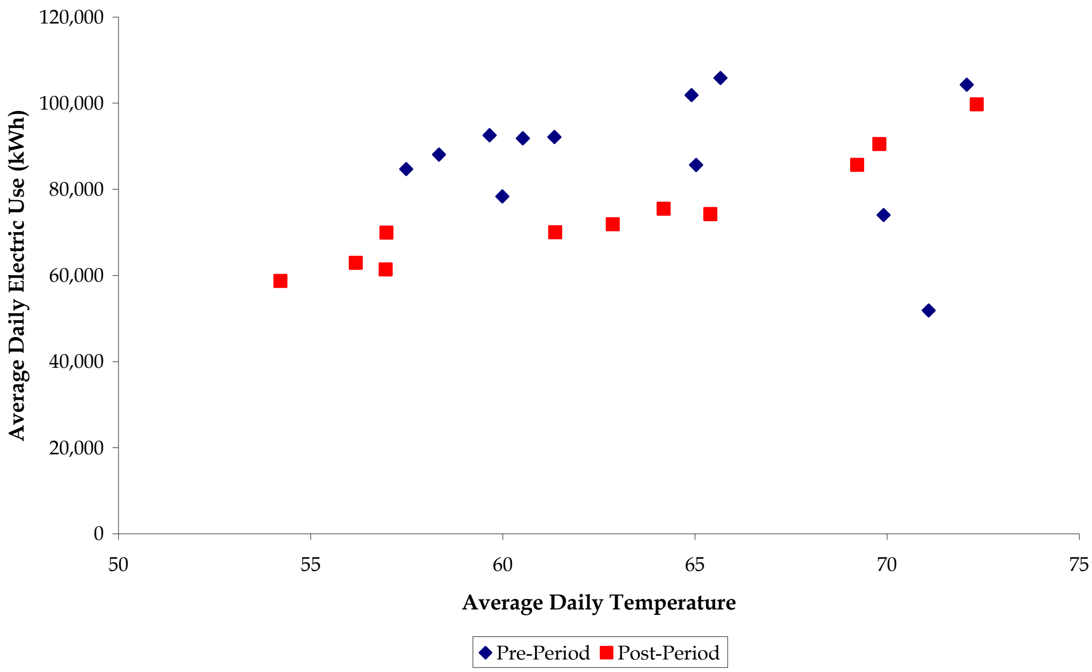
Figure 6-7: Participant C – Average Daily Gas Use versus Temperature



The gas use pattern for Participant C indicates that there was a significant change in how gas was used between the pre and post installation periods. This is supported by the results from the billing analysis. However, there was no reported natural gas savings associated with the RCx activity at this site. This suggests that there may have been a significant occupancy change between the two periods that resulted in an increase in gas use in the post RCx period. This might also explain why a larger reduction in electric use was not observed in post period for Participant C.

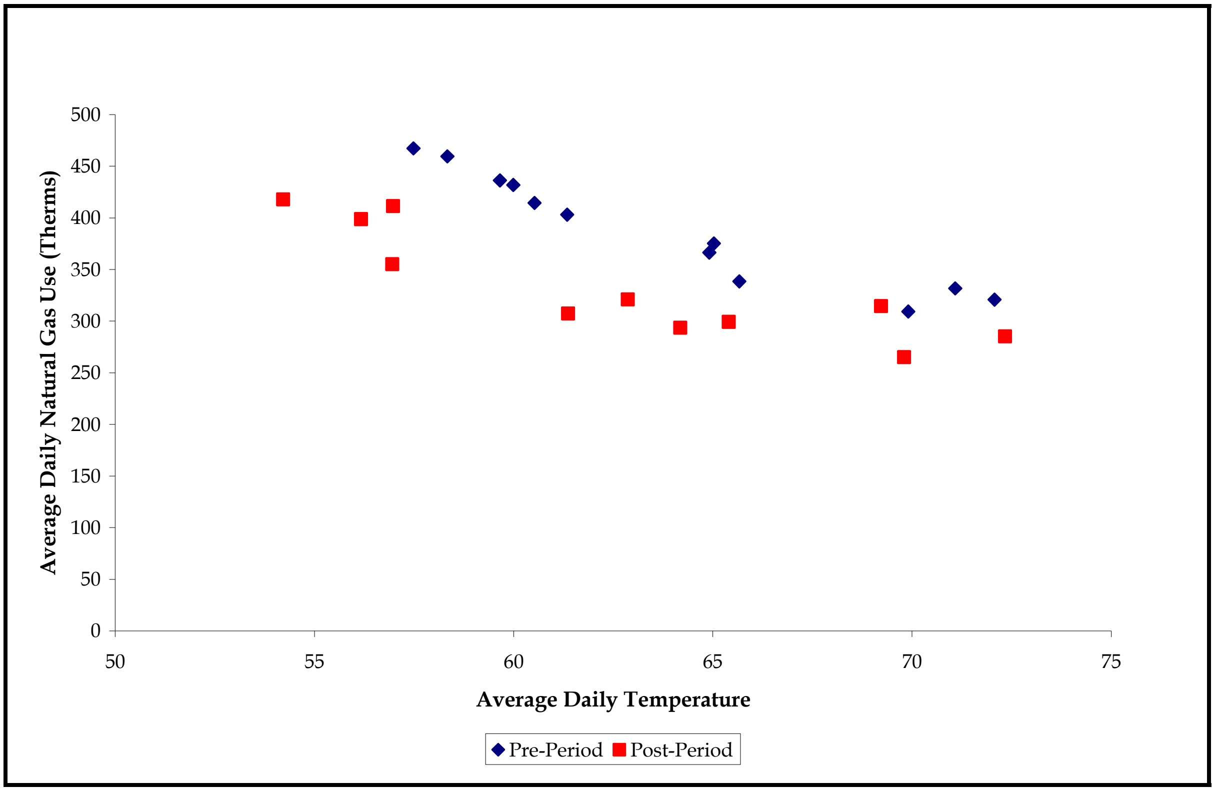
Participant D is shown in Figure 6-8 and Figure 6-9.

Figure 6-8: Participant D – Average Daily Electric Use versus Temperature



The pattern usage is also much better behaved in the post period suggesting much tighter control over the electric use. This is supported by the low R^2 resulting from the billing analysis regression for the pre period and the high R^2 in the post period. There is a very clear reduction in the electric use pattern for Participant D in the post period relative to the pre period. This too is supported by the billing analysis results.

Figure 6-9: Participant D – Average Daily Gas Use versus Temperature



The gas use pattern in both the pre and post periods appears to be typical for a coastal non-residential facility in San Diego. The post period natural gas usage is clearly lower for Participant D compared to its pre period usage. This supports the results from the billing analysis.

6.4 Summary of Itron's Findings

To summarize the billing analysis results, realization rates have been computed based on the reported ex ante savings by participant. Table 6-7 shows the ex ante savings estimates, the PRISM billing analysis results and the computed realization rates.

Table 6-7: PRISM Analysis Realization Rates

Participant	Fuel	Ex Ante Savings	PRISM Savings	Realization Rate
Participant A	Electric (kWh)	(1,470,615)	378,121	-26%
	Natural Gas (therms)	(88,305)	7,463	-8%
Participant B	Electric (kWh)	(267,165)	(230,187)	86%
	Natural Gas (therms)	*none reported*	(134,918)	n/a
Participant C	Electric (kWh)	(496,783)	(129,452)	26%
	Natural Gas (therms)	*none reported*	27,974	n/a
Participant D	Electric (kWh)	(7,654,273)	(4,537,081)	59%
	Natural Gas (therms)	(265,863)	(25,606)	10%

Participant A – Participant A does not appear to have any savings resulting from the RCx and on the face of it, it looks as though energy use has increased. The ex ante savings estimate amounts to approximately 6% of the total annual electricity use and therefore any occupancy changes could have masked any savings. However, the gas use for Participant A is in question. Itron had requested all of the gas accounts associated with the site and the total gas usage amounted to less than the ex ante savings. SDG&E was asked if they could find any additional gas accounts but were unsuccessful.

Participant B – The billing analysis results produce an electric savings realization rate of 86%. This would suggest that the RCx activities have been successful. The observance of a decline in natural gas use may have been as a result of some other activity as no gas savings were claimed.

Participant C – The billing analysis results produce an electric savings realization rate of 26%. This suggests that the RCx activities have been at least partially successful in producing electric savings. The gas use showed a slight increase, however no gas savings were claimed so this does not appear to be of any consequence.

Participant D – For Participant D, the billing analysis produced an electric savings realization rate of 59%. The ex ante savings estimate amounted to approximately 31% of the total electric use which is large relative to even an aggressive energy efficiency campaign. It seems clear that a significant amount of the electric savings was realized. The gas use data is in question, however even though the realization rate is 10%. The gas savings ex ante is slightly larger than the total annual gas use. SDG&E was asked if they could find any additional gas accounts but none were found.

6.5 Reconciling Onsite EM&V and Billing Analysis Results

The billing analysis used by Itron was not intended to be a tool for measuring energy savings resulting from the PECI RCx program. Its purpose is to provide support to ERS's EM&V

findings and further verification of the claimed savings. Because the ERS evaluation did not examine all measures and used a prioritized approach based on the magnitude of the measure ex antes, the ex post results are not directly comparable to the finds of Itron's billing analysis. Furthermore, several of the sites implemented other measures separate to the RCx program participation during roughly the same time period as RCx measure implementation. However, the estimated realization rates by participant can serve as a means of comparison. Table 6-8 provides a comparison of the two analyses' realization rates.

Table 6-8: Comparison of EM&V and PRISM Realization Rates

Participant	Fuel	EM&V Realization Rate	PRISM Realization Rate
Participant A	Electricity (kWh)	97%	-26%
	Natural Gas (therms)	n/a	8%
Participant B	Electricity (kWh)	61%	86%
	Natural Gas (therms)	n/a	n/a
Participant C	Electricity (kWh)	142%	26%
	Natural Gas (therms)	n/a	n/a
Participant D	Electricity (kWh)	52%	59%
	Natural Gas (therms)	42%	10%

In the case of Participant A, ERS estimates that a significant amount of the electric savings should be realized. Itron's billing analysis suggest otherwise. The weaknesses of the billing analysis are that a) it does not take into account any building occupancy effects and b) the size of the ex ante electric savings is small relative to the total electric consumption which makes it more difficult to see the savings through the noise. It is safe to assume that some portion of the electric savings has been realized. The gas savings is uncertain. ERS did not evaluate this measure as it had a low priority. Itron's billing analysis did not detect any savings but the models were weak due to the large amount of unexplained variation in the billing data.

For Participant B, the electric savings appears to be realized to a high degree. Both the EM&V and the billing analysis found evidence of significant savings.

For Participant C, the EM&V analysis found significantly more electric savings than did the billing analysis. It is possible that the billing analysis was not able to see the true savings. The ex ante value was about 5% of the total annual electric use at the site so the regression model may not have been able to pick out all of the savings from the noise.

For Participant D, both analyses resulted in almost the same electric savings realization rate. In this case, the ex ante electric savings was about 31% of the total site electric use. This large a savings should be much easier for the billing analysis to pick out giving a higher degree of confidence that this is the true savings. The gas savings realization rate is more uncertain due to the data issues described in section 6.4.

7

Recommendations

ERS and Itron recommend that the Implementer take the following actions to bring M&V realization rates closer to 100%.

1. Ask field engineers to perform spot power measurement before and after implementation when RCx measures save pump or fan energy, especially when VFDs are involved.[1] **ERS estimates that over the half of the difference between *ex ante* and *ex post* energy impact estimates would have been eliminated if spot before/after retrofit power measurement had been performed and incorporated into the *ex ante* analysis.** Many of the implementer's measure savings estimates depended on over half a dozen engineering design and part load assumptions (full load cfm, design fan static pressure, fan efficiency, motor efficiency, control pressure, "real" part load affinity law exponents, in one example) not to mention unknown design safety factors. Each estimate is burdened with uncertainty and the possibility of erroneous calculation to estimate what could have been measured directly and relatively inexpensively. Spot power measurement at best can be used directly in savings calculations and at least can be used to verify the reasonable range of calculations that don't use the results directly. For example, ERS found that overall the Site A impact estimates based on current measurement had realization rates closer to 100% than did the estimates at other sites used design cfm (with inherent design safety factors implicitly included), VFD speed, fan and motor efficiency, and assumed affinity law performance to estimate power.
2. Provide the implementers with the CPUC-definition of peak demand period and ask that they estimate demand savings on this basis for each measure. Most implementer cost savings were based on kWh/yr or therms/yr energy savings multiplied by the overall average energy rate. Demand savings did not play a role in the economic evaluation. This may be entirely sufficient for the purposes of helping the participant make decisions on which recommendations to pursue. However, the lack of need for demand savings for their own purposes meant that demand estimates were generally determined with less rigor than energy and based

[1] If the retrofit involves a large number of pumps or fans, the exercise could be for a sample. In cases where the motor is over 50% loaded, measuring current can be acceptable in lieu of real power. The recommendation can be applicable for other than pumps or fans but in this project such measures were found to most benefit from such a step. Short term metering would be even better, but this adds to cost. ERS believes spot metering adds significant value even if the application is variable speed and highly variable, as long as speed is recorded at the same time as power.

on varying definitions. A considerable portion of the difference between *ex ante* and *ex post* electric peak demand impact estimates would have been eliminated if the contractors knew and applied the CPUC definition of peak demand to their savings estimates.

3. <u>Continue the practice of involving implementation contractors with long-term relationships with the participants</u>. All four of the projects involved the use of implementation contractors that either were deeply involved with the site prior to RCx project implementation, continued with participant support after RCx project completion, or both. In two cases participant representatives used the phrase "virtually lived there" to describe the contractor's attention to their site. This is a powerful positive characteristic of the program. During our site interviews and metering visits it became clear that such relationships improves the quality of measure discovery, the viability of implementation, and persistence.

4. Develop a whole facility baseline using historical energy billing, weather, and occupancy data. Understanding these conditions prior to implementing an RCx project not only assists in the EM&V process but also provides the RCx customer with a benchmark that can be used compared to and give them greater confidence that actions taken are producing real savings.

Appendix A

A.1 Participant A Measure #2

Use VFD to Reduce Evaporator Water Pump Speed during Single-Chiller Operation

Measure Summary Description

Baseline condition: The central chiller plant has two chillers and two non-backup 20-hp evaporator water pumps. When load requires that both chillers run then both pumps run. The pumps were sized for this high head and high flow condition. When only one chiller is needed, a single pump runs. The baseline design had neither a VFD to control pump speed nor an automated throttle to restrict flow in the single pump condition. Thus the uncontrolled single speed flow followed the pump curve and was higher than necessary, as was the system head.

Actions taken and retrofit condition: Ideally, total system flow in one-pump condition would be 50% of the design conditions, as this is all the flow the chiller requires. System head would decrease by a corresponding 75% (according to the affinity law, 50% flow, squared), and power would decrease 87.5% (50% cubed) compared to the two-pump full flow conditions.

Participant A staff installed a VFD for pump control in July 2006. ERS understands that for a period of months after installation, the VFD was controlled manually according to chiller operation. This practice had been discontinued in anticipation of full system automation. As of February 1, 2008 the new configuration was not automated and manual implementation had been discontinued. Complete automation was reported to be scheduled for within a month.[1]

Because proposed retrofit operations did not exist during the M&V period, IPMVP Option-B type evaluation could not be conducted. ERS applied the close equivalent of IPMVP Option A.

[1] Late update: On March 20, Tom Broene of Participant A reported that the system was up and running as designed.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
Scoping Study	10/28/04	*Measure not identified*		
Detailed Investigation Study	9/2/2005	54,097	0	0
Post-Implement Report	9/12/2006	54,097	0	0
Persistence	9/30/2007	0%		

Description of Original Savings Estimation Approach

Post-implementation report savings was estimated as follows: Projected power was plotted using the manufacturer's pump curve and the system curve and assuming a motor efficiency (85%). Full flow power was estimated (16.25 bhp). Performance relationships were validated with spot current measurement. Single chiller hr/yr was estimated based on the total hr/yr under 70F (6,746 hr/yr). Post-retrofit performance assumed 92% VFD drive efficiency and ideal affinity law performance.

Pre-Site Visit Observations on Original Estimation Approach

None.

ERS Original M&V Plan

ERS would measure pump power over a one-month of the post-retrofit period and use trend data to track flow via VFD frequency data during the same period, then use chiller state data over the year to extrapolate to full year operation.

ERS Actual M&V Plan Executed

This was effectively a pre-retrofit impact estimation process.

The implementer computed facility load in tons from a year's trend data of secondary chilled water loops. ERS used this data to estimate the hours per year that the system is likely to operate in single chiller mode. ERS spot measured real power at full flow, the pre-retrofit condition, and estimated post-retrofit flow based on the implementer's pump curve and resulting forecast speed calculations.

Description of Findings

Spot real power measurement on evaporator water pump during single pump operation was 14.2 kW (100% of implementer-predicted power of 14.2 kW based on pump curve assumptions.

ERS's estimate of single-chiller mode annual hours was 6,225 hr/yr (92% of the implementer's 6,746 hr/yr implementer estimate). Either easily could be correct. The evaluation-predicted post-retrofit power was 6.46 kW compared to the 6.24 kW ex ante prediction, with the difference being that ERS used a less than ideal affinity law exponent of 2.7 instead of 3.0.

Impact Summary Ex Post Results

Result	Savings		
	Annual Electricity (kWh/yr)	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
ERS Evaluation Impact Estimate	48,203	0	0
Realization Rate*	89%		

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

Uncertainty Factor	Uncertainty at 90% Confidence
Metering equipment accuracy/uncertainty	±1%
Short-term to long-term extrapolation uncertainty	±1%
Baseline energy use uncertainty	±1%
Methodological uncertainty (weather, assumptions, approach, theory)	-5% to +20%
Other uncertainty factors	
Overall engineering estimate of uncertainty for measure	-5% to +20%

The Dent real power logger has better than 1% accuracy and better than 0.5% accuracy under typical conditions.

The 2005 to 2006 actual weather data used (64.2F average dry bulb temperature) is generally representative of long-term weather patterns (64.2F average annual dry bulb temperature).

As the participant gradually implements measure 12 to reduce simultaneous heating and cooling and reduce chiller load, the number of hours in single chiller mode should increase. This in turn should increase the savings for this measure.

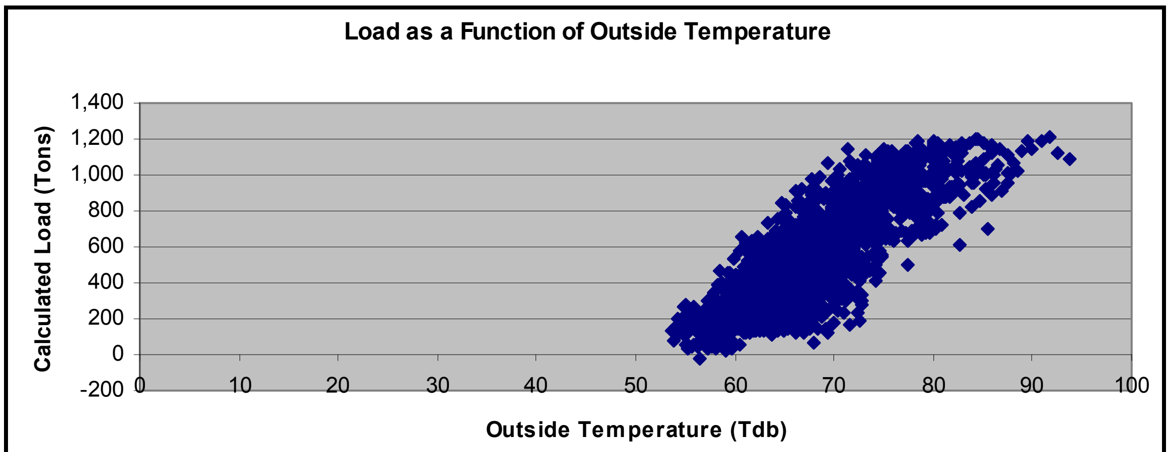
Net-to-Gross and Other Related Observations

While implementation has been delayed, long-term persistence is not going to be 0%. The project is being implemented.

Further, as ERS understands Participant A's description of actual manual VFD pump control between the time it was installed in 2006 and the beginning of the M&V period, actual persistence has been greater than 0% even though it has not been automated. ERS did not acquire trend data to validate this supposition.

Selected Backup Calculations, Intermediate Results, Exhibits

Chiller design capacity	600	tons	*from scoping report*
OATdb during ~600-700 ton load range	65 to 75	F	*from inspection of below graph*
Estimated condenser water temp decrease at 600-700 vs design	15	F	*assumed CW reset*
Estimated capacity at off-design conditions	107.5%		*ERS estimate. Typical 1% increase in capacity for every 2F decrease in leaving CW temperat*
Estim. chiller capacity during 600-700 ton load OAT range (~70F	645	tons	
Hr/yr with chiller at or below this tons/yr, single chiller mode	**6,225**	**hr/yr**	*92%*
Measured power in single chiller mode, full flow	14.2	kW	*from ERS spot measurement data*
Reduced speed possible with VFD	73.8%	of full flow	*from PECI "condenser water pump test r1.xls"*
Drive efficiency	97.0%		*ERS estimate. PECI used 90% in condenser water pump test r1.xls.*
Pump affinity law "real" exponent	2.7		*ERS estimate. 3 is ideal, and what was used in condenser water pump test r1.xls*
Forecast power	6.5	kW	
Average annual savings when in single chiller mode	**7.7**	**kW**	
	55%		
Annual pump energy savings	**48,203**	**kWh/yr**	
Ex ante savings estimate	54,097	kWh/yr	
Realization rate	89%		
CPUC peak period hrs/yr	758	hr/yr	
Weekday hr/yr in 2-chiller mode	1,811	hr/yr	
Peak period demand savings	0%	of average kW	
Peak period demand savings	**0**	**kW**	



A.2 Participant A Measure #4

Use VFD to Reduce Condenser Water Pump Speed during Single-Chiller Operation

The analysis approach, results, and text for this measure are similar to that for Measure #2.

Measure Summary Description

Baseline condition: The central chiller plant has two chillers and two non-backup 30-hp condenser water pumps. When load requires that both chillers run then both pumps run. The pumps were sized for this high head and high flow condition. When only one chiller is needed, a single pump runs. The baseline design had neither a VFD to control pump speed nor an automated throttle to restrict flow in the single pump condition. Thus the uncontrolled single speed flow followed the pump curve and was higher than ideal—ideal being half of the flow rate of the two pumps together—as was the system head. Pump energy use in turn exceeded chiller system requirements.

Actions taken and retrofit condition: Ideally, total system flow in one-pump condition would be 50% of the design conditions, as this is all the flow the chiller requires. System head would decrease by a corresponding 75% (according to the affinity law, 50% flow, squared), and power would decrease 87.5% (50% cubed) compared to the two-pump full flow conditions.

Participant A staff installed a VFD for pump control in July 2006. ERS understands that for a period of months after installation, the VFD was controlled manually according to chiller operation. This practice has been discontinued in anticipation of full system automation. As of February 1, 2008 the new configuration was not automated and manual implementation had been discontinued. Complete automation was reported to be scheduled for within a month.

Because proposed retrofit operations did not exist during the M&V period, IPMVP Option-B type evaluation could not be conducted. ERS applied the close equivalent of IPMVP Option A.

Implementer Ex Ante Impact Estimates

Estimate Period		**Savings**		
		Annual Electricity (kWh/yr)	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
Scoping Study	10/28/04	*Measure not identified*		
Detailed Investigation Study	9/2/2005	115,808	0	0
Post-Implement Report	9/12/2006	129,436	0	0
Persistence	9/30/2007	0%		

Description of Original Savings Estimation Approach

Post-implementation report savings was estimated as follows: Projected power was plotted using the manufacturer's pump curve and the system curve and assuming a motor efficiency (85%). Full flow power was estimated (30 bhp). Performance relationships were validated with spot current measurement. Single chiller hr/yr was estimated based on the total hr/yr under 70F (6,746 hr/yr). Post-retrofit performance assumed 90% VFD drive efficiency and ideal affinity law performance.

Pre-Site Visit Observations on Original Estimation Approach

None.

ERS Original M&V Plan

ERS would measure pump power over a one-month of the post-retrofit period and use trend data to track flow via VFD frequency data during the same period, then use chiller state data over the year to extrapolate to full year operation.

ERS Actual M&V Plan Executed

This was effectively a pre-retrofit impact estimation process.

The implementer computed facility load in tons from a year's trend data of secondary chilled water loops. ERS used this data to estimate the hours per year that the system is likely to operate in single chiller mode. ERS spot measured real power at full flow, the pre-retrofit condition, and estimated post-retrofit flow based on the implementer's pump curve and resulting forecast speed calculations.

Description of Findings

Spot real power measurement on condenser water pump during single pump operation was 22.7 kW (86% of implementer-predicted power of 26.3 kW based on assumptions).

ERS's estimate of single-chiller mode annual hours was 6,225 hr/yr (92% of the implementer's 6,746 hr/yr implementer estimate). Either easily could be correct.

Impact Summary Ex Post Results

Result	Savings		
	Annual Electricity (kWh/yr)	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
ERS Evaluation Impact Estimate	100,331	0	0
Realization Rate*	78%		

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

Uncertainty Factor	Uncertainty at 90% Confidence
Metering equipment accuracy/uncertainty	±1%
Short-term to long-term extrapolation uncertainty	±1%
Baseline energy use uncertainty	±1%
Methodological uncertainty (weather, assumptions, approach, theory)	-5% to +20%
Other uncertainty factors	
Overall engineering estimate of uncertainty for measure	-5% to +20%

The Dent real power logger has better than 1% accuracy and better than 0.5% accuracy under typical conditions.

The 2005 to 2006 actual weather data used (64.2F average dry bulb temperature) is generally representative of long-term weather patterns (64.2F average annual dry bulb temperature).

As the participant gradually implements measure 12 to reduce simultaneous heating and cooling and reduce chiller load, the number of hours in single chiller mode should increase. This in turn should increase the savings for this measure.

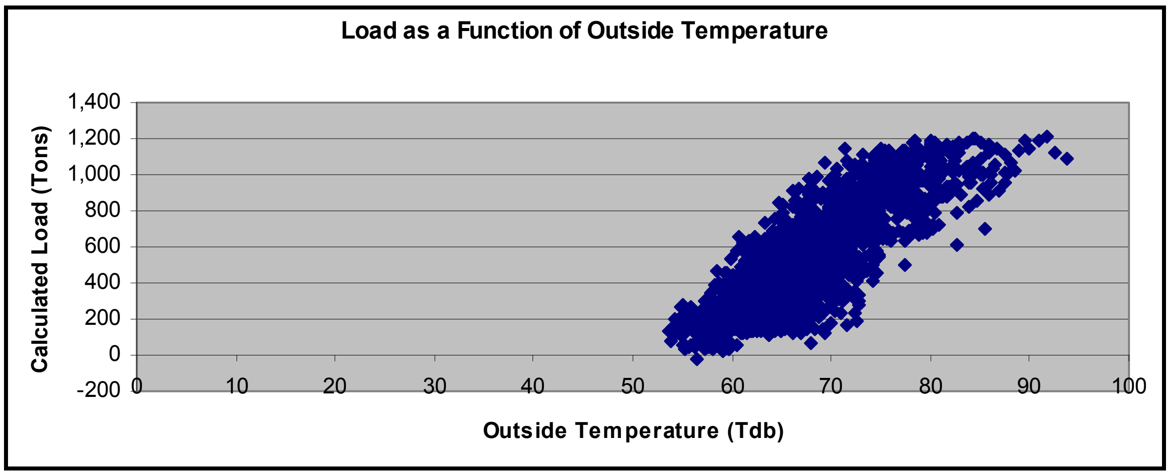
Net-to-Gross and Other Related Observations

While implementation has been delayed, long-term persistence is not going to be 0%. The project is being implemented.

Further, as ERS understands Participant A's description of actual manual VFD pump control between the time it was installed in 2006 and the beginning of the M&V period, actual persistence has been greater than 0% even though it has not been automated. ERS did not acquire trend data to validate this supposition.

Selected Backup Calculations, Intermediate Results, Exhibits

Chiller design capacity	600	tons	*from scoping report*
OATdb during ~600-700 ton load range	65 to 75	F	*from inspection of below graph*
Estimated condenser water temp decrease at 600-700 vs design	15	F	*assumed CW reset*
Estimated capacity at off-design conditions	107.5%		*ERS estimate. Typical 1% increase in capacity for every 2F decrease in leaving CW temperature*
Estim. chiller capacity during 600-700 ton load OAT range (~70F	645	tons	
Hr/yr with chiller at or below this tons/yr, single chiller mode	**6,225**	**hr/yr**	*92%*
Measured power in single chiller mode, full flow	22.7	kW	*from ERS spot measurement data*
Reduced speed possible with VFD	62.5%	of full flow	*from PECI "condenser water pump test r1.xls"*
Drive efficiency	97.0%		*ERS estimate. PECI used 90% in condenser water pump test r1.xls.*
Pump affinity law "real" exponent	2.7		*ERS estimate. 3 is ideal, and what was used in condenser water pump test r1.xls*
Forecast power	6.6	kW	
Average annual savings when in single chiller mode	**16.1**	**kW**	
	71%		
Annual pump energy savings	**100,331**	**kWh/yr**	
Ex ante savings estimate	129,436	kWh/yr	
Realization rate	78%		
CPUC peak period hrs/yr	758	hr/yr	
Weekday hr/yr in 2-chiller mode	1,811	hr/yr	
Peak period demand savings	0%	of average kW	
Peak period demand savings	**0**	**kW**	



A.3 Participant A Measure #5

Turn Off One of the Rear Waterfall Pumps

Measure Summary Description

Baseline condition: Two pumps worked together bring water up to north and south waterfalls that feed to a central main waterfall and central lower pool. Generally, the cascading flow follows a "Y" shape. The two branches of the "Y" were not perfectly equal in height, but the high volume flow rate overcame small differences and produced generally balanced flows with two pumps on.

If one pump was shut off, the Northern branch lost its water supply because its weirs were slightly higher than the Southern Branch.

Actions taken and retrofit condition: Sandbags were added to equalize the effective height of the weirs and balance the flow rate such that even with the lower flow rate produced by a single pump water flowed through the entire waterfall system. The controls were programmed so that only one pump runs.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
Scoping Study	10/28/04	*Measure not identified*		
Detailed Investigation Study	9/2/2005	65,286	9.9	0
Post-Implement Report text	3/31/06	70,749	N/A	0
Post-Implement Report table	9/12/2006	78,079	11	0
Persistence	9/30/2007	100%		

Description of Original Savings Estimation Approach

Savings was estimated based on spot current measurement before and after, then refined with an additional 66 days of logged post-retrofit current data. Demand was estimated assuming a motor power factor (89%).

Pre-Site Visit Observations on Original Estimation Approach

None.

ERS Original M&V Plan

ERS would spot measure pump real power and use the implementer's log data for duration on this constant load application.

ERS Actual M&V Plan Executed

Same as originally planned.

Description of Findings

This is a constant load application. Evaluator measurement of loaded power is close to that predicted. Most of the difference between the *ex ante* and *ex post* impact estimates is due to the predicted reduction in operating schedules (from nominally 18 to 8 hr/day for a 10 hr/day reduction) exceeding that measured (from 17 to 11 hr/day for a 6 hr/day reduction).

Impact Summary Ex Post Results

Result	Savings		
	Annual Electricity (kWh/yr)	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
ERS Evaluation Impact Estimate	44,749	8.9	0
Realization Rate*	57%	81%	Na

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

Uncertainty Factor	Uncertainty at 90% Confidence
Metering equipment accuracy/uncertainty	±1%
Short-term to long-term extrapolation uncertainty	±3%
Baseline energy use uncertainty	±10%
Methodological uncertainty (weather, assumptions, approach, theory)	-0%
Other uncertainty factors	
Overall engineering estimate of uncertainty for measure	±10%

The Dent real power logger has better than 1% accuracy and better than 0.5% accuracy under typical conditions.

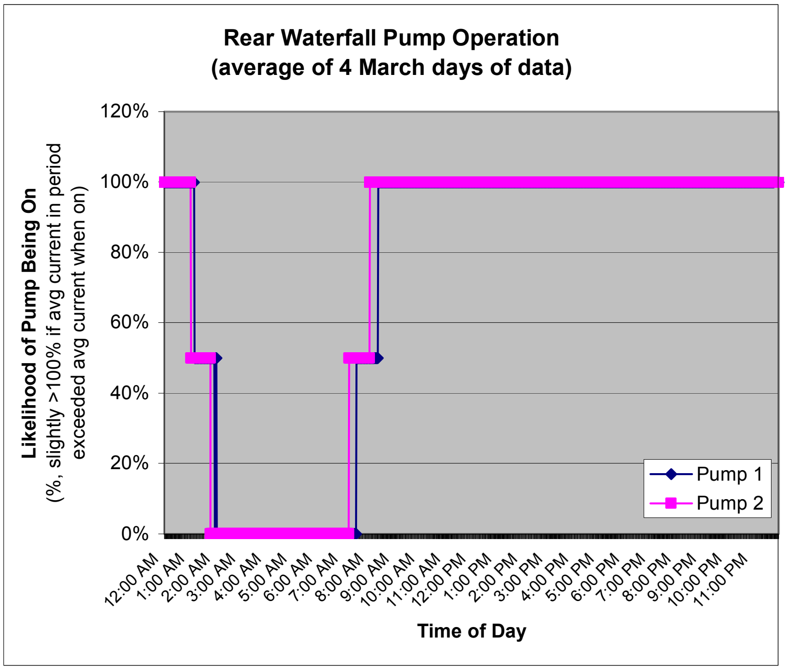
The high baseline uncertainty is due to having to estimate the annual schedule based on four days of measurement.

Net-to-Gross and Other Related Observations

While implementation has been delayed, long-term persistence is not going to be 0%. The project is being implemented.

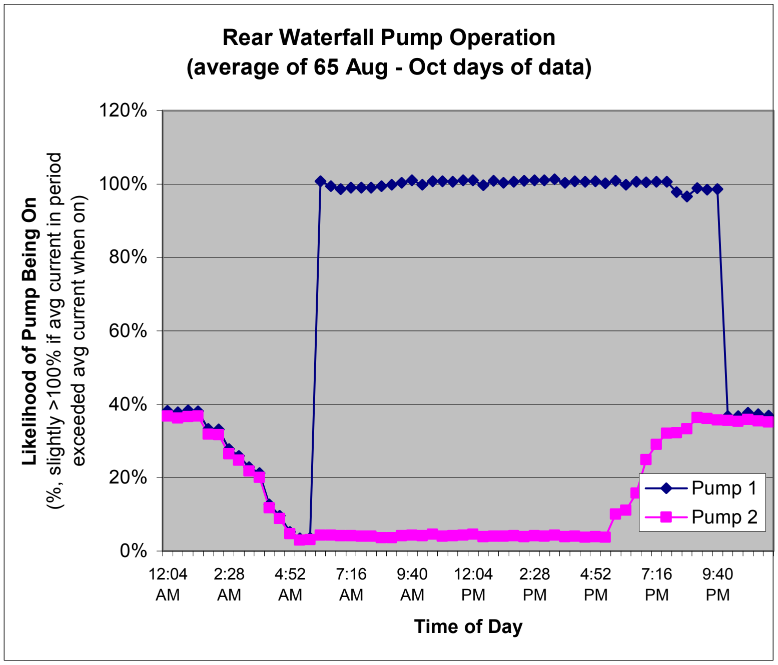
Further, as ERS understands Participant A's description of actual manual VFD pump control between the time it was installed in 2006 and the beginning of the M&V period, actual persistence has been greater than 0% even though it has not been automated. ERS did not acquire trend data to validate this supposition.

Selected Backup Calculations, Intermediate Results, Exhibits

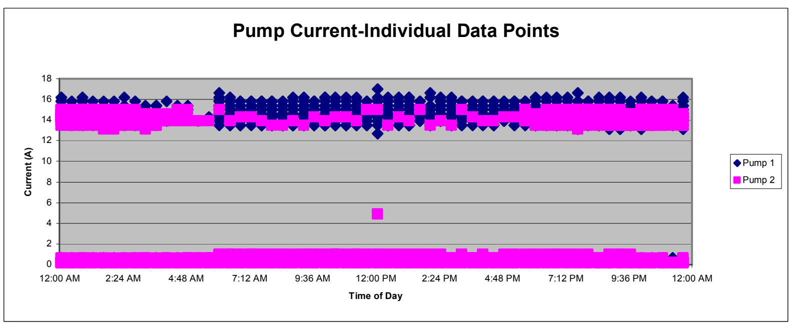


How Many Pumps On?	% of Time	
0	27%	
1	4%	
2	69%	
Avg	1.42	pumps on

			Implementer
Avg current per pump when on	14.6	A	
Avg total current during peak hrs	29.2	A	
Spot power factor (at spot 14.2A):	79%		
Spot voltage	479	V	
Avg power per pump when on	9.6	kW	10.4
Use	17.1	hr/day/pmp	18
Avg demand over 24 hrs	13.6	kW	
Peak demand	**19.1**	**kW**	
Annual energy	**119,134**	**kWh/yr**	136,717



Pumps are constant speed and flow.



How Many Pumps On?	% of Time	
0	25%	
1	61%	
2	14%	
Avg	0.89	pumps on

			Implementer	
Avg current per pump when on	14.6	A		
Avg total current during peak hrs	15.6	A		
Spot power factor (at spot 14.2A):	79%			
Spot voltage	479	V		
Avg power per pump when on	9.6	kW	10.0	*from spreadsheet*
Use	10.7	hr/day/pmp	8.0	*from spreadsheet*
Avg demand over 24 hrs	8.5	kW		
Peak demand	**10.2**	**kW**		
Annual energy	**74,384**	**kWh/yr**	58,639	*from spreadsheet*

Savings

Peak demand	**8.9**	**kW**	11.0	*from final table*
Annual energy	**44,749**	**kWh/yr**	78,079	*from final table*

A.4 Participant A Measure #6

Excess Front water Feature Pumping Energy

Measure Summary Description

Baseline condition: Two water pumps operated continuously to circulate water through the water feature in front of the hotel.

Actions taken and retrofit condition: It was determined that one pump would be adequate to operate the front water feature most of the time. In addition, increased savings could be realized if the water pumps were turned off all together during late night and early morning hours.

The initial rescheduling plan was to operate both pumps one day a week for 18 hours to ensure circulation through all of the pools and then run one pump 18 hours a day for the other six day per week. This operation was implemented manually as planned for some of the first year after implementation.

The current schedule followed is that one pump is always on, one is always off.

Other comments: An IDEC® Smart Relay was later purchased and partially installed. As of February 20, 2008, it was not controlling the pumps. If completely installed and activated, the savings has the potential to increase.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
Scoping Study	10/28/04	*measure savings not quantified*		
Detailed Investigation Study	9/2/2005	40,771	5.3	0
Post-Implementation	3/27/2006	67,131	Na	0
Revised Post-Implement Rpt	9/12/2006	67,131	0	0
Persistence	9/30/2007	100%		

Description of Original Savings Estimation Approach

The implementer used short-term on-time measurement combined with estimated power and power factor to estimate pre- and post-implementation energy use. The measure has no seasonal variation.

Pre-Site Visit Observations on Original Estimation Approach

Completion of automated controls where not complete assumption of manual scheduling needed to be proven by measured data. This data was being trended by Marriot staff. The measurement needs to analyze saving appropriate for the actual level of control.

ERS Original M&V Plan

ERS would spot measure real power on each of the each running motor. Marriot would provide recent logged current data for the front water feature pumps. The volts and power factor from the spot metering would be used with Participant A's current data to extrapolate yearly power usage if the ERS spot current measurement validated the Participant A trended current data. Combined with the baseline kW and kWh calculations from project implementer savings could be determined.

ERS Actual M&V Plan Executed

The actual plan followed the described original plan, using two months of Participant A-metered current trend data. This data was used with spot power data preformed on Feb 5 2008 to extrapolate yearly kWh and peak kW

Description of Findings

Two months metered current data received from Marriot showed that the manual scheduling of the measure was not persisting. Previous metering by Dave Steller of PECI showed that an evening shut off schedule of the pumps was occurring. The lack of persistence is most likely due to the difficultly of reaching the pump disconnect in the pump vault. Currently one pump is operating continuously and the second pump remains off.

The continuous operation of the pump removed an estimated 14,681 kWh from the savings calculation. The measured pump power was higher than the *ex ante* assumption, which more than offset the hours of use effect.

The analysis calculates savings in both the basic one on-one off mode and in the extra savings schedule mode, then weights the two modes (12.5% for the latter condition) to estimate overall lifetime average annual energy savings.

Impact Summary Ex Post Results

Result	Savings		
	Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
ERS Evaluation Impact Estimate	81,586	9	0
Realization Rate*	122%	N/A	0

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

Uncertainty Factor	Uncertainty at 90% Confidence
Metering equipment accuracy/uncertainty	±0.5%
Short-term to long-term extrapolation uncertainty	±3%
Baseline energy use uncertainty (unmetered by M&V team)	±1%
Methodological uncertainty (weather, assumptions, approach, theory)	0%
Other uncertainty factors Unpredictable O&M conditions significantly affects true savings	±1%
Overall engineering estimate of uncertainty for measure	±3%

The Dent real power logger has better than 1% accuracy and better than 0.5% accuracy under typical conditions.

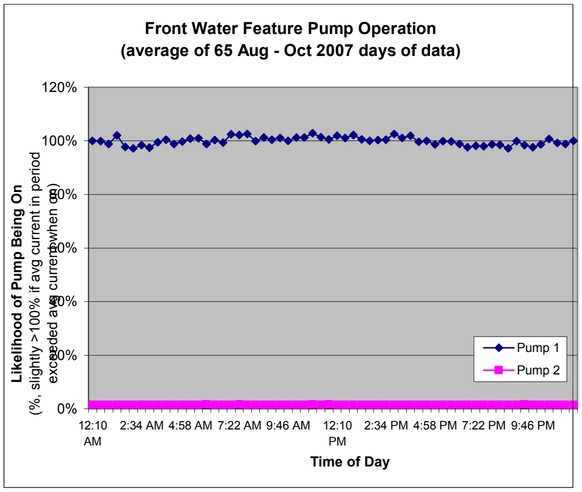
The uncertainty of baseline energy use is due to a lack of metered data. This is not considered significant due to consistent yearlong operation that is not susceptible to climate change or occupancy.

There is uncertainty regarding O&M conditions. Past meter data has shown a nighttime shut down of the pumps, but the bulk of the metered data no longer includes these conditions.

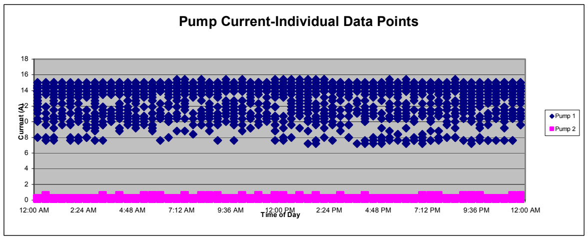
Net-to-Gross and Other Related Observations

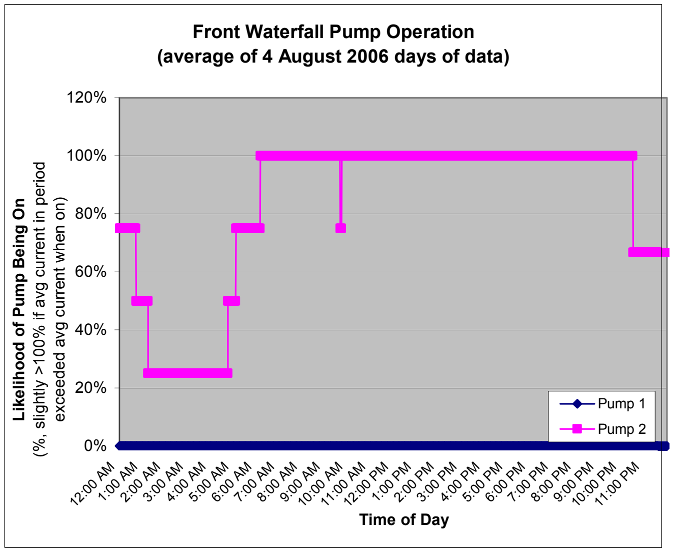
Complete installation and activation of the IDEC system plus ultimately integration of this into their larger building EMS system is still part of Participant A's plans. However, they want to use in-house staff to perform the installation and currently and into the near future expect to remain short-staffed. Presuming the automation system installation eventually is completed, savings likely will increase. Such savings are mostly excluded in this estimate.

Selected Backup Calculations, Intermediate Results, Exhibits



Pumps are constant speed and flow.





How Many Pumps On?	% of Time	
0	17%	
1	83%	
2	0%	
Avg	0.83	pumps on

ALL CONDITIONS

Avg current per pump when on	13.7	A
Avg total current during peak hrs	13.9	A
Spot power factor (at spot 12.2A):	81%	
Spot voltage	475	V
Avg power per pump when on	9.1	kW
Avg power per pump during su peal	9.3	kW

BEFORE

Average # of pumps on	2.00	
Average demand	18.2	kW
Summer peak demand	18.5	kW
Annual energy	159,702	kWh/yr

AFTER - SHORT TERM (from prior page)

Average # of pumps on	0.83	
Average # of pumps on during peak	1.00	
Average demand	7.6	kW
Summer peak demand	9.3	kW
Annual energy	66,536	kWh/yr

AFTER - MEDIUM TERM (this page)

How Many Pumps On?	% of Time	
0	0%	
1	100%	
2	0%	
Avg	1.00	pumps on
Average # of pumps on	1.00	
Average demand	9.1	kW
Summer peak demand	9.3	kW
Annual energy	79,771	kWh/yr

AFTER - PROJECTED LONG TERM

Percent time short vs. medium	12.5%	
Average demand	8.9	kW
Summer peak demand	9.3	kW
Annual energy	78,116	kWh/yr

SAVINGS

			Implementer	
Peak demand	**9.3**	**kW**	0.0	
Annual energy	**81,586**	**kWh/yr**	67,131	122%

A.5 Participant A Measure #7

Excess Front water Feature Pumping Energy

Measure Summary Description

Baseline condition: Two water pumps operated continuously to circulate water through the stream water feature.

Actions taken and retrofit condition: The implementer and staff found that one pump was adequate to operate the stream water feature once water level equalization lines that connect the intermediate pools were cleaned out and used. The schedule now followed is that one pump is always on while one is always off.

Other comments: Operation of a single pump is currently manually controlled. It is easy to do and does not jeopardize persistence. Eventually the stream control system will be reprogrammed to reflect single pump operation.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
Scoping Study	10/28/04	*measure savings not quantified*		
Detailed Investigation Study	9/2/2005	10,881	5.3	0
Post-Implementation	3/27/2006	119,692	10	0
Persistence	9/30/2007	100%		

Description of Original Savings Estimation Approach

A pair of motor on-time temperature logger was used to measure the stream pump schedule for four days. After the retrofit, a current logger was used to measure post-retrofit operation. Based on MotorMaster power factor data, savings was estimated.

Pre-Site Visit Observations on Original Estimation Approach

None.

ERS Original M&V Plan

ERS would spot measure real power on each of the each running motor. Marriot would provide recent logged current data for the front water feature pumps. The volts and power factor from the spot metering would be used with Participant A's current data to extrapolate yearly power usage if the ERS spot current measurement validated the Participant A trended current data. Combined with the baseline kW and kWh calculations from project implementer savings could be determined.

ERS Actual M&V Plan Executed

The actual plan followed the described original plan, using two months of Participant A-metered current trend data. This data was used with spot power data preformed on Feb 5 2008 to extrapolate yearly kWh and peak kW

Description of Findings

The original analysis estimated 24 hr/day savings for shutting off one continuously running pump completely plus and 9 hr/day savings for reducing the remaining pump's use from 24 to 15 hours per day, for an average reduction in use of 16.5 hr/day.

The short-term metered data received shows that both pump 17 hr/day before the retrofit and 12 hr/day (one on one off) after the retrofit for an average reduction in use of 5 hr/day.

The measured pump power also was about 10% lower than the *ex ante* assumption.

Impact Summary Ex Post Results

Result	Savings		
	Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
ERS Evaluation Impact Estimate	33,316	5	0
Realization Rate*	28%	50%	0

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

Uncertainty Factor	Uncertainty at 90% Confidence
Metering equipment accuracy/uncertainty	±0.5%
Short-term to long-term extrapolation uncertainty	0%
Baseline energy use uncertainty (unmetered by M&V team)	±15%
Methodological uncertainty (weather, assumptions, approach, theory)	0%
Other uncertainty factors Unpredictable O&M conditions significantly affects true savings	+1%
Overall engineering estimate of uncertainty for measure	+15%

The Dent real power logger has better than 1% accuracy and better than 0.5% accuracy under typical conditions.

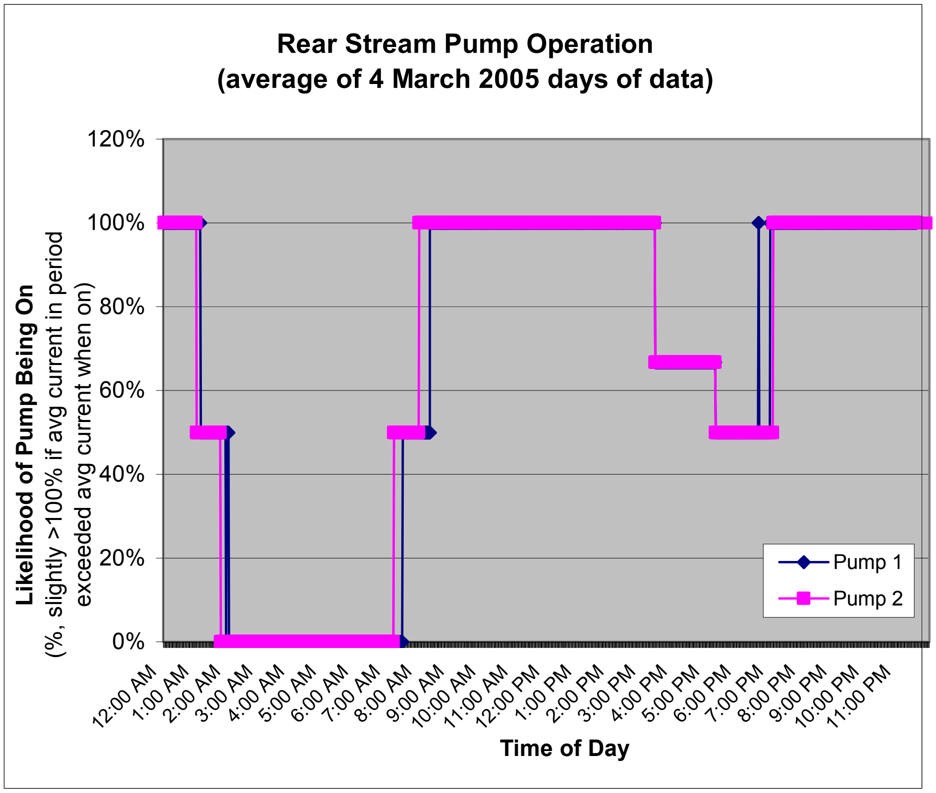
The uncertainty of baseline energy use is due to the short duration of metering.

Net-to-Gross and Other Related Observations

There is uncertainty regarding future scheduling. Resuming night shut-off would add to the savings.

Selected Backup Calculations, Intermediate Results, Exhibits

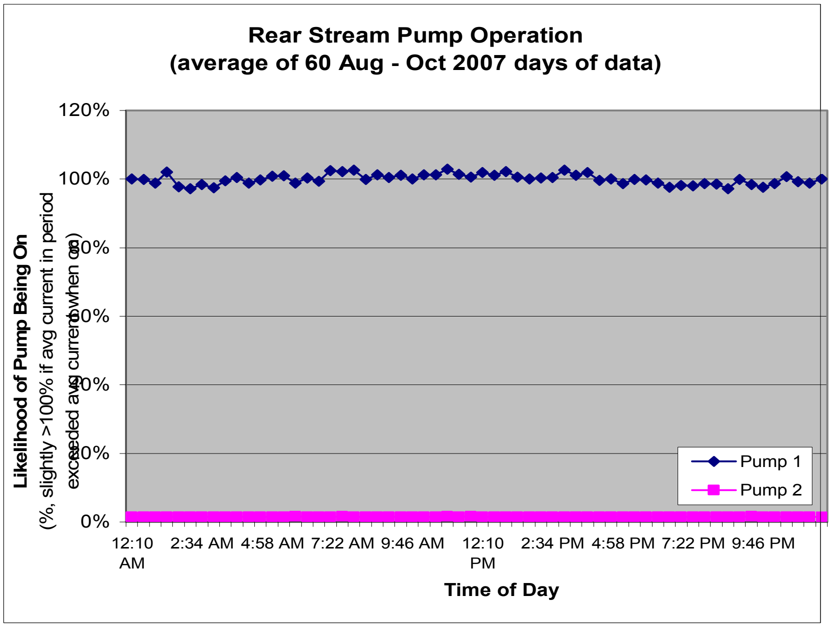
BEFORE



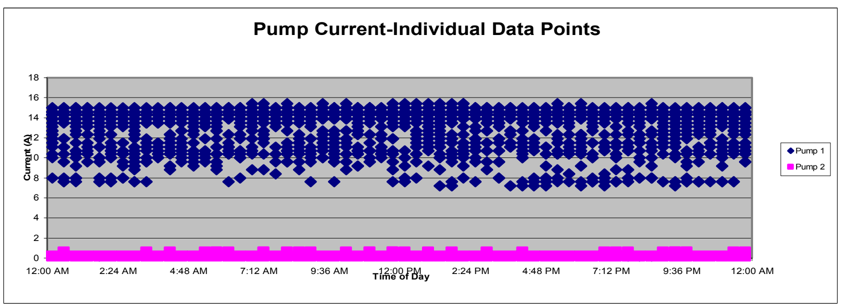
How Many Pumps On?	% of Time	
0	27%	
1	4%	
2	69%	
Avg	1.42	pumps on

Avg current per pump when on	13.7	A
Avg total current during peak hrs	21.6	A
Spot power factor (at spot 13.2A):	79%	
Spot voltage	480	V
Avg power per pump when on	9.0	kW
Use	17.1	hr/day/pmp
Avg demand over 24 hrs	12.8	kW
Peak demand	**14.2**	**kW**
Annual energy	**111,936**	**kWh/yr**

AFTER



Pumps are constant speed and flow.



How Many Pumps On?	% of Time	
0	0%	
1	100%	
2	0%	
Avg	1.00	pumps on

			Implementer
Avg current per pump when on	13.7	A	
Avg total current during peak hrs	13.9	A	
Spot power factor (at spot 13.2A):	79%		
Spot voltage	480	V	
Avg power per pump when on	9.0	kW	
Use	12.0	hr/day/pmp	
Avg demand over 24 hrs	9.0	kW	
Peak demand	**9.1**	**kW**	
Annual energy	**78,620**	**kWh/yr**	

Savings

Peak demand	**5.0**	**kW**	10.0	50%
Annual energy	**33,316**	**kWh/yr**	119,692	28%

A.6 Participant A Measure #8

Re-Enable Garage Fan Demand-Controlled Ventilation

Measure Summary Description

Baseline condition: One 50-hp axial fan on the west side and two 20-hp parallel double-width double-inlet centrifugal fans on the east side of the parking garage ran continuously and at constant load from 6 am to midnight. One of the fans ran backwards.

Actions taken and retrofit condition (final): Participant A staff rewired the backward running fan to reverse direction and repaired and reactivated the 16-point carbon monoxide sensor demand controlled ventilation (DCV) controls. Due to low traffic rates and the fact that the garage doors are normally left open, the DCV controls now rarely activate any of the fans.

Other comments: The original plan included installing VFDs. Post-retrofit hours of operation turned out to be so infrequent that taking this additional step was not economically justifiable or necessary. The savings estimates below are for the as-built non-VFD retrofit.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
Scoping Study	10/28/04	*Measure not identified*		
Detailed Investigation Study	9/2/2005	177,000	0	0
Post-Implementation	3/27/2006	378,451	Na	0
Revised Post-Implement Rpt	9/12/2006	475,931	0	0
Persistence	9/30/2007	100%		

Description of Original Savings Estimation Approach

Pre-retrofit and immediate post-retrofit fan operation was logged with a temperature logger. The motor control panel that includes the three motors also was logged. Post-retrofit operation further logged with a motor vibration logger. Later post-retrofit operation was logged with a set of current loggers.

Pre-Site Visit Observations on Original Estimation Approach

This measure is likely to contribute demand savings, which has not been claimed.

ERS Original M&V Plan

ERS would measure power on each of the fans over a one-month of the post retrofit period and use pre-retrofit cycle data from the implementer to estimate impact.

ERS Actual M&V Plan Executed

Because (a) the power when on is constant, and (b) the implementer had before and immediately after data, and (c) the implementer later after logged current data in six-minute intervals that was not known at the time of the original M&V plan development, ERS revised the plan to make a spot measurement of real kW and power factor on each of the fans and use implementer on-off data to extrapolate to long-term performance. ERS added to the scope estimation of peak demand savings, which the implementer did not claim but were believed to be likely after review of the use patterns.

Description of Findings

ERS measured the total real power for the fans at 83.6 kW. The 50 hp axial fan drew 43 kW; one of the 20-hp centrifugal fans drew 20 kW. The other centrifugal fan contactor relay had failed and could not be tested but was assumed the same as the other identical fan. The measured power exceeds the rated nameplate power of the motors, which is atypical, and increases savings. These amps are similar to that measured by the implementer.

Impact Summary Ex Post Results

Result	Savings		
	Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
ERS Evaluation Impact Estimate	502,688	83.6	0
Realization Rate*	105.6%	N/A	N/A

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

Uncertainty Factor	Uncertainty at 90% Confidence
Metering equipment accuracy/uncertainty	±0.5%
Short-term to long-term extrapolation uncertainty	0%
Baseline energy use uncertainty (unmetered by M&V team)	±2%
Methodological uncertainty (weather, assumptions, approach, theory)	0%
Other uncertainty factors Unpredictable O&M conditions significantly affects true savings	-24% to 1%
Overall engineering estimate of uncertainty for measure	-24% to 2%

The Dent real power logger has better than 1% accuracy and better than 0.5% accuracy under typical conditions.

The uncertainty of baseline energy use is due to small variations in constant load power, such as that due to gusts of wind affecting the fan and motor startup power. This is not considered significant.

Equipment use is seasonally independent, but will fluctuate according to hotel occupancy. The hotel reports consistently high occupancy rates throughout the year.

There is considerable uncertainty regarding O&M conditions. The fan motor operation was measured on three separate occasions where operation was other than 'normal.'

During pre-retrofit, one of the circuit breakers to the fans was discovered to have tripped. Evaluators do not know how long the motor had been cut off. If the tripped condition was considered 'normal,' savings would be reduced by 24%.

During post-retrofit persistence monitoring, the DCV controls failed. The persistence monitoring caught this failure and it was addressed. If not caught and addressed, this would have reduced savings by another 52%.

During M&V metering it was found that one of the three motor controllers had failed off. This conceivably increases savings by +0.04%.

Because the normal conditions assume that all the fans are on in the baseline and they are virtually never on in the post-retrofit, conditions other than normal tend to have a negative effect on impact. It is not certain what was and will be 'normal' in the future.

Net-to-Gross and Other Related Observations

None.

Selected Backup Calculations, Intermediate Results, Exhibits

Results Summary

#8 Garage Fans

Parameter		BASELINE PRE-RETROFIT 2005 'Normal'	2005 Measured	POST-RETROFIT 2006 'Normal'	2007 Measured	2008 'Normal'	MEASURE IMPACT UNDER 'NORMAL' CONDITIONS
Annual average power	kW	83.6	63.4	0.0	30.1	0.2	
Annual energy	kWh/yr	**503,481**	**381,827**	**62**	**263,399**	**1,525**	**502,688**
Peak period average power	kW peak	**83.6**	**63.4**	**0.0**	**19.8**	**0.0**	**83.6**

2008 Spot Real Power Measurement

Centrif1	Centrif2	Axial
Power when on (kW):		
20.2	**20.2**	**43.2**
83%	N/A	81%

power factor

2008 Monitoring Results

Overall %Time on		
0.43%	0.43%	0.0%

SummerPeak %Time On		
0.00%	0.0%	0.0%

2007 Monitoring Results. Temporary failed mode. Persistence monitoring caught the error.

Overall %Time on		
0.02%	1.4%	68.9%

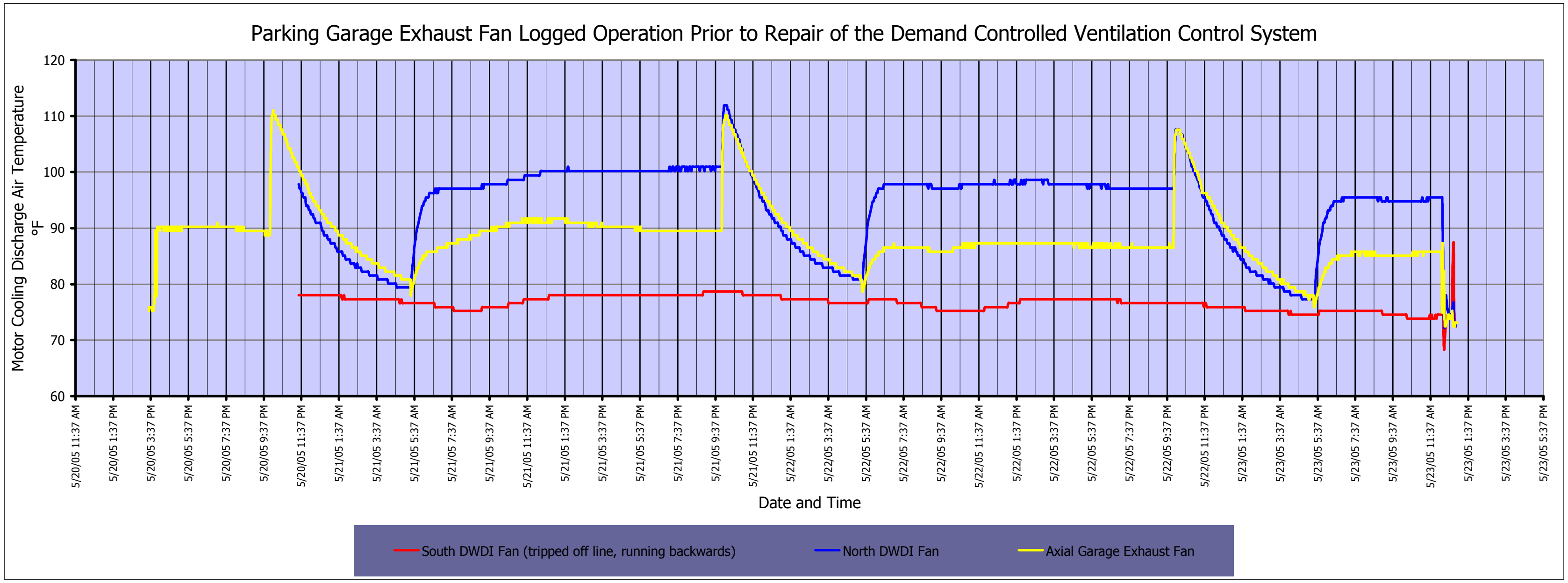
SummerPeak %Time On		
0.03%	1.8%	45.0%

2006 Monitoring Results. Non-summer months only.

Overall %Time on		
0.00%	0.03%	0.00%

2005 Pre-Retrofit Measured On-Off

Graph shows:	axial fan	off 10 pm to 5:30 am, on other times, every day
	north centrifugal fan	off 10 pm to 5:30 am, on other times, every day
	south centrifugal fan	Show ambient temperature at all times, indicating always off.
		RCx report noted this and that this tripped circuit breaker was immediately repaired and not representative of normal base case conditions.
		Reported to normally follow the same runtime patterns as the other fans



Friday Saturday Sunday Monday

A.7 Participant A Measure #12

Reduce Simultaneous Heating & Cooling

Measure Summary Description

Baseline condition: Test and examination of HVAC central plant trend data indicated a substantial amount of central cooling immediately offset by VAV coil reheating, simultaneous heating and cooling in room fan coil units, and other mechanical and control problems that caused air to be both cooled and then heated for no net comfort benefit. The main causes of the problem included:

- A failed VFD
- Multiple leaking ducts
- Failed fan coil valves, perhaps as many as 600 of them
- Improper 4-pipe fan coil wiring that caused the "off" signal to actually mean both hot and cold pipes "on."
- Failed DDC and pneumatic VAV boxes and fan coils

Actions taken and retrofit condition: Measure 12 had 9 major subparts and 12 subparts overall. Each remedied part or all of one of the noted problems. In certain instances as a short term solution the "symptom" was treated instead of the "root cause of illness" until the fundamental cause could be corrected. For example, it will take years to find and repair all corroded fan coil valves improper wiring. However, shutting down the hot water to coils whenever the outside temperature is above 65F can reduce associated energy waste until maintenance completes the repairs.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
Scoping Study	10/28/04	*Measure not identified*		
Detailed Investigation Study	9/2/2005	1,396,800	0	232,000
Post-Implement Rpt estimated	8/28/06	488,931	0	113,822
Post-Implement Rpt documented	8/28/06			
AHU#5 VFD Repair		145,576	0	0
All other subparts of measure		280,523	0	88,305
Total		426,099	0	88,305
Persistence	9/30/2007	100% for AHU VFD repair 50% to 100% for subparts tracked		

Description of Original Savings Estimation Approach

Gas. The gas savings was associated with the guest room tower repairs, especially the fan coil valve and the crossed control wire connection repairs. The 2005 savings estimate was based on top-down analysis, by estimating that half of the boiler gas use during hours above 65F (almost half the year) would be eliminated. Thus, the savings represents almost 25% of all boiler gas energy. It also represents about 10% of total facility gas use.

About 40% of the savings was associated with eliminating unnecessary heating directly offset by an equal amount of cooling and 60% of the savings was associated with eliminating heating not offset by cooling.

Electric. Methods varied by subpart. Some were measure-based—such as estimating duct leakage rates based on air gap size and estimating VFD losses through measurement. Others were top-down such as the gas savings calculations.

Pre-Site Visit Observations on Original Estimation Approach

None.

ERS Original M&V Plan

None. The savings appeared too fragmented—over 500 different pieces of equipment potentially were affected—and implementation period too gradual and ongoing to be a good candidate for metering based M&V.

ERS Actual M&V Plan Executed

The gas portion of savings for this measure seems to be a good candidate for whole facility bill-based impact analysis. Claimed savings is a measureable percentage of total facility use, no other measures claimed gas savings, and ERS knows of no other activities undertaken by Participant A external to the program that would cloud such analysis. Plus gas use is pretty independent of weather. Dave Sellers' commentary indicates that they have done some such analysis themselves and the savings does show up when persistence issues are set aside.

ERS reviewed and re-analyzed savings for the single biggest electric energy saver: North Tower AHU #5 VFD repair.

Description of Findings

The VFD repair measure savings approach is excellent and uses similar data and methodology to that ERS would have used for fan savings. It includes about two weeks of both before and after logging. The only added step recommended would have been to measure power factor with the VFD engaged, as not all VFDs manage to a constant high power factor at low loads. The analysis assumes constant high power factor. If this is not the case—and ERS found it not to be the case on two other VFDs at this site—energy savings will be up to 40,000 kWh/yr (25%) greater than estimated below.

ERS added likely demand savings for this measure as well as some avoided reheating energy.

The submitted VFD measure savings does not include the benefit to the chiller and boiler plants of avoiding excessive reheating due to constant volume operation.

Impact Summary Ex Post Results

AHU#5 VFD Repair

Result	Savings		
	Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
ERS Evaluation Impact Estimate	158,464	7	247
Realization Rate*	109%	*0 prior est.*	*0 prior est.*

Other Subparts

Not evaluated.

Engineering Uncertainty

Uncertainty Factor	Uncertainty at 90% Confidence	
	Repair VFD	Other
Metering equipment accuracy/uncertainty	±2%	*Not evaluated*
Short-term to long-term extrapolation uncertainty	±3%	
Baseline energy use uncertainty	±1%	
Methodological uncertainty (weather, assumptions, approach, theory)	-5% to + 10%	
Other uncertainty factors	0%	
Overall engineering estimate of uncertainty for measure	-6% to + 11%	

Net-to-Gross and Other Related Observations

Time considerations regarding the gradual implementation of this measure are not possible to determine precisely.

Selected Backup Calculations, Intermediate Results, Exhibits

PARAMETER	BEFORE All	BEFORE Same Time Range As After	AFTER		SAVINGS
Logged interval, days -	19.998	10.973		10.973	
Average power kW -	31.7	31.7		15.0	16.6
Average power when on full speed -	34.6	34.6	Max pwr -	34.4	
%Time on full speed -	92%	91%		91%	
%Time off -	8.3%	8.6%		8.8%	
Annual energy kWh -	278,106	277,052		131,783	145,270

Affinity exponent:	2.7
Fan*mtr eff.:	60%
Design static:	4.0

Power Range (kW)			Avg	Minutes	%Time	%Pwr	%Flow	cfm	Wtd Avg CFM	Avg CFM Savings	
0	to	10	off	1,398	9%	0%	0%	-			
10	to	15	12.5	6,860	43%	36%	69%	16,805			
15	to	20	17.5	5,100	32%	51%	78%	19,035			
20	to	25	22.5	1,257	8%	65%	85%	20,892			
25	to	30	27.5	1,186	8%	80%	92%	22,504			
over 30 kW			34.4	1	0%	100%	100%	24,441			
TOTAL				15,802	100%			24,441	16,791	7,650	cfm

Assumed %air that is RA cooled+reheated:	20%	
Cooling at 15F dT:	2.1	tons
Cooling efficiency:	0.80	kW/ton
Avoided precooling that will be reheated:	13,194	kWh/yr
Electric energy savings:	**158,464**	**kWh/yr**
Peak electric demand savings:	**7**	**kW**
Htg Efficiency:	80%	
Avoided reheating thermal savings:	**247**	**therms/yr**

A.8 Participant A Measure #14

Optimize South Tower Domestic Water Pump

Measure Summary Description

Baseline condition: The South Tower domestic water system used conventional constant speed water pumps that regulated flow to match demand via a pressure regulation valve.

Actions taken and retrofit condition: It was determined that upgrading to new motors and a variable speed pumping system would save energy.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas(therms/yr)
Scoping Study	10/28/04	*measure savings not quantified*		
Detailed Investigation Study	9/2/2005	260,625	0	0
Post-Implementation	3/27/2006	50,380	0	0
Revised Post-Implement Rpt	9/12/2006	50,380	5.6	0
Persistence	9/30/2007	100%		

Description of Original Savings Estimation Approach

Pre-retrofit current was logged from February 1, 2006 to February 21, 2006. Post-retrofit current was logged July 24, 2006 through July 26, 2006. Savings was calculated after assuming voltage and power factor.

Pre-Site Visit Observations on Original Estimation Approach

Participant A was able to supply more recent logged current data for a longer period, two months in 2007, for updated analysis.

ERS Original M&V Plan

ERS would spot measure real power on each of the each running motor. Participant A would provide recent logged current data for the domestic water pumps. The volts and power factor from the spot metering would be used with Participant A's current data to extrapolate yearly power usage if the ERS spot current measurement validated the Participant A trended current data. Combined with metered baseline data done by PECI kW and kWh calculations from project implementer savings could be determined.

ERS Actual M&V Plan Executed

The actual plan followed the described original plan.

Description of Findings

Two months metered data received from Marriot and spot real power measurement showed a savings higher than the *ex ante* assumption. This is due to the low power factor measured during post-retrofit conditions over that assumed, which decreases the calculated real power after the retrofit. It also is because the average amps decreased in 2007 over the 2006 *ex ante* assumption basis.

Impact Summary Ex Post Results

Result	Savings		
	Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
ERS Evaluation Impact Estimate	85,164	9.7	0
Realization Rate*	169%	173%	0

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

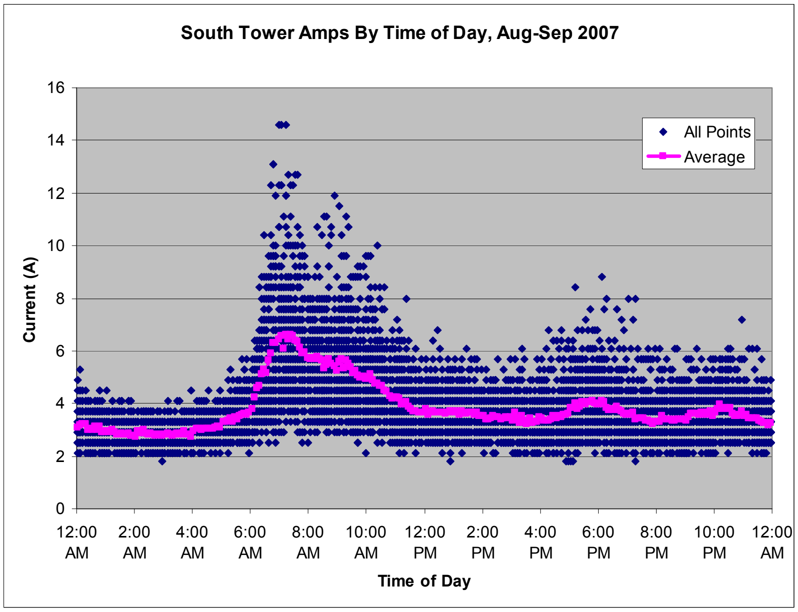
Uncertainty Factor	Uncertainty at 90% Confidence
Metering equipment accuracy/uncertainty	±0.5%
Short-term to long-term extrapolation uncertainty	0%
Baseline energy use uncertainty (unmetered by M&V team)	±4%
Methodological uncertainty (weather, assumptions, approach, theory)	0%
Other uncertainty factors Unpredictable O&M conditions significantly affects true savings	±15%
Overall engineering estimate of uncertainty for measure	±16%

The Dent real power logger has better than 1% accuracy and better than 0.5% accuracy under typical conditions.

Net-to-Gross and Other Related Observations

None.

Selected Backup Calculations, Intermediate Results, Exhibits



The 90% confidence value range on the means is less than 1% of the savings, but the fact that after energy use varied markedly for two different short term periods increased the overall savings uncertainty.

Power factor was less than 60%.

#14 South Tower		
Condition	**Su Pk kW**	**Energy**
Baseline Data	12.7 kW	113,330 kWh/yr
After – 2006	4.4 kW	40,233 kWh/yr
After – 2007	1.7 kW	16,098 kWh/yr
Average After	3.1 kW	28,165 kWh/yr
Savings	**9.7 kW**	**85,164 kWh/yr**

A.9 Participant A Measure #15

Optimize North Tower Domestic Water Pump

This measure is the same in all descriptive and methodological respects as Measure #14. Only the results differ.

Measure Summary Description

Baseline condition: The North Tower domestic water system utilized conventional constant speed water pumps that regulated flow to match demand via a pressure regulation valve.

Actions taken and retrofit condition: It was determined that upgrading to new motors and a variable speed pumping system would save energy.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
Scoping Study	10/28/04	*measure savings not quantified*		
Detailed Investigation Study	9/2/2005	112,937	0	0
Post-Implementation	3/27/2006	69,770	0	0
Revised Post-Implement Rpt	9/12/2006	69,770	6.2	0
Persistence	9/30/2007	100%		

Description of Original Savings Estimation Approach

Pre-retrofit current was logged from February 1, 2006 to February 21, 2006. Post-retrofit current was logged July 24, 2006 through July 26, 2006. Savings was calculated after assuming voltage and power factor.

Pre-Site Visit Observations on Original Estimation Approach

Participant A was able to supply more recent logged current data for a longer period, two months in 2007, for updated analysis.

ERS Original M&V Plan

ERS would spot measure real power on each of the each running motor. Participant A would provide recent logged current data for the domestic water pumps. The volts and power factor from the spot metering would be used with Participant A’s current data to extrapolate yearly power usage if the ERS spot current measurement validated the Participant A trended current data. Combined with metered baseline data done by PECI kW and kWh calculations from project implementer savings could be determined.

ERS Actual M&V Plan Executed

The actual plan followed the described original plan.

Description of Findings

Two months metered data received from Marriot and spot real power measurement showed a savings higher than the *ex ante* assumption. This is due to the low power factor measured during post-retrofit conditions over that assumed, which decreases the calculated real power after the retrofit. It also is because the average amps decreased in 2007 over the 2006 *ex ante* assumption basis.

Impact Summary Ex Post Results

Result	Savings		
	Annual Electricity (kWh/yr)	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
ERS Evaluation Impact Estimate	92,009	10.3	0
Realization Rate*	132%	166%	0

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

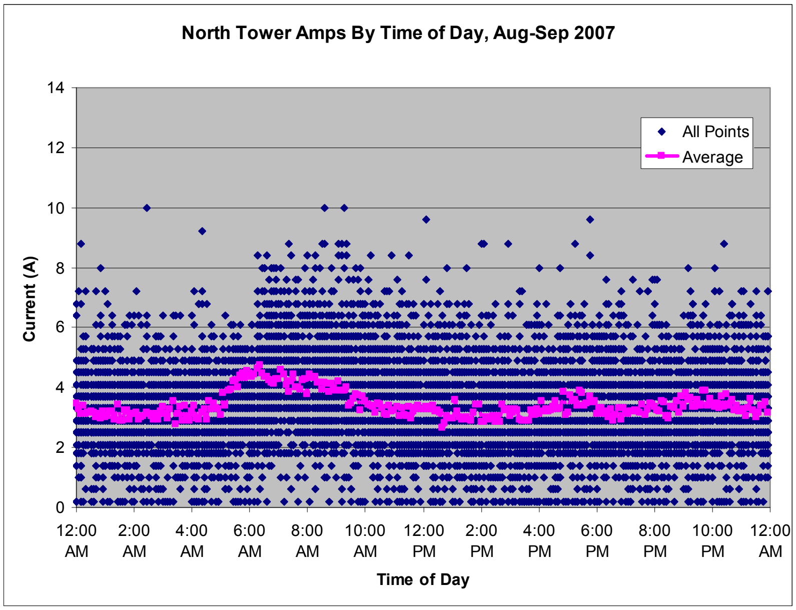
Uncertainty Factor	Uncertainty at 90% Confidence
Metering equipment accuracy/uncertainty	±0.5%
Short-term to long-term extrapolation uncertainty	0%
Baseline energy use uncertainty (unmetered by M&V team)	±4%
Methodological uncertainty (weather, assumptions, approach, theory)	0%
Other uncertainty factors Unpredictable O&M conditions significantly affects true savings	±8%
Overall engineering estimate of uncertainty for measure	±9%

The Dent real power logger has better than 1% accuracy and better than 0.5% accuracy under typical conditions.

Net-to-Gross and Other Related Observations

The persistence estimate was 100%. Increased metered data for both pre and post conditions increased the savings estimate calculation accuracy.

Selected Backup Calculations, Intermediate Results, Exhibits



The 90% confidence value range on the means is less than 1% of the savings, but the fact that after energy use varied markedly for two different short term periods increased the overall savings uncertainty.

Power factor was less than 60%.

#15 North Tower		
Condition	**Sur Peak Period Dem**	**Energy**
Baseline Data	12.8 kW	113,664 kWh/yr
After – 2006	3.3 kW	29,768 kWh/yr
After – 2007	1.7 kW	13,542 kWh/yr
Average After	2.5 kW	21,655 kWh/yr
Savings	**10.3 kW**	**92,009 kWh/yr**

A.10 Participant B Measure #1

Reduce Lobby Cold Deck Fan

Measure Summary Description

Baseline condition: This building has a dual deck VAV system whereby parallel ducts carry warm and cool air from a pair of VSD-controlled AHUs on each floor to mixing boxes before delivery to each space. The first floor AHU serves the lobby, halls, and a few retail establishments open on weekdays. The first floor hot deck fan shut off every day between 6 pm and 6 am weekdays and from 1 pm Saturday to 6 am Monday. The cold deck fan ran continuously.

Actions taken and retrofit condition: The cold deck fan schedule was reprogrammed to match the schedule of the hot deck fan. Cooling is no longer provided on nights or weekends.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
Scoping Study	3/31/2005	*Measure not identified*		
Detailed Investigation Study	5/2006	41,956	0	0
Post-Implement Report	9/12/2006	41,956	0	0
Persistence	10/18/2007	100%		

Description of Original Savings Estimation Approach

Energy use was estimated based on design flow, temperature, and locked 49% speed and the expected schedule.

Pre-Site Visit Observations on Original Estimation Approach

None.

ERS Original M&V Plan

- Short term metering of fan power after.
- Download correspond frequency trend data.
- Use power, freq after to estimate power before as a function of freq (constant 49%)
- Also add to savings by estimating OA and then chiller and boiler plant load changes at least due to OA and conductive heat exchange via estimating central plant efficiency, envelope UA, and OA input.

ERS Actual M&V Plan Executed

Trend speed data was not available. ERS regressed real power against outside temperature and time of day for retrofit conditions. ERS made spot power, frequency, and power factor measurements and developed the fan-specific "real" affinity law exponent and used that to estimate power at pre-retrofit 49% speed.

Description of Findings

The narrative for the measure notes that the VAV system is locked at a fixed 49% speed.[2] A portion of the savings is due to reducing the schedule at this speed.

The implementer's savings calculations also assume that the speed is reduced to the reported "minimum" of 45% when it is not turned off. This results in additional claimed savings that are not mentioned in the narrative.

During the evaluation data collection ERS found that schedule reduction was in fact introduced, and that the speed when on was lower still, 42%. The consequential savings is included in the *ex post* evaluation estimate.

Overall, the realization was less than 100%, however, because this small added savings paled in comparison with the fact that the implementer's savings calculations had two major errors, one which caused 100% overestimation of savings.

Impact Summary Ex Post Results

	Savings		
Result	**Annual Electricity (kWh/yr)**	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
ERS Evaluation Impact Estimate	29,747	1.9	0
Realization Rate*	71%	Na	

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

[2] Actually 49% "power" is the word used but that is incorrect. The accompanying graph and spreadsheet calculations correctly use 49% speed.

Engineering Uncertainty

Uncertainty Factor	Uncertainty at 90% Confidence
Metering equipment accuracy/uncertainty	±1%
Short-term to long-term extrapolation uncertainty	±10%
Baseline energy use uncertainty	±5%
Methodological uncertainty (weather, assumptions, approach, theory)	0%
Other uncertainty factors	
Overall engineering estimate of uncertainty for measure	±11%

The Dent real power logger has better than 1% accuracy and better than 0.5% accuracy under typical conditions.

The 2005 to 2006 actual weather data used (64.2ºF average dry bulb temperature) is generally representative of long-term weather patterns (64.2ºF average annual dry bulb temperature).

Net-to-Gross and Other Related Observations

None.

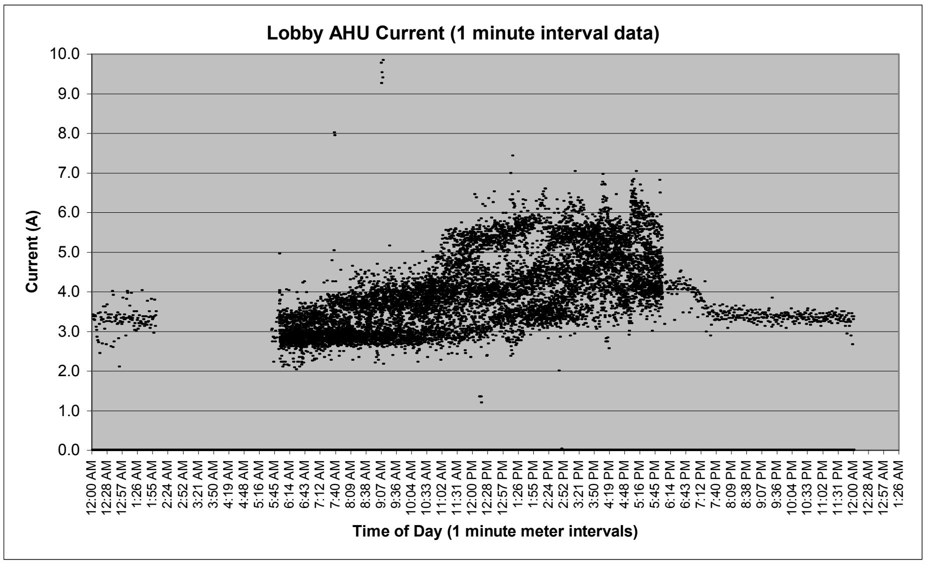
Selected Backup Calculations, Intermediate Results, Exhibits

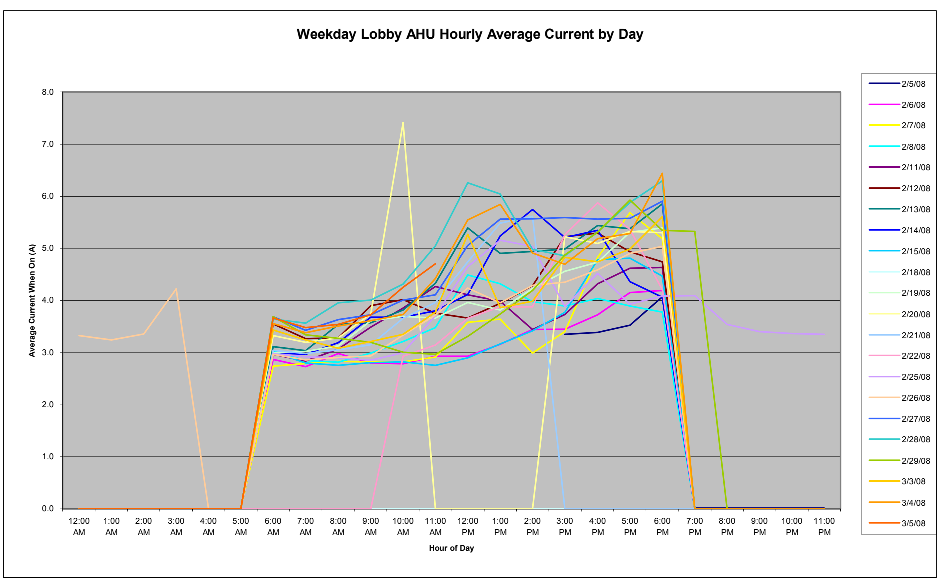
Baseline Condition: Fixed 49% Speed, 24/7 Operation		
Spot power measured:	2.7	kW
Spot power frequency / speed	25	Hz =
	42%	speed
Reported baseline fixed speed:	49%	speed
Tested affinity law coefficient at site:	2.7	
Estimated power at fixed speed:	4.2	kW
Annual operation	8,760	hr/yr
Annual Energy	36,641	kWh/yr

Retrofit: Variable Speed, Scheduled Hrs		
Spot volts measured:	483.0	V
Spot power factor measured:	64%	
On-Time (basis below):	3,129	hr/yr
Avg annual amps when on (basis below):	4.1	A
Avg demand when on:	2.2	kW
Peak period current:	4.3	A
Peak period demand:	2.3	kW
Annual Energy	6,894	kWh/yr

Annual energy savings	**29,747**	**kWh/yr**
Peak period power savings	**1.9**	**kW**

This evaluation gives credit for speed reduction that was not in measure narrative but was in the implementer calculations and which the metered data shows occurred.





Schedule shown by metering:			
Off all weekend, including Sat 8a - 1p	=	3,129	hr/yr
Off 95.7% of the time 6pm to 6 am weekdays	=	2,503	hr/yr
On	=	3,129	hr/yr

A.11 Participant B Measure #2

Reduce AHU Cold Deck Fan Energy

Measure Summary Description

Baseline condition: The building consists of twenty floors and each floor is served by an air handling unit (AHU) with hot deck/cold deck configuration. The fans have variable frequency drives (VFDs) installed and maintained a duct static pressure of 0.9" WC.

Actions taken and retrofit condition (final): The facility staff reduced the cold deck duct static pressure to 0.6" WC and implemented a strategy to reset the cold deck temperature setpoints based on return air temperature.

Other comments: Four floors were identified having difficulty maintaining the space temperature with the static pressure setpoint change in effect. A different static pressure setpoint strategy was suggested for these trouble floors.

The reports also recommend saving energy through two other related actions as part of this measure, free cooling changeover strategy and chilled water reset, but the actions were not taken, and did the implementer's original savings estimated include them. They have been excluded from the impact evaluation as well.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
Scoping Study	03/31/2005	*Measure not identified*		
Detailed Investigation Study	04/28/2006	127,320	264.8	0
Post-Implementation*	08/31/2006	170,851	138.8	0
Persistence	10/18/2007	59%		

* The original savings analysis spreadsheet indicates annual energy savings of 189,135 kWh and peak demand savings of 154.2 kW. However, the retro-commissioning documentation and O&M manual indicates a total energy saving of 170,851 kWh.

Description of Original Savings Estimation Approach

Percent fan speed, cold deck supply air temperature, fan design flow (CFM) and return air temperature – obtained from energy management system (EMS) – was used to calculate the cooling load on the unit for the given hour. The cooling load was then used to calculate the required fan CFM and static pressure, which in turn were used to calculate the baseline fan brake horsepower and power draw. A similar method was followed to calculate the installed system fan brake horsepower and power draw using the reduced cold deck temperature setpoint and static pressure.

Pre-Site Visit Observations on Original Estimation Approach

None.

ERS Original M&V Plan

ERS would measure power directly for a sample of fans over a one-month of the post-retrofit period, regress the data against simultaneous BMS trend data and outdoor weather, and use pre-retrofit data obtained from discussion with the facility staff to estimate the impact.

ERS Actual M&V Plan Executed

ERS logged the current for four cold deck fans (AHU-2, AHU-5, AHU-7 and AHU-16). ERS also took spot measurement of real kW and power factor on each of the fans. Because simultaneous trend data was not available, we regressed against outdoor weather conditions to project annual post-retrofit energy use. Pre-retrofit energy use then was estimated by calculating post-retrofit fan static pressure, adjusting it to pre-retrofit conditions, and then calculating estimated pre-retrofit power as a function of outside air temperature.

Description of Findings

The original savings estimates were calculated based on a constant cold deck supply air temperature of 55ºF (for AHUs with pneumatic controls) or 50ºF (for AHUs with DDC controls) whereas in actuality the cold deck supply air temperature was observed to vary between 55ºF and 70ºF. In addition, the original savings estimates considered the overall fan operating hours to be 3,492 as against 3,120 used in the verified savings analysis. These factors resulted in reduction in savings.

The second floor was unoccupied during the entire metering period. This is reflected by the relatively low current logged for that cold deck fan. Facility staff indicated that this is a short-term scenario as the floor will soon be occupied. The M&V results for this AHU were used for this AHU but were not used when estimating savings for non-metered AHUs. This likely reduces savings by about 2% compared to all floors being occupied.

The cold deck fans for AHUs on floor 3 through 19 are similar and hence the saving for these units were considered as the average of verified savings for AHU-5, AHU-7 and AHU-16 cold deck fans. Since the fan on 20th floor was not metered, the average savings for the above mentioned fans were also applied to this fan.

The principal reasons for differing *ex ante* and *ex post* impact energy estimates are that this evaluation uses a 10% lower annual hours of operation. This is because the original savings estimates considered that the fans operated six hours on Saturdays where as in actuality the fans were shut off on Saturdays.

The main reason for the difference in demand is that the evaluation estimate is based on average demand during the CPUC-defined summer weekday afternoon peak demand period of 12 noon to 7 pm and the implementer demand savings on sum of the maximum possible demand savings for each fan at the most extreme conditions.

Impact Summary Ex Post Results

Result	Savings		
	Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
ERS Evaluation Impact Estimate	133,479	45.8	0
Realization Rate*	78.1%	33.0%	N/A

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

Uncertainty Factor	Uncertainty at 90% Confidence
Metering equipment accuracy/uncertainty	±2.5%
Short-term to long-term extrapolation uncertainty	0%
Baseline energy use uncertainty (unmetered by M&V team)	±5%
Methodological uncertainty (weather, assumptions, approach, theory)	±20%
Other uncertainty factors Unpredictable O&M conditions significantly affects true savings	±10%
Overall engineering estimate of uncertainty for measure	±23%

The HOBO amp logger has better than 2.5% accuracy under typical conditions.

The uncertainty of baseline energy use is due to small variations in constant load power, such as that due to gusts of wind affecting the fan and motor startup power. This is not considered significant.

The cold deck fan operation to some extent was found to be a function of the ambient weather conditions, but the correlation was not as strong as might be desired.

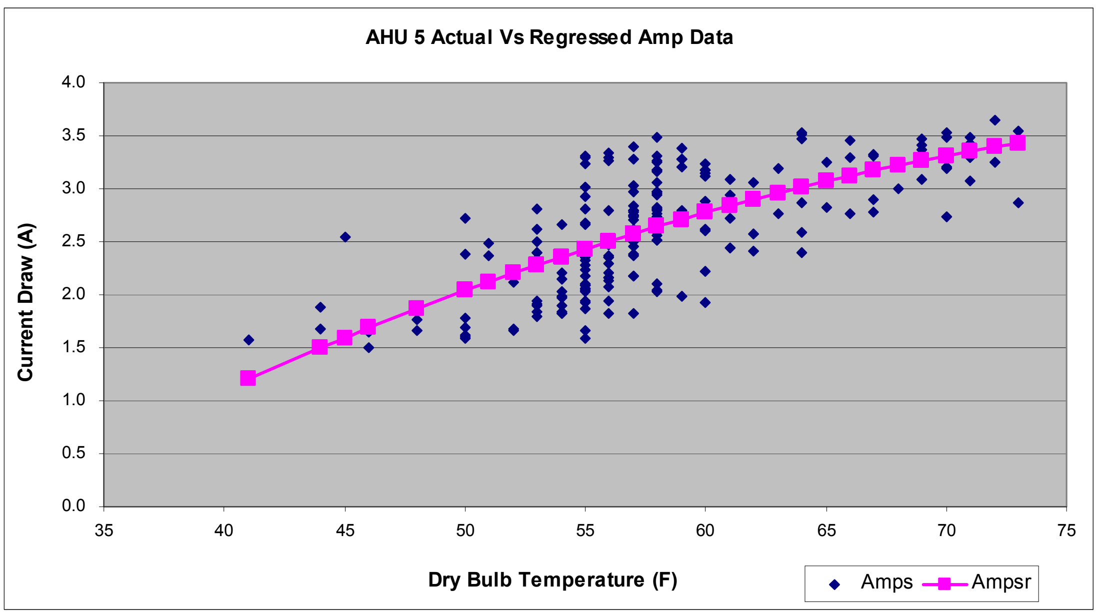
There is significant uncertainty regarding methodology due to variations in performance on the sampled floors, regression uncertainty, and on other factors for O&M conditions. One of the floors for which metering was conducted was found to be unoccupied. Although, the floor will be unoccupied for a short period, the load pattern on the cold deck fan for that AHU is atypical and resulted in reduction in energy savings by about 2%.

Net-to-Gross and Other Related Observations

The implementer expects reduced wear on cold deck fans and chiller plant equipment.

The persistence study documented a significant percentage of the time that AHUs exceeded the retrofit recommended target of 0.6 inches water column of pressure at the mixing boxes. Consequently, the persistence is well under 100%. To avoid reducing the implementer's gross savings twice for this effect (once with a low realization rate and again with a low persistence value), ERS estimated and reported impact as if the static was always reduced to 0.6 inches.

Selected Backup Calculations, Intermediate Results, Exhibits



Overall Savings

AHU #	Fan HP	kWh Savings	kW Savings
AHU 2	20	3,977	1.4
AHU 3	20	7,195	2.5
AHU 4	20	7,195	2.5
AHU 5	20	7,883	2.6
AHU 6	20	7,195	2.5
AHU 7	20	6,054	2.1
AHU 8	20	7,195	2.5
AHU 9	20	7,195	2.5
AHU 10	20	7,195	2.5
AHU 11	20	7,195	2.5
AHU 12	20	7,195	2.5
AHU 13	20	7,195	2.5
AHU 14	20	7,195	2.5
AHU 15	20	7,195	2.5
AHU 16	20	7,647	2.7
AHU 17	20	7,195	2.5
AHU 18	20	7,195	2.5
AHU 19	20	7,195	2.5
AHU 20	20	7,195	2.5
	Total:	**133,479**	**45.8**

Note:

Average cold deck fan kWh savings for AHUs 3 through 20:	7,195
Average cold deck fan kW savings for AHUs 3 through 20:	2.5

A.12 Participant B Measure #3

Reduce the Temperature of the Condenser Water Returned to the Chiller

Measure Summary Description

Baseline condition: The chiller plant had a fixed 75F condenser water return temperature.

Actions taken and retrofit condition: The recommendation was to reprogram the EMS so that the condenser water target return temperature is constantly reset to 7 to 10 degrees above the ambient wet bulb temperature, but no less than 60F.

The O&M manual narrative describes the action as having been implemented, however the persistence study data suggests it has not been implemented at all, or if it had, it was undone with the Hartman LOOP installation. Further, in ERS's discussions with the Participant B management, they twice clearly told us that the measure was not implemented as described for two reasons: (1) because of concerns with such a hard-coded instruction interfering with the Hartman LOOP's all variable optimization algorithms, and (2) because the Turbocor chiller does not operate well at lower condenser temperatures.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
Scoping Study	3/31/2005	*Measure not identified*		
Detailed Investigation Study	5/2006	54,358	0	0
Post-Implement Report	9/12/2006	54,358	0	0
Persistence	10/18/2007	0%		

ERS M&V Plan

None. Based on what we learned during the M&V scouting visit, no M&V was planned or executed and impact was considered 0. Any of the condenser water reset realized as part of the Hartman LOOP implementation would not be considered RCx program impact.

Impact Summary Ex Post Results

Result	Savings		
	Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
ERS Evaluation Impact Estimate	0	0	0
Realization Rate*	0%	N/A	N/A

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor

A.13 Participant C Measure #1

Correct Uneven Flow though Cooling Tower

Measure Summary Description

Baseline condition: Uneven flow balancing in the distribution header on the top of the cooling tower caused 25% of the tower media to run dry. Lack of heat transfer due to the dry media created unneeded load on the tower fan, reduced the chiller efficiency, load on the condenser water pumps, and interfered with the Hartman Loop optimization.

Actions taken and retrofit condition (final): The existing balancing valves in the cooling tower were adjusted at low pump speeds to achieve proper flow balance throughout the cells of the cooling tower. The condenser water pump minimum speeds were adjusted to provide proper condenser flow. The improved cooling tower conditions allowed the Hartman Loop to run more efficiently.

Other comments: After the original scoping this measure also included reducing the lower limit of the CWST from being in the 70 to 80 degree range to 60 degrees. ECS identified that the CWST setpoint is not an input in the Hartman Loop, which led EMC to investigate the savings potential with the Hartman Loop operating efficiently versus the proposed optimal CWST setpoint. The analysis indicated that the Hartman Loop was more efficient.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
Scoping Study	4/5/2005	*27,593*	*6.12*	*0*
Detailed Investigation Study	5/2006	94,675	39.1	0
Post-Implementation	8/2006	93,984	40	0
Persistence		100%		

Description of Original Savings Estimation Approach

Baseline chiller plant conditions where trended from the BAS for two weeks. This data was used to create models of yearly kW and kWh. Condenser Water Trend Data was analyzed for the model; specifically, the condenser water supply temperature and the outside air temperature were compared to predicted values from the model. Three models where created from this information to determine the most efficient course of action.

Pre-Site Visit Observations on Original Estimation Approach

The second analysis that included condenser water reset effects looked comprehensive and based on valid data.

ERS Original M&V Plan

Log the power of all chiller plant components as well as wet bulb temperature and download chiller load from EMS trend data. Calculate plant performance as a function of condenser water temperature and load, and then estimate plant savings from the condenser water reset. Use the implementer's pre-retrofit data to estimate tower fan savings. In particular, use trend and implementer data to validate the summer performance.

ERS Actual M&V Plan Executed

The described instrumentation was installed but the externally available trend data collection terminated before the field power measurement period started. Correlation with load was not possible. ERS instead relied on review of implementer's approach, which was comprehensive and itself based on log data.

Description of Findings

EMC's models of the chilled water plant and cooling tower where found to be thorough and reasonable, and savings estimates within standard engineering practices.

Impact Summary Ex Post Results

Result	Savings		
	Annual Electricity (kWh/yr)	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
ERS Evaluation Impact Estimate	93,984	40	0
Realization Rate*	100%	100%	N/A

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

Uncertainty Factor	Uncertainty at 90% Confidence
Overall engineering estimate of uncertainty for measure	±20%

Net-to-Gross and Other Related Observations

None.

A.14 Participant C Measure #4

Reduce AHU Fan Night Operation during Summer

Measure Summary Description

Baseline condition: Review of year 2004 electrical interval data and BAS data indicated that the HVAC system including the AHU fans and chilled water system operated 24 hours a day for 54 days in the summer. This indicated that the HVAC system was unable to maintain the space temperatures in the building during night time when the loads were at the minimum.

Actions taken and retrofit condition (final): The AHU fans summer time operating schedule was changed to 3 AM to 9 PM Tuesday to Friday, midnight to 9 PM on Mondays and 3 AM to 1 PM on Saturdays. In addition, the system was programmed to keep outside air dampers closed from 3 AM to 7 AM in order to allow for effective cooling.

Implementer Ex Ante Impact Estimates

		Savings		
Estimate Period		**Annual Electricity (kWh/yr)**	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
Scoping Study	4/5/2005	100,732	0	0
Detailed Investigation Study	5/2006	149,342	0	0
Post-Implementation*	8/2006	168,010	0	0
Persistence		100%		

* It is unclear from where the savings numbers are obtained. The savings analysis spreadsheet provided as supporting material indicates a different kWh savings number.

Description of Original Savings Estimation Approach

Electrical interval data for year 2004 was used to estimate the number of days when the HVAC system operated continuously. Average summer and winter energy use profiles were used to identify the baseline energy use levels when the HVAC system was not expected to operate. For each time bin, the energy use with and without HVAC system was obtained. The proposed energy use was obtained at each time bin after incorporating the new AHU fan schedule. When the HVAC system should not be running, the energy use without HVAC system, calculated earlier, is considered.

Pre-Site Visit Observations on Original Estimation Approach

The original savings estimated failed to calculate the natural gas savings from the reduced use of VAV boxes with hot water reheat. We estimate that there would be natural gas savings from reduced use of reheat in the VAV boxes when the AHU fans are not operation.

ERS Original M&V Plan

ERS would measure power directly for both all the air-handling unit fans over a one-month of the post-retrofit period, obtain the operating scheduled based on the actual readings and compare it with the BAS schedule/trend data.

ERS Actual M&V Plan Executed

ERS logged the current for all the air-handling unit fans (AH-1 through AH-4). ERS also took spot measurement of real kW and power factor on each of the fans. The metering was conducted in February and March. Since the measure is effective only in summer months, the metered data had no significance in evaluating this measure. The BAS data available was only for the month of March, April and May. Thus, the available BAS data could also not be used to evaluate the measure. Review was restricted to critique and independent calculations based on the submitted model.

Description of Findings

The original approach uses actual interval data and uses generally sound engineering principles. The approach used in estimating the energy savings is solid and based on available first hand data.

Since the measure involves limited used of AHU fans during non-peak hours, demand savings have not been calculated.

Gas savings were not identified for this measure.

Impact Summary Ex Post Results

	Savings		
Result	**Annual Electricity (kWh/yr)**	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
ERS Evaluation Impact Estimate	186,677	0	0
Realization Rate*	111%	N/A	N/A

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

Uncertainty Factor	**Uncertainty at 90% Confidence**
Metering equipment accuracy/uncertainty	±0%
Short-term to long-term extrapolation uncertainty	0%
Baseline energy use uncertainty (unmetered by M&V team)	±0%
Methodological uncertainty (weather, assumptions, approach, theory)	±15%
Other uncertainty factors: Unpredictable O&M conditions significantly affects true savings	±0%
Overall engineering estimate of uncertainty for measure	±15%

No site or data validation was possible. The savings methodology is solid and the interval data used in the analysis is actual building use data. Uncertainty lies in the assumption of what would be the energy use at the time when the HVAC system is not operating. In the analysis, it is assumed that when the energy use if above 200 kWh, the HVAC system is operating.

Net-to-Gross and Other Related Observations

The implementer expects reduced wear on AHU fans due to reduced usage.

A.15 Participant C Measure #6

AHU #2 and AHU #3 Repair Static Pressure Sensor & Supply Air Temperature reset

Measure Summary Description

Baseline condition: The building consists of 34 floors, and four air handling units (AH-1 through AH-4) and eight rooftop units serve the entire building. The fans have variable frequency drives (VFDs) installed and maintained a duct static pressure of 1.5" WC. AH-3 was found to operate at a constant fan speed of about 95%, forcing supply air backwards through the AH-2 supply air duct to AH-2, which operates with a fan speed in the 30 to 50% range. Also, AH-3 was found unable to maintain the supply air temperature of 55 F.

Actions taken and retrofit condition (final): The static pressure sensors for both the air-handling units were calibrated, the supply air temperature was reset based on the fan speed, and the static pressure was set at 1.25" WC.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
Scoping Study	4/5/2005	259,868	86.62	0
Detailed Investigation Study	5/2006	115,731	207.9	0
Post-Implementation	8/2006	115,731	208.0	0
Persistence		100%		

Description of Original Savings Estimation Approach

Percent fan speed, supply air temperature, return air temperature and mixed air temperature – obtained from energy management system (EMS) – for the baseline conditions was used to calculate the cooling load on the unit for the given hour. The baseline fan speed data was used to calculate the baseline fan power draw and the cooling load was then used to calculate the baseline chiller power draw. The new supply air temperature was used to calculate the maximum load on the system and further used to calculate the new fan speed and fan power draw. New mixed air temperature was also estimated, which was used to calculate the load on the chiller and consequently the new chiller power draw. Overall savings were calculated as the difference between the baseline and proposed energy use.

Pre-Site Visit Observations on Original Estimation Approach

None.

ERS Original M&V Plan

ERS would measure power directly for both the air-handling unit fans over a one-month of the post-retrofit period, regress the data against simultaneous BMS trend data and outdoor weather, and use pre-retrofit data obtained from discussion with the facility staff to estimate the impact.

ERS Actual M&V Plan Executed

ERS logged the current for both the air-handling unit fans (AH-2 and AH-3). ERS also took spot measurement of real kW and power factor on each of the fans. Since simultaneous trend data was not available, we regressed against outdoor weather conditions for metered period and projected the annual post-retrofit energy use. Pre-retrofit energy use then was estimated using the actual trend data from the original estimates.

Description of Findings

The original savings were calculated based on estimated mixed air temperatures and relatively constant supply air temperatures.

Controls on AH-2 unit may not be functioning correct or the EMS is reporting faulty data for this unit. Based on the EMS data the mixed air temperature for the unit was found to be high indicating faulty controls or fault EMS feed back. This resulted in lower energy savings for the unit.

The principal reason for differing *ex ante* and *ex post* impact energy estimates is the actual operating characteristics of the units. The verified savings is based on actual measured data where as the original estimated were based on assumed setpoints.

The main reason for the difference in demand is that the evaluation estimate is based on average demand during the CPUC-defined summer weekday afternoon peak demand period of 12 noon to 7 pm and the implementer demand savings on sum of the maximum possible demand savings for each fan at the most extreme conditions.

Impact Summary Ex Post Results

	Savings		
Result	**Annual Electricity (kWh/yr)**	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
ERS Evaluation Impact Estimate	252,993	52.4	0
Realization Rate*	218.6%	25.2%	N/A

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

Uncertainty Factor	Uncertainty at 90% Confidence
Metering equipment accuracy/uncertainty	±2.5%
Short-term to long-term extrapolation uncertainty	0%
Baseline energy use uncertainty (unmetered by M&V team)	±5%
Methodological uncertainty (weather, assumptions, approach, theory)	±10%
Other uncertainty factors: Unpredictable O&M conditions significantly affects true savings	±2%
Overall engineering estimate of uncertainty for measure	±12%

The HOBO amp logger has better than 2.5% accuracy under typical conditions.

The uncertainty of baseline energy use is due to small variations in constant load power, such as that due to gusts of wind affecting the fan and motor startup power. This is not considered significant.

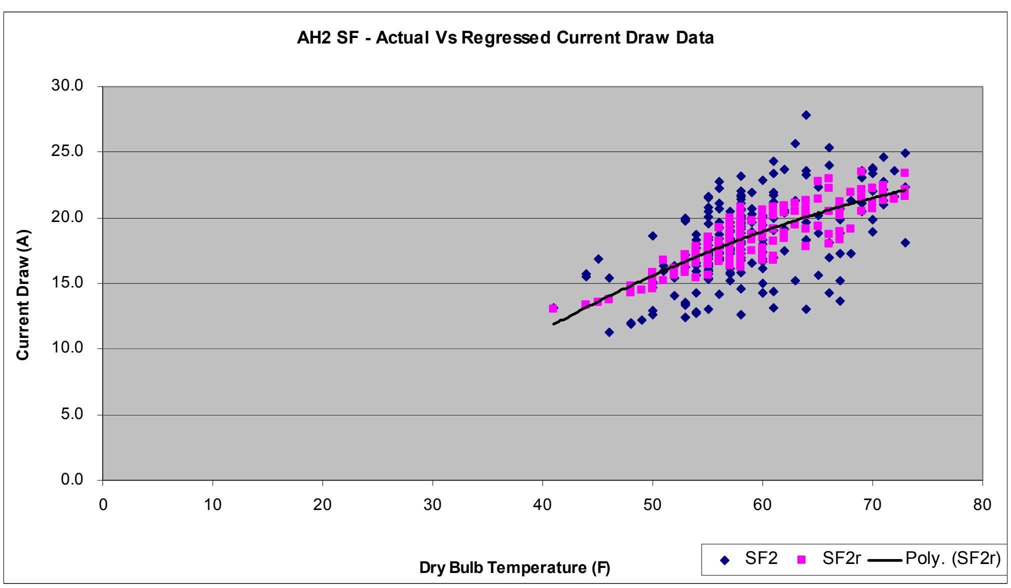
The air-handling unit fan operation to some extent was found to be a function of the ambient weather conditions, but the correlation was not as strong as might be desired.

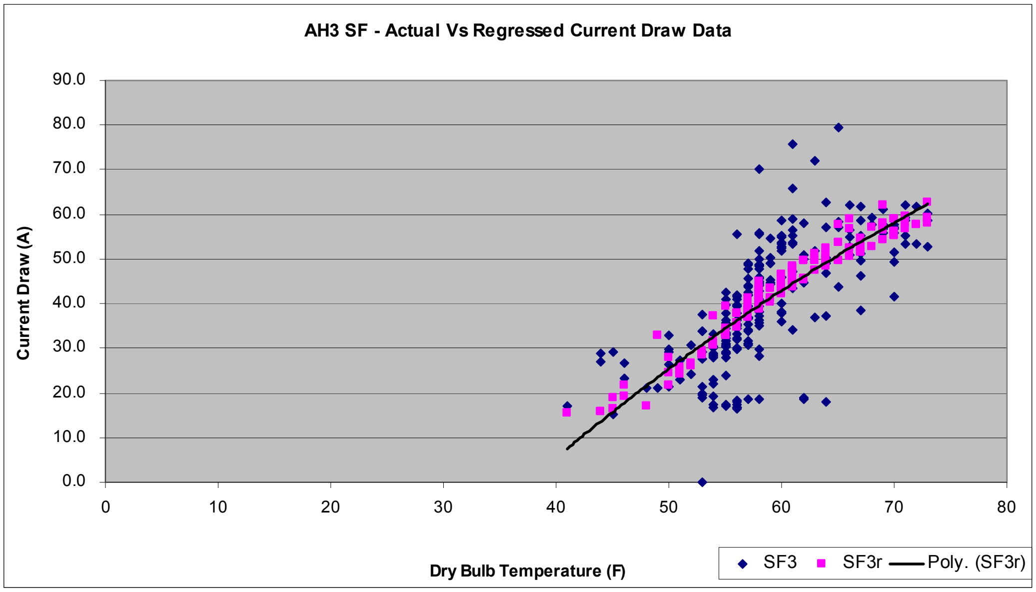
There is significant uncertainty regarding O&M conditions. It is suspected that the EMS may not be reporting accurate data back to the system or the controls on the units are faulty.

Net-to-Gross and Other Related Observations

Reduced wear on the AHU and chilled water valve.

Selected Backup Calculations, Intermediate Results, Exhibits





Overall Savings

AH #	Fan HP	kWh Savings	kW Savings
AH2	200	3,770	(4.6)
AH3	200	249,223	57.0
	Total:	**252,993**	**52.4**

A.16 Participant C Measure #7

Supply Air Reset on AHU#4

Measure Summary Description

Baseline condition: AHU #4 is part of a VAV system. It delivered supply air at a constant 50F to the VAV boxes.

Actions taken and retrofit condition: Repair a faulty temperature sensor valve and program a reset strategy to deliver 50F air at 100% flow, 60F air at minimum flow, and proportional temperatures in between. This will allow more economizer free cooling.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
Scoping Study	3/31/2005	*Measure not identified*		
Detailed Investigation Study	5/2006	3,888	41.4	0
Post-Implement Report	9/12/2006	3,888[3]	41	0
Persistence	10/18/2007	0%		

Pre-Site Visit Observations on Original Estimation Approach

In addition to reducing chiller energy by increasing economizing, cold deck reset also can save energy by reducing the amount of reheat required in perimeter VAV boxes serving "cold" zones. The implementer's computational approach does not include any potential savings for this aspect of the improvement.

The approach uses January-February data. Annual weather data could well reveal more savings potential due to a higher proportion of economizer candidate hours per year.

ERS Original M&V Plan

The energy savings for this measure is less than 0.04% of the program total savings and thus was not part of the original evaluation plan.

ERS Actual M&V Plan Executed

Unusually high peak savings relative to the energy savings were noted and the original analysis for this one consideration was reviewed.

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[3] The O&M report shows 388 kWh/yr but this is nearly certain to be a typo, as the peak demand savings is 41 kW, the same as in the detailed investigation report, which shows 3,888 kWh/yr, and the economic value of the annual savings is $505 /yr, which more closely corresponds to 3,888 kWh/yr.

Description of Findings

The *ex ante* savings was based on the sum of maximum chiller demand from a month and maximum (non-coincident) fan demand for the same month, subtracting after from before. Average demand and savings is a better definition for the purposes of this program to reflect average demand impact during the summer peak period. The implementer's data was used to compute *ex post* demand according to this definition of demand savings.

Impact Summary Ex Post Results

Result	Savings		
	Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
ERS Evaluation Impact Estimate	Not evaluated	13	0
Realization Rate*	N/A	32%	

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

Not evaluated for this measure.

Net-to-Gross and Other Related Observations

None.

A.17 Participant D Measure #1

Reduce Cold Deck Static Pressure at VAV Boxes

Measure Summary Description

Baseline condition: The AHU pressure setpoint was 1.5 inches to 1.75 inches of water column.[4] The VAV boxes required only 1.0 inches.

Actions taken and retrofit condition: Reduce the setpoints to an average of 1.045 inches of water column.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
Scoping Study	8/2005	1,117,048		0
Detailed Investigation Study	3/7/2006	666,521	180	0
Detailed Investigation Study *	3/9/2006	333,260	90	0
Post-Implement Report	8/28/2006	569,402	70	0
Performance Tracking Rpt*	12/17/2007	798,878		0
Performance Tracking Rpt	1/4/2008	569,402	70	0
Persistence	12/17/2007	94%		

* Understood to be inaccurate or outdated results (at the time of reporting) and not representing revised estimates.

Description of Original Savings Estimation Approach[5]

The analysis assumes in the base case that airflows already have been reduced as described in measures 3 and 5. The post-retrofit airflow rates were extracted from the BAS after implementation for each of the 17 air handling units (AHUs) in the four buildings.[6] The flow rates were averaged over time within each 5F temperature bin for unoccupied hours. The flow rate was adjusted upward during extreme temperature conditions, which affected less than 10% of the hours. Overall, the air flow rates averaged slightly more than 60% of design.

Ideal affinity law performance calculations were then used to estimate power. Assumed values were used for the plug fan efficiency (60%) and motor efficiency (90%).

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4 The narrative notes a 1.5-inch setting as the pre-retrofit setting in both the scoping report and the post-installation manual. The savings calculations are based on a 1.75-inch pre-retrofit setting. The true correct number is unknown to evaluators and could not be validated. This adds to uncertainty. One and a half inches was used in the M&V analysis. If 1.75 inches is correct the savings rise to the amount shown in the performance tracking report.

5 This describes the Post-Implementation Report results approach.

6 Presumably based on design cfm and VFD speeds, but this calculation was not shown.

Pre-Site Visit Observations on Original Estimation Approach

The pre-retrofit pressure is unclear. It is inconsequential to the extent that savings depends on the change in pressure not the absolute pressure. This true change in static pressure needs to be resolved.

ERS Original M&V Plan

None.

ERS Actual M&V Plan Executed

Engineering review of implementer analysis.

Description of Findings

The analysis led to substantially lower impact estimation due to the evaluator's more conservative assumption that the static pressure decrease was 0.455 inches instead of the final analysis's 0.705. This decrease affects savings proportionally. With the 0.705 inches, the realization rate would be 100%.

Because this different is due solely to analytical methods and not M&V instrumentation, ERS has attempted to contact the original analyst, Arup, to review the discovery to discuss the correct inputs and calculations. As of March 25, this conversation has not been held.

Impact Summary Ex Post Results

	Savings		
Result	**Annual Electricity (kWh/yr)**	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
ERS Evaluation Impact Estimate	368,554	46	0
Realization Rate*	65%	65%	0%

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

Uncertainty Factor	Uncertainty at 90% Confidence
Metering equipment accuracy/uncertainty	±0%
Short-term to long-term extrapolation uncertainty	±0%
Baseline energy use uncertainty	-15% to +25%
Methodological uncertainty (weather, assumptions, approach, theory)	±10%
Other uncertainty factors	
Overall engineering estimate of uncertainty for measure	-18% to 27%

No site or data validation was possible.

Net-to-Gross and Other Related Observations

None.

Selected Backup Calculations, Intermediate Results, Exhibits

BIN DATA AND CALCS

Temperature bin	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**Wted Avg**	**Total**	**Annualized**
Actual occupied CFM (after measure 3)	463,692	466,774	464,695	461,367	484,284	509,261	506,985	499,212	514,828	524,430	0	490,806		
Occupied hours during measurement period	9	34	62	156	303	336	143	35	14	2	0		1,093	2,750
Actual unoccupied CFM (after measure 5)	420,561	414,192	412,758	424,959	443,582	443,808	433,933	437,328	449,724	473,667	0	436,849		
Unoccupied hours during measurement period	19	75	196	490	1,061	316	106	23	1	0	0		2,286	6,010

GLOBAL INPUTS

Assumed affinity law real coefficient:	2.7	*ERS assumption*

SAVINGS CALCULATIONS

		Design		Baseline		Retrofit	Savings	Implemente	Realization
Occupied									
Supply nameplate hp	hp	2,035	*from scoping study inventory*						Rate
Supply airflow	cfm	1,008,000	*from scoping study inventory*	490,806		490,806	0		
Supply weighted average fan static pressure at box	inw	1.50	*from measure*	1.50		1.045			
Supply weighted average fan static pressure across fa	inw	6.38	*from scoping study equip. list*	2.66		2.20	0.455		
Motor efficiency:		96%	*assumed in final analysis*	96%		96%			
Fan efficiency:		60%	*assumed in final analysis*	60%		60%			
Brake horsepower	bhp	1,686		342		283	59		
Input power via ideal affinity coeff but s.p. control co	kW	1,310		266		220	46	70	65%
FYI Alternate calc: Input power via simple speed proportions w/o control pressure set aside but "real" not ideal affinity l				188		188	0		
Total annual fan energy				730,541		605,403	125,137		
Unoccupied									
Supply nameplate hp	hp	2,035	*from scoping study inventory*						Rate
Supply airflow	cfm	1,008,000	*from scoping study inventory*	436,849		436,849	0		
Supply weighted average fan static pressure at box	inw	1.50	*from measure*	1.50	*from final analysis M1*	1.045			
Supply weighted average fan static pressure across fa	inw	6.38	*from scoping study equip. list*	2.42		1.96	0.46		
Motor efficiency:		96%	*assumed in final analysis*	96%		96%			
Fan efficiency:		60%	*assumed in final analysis*	60%		60%			
Brake horsepower	bhp	1,686		277		225	52		
Input power via ideal affinity coeff but s.p. control co	kW	1,310		215		175	41		
FYI Alternate calc: Input power via simple speed proportions w/o control pressure set aside but "real" not ideal affinity l				137		137	0		
Total annual fan energy				1,292,512		1,049,096	243,416		
TOTAL									
Total annual fan energy				2,023,053		1,654,499	368,554	569,402	65%

A.18 Participant D Measure #2

Reduce Exhaust Static Pressure

Measure Summary Description

Baseline condition: The exhaust fans' pressure setpoint ranged from 1.59 inches to 0.98 inches of water column. The average pressure was 1.27 inches. They can effectively perform at a lower pressure of 1.0 inches.

Actions taken and retrofit condition: Pressure was reduced to a weighted average of 1.12 inches.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
Scoping Study	8/2005	1,228,500		0
Detailed Investigation Study	3/7/2006	301,952	156	0
Detailed Investigation Study *	3/9/2006	150,976	78	0
Post-Implement Report	8/28/2006	192,127	22	0
Performance Tracking Rpt*	12/17/2007	301,952		0
Performance Tracking Rpt	1/4/2008	192,127	22	0
Persistence	12/17/2007	83%		

* Understood to be inaccurate or outdated results (at the time of reporting) and not representing revised estimates.

Description of Original Savings Estimation Approach[7]

The post-retrofit airflow rates were extracted from the BAS after implementation of other measures based on design cfm and VFD speeds. Overall, the air flow rates averaged 60% of design.

Ideal affinity law performance calculations were then used to estimate power. Assumed values were used for the exhaust fan efficiency (55%) and motor efficiency (94%).

Pre-Site Visit Observations on Original Estimation Approach

None.

ERS Original M&V Plan

None.

[7] This describes the Post-Implementation Report results approach.

ERS Actual M&V Plan Executed

Engineering review of implementer analysis.

Description of Findings

None.

Impact Summary Ex Post Results

Result	**Savings**		
	Annual Electricity (kWh/yr)	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
ERS Evaluation Impact Estimate	192,419	22	0
Realization Rate*	100%	100%	

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

Uncertainty Factor	**Uncertainty at 90% Confidence**
Metering equipment accuracy/uncertainty	±0%
Short-term to long-term extrapolation uncertainty	±0%
Baseline energy use uncertainty	±0%
Methodological uncertainty (weather, assumptions, approach, theory)	±10%
Other uncertainty factors	
Overall engineering estimate of uncertainty for measure	±10%

No site or data validation was possible. The data used as the implementer's basis appears sound and the equipment runs at near constant load.

Net-to-Gross and Other Related Observations

None.

Selected Backup Calculations, Intermediate Results, Exhibits

		Design		Baseline		Retrofit	Savings	Implemente	Realization
All									
Exhaust nameplate hp	hp	1,160	*wted avg from final analysis*						Rate
Exhaust airflow	cfm	988,150	*wted avg from final analysis*	597,261	*wted avg from final analysis*	597,261	0		
Exhaust weighted average fan static pressure at box	inw	1.27	*wted avg from final analysis*	1.27		1.110			
Exhaust weighted average fan static pressure across f	inw	3.23	*wted avg from final analysis*	1.99		1.83	0.162		
Motor efficiency:		94%	*assumed in final analysis*	94%		94%			
Fan efficiency:		55%	*assumed in final analysis*	55%		55%			
Brake horsepower	bhp	913		339		312	28		
Input power via ideal affinity coeff but s.p. control co	kW	725		269		247	22	22	100%
Total annual fan energy				2,360,170		2,167,751	192,419	192,127	100%

A.19 Participant D Measure #3

Reduce CFM When Occupied

Measure Summary Description

Baseline condition: Weekday daytime operation of 633,000 cfm, 100% outside air HVAC system in buildings CB-4 through CB-7. The sum of the static pressure across the supply fans and the exhaust fans was 9.4 inches of water.

Actions taken and retrofit condition: Reduce airflow by 22%, 142,000 cfm, for 2,750 occupied hours year (11 hr/non-holiday weekday) by preprogramming the building automation system (BAS) and re-setting VAV boxes' minimum air discharge setpoint.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
Scoping Study	8/2005	*Measure not identified*		
Detailed Investigation Study	3/7/2006	1,260,196	770	79,104
Detailed Investigation Study *	3/9/2006	630,098	385	39,552
Post-Implement Report	8/28/2006	1,744,673	705	44,694
Performance Tracking Rpt*	12/17/2007	1,260,196	0	79,104
Performance Tracking Rpt	1/4/2008	1,744,673	705	44,694
Persistence	12/17/2007	100%		

* Understood to be inaccurate or outdated results (at the time of reporting) and not representing revised estimates.

Description of Original Savings Estimation Approach[8]

Airflow rates were extracted from the BAS cfm both before and after implementation for each of the 17 air handling units (AHUs) in the four buildings.[9] The flow rates were averaged over time within each 5F temperature bin for unoccupied hours. The flow rate was adjusted upward during extreme temperature conditions, which affected less than 10% of the hours. Overall, the air flow rates averaged slightly more than 60% of design.

Ideal affinity law performance calculations were then used to estimate power, after excluding 2.2 inches control static pressure from the cube law relationships. Assumed values were used for the plug fan efficiency (60%) and motor efficiency (90%). Design static pressure was assumed for the base case.

8 This describes the Post-Implementation Report results approach.

9 Presumably based on design cfm and VFD speeds, but this calculation was not shown.

Pre-Site Visit Observations on Original Estimation Approach

The original approach uses excellent BMS data and uses generally sound engineering principles. It lacks power measurement and the static pressure across the fan, a key savings parameter, appears to be taken from design not BMS data. The correction factor for extreme temperatures is unclear. In the on-site interview staff reported that they had lowered the chiller plant kW/ton considerably since the original analysis.

The original analysis appears to assume that all spaces were retrofit, not just offices (or the documented cfm data already accounts for this factor).

The analysis is careful to avoid double counting any of the multiple interactive effects between measures.

The static pressure across the fan used in the analysis for the baseline case appears to be the design value. The baseline flow rate was 40% lower than design, and we would expect the baseline static pressure to have dropped considerably. This has a major impact on the savings estimate.

The gas savings calculations assume that above 58F, every Btu of OA that is cooled is also heated. The rationale for this assumption in unknown.

ERS Original M&V Plan

For a sample building, CB-6, spot measure all of the AHU and exhaust fan kW, current, and speed. Run in pre-retrofit mode for two weeks, which Participant D has agreed to do for this building, and then run in post-retrofit model for two weeks, logging the same data and extracting temperature and SA OA trend data for the same periods. Collect last boiler combustion efficiency test results. Compute central chiller plant overall average kW/ton from snapshot data.

Perform simplified thermal mass and envelope assumptions to estimate added heat gain/loss savings.

Extrapolate to all four buildings.

ERS Actual M&V Plan Executed

No site visit was permitted, thus there could be no power measurement. None of the provided BMS data could compensate. Review was restricted to critique and independent calculations based on the submitted model and a limited set of post-retrofit non-power trend data.

Description of Findings

The analysis led to substantially lower impact estimation due to what appears to be an erroneous calculation and an improperly adjusted input value. Because this different is due solely to analytical methods and not M&V instrumentation, ERS has attempted to contact the original analyst, Arup, to review the discovery to discuss the correct inputs and calculations. As of 3/25 this conversation has not been held.

Impact Summary Ex Post Results

Result	Savings		
	Annual Electricity (kWh/yr)	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
ERS Evaluation Impact Estimate	926,204	255	17,485
Realization Rate*	53%	36%	39%

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

Uncertainty Factor	Uncertainty at 90% Confidence
Metering equipment accuracy/uncertainty	±0%
Short-term to long-term extrapolation uncertainty	±0%
Baseline energy use uncertainty	±0%
Methodological uncertainty (weather, assumptions, approach, theory)	±25%
Other uncertainty factors	
Overall engineering estimate of uncertainty for measure	±25%

No site or data validation was possible and the estimates vary significantly from all of the implementer's prior estimates.

Net-to-Gross and Other Related Observations

The cooling kW/ton in the evaluation was modeled at 0.75 kW/ton as the implementer estimated, but if the central plant overall is now down to 0.60 kW/ton then the net to gross analysis likely should reduce savings for this measure by about 64,000 kWh/yr.

Selected Backup Calculations, Intermediate Results, Exhibits

BIN DATA AND CALCS

Temperature bin	40	45	50	55	60	65	70	75	80	85	90	Wted Avg	Total	Annualized
Actual CFM	646,558	650,855	647,956	643,316	625,252	633,915	625,232	635,784	626,418	638,101	0	633,099		
Revised unoccupied flow:	463,692	466,774	464,695	461,367	484,284	509,261	506,985	499,212	514,828	524,430	0	490,806		
Unoccupied hours during measurement period	9	34	62	156	303	336	143	35	14	2	0		1,093	2,750
Typical humidity ratio (lbm/lbdryair)	0.0040	0.0050	0.0046	0.0066	0.0082	0.0100	0.0100	0.0130	0.0095	0.0058	0.0044			
Approx. %cooled air reheated	0%	0%	0%	0%	75%	50%	25%	0%	0%	0%		37%		
CDD58 during measurement period, sensible					25	98	72	24	12	3	0		234	590
Humidity ratio difference for latent (lbmoisture/lbdryair)					0.0000	0.0010	0.0010	0.0040	0.0005	0.0000	0.0000	0.000749		
HDD58 during measurement period (preheat coil)	7	18	21	19									65	163

Jon Maxwell:
Implementer assumes every OA Btu above 58 has to be both heated and cooled. Major effect on htg savings. Why?

GLOBAL INPUTS

Chiller plant total efficiency:	0.75	kW/ton	interview
Boiler efficiency:	80%		ERS rule of thumb for non-condensing boiler
Interior target humidity ratio at 74F, 50%RH	0.0090	lbmoisture	psych chart
Assumed affinity law real coefficient:	2.7		*ERS assumption*

Jon Maxwell:
Implementer used 0.75. Reasonable at time. Since then, site staff reported a drop from 1.2 to 0.6 kW/ton due to non-program measures taken during or shortly after this installation.

SAVINGS CALCULATIONS

		Design		Baseline		Retrofit	Savings	Implemente	Realization Rate
Supply nameplate hp	hp	2,035	*from scoping study inventory*						
Supply airflow	cfm	1,008,000	*from scoping study inventory*	633,099		490,806	142,293		
Supply weighted average fan static pressure at box	inw	1.50	*from scoping study narrative*	1.05	*from final analysis M1*	1.05			
Supply weighted average fan static pressure across fa	inw	6.38	*from scoping study equip. list*	**2.97**		2.20	0.77		
Motor efficiency:		96%	*assumed in final analysis*	96%		96%			
Fan efficiency:		60%	*assumed in final analysis*	60%		60%			
Brake horsepower	bhp	1,686		493		283	210		
Input power via ideal affinity coeff but s.p. control co	kW	1,310		383		220	163		
FYI Alternate calc: Input power via simple speed proportions w/o control pressure set aside but "real" not ideal affinity l				373		188	185		
Exhaust nameplate hp	hp	1,160	*from scoping study inventory*						
Exhaust design cfm	cfm	988,150	*from scoping study inventory*	620,632		481,141	139,491		
Exhaust design static pressure at box	inw	1.50	*from scoping study narrative*	1.12	*from final analysis M1*	1.12			
Exhaust design static pressure across fan	inw	3.24	*from M-2*	**1.80**		1.53	0.27		
Motor efficiency:		96%		96%		96%			
Fan efficiency:		60%		60%		60%			
Brake horsepower	bhp	838		294		193	100		
Input power via ideal affinity coeff but s.p. control co	kW	651		228		150	78		
FYI Alternate calc: Input power via simple speed proportions w/o control pressure set aside but "real" not ideal affinity l				186		93	92		
Total fan bhp	bhp	2,524							
Total input power (using the ideal affinity law)	kW	1,961		569		313	**255**	705	36%
Total annual fan energy				1,563,597		862,088	701,509	1,529,715	46%
Annual cooling load, sensible	ton-hr/yr	1,284,662		806,864		625,516	181,348		
Annual cooling load, latent	ton-hr/yr	837,650		526,107		407,861	118,246		
Annual cooling energy	kWh/yr	1,591,734		999,728		775,033	224,695	214,958	105%
Total annual electric energy	kWh/yr			2,563,325		1,637,121	**926,204**	**1,744,673**	53%
Annual preheating load	MMBtu/yr	4,262		2,677		2,075	602		
Annual reheating load	MMBtu/yr	5,647		3,547		2,750	797		
Annual heating energy	therms/yr	123,862		77,794		60,310	**17,485**	**44,694**	39%

Jon Maxwell:
This is where the big difference is between Arup's calculations and these lies. Arup's does not drop the s.p. across the fan due to the decrease in flow between design & baseline.

Jon Maxwell: Same.

926,204	.75 kW/ton chiller savings
881,265	.60 kW/ton chiller savings
44,939	difference

A.20 Participant D Measure #4

Increase Occupied Cooling Temperature and Decrease Occupied Heating Temperature

Measure Summary Description

Baseline condition: The setpoint was set at 72F for both heating and cooling for all times.

Actions taken and retrofit condition: A deadband was inserted so that the heating setpoint was 70F and the cooling setpoint was 73F. Measure 14 separately addresses increasing this deadband during unoccupied periods.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
Scoping Study	8/2005	*Measure not identified*		
Detailed Investigation Study	3/7/2006	548,429	435	28
Detailed Investigation Study *	3/9/2006	274,215	217	14
Post-Implement Report	8/28/2006	409,608	174	568
Performance Tracking Rpt*	12/17/2007	563,425	$40,528 value	$24 value
Performance Tracking Rpt	1/4/2008	409,608	174	568
Persistence	12/17/2007	80%		

* Understood to be inaccurate or outdated results (at the time of reporting) and not representing revised estimates.

Description of Original Savings Estimation Approach[10]

The post-retrofit airflow rates were extracted from the BAS after implementation of other measures based on design cfm and VFD speeds. The heating savings was assumed to be the difference in temperature setpoints between existing and proposed for all OA cfm drawn in during unoccupied hours.

Pre-Site Visit Observations on Original Estimation Approach

For a system with preheat coils and constant AHU supply air temperature, setback savings has little relationship to OA cfm and temperature difference. The AHU will supply 55F air to the VAV boxes, all from OA, regardless of the room setpoints. Setback savings is due to reducing undesirable heat gain/loss through the envelope.

ERS Original M&V Plan

None.

[10] This describes the Post-Implementation Report results approach.

ERS Actual M&V Plan Executed

Review trend data to determine actual in-room temperature drift during unoccupied hours. Perform conduction heat loss analysis based on scoping study envelope characteristics to estimate the net reduction in central plant energy use from the monitored temperature drift.

Description of Findings

Limited return air temperature data was available. For the rooms/AHU for which data was available, ERS found that the winter unoccupied temperature averaged 1.8ºF less than during occupied periods. Summer unoccupied temperatures average 2.6ºF greater than during occupied periods. The buildings' thermal mass explains why the difference is less than the setpoint amount.

Impact Summary Ex Post Results

Result	Savings		
	Annual Electricity (kWh/yr)	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
ERS Evaluation Impact Estimate	465,860	67	6,252
Realization Rate*	114%	39%	1,101%

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

Uncertainty Factor	Uncertainty at 90% Confidence
Metering equipment accuracy/uncertainty	±0%
Short-term to long-term extrapolation uncertainty	±0%
Baseline energy use uncertainty	±0%
Methodological uncertainty (weather, assumptions, approach, theory)	±30%
Other uncertainty factors	
Overall engineering estimate of uncertainty for measure	±30%

No site or data validation was possible.

Net-to-Gross and Other Related Observations

None.

Selected Backup Calculations, Intermediate Results, Exhibits

ENVELOPE INFORMATION

Total perimeter from CB-4 to CB-7		Perimeter		Ceiling Area		Floor		Total	Source
CB4		2,500	ft	46,400	ft2	46,400	ft2		*scoping study p 1-2*
CB5		14,170	ft	42,070	ft2	42,070	ft2		*scoping study p 1-2*
CB6		12,130	ft	24,900	ft2	24,900	ft2		*scoping study p 1-2*
CB7		25,940	ft	70,300	ft2	70,300	ft2		*scoping study p 1-2*
Avg floor-ceiling ht		9	ft						
Gross area	ft2	492,660		183,670		183,670			
Typical wall R-value	1/ (Btuh/ft2/F)	11		11		40			*scoping study p. 4 except floor R*
Typical window R-value	1/ (Btuh/ft2/F)	0.9		0.9					*scoping study p. 4*
Percent window		20%		0%					*scoping study p. 4*
Overall U-value	Btuh/ft2/F	0.12		0.10		0.03			
Total conduction heat loss factor	Btuh/F	60,761		18,534		4,592		83,887	
Ignore infiltration since 100% OA. Ignore radiation since night.									

HEATING

Avg reduction in unoccupied temperatu	F	1.5	
Savings	MMBtu/hr average heating load reduction	0.13	
Boiler efficiency	%	80%	*ERS estimate*
Unoccupied heating hr/yr	%of heating season hours	61%	ERS from M#14
Perimeter heating during unoccupied hr	months/yr	8	*ERS estimate*
Unoccupied heating hr/yr	hr/yr	3,562	
Occupied hr/yr	hr/yr	2,750	
%of occupied time perim is heating	months/yr	15%	*ERS coarse estimate*
Occupied heating hr/yr	hr/yr	413	
Boiler gas savings	therms/yr	6,252	

COOLING

Avg increase in unoccupied temperature		1.5	*from trend data*
Savings	tons average cooling load reduction	10.5	
Central plant overall efficiency	kW/ton	0.75	*ERS estimate*
Occupied cooling demand savings	kW	8	
Unoccupied cooling hr/yr	%of cooling season hours	61%	
Perimeter cooling during unoccupied hr	months/yr	4	*ERS estimate*
Unoccupied cooling hr/yr	hr/yr	1,781	
Occupied hr/yr	hr/yr	2,750	
%of occupied time perim is heating	months/yr	75%	*ERS coarse estimate*
Occupied heating hr/yr	hr/yr	2,063	
Central cooling plant savings	kWh/yr	30,228	

FAN

Occupied demand savings		59	*from trend data*
Occupied energy savings	kWh/yr	163,102	
Unoccupied energy savings	kW/ton	272,530	
Fan annual energy savings	kWh/yr	435,632	

TOTAL

Peak demand	**kW**	**67**	**kW**
Gas savings	**therms/yr**	**6,252**	**therms/yr**
Electricity	**kWh/yr**	**465,860**	**kWh/yr**

No analysis of reheat or benefits of avoiding quick switching between heating and cooling

OCCUPIED BIN DATA AND CALCS

Temperature bin	40	45	50	55	60	65	70	75	80	85	90	Wted Avg	Total	Annualized
Actual CFM	463,692	466,774	464,695	461,367	484,284	509,261	506,985	499,212	514,828	524,430	0	490,806		
Revised unoccupied flow:	454,099	417,515	418,410	414,205	438,562	467,085	462,331	455,258	467,345	475,631	0	446,287		
Unoccupied hours during measurement period	9	34	62	156	303	336	143	35	14	2	0		1,093	2,750
Typical humidity ratio (lbm/lbdryair)	0.0040	0.0050	0.0046	0.0066	0.0082	0.0100	0.0100	0.0130	0.0095	0.0058	0.0044			
Approx. %cooled air reheated	0%	0%	0%	0%	75%	50%	25%	0%	0%	0%		37%		
CDD58 during measurement period, sensible					25	98	72	24	12	3	0		234	590
Humidity ratio difference for latent (lbmoisture/lbdryair)					0.0000	0.0010	0.0010	0.0040	0.0005	0.0000	0.0000	0.000749		
HDD58 during measurement period (preheat coil)	7	18	21	19									65	163

GLOBAL INPUTS

Chiller plant total efficiency:	0.75	kW/ton	interview
Boiler efficiency:	80%		ERS rule of thumb for non-condensing boiler
Interior target humidity ratio at 74F, 50%RH	0.0090	lbmoisture	psych chart
Assumed affinity law real coefficient:	2.7		*ERS assumption*

SAVINGS CALCULATIONS

		Design		Baseline		Retrofit	Savings	Implemente	Realization Rate
Supply nameplate hp	hp	2,035	*from scoping study inventory*						
Supply airflow	cfm	1,008,000	*from scoping study inventory*	490,806		446,287	44,519		
Supply weighted average fan static pressure at box	inw	1.50	*from scoping study narrative*	1.05	*from final analysis M1*	1.05			
Supply weighted average fan static pressure across fa	inw	6.38	*from scoping study equip. list*	**2.20**		2.00	0.20		
Motor efficiency:		96%	*assumed in final analysis*	96%		96%			
Fan efficiency:		60%	*assumed in final analysis*	60%		60%			
Brake horsepower	bhp	1,686		283		234	49		
Input power via ideal affinity coeff but s.p. control co	kW	1,310		220		182	38		
FYI Alternate calc: Input power via simple speed proportions w/o control pressure set aside but "real" not ideal affinity l				188		145	42		
Exhaust nameplate hp	hp	1,160	*from scoping study inventory*						
Exhaust design cfm	cfm	988,150	*from scoping study inventory*	481,141		437,499	43,643		
Exhaust design static pressure at box	inw	1.50	*from scoping study narrative*	1.12	*from final analysis M1*	1.12			
Exhaust design static pressure across fan	inw	3.24	*from M-2*	**1.53**		1.46	0.07		
Motor efficiency:		96%		96%		96%			
Fan efficiency:		60%		60%		60%			
Brake horsepower	bhp	838		193		168	26		
Input power via ideal affinity coeff but s.p. control co	kW	651		150		130	20		
FYI Alternate calc: Input power via simple speed proportions w/o control pressure set aside but "real" not ideal affinity l				93		72	21		
Total fan bhp	bhp	2,524							
Total input power (using the ideal affinity law)	kW	1,961		313		254	**59**	118	50%
Total annual fan energy				862,088		698,986	163,102	340,595	48%

UNOCCUPIED BIN DATA AND CALCS

Temperature bin	40	45	50	55	60	65	70	75	80	85	90	Wted Avg	Total	Annualized
Actual CFM	420,561	414,192	412,758	424,959	443,582	443,808	433,933	437,328	449,724	473,667	0	436,025		
Revised unoccupied flow:	*411,860*	*370,482*	*371,646*	*381,519*	*401,702*	*407,053*	*395,713*	*398,822*	*408,246*	*429,592*	*0*	395,065		
Unoccupied hours during measurement period	15	56	165	407	993	303	104	26	6	1	0		2,076	6,010
Typical humidity ratio (lbm/lbdryair)	0.0040	0.0050	0.0046	0.0066	0.0082	0.0100	0.0100	0.0130	0.0095	0.0058	###			
Approx. %cooled air reheated	0%	0%	0%	0%	75%	50%	25%	0%	0%	0%		48%		
CDD58 during measurement period, sensible					83	88	52	18	6	1	0		248	718
Humidity ratio difference for latent (lbmoisture/lbdryair)					0.0000	0.0010	0.0010	0.0040	0.0005	0.0000	###	0.000359		
HDD58 during measurement period (preheat coil)	11	30	55	51									147	427

GLOBAL INPUTS

Chiller plant total efficiency:	0.75	kW/ton	interview
Boiler efficiency:	80%		ERS rule of thumb for non-condensing boiler
Interior target humidity ratio at 74F, 50%RH	0.0090	lbmoisture/l	psych chart
Assumed affinity law real coefficient:	2.7		*ERS assumption*

SAVINGS CALCULATIONS

		Design		Baseline		Retrofit	Savings	Implemente	Realization Rate
Supply nameplate hp	hp	2,035	*from scoping study inventory*						
Supply airflow	cfm	1,008,000	*from scoping study inventory*	436,025		395,065	40,961		
Supply weighted average fan static pressure at box	inw	1.50	*from scoping study narrative*	1.05	*from final analysis M1*	1.05			
Supply weighted average fan static pressure across fa	inw	6.38	*from scoping study equip. list*	1.96		1.79	0.16		
Motor efficiency:		96%	*assumed in final analysis*	96%		96%			
Fan efficiency:		60%	*assumed in final analysis*	60%		60%			
Brake horsepower	bhp	1,686		224		186	38		
Input power via ideal affinity coeff but s.p. control co	kW	1,310		174		144	29		
FYI Alternate calc: Input power via simple speed proportions w/o control pressure set aside but "real" not ideal affinity law c				136		104	32		
Exhaust nameplate hp	hp	1,160	*from scoping study inventory*						
Exhaust design cfm	cfm	988,150	*from scoping study inventory*	427,439		387,285	40,154		
Exhaust design static pressure at box	inw	1.50	*from scoping study narrative*	1.12	*from final analysis M1*	1.12			
Exhaust design static pressure across fan	inw	3.24	*from M-2*	1.44		1.39	0.06		
Motor efficiency:		96%		96%		96%			
Fan efficiency:		60%		60%		60%			
Brake horsepower	bhp	838		162		141	21		
Input power via ideal affinity coeff but s.p. control co	kW	651		126		109	16		
FYI Alternate calc: Input power via simple speed proportions w/o control pressure set aside but "real" not ideal affinity law c				68		52	16		
Total fan bhp	bhp	2,524							
Total input power (using the ideal affinity law)	kW	1,961		242		196	45	0	#DIV/0!
Total annual fan energy				1,452,838		1,180,308	272,530	0	#DIV/0!

A.21 Participant D Measure #5

Reduce CFM When Unoccupied

Measure Summary Description

Baseline condition: Night and weekend operation of 601,000 cfm, 100% outside air HVAC system in buildings CB-4 through CB-7. The sum of the static pressure across the supply fans and the exhaust fans was 9.4 inches of water.

Actions taken and retrofit condition: Reduce airflow by 30%, 180,000 cfm, for 6,010 unoccupied hours per year (13 hr/weekday and all weekends and holidays) by preprogramming the building automation system (BAS) and re-setting VAV boxes' minimum air discharge setpoint.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
Scoping Study	8/2005	*Measure not identified*		
Detailed Investigation Study	3/7/2006	5,014,946	0	140,974
Detailed Investigation Study *	3/9/2006	2,507,473	0	70,487
Post-Implement Report	8/28/2006	4,281,882	0	82,250
Performance Tracking Rpt*	12/17/2007	5,058,822	0	314,183
Performance Tracking Rpt	1/4/2008	4,281,882	0	82,250
Persistence	12/17/2007	100%		

* Understood to be inaccurate or outdated results (at the time of reporting) and not representing revised estimates.

Description of Original Savings Estimation Approach[11]

Airflow rates were extracted from the BAS cfm both before and after implementation for each of the 17 air handling units (AHUs) in the four buildings.[12] The flow rates were averaged over time within each 5F temperature bin for unoccupied hours. The flow rate was adjusted upward during extreme temperature conditions, which affected less than 10% of the hours. Overall, the air flow rates averaged about 60% of design.

Ideal affinity law performance calculations were then used to estimate power, after excluding 2.2 inches control static pressure from the cube law relationships. Assumed values were used for the plug fan efficiency (60%) and motor efficiency (90%). Design static pressure was assumed for the base case.

[11] This describes the Post-Implementation Report results approach.

[12] Presumably based on design cfm and VFD speeds, but this calculation was not shown.

Pre-Site Visit Observations on Original Estimation Approach

The original approach uses excellent BMS data and uses generally sound engineering principles. It lacks power measurement and the static pressure across the fan, a key savings parameter, appears to be taken from design not BMS data. The correction factor for extreme temperatures is unclear. In the on-site interview staff reported that they had lowered the chiller plant kW/ton considerably since the original analysis.

The original analysis appears to assume that all spaces were retrofit, not just offices (or the documented cfm data already accounts for this factor).

The analysis is careful to avoid double counting any of the multiple interactive effects between measures.

The original analysis does not give any credit for conventional setback conduction or convection energy savings due to setback indoor temperatures.

The static pressure across the fan used in the analysis for the baseline case appears to be the design value. The baseline flow rate was 40% lower than design, and we would expect the baseline static pressure to have dropped considerably. This has a major impact on the savings estimate.

The gas savings calculations assume that above 58F, every Btu of OA that is cooled is also heated. The rationale for this assumption in unknown.

ERS Original M&V Plan

Analyze this measure together with Measure 6 Night Setback.

For a sample building, CB-6, spot measure all of the AHU and exhaust fan kW, current, and speed. Run in pre-retrofit mode for 2 weeks, which Participant D has agreed to do for this building, and then run in post-retrofit model for 2 weeks, logging the same data and extracting temperature and SA OA trend data for the same periods. Collect last boiler combustion efficiency test results. Compute central chiller plant overall average kW/ton from snapshot data.

Perform simplified thermal mass and envelope assumptions to estimate added heat gain/loss savings.

Extrapolate to all four buildings.

ERS Actual M&V Plan Executed

No site visit was permitted, thus there could be no power measurement. None of the provided BMS data could compensate. Review was restricted to critique and independent calculations based on the submitted model and a limited set of post-retrofit non-power trend data.

Description of Findings

The analysis led to substantially lower impact estimation due to what appears to be an erroneous calculation and an improperly adjusted input value. Because this different is due solely to analytical methods and not M&V instrumentation, ERS has attempted to contact the original analyst, Arup, to review the discovery to discuss the correct inputs and calculations. As of 3/25 this conversation has not been held.

Impact Summary Ex Post Results

Result	Savings		
	Annual Electricity (kWh/yr)	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
ERS Evaluation Impact Estimate	2,015,828	0	44,035
Realization Rate*	47%	Na	54%

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

Uncertainty Factor	Uncertainty at 90% Confidence
Metering equipment accuracy/uncertainty	±0%
Short-term to long-term extrapolation uncertainty	±0%
Baseline energy use uncertainty	±0%
Methodological uncertainty (weather, assumptions, approach, theory)	±25%
Other uncertainty factors	
Overall engineering estimate of uncertainty for measure	±25%

No site or data validation was possible and the estimates vary significantly from all of the implementer's prior estimates.

Net-to-Gross and Other Related Observations

The cooling kW/ton in the evaluation was modeled at 0.75 kW/ton as the implementer estimated, but if the central plant overall is now down to 0.60 kW/ton then the net to gross analysis likely should reduce savings for this measure by about 64,000 kWh/yr.

Selected Backup Calculations, Intermediate Results, Exhibits

BIN DATA AND CALCS

Temperature bin	40	45	50	55	60	65	70	75	80	85	90	Wted Avg	Total	Annualized
Actual CFM	601,484	592,375	590,324	626,288	610,613	610,680	614,170	627,465	645,250	679,603	0	612,048		
Revised unoccupied flow:	420,561	414,192	412,758	424,959	443,582	443,808	433,933	437,328	449,724	473,667	0	436,025		
Unoccupied hours during measurement period	15	56	165	407	993	303	104	26	6	1	0		2,076	6,010
Typical humidity ratio (lbm/lbdryair)	0.0040	0.0050	0.0046	0.0066	0.0082	0.0100	0.0100	0.0130	0.0095	0.0058	0.0044			
Approx. %cooled air reheated	0%	0%	0%	0%	75%	50%	25%	0%	0%	0%		48%		
CDD58 during measurement period, sensible					83	88	52	18	6	1	0		248	718
Humidity ratio difference for latent (lbmoisture/lbdryair)					0.0000	0.0010	0.0010	0.0040	0.0005	0.0000	0.0000	0.000359		
HDD58 during measurement period (preheat coil)	11	30	55	51									147	427

Jon Maxwell:
Implementer assumes every OA Btu above 58 has to be both heated and cooled. Major effect on htg savings. Why?

Jon Maxwell:
Implementer used 0.75. Reasonable at time. Since then, site staff reported a drop from 1.2 to 0.6 kW/ton due to non-program measures taken during or shortly after this installation.

GLOBAL INPUTS

Chiller plant total efficiency:	0.75	kW/ton	interview
Boiler efficiency:	80%		ERS rule of thumb for non-condensing boiler
Interior target humidity ratio at 74F, 50%RH	0.0090	lbmoisture	psych chart
Assumed affinity law real coefficient:	2.7		*ERS assumption*

SAVINGS CALCULATIONS

		Design		Baseline		Retrofit	Savings	Implemente	Realization Rate
Supply nameplate hp	hp	2,035	*from scoping study inventory*						
Supply airflow	cfm	1,008,000	*from scoping study inventory*	612,048		436,025	176,022		
Supply weighted average fan static pressure at box	inw	1.50	*from scoping study narrative*	1.05	*from final analysis M1*	1.05			
Supply weighted average fan static pressure across fa	inw	6.38	*from scoping study equip. list*	**2.84**		1.96	0.89		
Motor efficiency:		96%	*assumed in final analysis*	96%		96%			
Fan efficiency:		60%	*assumed in final analysis*	60%		60%			
Brake horsepower	bhp	1,686		456		224	232		
Input power via ideal affinity coeff but s.p. control co	kW	1,310		355		174	181		
FYI Alternate calc: Input power via simple speed proportions w/o control pressure set aside but "real" not ideal affinity l				341		136	204		
Exhaust nameplate hp	hp	1,160	*from scoping study inventory*						
Exhaust design cfm	cfm	988,150	*from scoping study inventory*	599,995		427,439	172,556		
Exhaust design static pressure at box	inw	1.50	*from scoping study narrative*	1.12	*from final analysis M1*	1.12			
Exhaust design static pressure across fan	inw	3.24	*from M-2*	**1.76**		1.44	0.32		
Motor efficiency:		96%		96%		96%			
Fan efficiency:		60%		60%		60%			
Brake horsepower	bhp	838		277		162	115		
Input power via ideal affinity coeff but s.p. control co	kW	651		215		126	89		
FYI Alternate calc: Input power via simple speed proportions w/o control pressure set aside but "real" not ideal affinity l				169		68	102		
Total fan bhp	bhp	2,524							
Total input power (using the ideal affinity law)	kW	1,961		524		242	282	675	
Total annual fan energy				3,149,013		1,452,838	1,696,175	3,908,539	43%
Annual cooling load, sensible	ton-hr/yr	1,564,245		949,795		676,638	273,157		
Annual cooling load, latent	ton-hr/yr	876,428		532,158		379,112	153,047		
Annual cooling energy	kWh/yr	1,830,505		1,111,465		791,812	319,653	373,342	86%
Total annual electric energy	kWh/yr			4,260,478		2,244,650	**2,015,828**	**4,281,882**	47%
Annual preheating load	MMBtu/yr	11,154		6,772		4,825	1,948		
Annual reheating load	MMBtu/yr	9,020		5,477		3,902	1,575		
Annual heating energy	therms/yr	252,168		153,114		109,079	**44,035**	**82,250**	54%

Jon Maxwell:
This is where the big difference is between Arup's calculations and these lies. Arup's does not drop the s.p. across the fan due to the decrease in flow between design & baseline.

Jon Maxwell: Same.

A.22 Participant D Measure #14

Increase Unoccupied Setback Temperatures

Measure Summary Description

Baseline condition: The unoccupied setpoint was the same as the occupied setpoint in all areas, 70F for heating and 73F for cooling.

Actions taken and retrofit condition: The heating and cooling temperature during unoccupied periods were set back to 65F and 78F, respectively.

Implementer Ex Ante Impact Estimates

Estimate Period		Savings		
		Annual Electricity (kWh/yr)	Summer Peak Demand (kW)	Annual Gas (therms/yr)
Scoping Study	8/2005	*Measure not identified*		
Detailed Investigation Study	3/7/2006	610,317	0	5,888
Detailed Investigation Study *	3/9/2006	305,159	0	2,944
Post-Implement Report	8/28/2006	456,581	0	50,047
Performance Tracking Rpt*	12/17/2007	878,888	$17,879 value	$6,84 value
Performance Tracking Rpt	1/4/2008	456,581	0	50,047
Persistence	12/17/2007	100%		

* Understood to be inaccurate or outdated results (at the time of reporting) and not representing revised estimates.

Description of Original Savings Estimation Approach[13]

The post-retrofit airflow rates were extracted from the BAS after implementation of other measures based on design cfm and VFD speeds. The heating savings was assumed to be the difference in temperature setpoints between existing and proposed for all OA cfm drawn in during unoccupied hours.

Pre-Site Visit Observations on Original Estimation Approach

For a system with preheat coils and constant AHU supply air temperature, setback savings has little relationship to OA cfm and temperature difference. The AHU will supply 55F air to the VAV boxes, all from OA, regardless of the room setpoints. Setback savings is due to reducing undesirable heat gain/loss through the envelope.

ERS Original M&V Plan

None.

[13] This describes the Post-Implementation Report results approach.

ERS Actual M&V Plan Executed

Review trend data to determine actual in-room temperature drift during unoccupied hours. Perform conduction heat loss analysis based on scoping study envelope characteristics to estimate the net reduction in central plant energy use from the monitored temperature drift.

Description of Findings

Limited return air temperature data was available. For the rooms/AHU for which data was available, ERS found that the winter unoccupied temperature averaged 1.8ºF less than during occupied periods. Summer unoccupied temperatures average 2.6 ºF greater than during occupied periods. The buildings' thermal mass explains why the difference is less than the setpoint amount.

Impact Summary Ex Post Results

Result	Savings		
	Annual Electricity (kWh/yr)	**Summer Peak Demand (kW)**	**Annual Gas (therms/yr)**
ERS Evaluation Impact Estimate	30,549	0	7,594
Realization Rate*	7%	N/A	15%

* Evaluation Savings/Last Documented Implementation Contractor Savings Estimate. Excludes Persistence Factor.

Engineering Uncertainty

Uncertainty Factor	Uncertainty at 90% Confidence
Metering equipment accuracy/uncertainty	±0%
Short-term to long-term extrapolation uncertainty	±0%
Baseline energy use uncertainty	±0%
Methodological uncertainty (weather, assumptions, approach, theory)	±25%
Other uncertainty factors	
Overall engineering estimate of uncertainty for measure	±25%

No site or data validation was possible.

Net-to-Gross and Other Related Observations

None.

Selected Backup Calculations, Intermediate Results, Exhibits

ENVELOPE INFORMATION

Total perimeter from CB-4 to CB-7		Perimeter		Ceiling Area		Floor		Total	Source
CB4		2,500	ft	46,400	ft2	46,400	ft2		*scoping study p 1-2*
CB5		14,170	ft	42,070	ft2	42,070	ft2		*scoping study p 1-2*
CB6		12,130	ft	24,900	ft2	24,900	ft2		*scoping study p 1-2*
CB7		25,940	ft	70,300	ft2	70,300	ft2		*scoping study p 1-2*
Avg floor-ceiling ht		9	ft						
Gross area	ft2	492,660		183,670		183,670			
Typical wall R-value	1/ (Btuh/ft2/F)	11		11		40			*scoping study p. 4 except floor R*
Typical window R-value	1/ (Btuh/ft2/F)	0.9		0.9					*scoping study p. 4*
Percent window		20%		0%					*scoping study p. 4*
Overall U-value	Btuh/ft2/F	0.12		0.10		0.03			
Total conduction heat loss factor	Btuh/F	60,761		18,534		4,592		83,887	
Ignore infiltration since 100% OA. Ignore radiation since night.									

HEATING

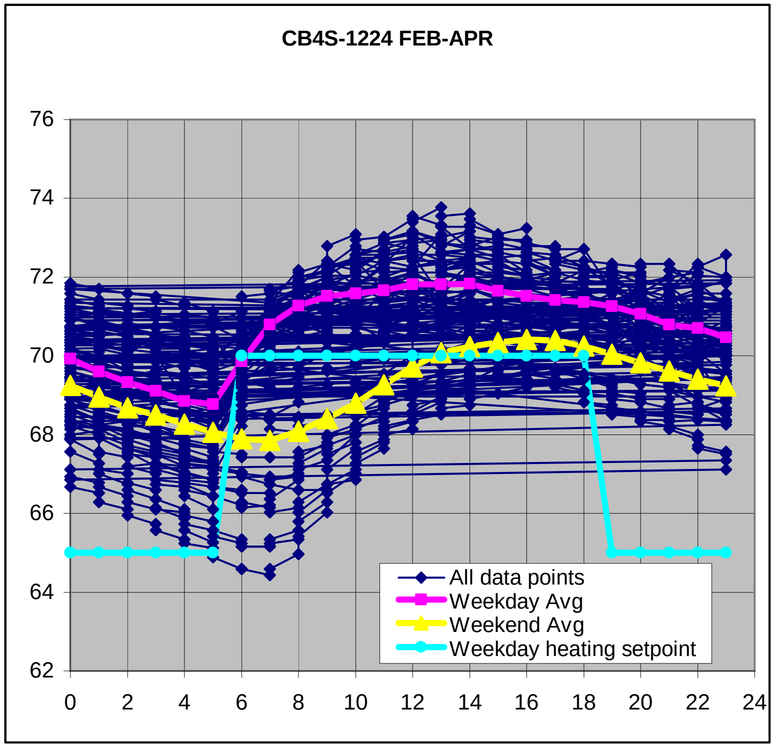
Avg reduction in unoccupied temperatu	F	1.8	*from trend data*
Savings	MMBtu/hr average heating load reduction	0.15	
Boiler efficiency	%	80%	*ERS estimate*
Unoccupied heating hr/yr	%of heating season hours	61%	
Perimeter heating during unoccupied h	months/yr	8	*ERS estimate*
Unoccupied heating hr/yr	hr/yr	3,587	
Boiler gas savings	**therms/yr**	**6,604**	

COOLING

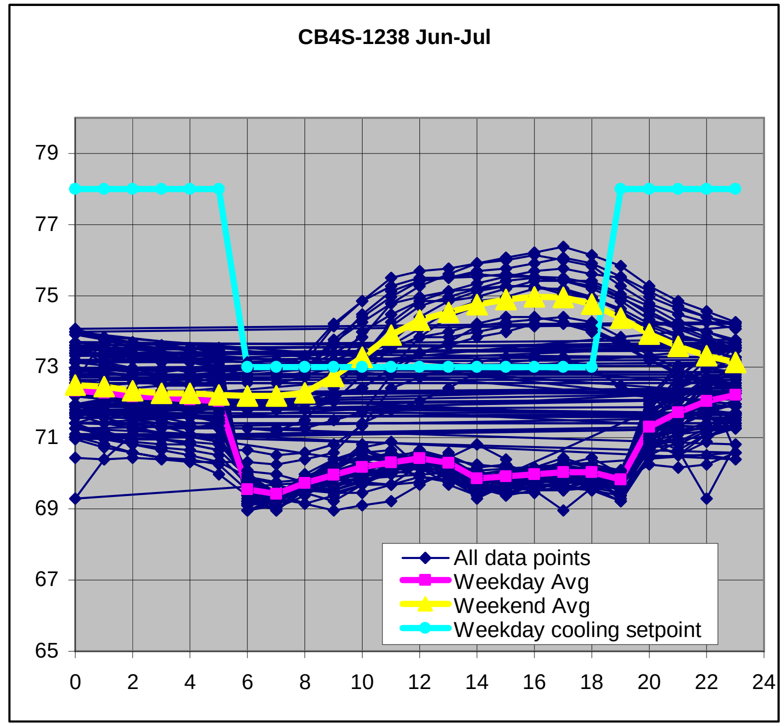
Avg increase in unoccupied temperature		2.6	*from trend data*
Savings	tons average cooling load reduction	18.1	
Central plant overall efficiency	kW/ton	0.75	*ERS estimate*
Unoccupied cooling hr/yr	%of cooling season hours	61%	
Perimeter cooling during unoccupied h	months/yr	4	*ERS estimate*
Unoccupied cooling hr/yr	hr/yr	1,793	
Central cooling plant savings	**kWh/yr**	**24,358**	

TOTAL

Add for VAV reheating of mechanically cooled air		15%
Boiler gas savings	**therms/yr**	**7,594**
Central cooling plant savings	**kWh/yr**	**30,549**



Avg occ temperature WD 6 am - 6 pm (on at 5 am off at 6 pm) 71.4 F
Avg unocc temperature all other times 69.6 F
Reduction contributing to reduced conduction heat gain 1.8 F



Avg occ temperature WD 6 am - 6 pm (on at 5 am off at 6 pm) 70.0 F
Avg unocc temperature all other times 72.6 F
Reduction contributing to reduced conduction heat gain 2.6 F