2004-2005 Los Angeles County-Internal Services Department/Southern California Edison/Southern California Gas Company Energy Efficiency Partnership Impact Evaluation Study

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2004-2005 LAC-ISD/SCE/SoCalGas Partnership Impact Evaluation

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1. Executive Summary

The 2004-2005 Los Angeles County (LAC) - Internal Services Department (ISD) - Southern California Edison (SCE) - Southern California Gas Company (SoCalGas) Energy Efficiency Partnership Program was funded as a California Public Utilities Commission Third Party Local Program. The Partnership Program was a continuation of ISD Energy Division's history of efforts to reduce energy usage at county facilities.

The immediate and concrete savings impacts of the program came from five program elements.

- **Retrocommissioning:** Systematic optimization of HVAC systems were performed at ten courthouses and the county public library headquarters.
- **Building-Wide Lighting Controls:** Control systems were implemented at two large county buildings.
- **Lighting Retrofits:** Fixture for fixture lighting system efficiency retrofits were installed at 33 fire stations and 23 branch libraries throughout the county.
- **Boiler Retrofits:** Boilers were replaced with higher thermal efficiency units at 23 branch libraries and seven courthouses throughout the county, and at ISD Headquarters.
- **Chiller Retrofits:** One 150-ton chiller at ISD Headquarters and one 80-ton chiller at a residential treatment center in East Los Angeles were replaced with more efficient units.

The energy savings and demand impacts of the program were evaluated by RLW Analytics with assistance from ASW Engineering. Site impacts were evaluated with site visits, short term monitored data, billing data, equipment manufacturer specifications and permanently monitored building data extracted from the County's central web-based energy management system. Table 1 shows the aggregate gross and net ex-post impacts of the Partnership Program as estimated by the evaluation team. The site energy in the table is simply the therm and kWh savings converted to a common unit of kBtu and summed to express the energy savings impact of the Partnership Program in a single metric.

Table 1: Partnership Program Energy and Demand Impacts

	Unit	Revised Program Goals	Ex Ante (Tracking) Estimates	Ex Ante % of Program Goals	Ex Post (Evaluated) Savings	Realization Rate (Ex Post/ Ex Ante)	Ex Post % of Program Goals
Electrical Energy	kWh	4,723,641	6,935,754	147%	6,041,770	87%	128%
Coincident Peak Demand	kW	1,902	424	22%	620	146%	33%
Natural Gas Energy	therm	402,428	398,590	99%	302,273	76%	75%
Site Energy	kBtu	56,364,630	63,530,729	113%	50,847,836	80%	90%

The retrocommissioning, building-wide lighting controls and chiller retrofit elements were evaluated with a census of project sites; therefore there is no sampling error, expressed as relative precision, for those elements. The lighting retrofit element was evaluated via a stratified sample of three project sites. All but two of the boiler retrofit project sites were evaluated, and the realization rate from similar projects was used to estimate the savings for the two sites where billing data were not available. Hence, there are calculated relative precisions associated with those two elements. The relative precisions shown in Table 2 were calculated at the 90% level of confidence.

The "tracking savings" shown in Table 2 are the implementation team's final ex ante savings estimates, while the "evaluated savings" refer to the ex post estimates. The realization rates, abbreviated as RR in Table 2, are the evaluated savings divided by the tracking savings. The kBtu savings are the aggregate electrical and natural gas savings for the program, kWh and therms, converted to a common unit to provide a comprehensive metric.

Table 2: Program Summary by Element

	Retrocommissioning	Building Wide Lighting Controls	Lighting Retrofits	Boiler Retrofits	Chiller Retrofits	Total
Projects	11	2	56	31	2	**102**
Sample	10	2	3	29	2	**46**
kWh Savings Tracking	4,694,138	943,218	1,161,097		137,301	**6,935,754**
kWh Savings Evaluated	4,205,533	688,737	921,654		225,847	**6,041,770**
kWh RR	90%	73%	79%		164%	**87%**
kWh Relative Precision	7%	0%	67%		0%	**11%**
Coincident Peak kW Tracking	50	-	279		94	**424**
Coincident Peak kW Evaluated	366	-	165		90	**620**
kW RR	732%	-	59%		95%	**146%**
kW Relative Precision	8%	-	43%		0%	**30%**
Therm Savings Tracking	284,047			114,543		**398,590**
Therm Savings Evaluated	271,880			30,393		**302,273**
Therm RR	96%			27%		**76%**
Therm Relative Precision	4%			13%		**4%**
kBtu Savings Tracking	44,425,793	3,219,203	3,962,826	11,454,300	468,608	**63,530,729**
kBtu Savings Evaluated	41,541,438	2,350,660	3,145,604	3,039,318	770,816	**50,847,836**
kBtu RR	94%	73%	79%	27%	164%	**80%**
kBtu Relative Precision	4%	0%	67%	13%	0%	**5%**

The realization rates of the program elements varied greatly, ranging from 164% for the chiller retrofits kWh savings to 27% for the boiler retrofits therm savings. For these two elements, the program used deemed per-unit equipment savings as the program estimates. For the other program elements (retrocommissioning, lighting retrofits and lighting controls), ex ante estimates were customized to the site. The chiller retrofit element benefited from longer-than-assumed hours of operation leading to increased energy savings. Conversely, the boiler retrofits had much lower than deemed savings in all circumstances due to lower-than-assumed heating load per boiler.

A decision-maker survey was used assess net savings with a standardized self-report methodology. For the 2004-2005 program cycle, net savings is defined simply as net of participant freeridership. The standardized methodology did not detect any freeridership; hence the net-to-gross ratio for all Program elements was estimated at 1.0. According to the County decision-makers, who are also program participants, the County, absent this Program, would not have undertaken these projects or similar projects in 2004-2005 or in the foreseeable future. The county has no funding mechanism for energy efficiency upgrades, and replace upon failure with least costly option, typically standard efficiency equipment, is the standard practice in county buildings. .

Since this program is a continuation of County energy efficiency programs, there is a question of what would have occurred absent any this series of programs, and whether the County has become dependent on the external funding of these programs. Would the County have developed internal funding for energy efficiency upgrades in the absence of these programs with outside funding? Would the County have, on its own, looked into reducing their energy expense through energy efficiency? Possibly, and given the return on investment for the most cost effective measures, it can be argued that at least some would be likely. However, this question can not be answered easily and is well beyond the scope and resources of this evaluation. It is the belief of the evaluation team that the effect of long-term funding on governmental and other large institutions warrants further study.

The program TRC (total resource cost ratio) as calculated from ex post savings is 1.45. The value is lower than the program planning estimate of 1.64. The difference is mainly due to the unmet natural gas energy savings goal. However the ex post TRC is indicative of a cost-effective program as it is greater that 1.0.

The California Public Utilities Commission (CPUC) reporting table is shown in Table 3. The table shows the Program savings as projected into the future by the estimated effective useful life (EUL) for each category of measure that composed the Program. The retrocommissioning effective useful life is estimated at 15 years[1]. The lighting retrofit and building wide lighting controls measure used the DEER EUL of 16 years. Likewise, the boiler and chiller replacement measures used the DEER EUL for of 20 years (the CPUC maximum) for HVAC equipment life.

Table 3: CPUC Reporting Table

Year	Calendar Year	Ex-ante Gross Program-Projected Program MWh Savings (1)	Ex-Post Net Evaluation Confirmed Program MWh Savings (2)	Ex-Ante Gross Program-Projected Peak Program MW Savings (1**)	Ex-Post Evaluation Projected Peak MW Savings (2**)	Ex-Ante Gross Program-Projected Program Therm Savings (1)	Ex-Post Net Evaluation Confirmed Program Therm Savings (2)
1	2004	6,946	6,041	0.42	0.62	398,590	302,273
2	2005	6,946	6,041	0.42	0.62	398,590	302,273
3	2006	6,946	6,041	0.42	0.62	398,590	302,273
4	2007	6,946	6,041	0.42	0.62	398,590	302,273
5	2008	6,946	6,041	0.42	0.62	398,590	302,273
6	2009	6,946	6,041	0.42	0.62	398,590	302,273
7	2010	6,946	6,041	0.42	0.62	398,590	302,273
8	2011	6,946	6,041	0.42	0.62	398,590	302,273
9	2012	6,946	6,041	0.42	0.62	398,590	302,273
10	2013	6,946	6,041	0.42	0.62	398,590	302,273
11	2014	6,946	6,041	0.42	0.62	398,590	302,273
12	2015	6,946	6,041	0.42	0.62	398,590	302,273
13	2016	6,946	6,041	0.42	0.62	398,590	302,273
14	2017	6,946	6,041	0.42	0.62	398,590	302,273
15	2018	6,946	6,041	0.42	0.62	398,590	302,273
16	2019	2,242	1,836	0.37	0.25	114,543	30,393
17	2020	137	226	0.09	0.09	114,543	30,393
18	2021	137	226	0.09	0.09	114,543	30,393
19	2022	137	226	0.09	0.09	114,543	30,393
20	2023	137	226	0.09	0.09	114,543	30,393

2. Introduction

This document is the impact evaluation conducted by RLW Analytics for the LAC-ISD-SCE-SoCalGas Energy Efficiency Partnership Program (Partnership Program) for 2004-2005. This report is the companion to the LAC-ISD-SCE-SoCalGas Energy Efficiency Partnership Program Process Evaluation

[1] See Program Results (page 19) for the discussion of RCx EUL

report[2]. This impact report represents the culmination of evaluation activities that began in July 2004. This report focuses on the energy savings and peak demand reductions achieved by the Partnership Program. A program history and a description of the program logic model, structure, and delivery are found in the process evaluation report.

This study was conducted at the request of the California Public Utilities Commission. The study was managed by Pierre Landry of Southern California Edison. It was funded through the public goods charge (PGC) for energy efficiency and is available for download at www.calmac.org.

Program Description

The Partnership Program consisted of a group of discrete program elements with the common goal of realizing energy savings and peak demand reduction. The elements that directly resulted in measurable energy savings and peak demand reduction included

- Retrocommissioning,
- Building-Wide Lighting Controls,
- Lighting Retrofits,
- Chiller Retrofits, and
- Boiler Retrofits.

Other Partnership elements, such as the multifamily public housing metering element and the public technology transfer element, did not have direct and immediate measurable savings associated with them. These elements are discussed in detail in the process evaluation report.

[2] *Los Angeles County-Internal Services Department/Southern California Edison/Southern California Gas Company Energy Efficiency Partnership Process Evaluation*, RLW Analytics, 2008

3. Evaluation Objectives and Methodology

The fundamental approach to the evaluation was to draw a statistical sample of the sites in a given program element, perform evaluation activities on the sample sites in order to calculate realization rates at the site level, and expand the results back to the element population. Some of the elements were evaluated via a census, so no sampling or extrapolation was necessary. Total program impacts are simply the sum of program element impacts.

3.1 Sampling Methodology

The official research plan, as approved by the CPUC and Master Evaluation Contractor, for the study included a provisional sampling plan using anticipated program activities. The method used to formulate this plan was the Optimal Allocation for the Overall Savings of the Portfolio as described on page 310 of California Evaluation Framework[3]. The specific technique utilized, illustrated in Table 12.12 of the Framework, is called Optimal Allocation with Different Unit Costs in Each Program. The goal of this technique is to allocate the evaluation budget among the different "programs" to optimize the relative precision for the aggregate savings for the entire portfolio. For this evaluation the discrete program elements are equivalent to "programs" as used for this technique.

The original provisional sampling plan is shown in Table 4 and was based upon program targeted savings and participants. The goal of the plan was to optimize the relative precision for the total electrical energy savings estimate. It also called for a census of all elements except for the lighting retrofit element. Using typical error ratios for retrofit and lighting controls elements and a conservative error ratio of 0.8 for the retrocommissioning element, the provisional sampling plan estimated a relative precision of 6% at the 90% confidence interval. The kWh savings shown in Table 4 were the revised program goals.

Table 4: Provisional Sampling Plan

Programs	Projects	kWh Savings	Error Ratio	Cost / Project	Allocator	Optimal Sample Size	Relative Precision	Error Bound (kWh)	Evaluation Cost
Lighting Retrofits	62	667,440	0.5	$ 1,500	8,617	8	27%	181,000	$ 12,000
Lighting Controls	3	424,200	0.5	$ 1,500	5,476	3	-	-	$ 4,500
Chiller Retrofits	2	137,301	0.3	$ 1,000	1,303	2	-	-	$ 2,000
Retrocommissioning	10	1,830,000	0.8	$ 2,800	27,667	10	-	-	$ 28,000
Total		**3,058,941**			**43,063**	**23**	**6%**	**181,000**	**$ 46,500**

Once program activities were finalized, the provisional sampling plan was revised. The most profound change in program activities was the addition of a boiler retrofit element, which had no associated kWh savings. Therefore, to use the optimal allocation technique for savings of two different fuel types, natural gas therm and electrical energy kWh savings were converted to the common unit of kBtu. By the time the evaluation team learned that the program would have a boiler retrofit element, evaluation activities had already commenced for the lighting controls, chiller retrofits and retrocommissioning element sites and we were committed to a census of these elements. In order to add the boiler retrofits in the evaluation under the existing budget, the sample sites were reduced for the lighting retrofits elements as shown in the Revised Provisional Sampling Plan.

Table 5: Revised Provisional Sampling Plan

[3] *California Evaluation Framework,* TecMarket Works Framework Team, 2004

Programs	Projects	kWh Savings	Therm Savings	kBTU Savings	Error Ratio	Cost / Project	kBTU Allocator	Optimal Sample Size	Relative Precision	Error Bound (KBTU)	Evaluation Cost
Lighting Retrofits	55	256,492	-	806,156	0.5	$ 1,500	10,407	3	46%	372,000	$ 4,500
Lighting Controls	2	424,200	-	1,333,261	0.5	$ 1,500	17,212	2	-	-	$ 3,000
Chiller Retrofits	2	137,301	-	431,536	0.3	$ 1,000	4,094	2	-	-	$ 2,000
Retrocommissioning	10	1,830,000	219,630	27,714,655	0.8	$ 2,800	419,006	10	-	-	$ 28,000
Boiler Retrofits	31		108,669	10,866,900	0.8	$ 1,500	224,466	6	48%	5,243,000	$ 9,000
Total		**2,647,993**	**328,299**	**41,152,508**			**450,720**	**17**	**13%**	**5,256,180**	**$ 46,500**

A revised sampling plan was created, which called for a sample of six boiler retrofit sites; however a site analysis of all boiler sites with available billing data was performed to optimize the relative precision. This was possible under the same budget due to the billing analysis approach used to evaluate estimate savings.

An eleventh retrocommissioning site was added toward the end of the program. Since there were no resources available for evaluation activities for this additional site, the retrofit savings were estimated as a sample of ten from a population of eleven projects. The final population and sample sizes are shown in Table 6.

Table 6: Final Population and Sample

	Projects	Sample
Lighting Retrofits	56	3
Building Wide Lighting Controls	2	2
Chiller Retrofits	2	2
Retrocommissioning	11	10
Boiler Retrofits	31	29

4. Impact Evaluation of Program Activities

This section describes the program elements and general approach used to verify energy savings and peak demand reductions produced by this program. The overall approach categorized by International Performance and Measurement Verification Protocol M&V option is shown in Table 7. Although the retrocommissioning element used whole premise simulation to generate the ex post estimates, the absence of whole premise calibration leaves the approach best described as Option B, retrofit isolation.

Table 7: Evaluation Approach by Program Element

Program Element	IPMVP Option	Utilized Evaluation Data
Retrocommissioning	Option B	Various Short Interval Pre and Post HVAC Data Streams (continuous)
Building-wide Lighting Controls	Option A	Pre and Post Lighting Run-time (3-4 weeks)
Lighting Retrofits	Option A	Post Lighting Run-time (3-4 weeks)
Chiller Retrofits	Option B	Short Interval Post Chiller Power Draw (continuous)
Boiler Retrofits	Option C	Pre and Post Monthly Premise Billing Gas Usage

4.1 Retrocommissioning Element Evaluation

Systematic HVAC retrocommissioning (RCx) procedures were implemented at eleven facilities throughout the county as part of the program. Most of the savings from this component were realized through optimization of the equipment start/stop schedules. Other measures included economizer implementation (repair, adjustments and utilization), condenser water set point changes, supply air temperature reset, and night time set point setback. An eleventh site began RCx procedures, but the activities were not completed in time to be included in the 2004-2005 program evaluation.

The RCx contractor created eQUEST® [4] simulation models to estimate the savings for these activities. The models were provided to the evaluation team and were used extensively in the evaluation. Originally the RFP had specified spreadsheet analysis to generate program estimates for this program element. However, the RCx contractor was able to convince the Partnership Program stakeholders that a simulation program was more appropriate for the types of measures implemented at these facilities.

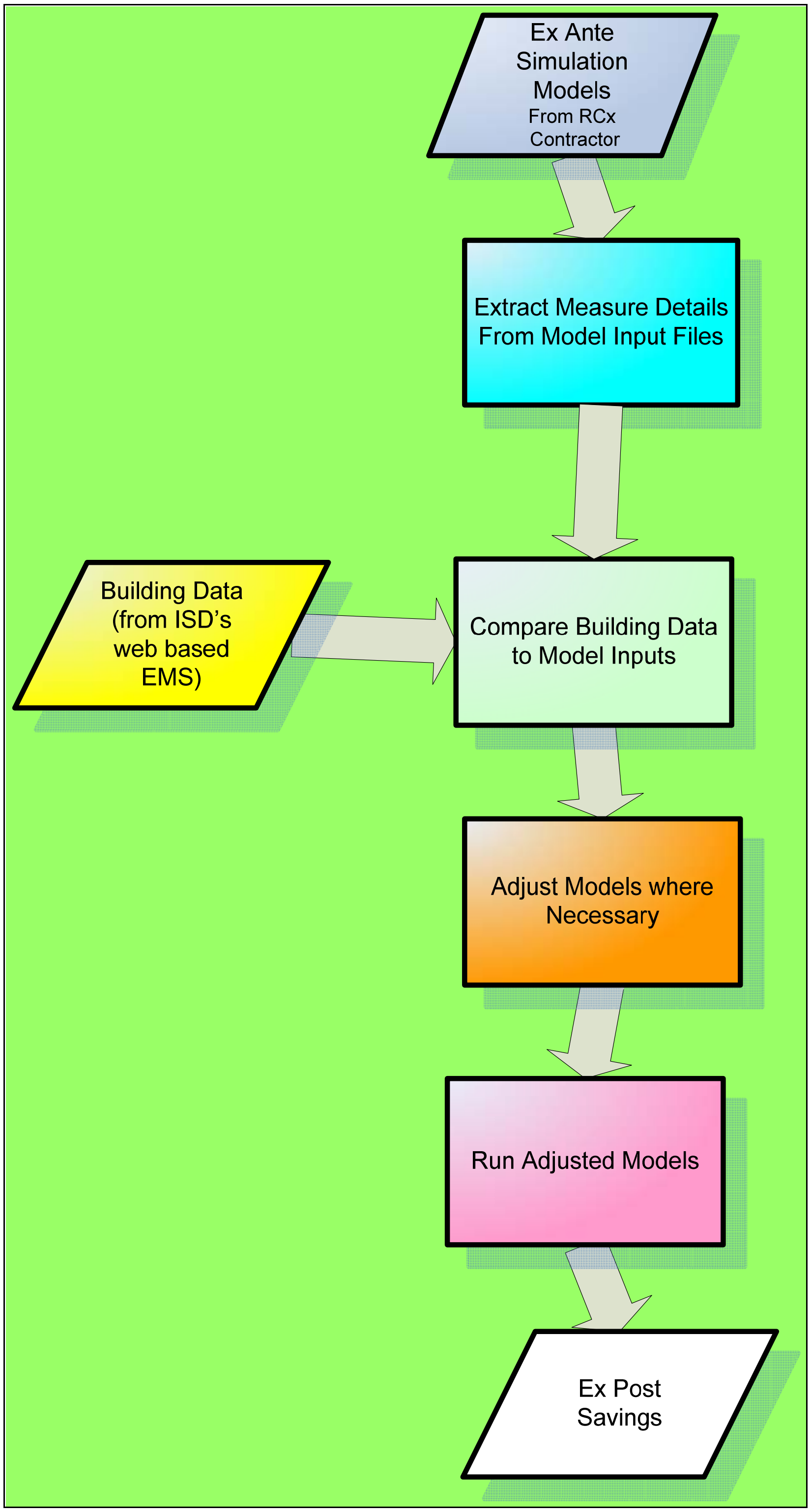
The evaluation steps are shown in Figure 1. In summary, the individual RCx measures were extracted from the RCx contractor's simulation models and compared with building data. Models were modified to reflect the actual building data wherever it deviated from modeled behavior, and

[4] eQUEST® is a freeware building energy use analysis tool that is, essentially, a front end for DOE-2 (version 2.2) building energy use simulation program. The application's EEM (energy efficiency measure) wizard aids in detailed comparative analysis of proposed efficiency measures and/or building designs.

then the modified models were run to generate evaluated energy and coincident peak savings and the associated site realization rates.

Notably, there were no evaluation site visits made to any of the retrocommissioning sites. All of the data were gathered from the County's centralized energy management system. Since the overwhelming majority of program savings came from control system measures, any on-site verification activities would have had little value for the evaluation. The data streams from the county wide energy management system were well-labeled and of high quality (the values were always found to be within the reasonableness range for the measurement under consideration, temperature, amperage, wattage etc.). Therefore, the evaluation team has confidence that the correct data were used to evaluate the incented measures for this evaluation.

Figure 1: RCx Site Evaluation Procedure



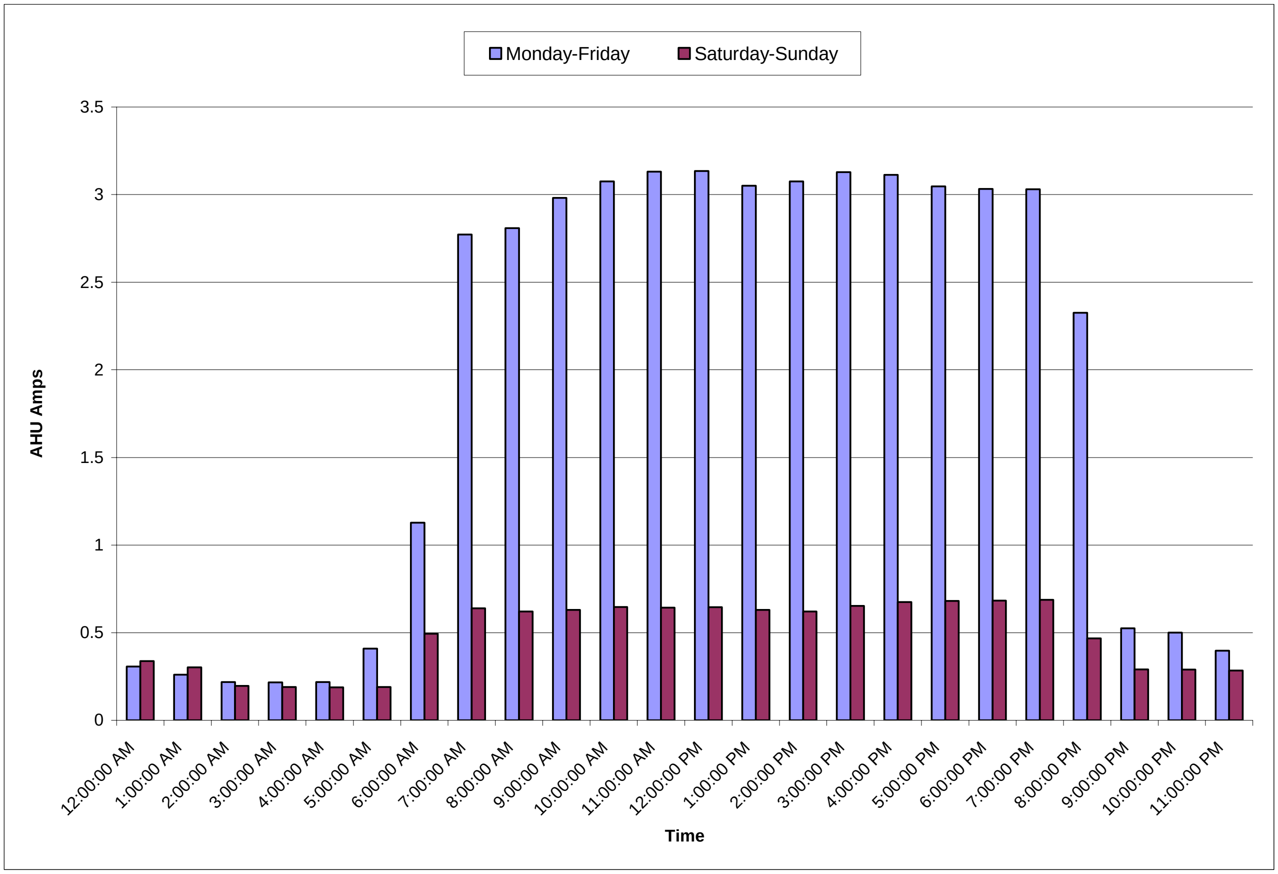
The eQUEST® EEM wizard was used by the RCx contractor to create the simulation models for program estimates. This tool generates a unique simulation model input file for the facility baseline and for each measure modeled. As a first step, the evaluation team performed file comparisons on these input files to isolate the exact code changes that modeled the measure. The code changes were deciphered to determine the actual measure modeled rather than assuming the description indicated in the RCx contractor reports were accurate. The code changes extracted from a scheduling measure and a translation of what code means are shown in Table 8. Essentially, the measure was simulated by applying a new operational schedule.

Table 8: Simulation Code Changes for a Start/Stop Scheduling Measure

Baseline Model	***Scheduling Measure***
Baseline	**EEM 1**
Fan Schedule - Day" = DAY-SCHEDULE-PD	“EEM 1 Fan Schedule - Day" = DAY-SCHEDULE-PD
TYPE = ON/OFF/FLAG	TYPE = ON/OFF/FLAG
VALUES = (1, &D, &D, &D, 1, 1, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, 1, &D, 1)	**VALUES = (0, &D, &D, &D, &D, 1, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, 0)**
Always ON	**5am -7pm**
"Fan Schedule - Wknd Day" = DAY-SCHEDULE-PD	"EEM 1 Fan Sch - WEH" = DAY-SCHEDULE-PD
TYPE = ON/OFF/FLAG	TYPE = ON/OFF/FLAG
VALUES = (1)	**VALUES = (0)**
Always On	**Always Off**

After the measure was defined in specific detail, the pertinent building data streams were downloaded from the County’s centralized web-based energy management system. Pre implementation data were evaluated to determine if the measure baseline had been modeled correctly and post-implementation data were analyzed to see if the measure had performed as modeled. In our example, the measure changed an always-running fan system to run 5AM to 7PM on weekdays, and always-off on weekends. However, actual post implementation building data, average air handler amp draw as seen in Figure 2, reveal that the fan schedule is 5AM to 8PM weekdays and is off on the weekends. For this case, the chart shows the average amp draw by hour and day type for only one air handler. However, all other air handlers at the site followed a similar schedule and this air handler was considered to be representative of the other air handlers.

Figure 2: Average AHU Amp Draw of AHU1 to Verify Fan Schedule Measure



The actual schedule was input into the simulation model to create an "evaluation model", which reflects actual post-implementation operation. After all of the measures had been analyzed and subsequently verified or modified in the evaluation model, the baseline model was analyzed in the same manner to determine if modifications were necessary. Once modifications to the baseline model were complete, the evaluation model and the modified baseline were run with the appropriate CEC weather data. The evaluated ex post energy savings were calculated as the difference in consumption between the evaluation and modified baseline models. The coincident peak demand kW savings were estimated as the difference between the models' hourly consumption that was coincident with the highest weekday dry bulb temperature between 3PM and 4PM in the weather data.

Some RCx measures, such as the scheduling measures, supply air temperature reset, and condenser set point measures were very easy to verify with available data. Other measures, such as mixing box repair, boiler tune-ups, and air side economizer implementation (where mixed air temperature was not monitored) were more difficult to determine. Wherever the evaluation team was unable to discern if a measure was working or not, the implementers were given the benefit of the doubt and the measures remained as originally modeled by the RCx contractor. Although this approach may have given credit for measures not functioning as intended, the risk associated with the approach should be considered negligible due to the small proportion of savings associated with these difficult-to-determine measures. These measures only represented 8% of electrical savings and 4% of natural gas savings for the entire component. The easiest of all measures to verify were the scheduling measures, which accounted for 64% of ex ante kWh savings and 43% of ex ante therm savings.

Figure 3: Classification of Measures by Ease of Evaluation through Web Based Data Collection

Easy	Harder	Difficult
• Start/Stop Scheduling Measures	• Air-Side Economizer	• TAB Measures (VAV Box Repair, Valve Repair, Damper Repair, Air Balance)
• Hot and Cold Deck Reset	• Night Purge	• Boiler Tune-Up
• Condenser Water Set Points		• Measures where the critical point is not being monitored
• Room Temperature Set Point Setbacks		• Air-Side Economizer where mixed air temperature is not monitored
• Garage Fan CO Control		

Proportion of RCx Element Ex Ante Savings

	Easy	Harder	Difficult
kW	**33%**	**59%**	**8%**
kWh	**83%**	**9%**	**8%**
therm	**90%**	**6%**	**4%**

4.2 Building-Wide Lighting Controls Project Evaluation

Lighting control systems were installed at two county facilities, the Department of Health Services Center and the Edmund G. Edelman Children's Court, to reduce the run time of the lighting during unoccupied periods. These sites had no effective control system prior to implementation and had considerable "always on" lighting load as a consequence.

Site visits were made to these two sites in order to install run time loggers on a sample of controlled lighting fixtures. The loggers were installed prior to the implementation of the lighting controls, and were left in place for at least 4 weeks after implementation of the control system to capture pre implementation and post implementation run time data. After the loggers were retrieved and the data downloaded, the data were separated into pre and post implementation periods, which were then imported into data analysis and visualization software. The average load profiles for weekdays, weekends, and holidays created from the run time data were extrapolated to estimate annual usage. The annual energy savings were calculated as simply the difference in consumption between the pre and post annual usage estimates.

SCE provided the controlled lighting kW, annual tracking hours and baseline hours for each facility in the site level documentation. The kWh savings were calculated by simply multiplying the controlled kW by the controlled annual hours. The lighting controls at both of these facilities were designed to reduce lighting run time during non-peak period hours, therefore there are no coincident peak kW savings associated with these measures.

4.3 Lighting Retrofits Project Evaluation

Lighting retrofits were performed at 56 sites throughout the county, 33 fire stations and 23 libraries. The retrofit measures were mostly lamp-for-lamp replacements including T-8 for T-12 linear fluorescents, screw based compact fluorescents for incandescents, metal halide for mercury vapor exterior fixtures, and LED for incandescent exit signs.

The evaluation team made pre-implementation site visits at eight randomly selected sites in order to observe existing fixture types and counts. These counts were used to verify contractor fixture counts found in the program documentation. There were discrepancies found in the initial counts, but all the discrepancies found at the sample sites were corrected in post implementation "as-built" documentation. Therefore, the corrected counts for the entire lighting retrofit population were assumed to be accurate like the sample, i.e. no "true-up" of fixture counts was necessary based upon the sample count verification.

The contractor's documentation that was used to generate program savings estimates was provided to the evaluation team. The documentation was in the form of MS Excel spreadsheets showing measure location, and all other pertinent information about retrofitted lighting fixtures including the estimates of annual run time.

After the retrofits were implemented, site visits were made to verify the installed equipment and to install run time loggers on a sample of representative lighting fixtures for three sample sites according to the revised sampling plan. The loggers were left in place for three to four weeks. The logger data were imported into data analysis and visualization software and weekday and weekend run time profiles were created. These profiles were annualized to estimated run time hours for the year. Observed holidays were mapped into "weekend" or closed day profiles for the annualization process. Adjustments were made to annual hours in as-built documentation in order to calculate the ex-post energy savings.

The Program reported the lighting retrofit kW savings as simply the kW reduction of the fixtures. Although CPUC definition of coincident peak kW savings leaves room for some interpretation, it is clear that demand reduction during the time period where system critical peak events are likely to occur should be considered. The evaluation team calculated a coincident factor, defined as the percentage of time during weekdays from 3PM to 4PM, where the fixtures were operational. This was multiplied by the fixture kW reduction to calculate coincident peak kW reduction.

4.4 Chiller Retrofits Project Evaluation

Program activities included two chiller retrofits, one 80-ton chiller at Dorothy Kirby Center and one 150-ton at ISD Headquarters on Eastern Avenue. A site visit was made to the Dorothy Kirby Center and a current logger was installed on the preexisting chiller before it was removed. Shortly after the new chiller was installed, a data logger was placed on the new chiller and was left in place until after a "hot spell", a period of high temperatures, had occurred. This was done to more accurately predict facility load and chiller performance. The preexisting and new chillers at ISD Headquarters were connected to the county-wide data management system (EEMIS), so no site visits were necessary for that facility.

Chiller supply and return temperatures were available at ISD Headquarters. Consequently, the evaluation of site savings for this facility was performed with two sets of regressions. A regression equation of facility load versus ambient dry-bulb temperature was applied to CEC climate zone typical meteorological year weather to get a facility load profile for a typical year. Then the regression equations of the new chiller power draw as a function of facility load and preexisting chiller curves were applied to the typical year load. Site savings were estimated as the difference between preexisting and new chiller typical year usage estimates. The coincident peak savings were determined in a manner similar to the retrocommissioning element and were estimated as the kW savings for the highest dry-bulb temperature hour of the typical year.

Since chilled water temperatures were not available at Dorothy Kirby Center, the evaluation was performed with a single set of regressions. Regression equations for chiller power draw for the new and preexisting chillers as function of ambient dry bulb temperature were applied to the CEC climate zone weather data to calculate annual usage for a typical year. Once again, the savings were simply the difference between annual usage estimates, and the coincident peak kW savings were the kW difference during the hour with the highest dry-bulb temperature in the typical year weather data.

4.5 Boiler Retrofits Project Evaluation

Aging boilers with nominal thermal efficiencies of 0.80 were replaced at 31 facilities throughout the county. A single boiler was replaced at 24 branch libraries and two boilers at each site were replaced at six courthouses and the ISD Headquarters. A sample of flue gas analyses from boilers of similar size, age and efficiency showed, on average, an actual operating efficiency of 78.2%. The new boilers had nominal thermal efficiencies of 0.83 or 0.85.

The implementation contractor provided documentation which included the model number of the new boiler. Six boiler sites were visited and all equipment found on-site matched the contractor's documentation. A walk through was performed at each site to aid in association of natural gas usage to facility loads. All of the visited sample sites had natural gas loads that served space heating and water heating for hand washing only. The results of these site visits, specifically that the contractor's documentation was accurate and the natural gas load in the facility were limited to space heating and water heating were assumed to be representative of the entire boiler retrofit population.

The natural gas billing data for two years were acquired from the Internal Services Department's Energy Division for 29 of the 31 sites. The Internal Services Department Headquarters was master metered with several other facilities, so usage for that specific building could not be determined from billing data alone and therefore was excluded from the billing analysis.

First, weather normalized annual usage for each site was calculated using monthly billing data and local weather data. Linear regressions of monthly facility therm usage against heating degree days, HDD_{65}, from the nearest available actual weather station data were performed to produce usage equations. Next, typical annual cooling degree days, from CEC typical weather year data for the appropriate climate zone was applied to the regression equations in order to estimate annual facility gas usage.

Next, a base load was determined for all analyzed sites. The base load was simply water heating load in most cases, but included cafeterias in two courthouses. This was done through analysis of gas usage during summer months to estimate a monthly base load and multiplying it by 12. This method assumes base load is fairly constant throughout the year, and space heating is nil or near nil during July and August. Some subjective analysis was made on a site by site basis to determine if the lowest month billed was the actual therm usage for the month and not a "make-up" for a prior month's meter misread.

Then the base load was subtracted for the annual usage to estimate annual heating load. The savings was calculated using the difference in thermal efficiencies, TE, of the existing and new boiler.

$$BoilerSavings = AnnualHeatingUsage * (\frac{TE_{new}}{TE_{old}} - 1)$$

For the ISD Headquarters and Pasadena Courthouse, the average savings of all other sites where two boilers were replaced were used as the ex post site estimate. These two sites, where billing information was not available, were considered as "not sampled" and the relative precision of the element was calculated as the savings of the one site that could not be evaluated.

4.6 Net Savings

A decision-maker survey was used assess net savings with a standardized self-report methodology. For the 2004-2005 program cycle, net savings is defined simply as net of program participant freeridership. . The respondents, also program participants, were decision-makers at the Los Angeles County Internal Services Department and included a program manager, two section managers, and a project manager.

All were asked:

- How influential was the program in the implementation of the measures?
- How did the program influence the implementation?
- What would have occurred absent program influence?

All of them responded that the program was extremely influential as it brought funding for these implementations, as well as an educating county staff on current energy efficient technologies. All agreed that there would have been no implementation in the absence of the program The County has no funding mechanism for energy efficiency upgrades and replace upon failure for the least cost is standard practice in county buildings.

One weakness of the self-report approach is an inability to consider alternative scenarios. The self-report approach focuses strictly on the circumstances and conditions in effect at the time the decision to implement was made. Since this program is a continuation of county energy efficiency programs, there is a question whether the county has become dependent on the external funding of these programs. Would the County have developed internal funding for energy efficiency upgrades in the absence of these externally funded programs? Would the county have on its own looked into reducing their energy expense through energy efficiency? Possibly, and given the return on investment for the most cost effective measures, it can be argued that at least some would be likely. However, this question can not be answered easily and is well beyond the scope and resources of this evaluation. It is the belief of the evaluation team that the effect of long-term external funding on governmental and other large institutions warrants further study.

Using the standardized self report methodology, the net to gross ratio of all program elements was estimated at 1.0. This net to gross ratio asserts that no such activities would have been implemented absent the program during the period of the Program. Therefore, under the current standardized self report methodology, without any consideration of alternative scenarios, all of the ex post evaluated savings presented in this report reflect gross and net values. The program goals were estimated using the Energy Efficiency Policy Manual Version 2[5] default net-to-gross ratio of 0.8.

5. Results

5.1 Program Results

The program's original saving goals were revised during the course of implementation of the program after mid-program changes in program activities were finalized. The changes were substantial and since the initial goals do not reflect the finalized activities, the program results are only compared to the revised goals. Overall the program achieved 90% of the revised site energy goal and 33% of the revised coincident peak demand goal. While electrical energy exceeded the revised program goal by 28%, the natural gas energy savings were only 75% of the revised program goal.

Table 9: Program Summary

	Unit	Revised Program Goals	Ex Ante (Tracking) Estimates	Ex Ante % of Program Goals	Ex Post (Evaluated) Savings	Realization Rate (Ex Post/ Ex Ante)	Ex Post % of Program Goals
Electrical Energy	kWh	4,723,641	6,935,754	147%	6,041,770	87%	128%
Coincident Peak Demand	kW	1,902	424	22%	620	146%	33%
Natural Gas Energy	therm	402,428	398,590	99%	302,273	76%	75%
Site Energy	kBtu	56,364,630	63530729.25	113%	50847835.69	80%	90%

[5] Energy Efficiency Policy Manual version 2, California Public Utilities Commission, August 2003

The shortfall in the natural gas savings goals had two main causes. Three gas savings measures included in the program goals, high efficiency storage water heaters, boiler controllers and instantaneous water heaters, were not implemented for the Partnership Program. Also, many of the boiler retrofits implemented were at facilities with light heating loads.

The electric energy savings exceeded goals due to greater than expected savings for the RCx element. However, much of the savings from the RCx measures occurred during unoccupied periods and consequently, the coincident peak kW reduction was a fraction of program goals.

Table 10: Program Summary by Element

	Retro-commissioning	Building Wide Lighting Controls	Lighting Retrofits	Boiler Retrofits	Chiller Retrofits	Total
Projects	10	2	56	31	2	**101**
Sample	10	2	3	30	2	**47**
kWh Savings Tracking	4,198,422	943,218	1,161,097		137,301	**6,440,038**
kWh Savings Evaluated	3,826,610	688,737	921,654		225,847	**5,662,848**
kWh RR	91%	73%	79%		164%	**88%**
kWh Relative Precision	0%	0%	67%		0%	**15%**
Coincident Peak kW Tracking	11	0	279		94	**385**
Coincident Peak kW Evaluated	337	0	165		90	**592**
kW RR	3064%	-	59%		95%	**154%**
kW Relative Precision	0%	-	43%		0%	**30%**
Therm Savings Tracking	261,486			111,606		**373,092**
Therm Savings Evaluated	259,848			17,818		**277,666**
Therm RR	99%			16%		**74%**
Therm Relative Precision	0%			10%		**1%**
kBtu Savings Tracking	40,477,814	3,219,203	3,962,826	11,160,600	468,608	**40,477,814**
kBtu Savings Evaluated	39,045,020	2,350,660	3,145,604	1,781,780	770,816	**39,045,020**
kBtu RR	96%	73%	79%	16%	164%	**96%**
kBtu Relative Precision	0%	0%	67%	14%	0%	**5%**

An estimation of effective useful life (EUL) is required and the retrofit measures use industry standard lengths of 16 years for lighting measures and 20 years for chiller and boiler replacements. These estimates are conservative in public buildings, many of which had systems over 30 years old prior to this program. Since Los Angeles County is a cooling dominated climate, the life expectancy of boilers at county facilities would naturally be longer than national averages.

The EUL of the retrocommissioning measure was estimated at 15 years by the Program. Although persistence of retrocommissioning impact is still under debate, this EUL was estimated through consideration of the web-based building data management and control system, the training of County personnel, and the documentation of control sequences. Additionally, the retrocommissioning contractor has produced a training manual for all participating facilities and has held staff training for facility staff. In light of all these considerations, an expected useful life of 15 years is a reasonable estimate for the measure. However, to make certain that 15 years of persistence are attained, periodic oversight is highly recommended to assure that the necessary procedures are continued. A significant risk to persistence is staff turnover, which can be mitigated by making certain the lessons learned from the RCx training session is transferred to new staff as they assume responsibility for building operation.

The California Public Utilities Commission (CPUC) reporting table is shown in Table 3. The table shows the Program savings as projected by the estimated effective useful life (EUL) for each category of measure that composed the Program.

Table 11: CPUC Reporting Table

Year	Calendar Year	Ex-ante Gross Program-Projected Program MWh Savings (1)	Ex-Post Net Evaluation Confirmed Program MWh Savings (2)	Ex-Ante Gross Program-Projected Peak Program MW Savings (1**)	Ex-Post Evaluation Projected Peak MW Savings (2**)	Ex-Ante Gross Program-Projected Program Therm Savings (1)	Ex-Post Net Evaluation Confirmed Program Therm Savings (2)
1	2004	6,946	6,041	0.42	0.62	398,590	302,273
2	2005	6,946	6,041	0.42	0.62	398,590	302,273
3	2006	6,946	6,041	0.42	0.62	398,590	302,273
4	2007	6,946	6,041	0.42	0.62	398,590	302,273
5	2008	6,946	6,041	0.42	0.62	398,590	302,273
6	2009	6,946	6,041	0.42	0.62	398,590	302,273
7	2010	6,946	6,041	0.42	0.62	398,590	302,273
8	2011	6,946	6,041	0.42	0.62	398,590	302,273
9	2012	6,946	6,041	0.42	0.62	398,590	302,273
10	2013	6,946	6,041	0.42	0.62	398,590	302,273
11	2014	6,946	6,041	0.42	0.62	398,590	302,273
12	2015	6,946	6,041	0.42	0.62	398,590	302,273
13	2016	6,946	6,041	0.42	0.62	398,590	302,273
14	2017	6,946	6,041	0.42	0.62	398,590	302,273
15	2018	6,946	6,041	0.42	0.62	398,590	302,273
16	2019	2,242	1,836	0.37	0.25	114,543	30,393
17	2020	137	226	0.09	0.09	114,543	30,393
18	2021	137	226	0.09	0.09	114,543	30,393
19	2022	137	226	0.09	0.09	114,543	30,393
20	2023	137	226	0.09	0.09	114,543	30,393

5.2 Program Element Results

5.2.1 Retrocommissioning Results

Prediction of energy and demand impacts of HVAC retrocommissioning are more uncertain than typical equipment-based energy efficiency measures since the final savings are dependent upon how well (or how poorly) the systems are functioning prior to the process. Although there may be indications of building operation deficiencies, the energy and demand impacts of these deficiencies are typically not known until the process has begun. From a building operator's point of view, energy savings and demand reduction are not necessarily the best metrics for contractor performance or process success. With the goal of optimal operation of the HVAC system, energy savings comes as a by-product of goals like maximizing comfort, productivity, property value, etc. However, PGC-funded program efforts are intended to produce energy savings, and those retrocommissioning results are the only ones appropriate to report here.

The initial program goals for the retrocommissioning element were based upon limited data from other regions and not specifically publicly-owned buildings in Southern California. The Partnership Program estimated a savings per square foot of floor area for therms, kWh and kW. The ex ante savings were based upon simulation models created by the retrocommissioning contractor to generate measure savings estimates. The ex post savings are the evaluation team's estimates of facility savings, which were calculated by adjustment of the RCx contractor's models to match post implementation data.

Although the evaluation team is fairly confident with this evaluation approach, there would have been additional benefits for whole premise calibration of these models to facility energy usage. The RFP stated there would be spreadsheet estimations of RCx measures with engineering calculations. The evaluation team bid the work based upon verification of the calculations compared with actual building data. However, the RCx contractor successfully argued to estimate impacts via a simulation tool and the evaluation team attempted to quantify the impacts using the RCx contractor's simulation models. The evaluation team had chosen to obtain and modify the contractor's models to estimate ex post evaluation to remain within the original budget. In hindsight, a change order for additional funding could have added certainty to the impact estimate with site visits to verify model accuracy and/or whole premise calibration. A potential risk in this evaluation methodology stems from the uncertainty in facility heating and cooling loads. The lack of calibration of the ex post simulation models leaves an opening for over or underestimation of facility loads.

An eleventh retrocommissioning site was added to the RCx toward the end of the program. Savings for this site, the San Fernando Courthouse, were estimated by applying the realization rates for the ten evaluated site to the ex ante estimates. The error bound and relative precision shown below account for sampling error for the sample of ten from a population of eleven sites. The error bound and relative precision, at the 90% confidence level, of kWh savings are as calculated. However, since the calculated error bound of therm and kW savings were greater than the estimate for the one not sampled site, the savings for the site are given as the error bound.

Using the analysis approach applied in this study it appears that the retrocommissioning element achieved over and above the program goals for kWh savings. However, the coincident peak demand reduction was much less than anticipated. This occurred because most of the savings were realized through stop/start scheduling measures. These measures save energy by reducing energy usage during unoccupied hours, and therefore have no effect on coincident peak demand. The ex ante and ex post therm savings were greater than program goals.

Table 12: Retrocommissioning Element Savings Summary

	kWh	kW	Therms
Revised Program Goals	2,713,319	1,401	219,630
Ex Ante Savings	4,694,138	50	284,047
Ex Post Savings	4,205,533	366	271,880
Realization Rate	90%	732%	96%
% of Revised Goal	155%	26%	124%
Error Bound (Ex Post)	289,666	29	12,032
Relative Precision	7%	8%	4%

Table 13 shows the ex post savings and realization rate, the ratio of ex post to ex ante savings, for each site. The differences in ex ante (tracking) savings and the ex post evaluated savings stem from several causes. Modifications were made to baseline models in order to better reflect pre-retrocommissioning operation. Modifications were made to the "as-built" models to better reflect post-retrocommissioning operation. Most of these modifications were adjustments to the operational schedules, and adjustments to air and water temperature set-points. The ex ante models were run with actual year weather data while the ex post evaluation models were run with typical year weather data, specifically the California Energy Commission's climate zone weather data for the climate zone where the facility under consideration was located.

Table 13: Retrocommissioning Site Results Summary

Site	kWh Savings Tracking	kWh Savings Evaluated	kWh RR	Coincident Peak kW Tracking	Coincident Peak kW Evaluated	kW RR	Therm Savings Tracking	Therm Savings Evaluated	Therm RR
Bellflower CH	369,808	346,908	94%	4	22	555%	34,915	27,610	79%
Beverly Hills CH	331,656	85,384	26%	-23	-19		15,943	12,054	76%
Compton CH	376,139	365,453	97%	-108	180		46,873	63,281	135%
Downey CH	696,401	841,095	121%	14	11	76%	29,893	36,178	121%
Public Library HQ	246,182	285,394	116%	10	36	355%	33,696	33,597	100%
East LA CH	687,839	690,250	100%	29	26	89%	45,555	47,309	104%
El Monte CH	549,007	286,259	52%	12	5	43%	12,570	9,669	77%
Malibu Center & CH	198,753	174,824	88%	53	6	10%	9,354	10,171	109%
Santa Monica CH	267,108	12,427	5%	-14	16		22,397	-310	
Whittier	535,390	727,051	136%	69	55	79%	20,281	20,289	100%
San Fernando CH (est)	435,855	390,488	90%	4	29	732%	12,570	12,032	96%
Total	**4,694,138**	**4,205,533**	**90%**	**50**	**366**	**732%**	**284,047**	**271,880**	**96%**

Overall the evaluation models showed 90% of the kWh savings compared to the ex ante savings, while the ex post therm savings were estimated at 99% of program estimates. Detailed individual site write-ups for these facilities are included in appendices.

5.2.2 Building-Wide Lighting Controls Results

Building-wide lighting controls were implemented at two large county buildings, the Ed Edelman Children's Court and the Department of Health Services Administration Building. Both of these facilities had considerable lighting load running continuously due to limited control functionality. The implementations at these sites resulted in kWh savings, but there were no coincident peak savings since the controls work to reduce lighting during unoccupied periods.

Table 14: Building-Wide Lighting Controls Element Savings Summary

	kWh
Revised Program Goals	565,600
Ex Ante Savings	943,218
Ex Post Savings	688,737
Realization Rate	73%
% of Revised Goal	122%

Site-level results are shown in Table 15. Low realization rates show reduced energy savings due to a less-than-expected ability to control lighting in the evenings and, to a lesser extent, weekends. Monitored data at the Children's Court showed little ability to control lighting until after midnight. More detailed site information is given in the appendices.

Table 15: Building-Wide Lighting Controls Site Results Summary

	Annual kWh Savings	Realization Rate
Children's Court		
Tracking	640,463	
Evaluated	435,988	68%
Health Services Administration		
Tracking	302,755	
Evaluated	252,750	83%
Total		
Tracking	943,218	
Evaluated	688,737	73%

Although a common approach, methodology of using run time loggers for the evaluation of lighting controls projects has risk associated with actual versus surveyed controlled lighting. True power metering of the controlled lighting is a more accurate approach, but was not within the scope of the project budget. True-power logging is frequently infeasible due to space constraints inside the lighting electrical panel.

5.2.3 Lighting Retrofit Results

Lighting retrofits were performed at 56 fire stations and libraries throughout the county. The element level results are shown in Table 16. In general, the program did meet goals in terms of number of fixtures retrofitted.

The low realization rates are due to inflated ex ante savings which used constant operation, 8760 hours per year, as annual runtime for the calculations for all lighting at all fire stations. Runtime monitoring at a random sample of sites showed less than constant operation.

The high relative precision for the lighting retrofit element is a result of a small sample relative to the population and a high degree of variation in realization rates for the sample sites. The realization rates of the fire stations were low due to the aforementioned overestimation of runtime. Alternatively, the library sample sites had fixture runtime underestimated in all cases.

Table 16: Lighting Retrofit Element Savings Summary

	kWh	kW
Revised Program Goals	1,334,881	425
Ex Ante Savings	1,161,097	279
Ex Post Savings	921,654	165
Realization Rate	79%	59%
% of Revised Goal	69%	39%
Error Bound	614,294	71
Relative Presision	67%	43%

Although the use of sample lighting loggers to evaluate lighting retrofit project is standard practice, there is some uncertainty inherent in the technique. The primary source of potential error stems from load-to-logger association. Ideally, the logger data for a sample fixture is on the same switch as the rest of the lighting load associated with that logger. However that is not always possible as the number of loggers budgeted for each site often outnumber the switches for the project. Therefore, compromises are often made by the evaluation team to obtain the most representative data possible. Other sources of error include sunlight interference upon logger sensors giving false "on" events as well as typical miscounting errors.

5.2.4 Chiller Retrofit Results

The chiller retrofit element was the most successful of the element in meeting savings goals. Two chillers were replaced for the program. The program goals were formulated with these two sites in mind and there were no participation adjustments. The "Revised Program Goals (net) shown in Table 17 are simply the program goal savings with program planning 0.80 net to gross ratio applied to the ex ante savings estimate for 230 tons of chillers. The evaluated net to gross ratio of 1.0 gives a 25% boost to the net savings by comparison and contributes to the high realization rate. As can be seen, the kW savings came a little short of goals, yet the energy savings exceeded the goals and the ex ante estimates.

Table 17: Chiller Retrofit Element Savings Summary

	kWh	kW
Revised Program Goals (net)	109,841	75
Ex Ante Savings	137,301	94
Ex Post Savings	225,847	90
Realization Rate	164%	95%
% of Revised Goal	206%	119%

Although the chiller at ISD headquarters shows greater than expected kWh savings, the Dorothy Kirby Center shows even greater realized savings than anticipated. Likely, the overestimation stems from continuous set point temperature control of the Dorothy Kirby Center, a residential treatment facility, which may not have been considered in calculation of ex ante savings.

Table 18: Chiller Retrofit Element Site Results

Site	kWh Savings Tracking	kWh Savings Evaluated	kWh RR	Coincident Peak kW Tracking	Coincident Peak kW Evaluated	kW RR
Dorothy Kirby Center	47,757	112,857	236%	32.8	25.1	76%
ISD Headquarters	89,544	112,990	126%	61.5	64.7	105%
Total	**137,301**	**225,847**	**164%**	**94.3**	**89.7**	**95%**

The regression techniques used to evaluate the chiller savings give a very good estimate. Calculation of facility cooling load as function ambient temperature can introduce some error by neglecting solar radiation and heat build-up within the building. However, the over and under estimation errors tend to balance out and a good estimate of annual load can be generated, especially if the weather data used is similar to a "typical year".

5.2.5 Boiler Retrofit Results

Table 19 shows the overall therm savings for the boiler retrofit element. Although the program implemented more boiler retrofits than the program goals, the ex post savings were considerably less. The ex ante estimates were calculated by simply multiplying a stipulated therm savings per boiler times the number of boilers replaced. No adjustments or considerations were given to boiler capacity, new boiler efficiency, or size of the facilities where these boilers were installed. As a result, the savings were over-predicted in all but one installation, many by an order of magnitude.

Table 19: Boiler Retrofit Element Summary

	Therms
Revised Program Goals	82,236
Ex Ante Estimates	114,543
Ex Post Evaluation	30,393
Realizaton Rate	27%
% of Program Goals	37%
Error Bound	3,956
Relative Precision	13%

A summary of the realization rates site by site is shown in Table 20. The savings at these sites were from thermal efficiency increases of 4.8% or 6.8% of the new boiler. Several of these sites had an entire facility heating load that was less than the boiler stipulated savings.

A census of all sites was attempted and ex post savings were calculated for 29 of the 31 boiler replacement sites. The ISD headquarters did not have a dedicated meter, which means that billing data specific to the site was not available. No site billing data makes a cursory estimate of heating load beyond the scope of this evaluation. The average realization rate for all other sites in this element with two boilers was used as the ex post estimate for the ISD headquarters.

Due to the wide variation in ex post savings, the actual calculated relative precision for this element is very high for a sample of 29 from a population of 31, 18%. Using this relative precision, the calculated error bound is 5,471 therms. The calculated error bound is slightly higher than the estimated site savings for the two sites with projected savings, and much greater than the estimated error bound of these sites. It does not make sense to have 18% relative precision when the combined error bound of the two sites not evaluated is 13% of the savings. Since this was a nearly complete census, as opposed to a sample design, such anomalies can occur. However, two projected site estimates can not worsen the actual relative precision of the census of 29 sites. Therefore, the reported error bound, is the square root of the sum of the squared individual site savings of the two projected sites, 3,956 therms, and the reported “relative precision” is that error bound divided by the evaluated element savings, 13%.

Table 20: Boiler Retrofit Element Site Summary

Site	Boilers	Tracking Savings (Therms)	Normalized Annual Consumption (Therms)	Base Load (Therms)	Heating Load (Therns)	New Boiler Eff.	Annual Savings (Therms)	Realization Rate
Bellflower Courthouse	2	5,874	25,537	1,696	23,841	0.85	2,073	35%
Norwalk Library	1	2,937	10,624	763	9,861	0.83	605	21%
Hawthorne Library	1	2,937	11,117	851	10,266	0.85	893	30%
Manhattan Bh Library	1	2,937	2,349	77	2,273	0.83	140	5%
La Mirada Library	1	2,937	2,120	136	1,984	0.83	122	4%
AC Bilbrew Library	1	2,937	5,661	254	5,407	0.83	332	11%
Montebello Library	1	2,937	13,045	855	12,190	0.83	748	25%
West Covina Library	1	2,937	14,715	804	13,911	0.83	854	29%
West LA Courthouse	2	5,874	12,559	787	11,772	0.85	1,024	17%
Gardena Library	1	2,937	4,344	233	4,111	0.85	357	12%
Rowland Heights Library	1	2,937	2,237	125	2,111	0.83	130	4%
East LA Courthouse	2	5,874	38,092	2,924	35,167	0.83	2,159	37%
Hollypark Library	1	2,937	4,497	210	4,287	0.85	373	13%
Compton Library	1	2,937	5,897	545	5,352	0.83	328	11%
El Monte Library	1	2,937	2,375	197	2,177	0.83	134	5%
Pomona Courthouse	2	5,874	74,017	5,713	68,304	0.85	5,939	101%
Baldwin Park Library	1	2,937	3,701	291	3,409	0.85	296	10%
La Canada Library	1	2,937	8,517	490	8,028	0.83	493	17%
Culver City Library	1	2,937	8,240	380	7,860	0.83	482	16%
Iacoboni Library	1	2,937	8,624	242	8,383	0.83	515	18%
Temple City Lib.	1	2,937	5,992	349	5,643	0.85	491	17%
Glendale Courthouse	2	5,874	23,123	1,196	21,927	0.85	1,907	32%
Huntington Park Library	1	2,937	3,095	163	2,932	0.85	255	9%
San Fernando Courthouse	2	5,874	34,270	2,277	31,992	0.85	2,782	47%
Pico Rivera Library	1	2,937	2,069	168	1,901	0.85	165	6%
South El Monte Lib.	1	2,937	3,890	232	3,658	0.85	318	11%
Hacienda Heights Library	1	2,937	2,068	200	1,868	0.85	162	6%
La Puente Library	1	2,937	3,695	259	3,436	0.85	299	10%
Lawndale Library	1	2,937	7,256	357	6,899	0.83	423	14%
ISD Headquarters (est)	2	5,874	34,600	2,432	32,167	0.85	2,797	48%
Pasadena Courthouse (est)	2	5,874	34,600	2,432	32,167	0.85	2,797	48%
Total	**39**	**114,543**	**412,925**	**27,638**	**385,287**		**30,393**	**27%**

Billing analyses with whole premise data to determine the savings of a single measure is not an ideal approach, but was the only feasible approach under the given budget. Errors from billing analyses arise from changes in occupant usage from pre and post implementation period and incorrect assumptions, such as near zero heating loads during summer months. However the robust sample of sites and several years of billing data likely lead to a reasonable estimate at the population level as over and under estimation tend to balance each other out. The risk of bias comes from an across the board change in occupancy, for instance, if the County increased library or courthouse hours county-wide within the study period. The evaluation team did enquire whether any occupancy changes took place during the period in question and were told it did not.

More boiler retrofit site details are found in the appendices.

6. Conclusions and Recommendations

The process evaluation report has recommendations for general program delivery and issues brought forth from market actor interviews. The recommendations below speak to issues directly related to program impacts and calculation of Partnership Program estimates.

6.1 Retrocommissioning

- **Assure that a comprehensive post-implementation savings "true-up" is performed.**

For more accurate ex ante estimates, RCx contractors should consider budgeting time for a more detailed analysis building energy management system data of the after implementation to determine measure impacts. The RCx contractor identified the possible measures and produced simulation models to estimate measure savings. These measure savings estimates and cost estimates for the implementation of each measure were used to decide which measures would be implemented. Subsets of these measures were selected for implementation, and the site level ex ante impacts were estimated by a building simulation with only implemented measures, i.e. non-implemented measures were removed from the "possible measures" model.

The schedules and measures were not always implemented exactly as modeled. For example, several cold deck reset measures were not realized. As a quality control, a cursory check of supply air temperature versus outdoor air temperature can quickly determine whether the reset is working or not. If a measure is not working, the contractor could diagnose and/or repair the system as part of the retrocommissioning process, or if the measure turns out unattainable, the ex ante estimation model can be changed to reflect actual conditions. According to implementation staff, the RCx contractor was to "true up" the savings based upon post-implementation building data; however there is no indication that any true up of site savings occurred.

- **Use sound industry standard approaches to model calibration.**

Although the evaluation team was not informed as to whether the contractor's estimation models were calibrated, some of the models appeared to have been calibrated to monthly billing data using extraordinary means that would often not be seen in typical building operation. Several models had one or more mid-year changes in building schedules. It is a rare case where building schedules change in the course of a year, it is not likely that these changes will take place annually as the estimation models indicated. When building data show a "ramp up" or "ramp down" in operation that can't be explained by seasonal business fluctuation, it is standard practice to assume that the final conditions seen in the data best reflect future operation.

- **Use typical meteorological weather data for savings estimates, not actual weather data.**

Furthermore, estimation models were apparently run with actual weather data to generate savings estimates, rather than the standard typical meteorological year data or, more appropriately, CEC weather data by climate zone. When estimating impacts in the future, the sensible and accepted practice is to use typical year data. Using actual weather data can underestimate or overestimate savings, depending on whether the year used was more or less extreme than a typical year.

- **Estimate peak demand with the difference between pre and post model simulated consumption on the hottest afternoon hour of the year.**

Finally, ex ante peak coincident demand savings were calculated as the difference in building peaks over the entire simulated year. The implemented measures resulted in a building energy demand response to temperature different enough that building peak of the baseline and post-implementation models had building peaks on different days. By comparing peak demand at differing conditions, this methodology resulted in an underestimation of peak savings for system peak, which is best estimated as the difference in peak demand at the hottest weekday afternoon hour of the year as found in the CEC weather data for that climate zone..

6.2 Building-Wide Lighting Controls

- **Consider building occupancy schedules in post-implementation hours of operation for lighting control projects**

The building-wide lighting controls element had less than anticipated reduced runtime in the evenings, resulting in lower than desired realization rates. The original Partnership Program documentation showed many lighting control sites with the same post-implementation runtime estimates. A short assessment of night and morning occupancy in these buildings could help tune the estimates to site specific and more accurate post-implementation runtime. Common area lighting can not be reduced to standard business hours if a substantial portion of building occupants work outside the range of normal business hours.

6.3 Lighting Retrofits

- **Use an estimate more conservative than constant operation if the lighting can be controlled by occupants**

The lighting retrofit contractor submitted the annual hours of fixture operation at all fire stations as 8760 hours per year, constant operation. This estimate included all fixtures found at the facility including closet and attic fixtures. As expected, runtime data loggers at the facility show considerably less than constant usage. A simple “reality check” of the hours of use could have produced more accurate estimates. It is not conservative to assume constant operation of any lighting except for emergency fixtures and exit signs. It is a rare closet and attic fixture that has run time great enough to warrant a retrofit.

- **Estimate library lighting run-time hours to be greater than hours open to the public.**

Alternatively, the contractor’s run time hours for the library wound up being significantly less than metered runtime. This may have been caused by using library operating hours as estimates of runtime. The library lighting run times for the fixtures in the common areas should be assumed to be slightly longer than the hours that the facility is open to the public, due to pre-opening and post-closing activities. The inaccurate estimation of lighting run times resulted in a higher than typically calculated error ratio for lighting retrofit impacts and a relative precision that was worse than anticipated.

- **Apply a reasonable coincident factor to the aggregate wattage reduction to estimate a peak demand estimate.**

The lighting retrofit element program documentation only submitted the aggregate reduction in fixture kW as “kW savings” Although this estimate can be accurate for some commercial lighting systems that are in constant operation during peak periods, the facilities under consideration are not. Since there was diversity of operation during the peak periods, (summer afternoons), the peak kW is a fraction of total kW reduction. Application of a realistic coincident factor to fixtures that will not necessarily be operated constantly generates a more realistic coincident peak kW. The coincident factor to be applied is the best estimate of the percentage of retrofitted lighting wattage on during summer afternoons.

6.4 Chiller Retrofits

- **Add chiller runtime as an additional variable in generating chiller replacement energy savings.**

The chiller retrofit ex ante savings were calculated with a per-ton stipulated savings for kWh and kW. The ex post savings were found to be considerably higher than anticipated due to longer runtimes. If better ex ante chiller replacement savings are desired, an adjustment to savings based upon runtime could be integrated into the calculation.

6.5 Boiler Retrofits

- **Consider building heating load and installed equipment efficiencies in the estimation of boiler savings.**

The boiler retrofit savings estimates used a single stipulated "therm savings" estimate for all boilers regardless of installation. Facilities with two units were given twice the therm savings of the one boiler sites. There were no adjustments made for size of boiler, size of building, climate, or hours of operation. Actual savings varied a great deal from the stipulated estimate, resulting in an unfavorable error ratio, 0.93, for the element.

Some of the new boilers had thermal efficiencies of 0.85 and others had thermal efficiencies 0.83. This difference represents a substantial difference in savings. There was a wide diversity of facility sizes and natural gas usage among the boiler retrofit population. Future boiler retrofits should consider cursory billing analysis or a square footage rule of thumb and/or consideration of inland/coastal climate differences, for generating preliminary estimates. More accurate estimates could assist in prioritizing the retrofit schedule for the county, resulting in increased natural gas savings if boilers with more annual usage were replaced first. Several of the sites had annual natural gas usage for the entire facility that was less than stipulated savings for a single boiler, resulting in single-digit realization rates. Given such small savings, these sites will not provide a payback for the retrofit boiler investment in most cases. Certainly these funds could be used more cost effectively at some other county facility, and a replacement-upon-failure policy would be a more prudent approach on such rarely used equipment.

6.6 Error Ratios

One of the key parameters of the ratio estimation model is the error ratio. The error ratio is a measure of the strength of the association between y and x, (in our case the ex ante savings and ex post savings). The error ratio is suitable for measuring the strength of a heteroscedastic relationship and for choosing sample sizes. It is somewhat analogous to a coefficient of variation, except that it describes the association between two or more variables rather than the variation in a single variable.

An error ratio of 0.2 represents a very strong association between y and x, whereas an error ratio of 0.8 represents a weak association. Loosely speaking, an error ratio of 0.75 implies that the measured savings is typically within ±75% of the tracking estimate of savings, adjusted for the realization rate. The smaller the error ratio, the stronger the association between tracking and measured savings, and the smaller the sample size needed to estimate the program realization rate with a fixed precision.

The error ratio is the principle determinant of the sample size required to satisfy the 90/10 criteria for estimating y. If the error ratio is small, then the required sample is correspondingly small. In our case, a large error ratio indicates a poor estimation of savings. When faced with a large error ratio, one can either choose to improve estimation methodology or resort to increasing sample size to attain a target relative precision.

The error ratios are provided for all elements for future program and evaluation planning. Even in elements where a census of sites evaluated, the error ratios will be helpful in the future for determining the feasibility and approach of similar projects.

Table 21: Program Error Ratios

	Estimated kWh Error Ratio	Actual kWh Error Ratio	Actual kW Error Ratio	Estimated Therm Error Ratio	Actual Therm Error Ratio
Retrocommissioning	0.80	0.43	1.05	0.80	0.40
Building Wide Lighting Controls	0.50	0.18	-	-	-
Lighting Retrofits	0.50	0.74	0.45	-	-
Boiler Retrofits	-	-	-	0.80	0.93
Chiller Retrofits	0.30	0.57	0.19	-	-

The estimated error ratios, shown in Table 21, were estimated for the provisional sampling plan. The actual were calculated from evaluated activities. The 0.8 estimate for retrocommissioning was a conservative estimate for activities without historical evaluation data. The boiler retrofit error ratio of 0.8 was estimated due to the inherent inaccuracy of a “per boiler” stipulated savings, even though this was considered a conservative estimate, the actual error ratio was greater. Note that there was no preliminary estimate of kW error ratio and only the actual error ratio for coincident peak demand is presented above.

6.7 Net-to-gross

Since this program is a continuation of county energy efficiency programs, there is a question of self-report bias, whether the county has become dependent on the external funding of these programs. Would the County have developed internal funding for energy efficiency upgrades in the absence of these programs with outside funding? Would the county have on its own looked into reducing their energy expense through energy efficiency? Possibly, and given the return on investment for the most cost effective measures, it can be argued that at least some would be likely. However, this question can not be answered easily and is well beyond the scope and resources of this evaluation. It is the belief of the evaluation team that the effect of long-term funding on governmental and other large institutions warrants further study.