SOUTHERN CALIFORNIA EDISON 1998 NON-RESIDENTIAL NEW CONSTRUCTION EVALUATION

FINAL REPORT

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Executive Summary

Introduction

This is the final report of the 1998 Non-Residential New Construction (NRNC) Program evaluation. The evaluation was conducted by RLW Analytics, Architectural Energy Corporation and ASW Engineering from May 1999 through November 1999.

This report details findings of energy and demand savings at the whole building level and for lighting, HVAC, and shell & daylighting end-uses. Both net and gross savings are presented.

The evaluation relied on the use of model-based statistical sampling, on-site engineering surveys, and DOE –2.1 building simulation models to determine the findings presented. A sample of 49 participant buildings were surveyed and modeled to estimate gross energy savings relative to a baseline level. Net savings are based on the 1996 net-to-gross ratio, which was developed using logistic and linear regression modeling to predict efficiency choice in the absence of the program. A CADMAC waiver was filed by Southern California Edison Company requesting three deviations from the Protocols for the first-year impact evaluation of this 1998 Nonresidential New Construction Program activity. The three deviations are as follows:

1. Achieve the requisite precision and confidence levels with a reduced sample size of 49 participants.
2. Require the use of billing data only for sites for which reliable data are available, and the metered area corresponds well to the area affected by the program.
3. Use the net-to-gross ratio adopted from the difference of differences estimated for the 1996 Nonresidential New Construction Program rather than developing a new one from new comparison group data.

The waiver was approved June 16, 1999, it can be found in Appendix A.

The 1998 evaluation benefited greatly from the project team's experience with the 1994 and 1996 PG&E / SCE NRNC evaluations. Valuable lessons were learned during these evaluations that helped to refine the methodology used in this study. A comparison to the 1996 SCE NRNC evaluation is provided in the section named 'Comparison Between the 1998 and 1996 Findings' at the end of the report.

A brief overview of the 1998 evaluation methodology appears below.

Study Design

The goal of this evaluation was to estimate the gross energy and demand savings of the 1998 nonresidential new construction program.

The primary deliverables of this evaluation were:

1. Gross savings estimates of annual energy and summer peak demand
2. Net savings estimates of annual energy and summer peak demand (based on 1996 net-to-gross ratio)

3. Gross savings of lighting, HVAC, and shell / daylighting end-uses.

The RLW Analytics/AEC/ASW team used a methodology similar to the 1994 and 1996 studies, with important modifications to reflect what was learned from those studies. The basic approach relied on engineering models to develop gross savings estimates. This methodology conforms to the CADMAC protocols with the important exception that statistical sampling was used in the place of an attempted census of program participants. On June 16, 1999 CADMAC approved a waiver for this change in methodology.

The study was carried out in three phases – design, data collection, and data analysis – plus reporting. Each phase builds on the results of the previous phase. Figure 1 shows the major tasks for this project and their relationships.

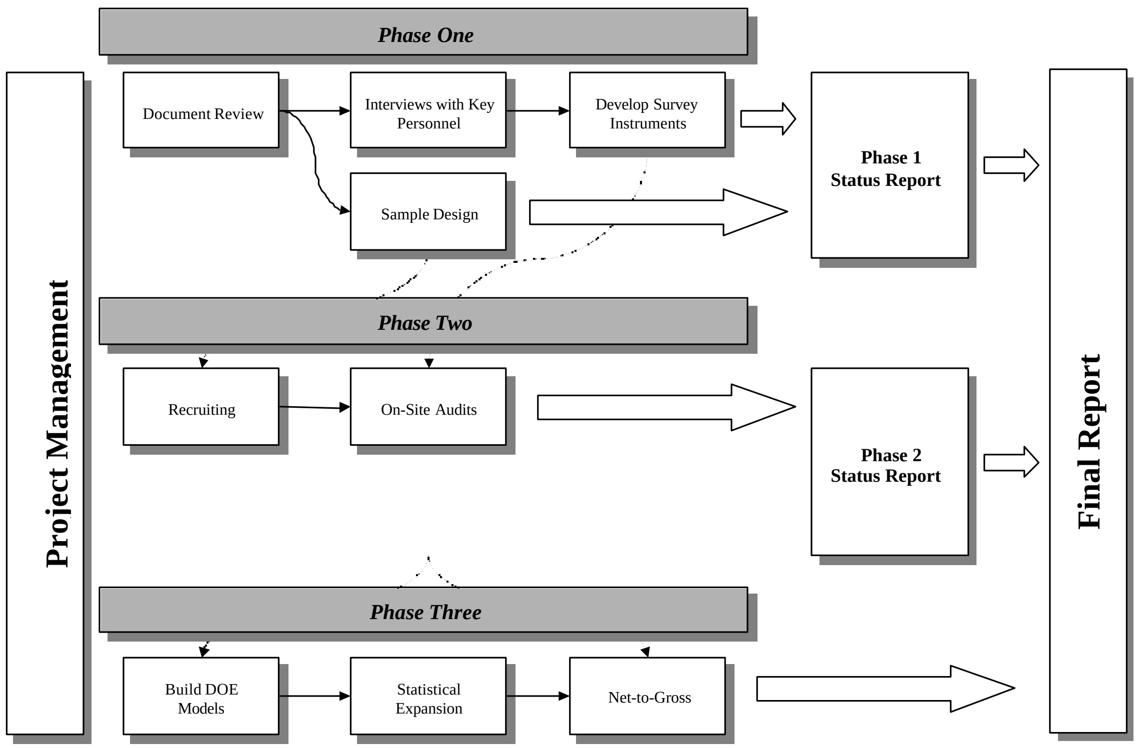


Figure 1: Study Flowchart

Data Collection

A major portion of this project was the collection of the building data necessary to determine the program impacts. Overall, the data collection process ran quite smoothly; no problems were encountered that had an adverse impact on the overall quality of the data.

The data collection process was designed to collect the highest quality data in the most efficient manner possible. This process relied on several people working together to ensure a seamless flow of information.

The recruiter was responsible for making contact with the site and securing its participation in the study. Once that was accomplished, the recruiter scheduled the on-site visit and provided the information to the field surveyors from RLW Analytics and ASW.

The on-site surveyor collected building description and operation information from the site and entered the data into a database. Automated modeling software was used to create DOE-2 input files from each of the auditors databases. The surveyors were responsible for quality control of the models created from the field data, and correcting the data if necessary. Once the models had undergone auditor quality control they were shipped to RLW and AEC for calibration. Senior staff of AEC and RLW calibrated the sites and checked the final model results for reasonableness.

Engineering Models

Engineering models were developed for each building in the on-site survey sample using the DOE-2.1E building simulation program. The models underwent AEC and SCE peer review during a "data party" held at SCE offices in San Dimas. SCE engineers were invited to the meeting to discuss outlier sites before the final parametric runs were completed for the 49 models. The meeting facilitated engineering discussions aimed at understanding why sites were saving less than 50% or greater than 150% of the programs estimated savings. Senior AEC engineers reviewed these models one last time before the final parametric runs were completed. A series of models were spawned for each sample site, including:

- A "baseline" model representing the building with minimally compliant equipment and envelope efficiencies.
- An "as-built" model representing the building as found by the surveyors.
- A series of parametric runs to isolate the impact on HVAC, lighting, and shell / daylighting end-uses.

The models were built using an automated BDL[1] generator, developed by AEC and RLW Analytics. This method ensured that all of the models were consistent, thus eliminating a potential source of bias in the results.

Analysis Baseline and Gross Savings Calculations

The estimates of gross program savings were made by comparing the as-built simulated building energy consumption to a baseline level of energy consumption. The baseline energy consumption for all buildings was defined to be the energy consumption of the building as if all of the equipment was specified to be minimally compliant with Title 24 and the building was operated on the schedule found during the on-site survey. *Because the default Title 24 operating schedules were not used to develop the baseline and because the area category method was used for each building regardless of the Title 24 compliance path actually elected, the savings calculated relative to the baseline in this study cannot be interpreted as the degree of compliance with Title 24.*

A gross savings estimate was calculated for each building in the sample. The savings estimated were projected to the population of participants using model-

[1] BDL is DOE-2's Building Description Language

based statistical sampling procedures. Gross savings estimates were then developed for the participant population.

Net Savings Methodologies

A 62.3% net-to-gross ratio for energy was developed for the 1996 NRNC study. The net-to-gross ratio developed in the 1996 study for summer on-peak demand was 52.0%. This ratio was used for the 1998 NRNC study in accordance with a waiver filed and approved June 16, 1999. The approach used in 1996 to determine the net savings is described below.

Net program savings estimates are the savings that directly result from program participation. Effects of free-ridership, or what the customer would have done anyway, have been factored out.

Difference of Differences

The 1996 study included a simple "difference of differences" estimation approach to net savings. This method estimated net savings by comparing the savings of the participants in the sample to a "matched" sample of non-participants. The savings of the non-participant group were assumed to be the savings of the participants in the absence of the program. In this methodology, spillover among the non-participants was assumed to be offset by free-ridership among the participants but no attempt was made to measure either spillover or free-ridership. According to the waiver filed by SCE, the results from the 1996 study will be used for the 1998 evaluation.

The Buildings

There were a total of 99 buildings in the program population. Table 1 summarizes the building type, tracking savings, and square footage of all 99 buildings.

	Total Tracking Savings (kWh)	Total Square Footage	Number of Sites
C&I Storage	4,264,676	2,222,709	7
General C&I	1,355,242	760,600	4
Grocery	1,247,876	473,197	7
Hospital	2,027,937	411,674	4
Libraries	63,087	10,000	1
Office	7,076,928	1,486,338	16
Other	1,873,990	427,592	2
Restaurant	79,408	32,190	11
Rel. Wor., Audit., Convention	1,612,632	250,422	7
Retail	6,128,200	2,257,480	29
School	1,656,212	436,766	10
Theater	135,836	56,516	1

Table 1: Number of Buildings, Square Footage, and Tracking Savings by Building Type

Findings

This section presents gross and net savings estimates for the population of program participants. Table 2 and Table 3 show the tracking savings for the program and the gross and net savings measured for the evaluation. The associated realization rates and the net-to-gross ratio for annual energy and summer on-peak demand are also presented in the tables below. The gross realization rate for demand and energy are calculated as the *gross measured savings / program savings estimate.* The net realization rate for demand and energy are calculated as the *net measured savings / program savings estimate.*

Program Savings Estimate (MWh)	27,522
Gross Savings (MWh)	28,813
Gross Realization Rate	104.7%
Net to Gross Ratio	62.3%
Net Savings (MWh)	17,951
Net Realization Rate	65.2%

Table 2: Tracking, Gross, and Net Annual Energy Savings and Realization Rates[2]

Program Savings Estimate (MW)	5.97
Gross Savings (MW)	5.56
Gross Realization Rate	93.1%
Net to Gross Ratio	52.0%
Net Savings (MW)	2.89
Net Realization Rate	48.4%

Table 3: Tracking, Gross, and Net Summer On-Peak Demand Savings and Realization Rates[3]

Gross Savings

Table 4 shows the estimated gross energy savings of the program. Program participants saved 28,813 MWh of energy in their first year of operation. This is a realization rate of 104.7% of the verified savings estimate. The relative precision of the estimate is ±6.7% at the 90% confidence level, meaning that the gross program energy savings is estimated to be between 26,885 MWh and 30,742 MWh. [4]

We can be quite confident that this interval contains the total program gross savings that would have been obtained by developing onsite surveys and building engineering simulation models for all program participants using the methodology of this study. The confidence interval reflects sampling variability and random measurement error but does not reflect any possible systematic measurement error that might be repeated throughout the data collection and engineering simulation. Of course, we have sought to minimize both systematic and random measurement errors.

[2] Net-to-Gross ratio is from 1996 SCE NRNC Evaluation.

[3] The Net-to-Gross Ratio is from 1996 SCE NRNC Evaluation

[4] Some definitions: The standard error reflects the standard deviation of an estimate in repeated sampling. The error bound at the 90% level of confidence is 1.645 times the standard error. The confidence interval is the estimate plus or minus the error bound. The relative precision is the error bound divided by the estimate itself.

The summer on-peak demand savings is 5.56 MW. The realization rate is 93.1% of the verified program savings. The relative precision is ±6.9% at the 90% confidence level for the summer on-peak demand, meaning that the gross program demand savings is between 5.18 MW and 5.94 MW.

Period	Energy Savings (MWh)	Energy Rel. Precision (+/-)	Demand Savings (MW)	Demand Rel. Precision (+/-)
Annual	**28,813**	**6.7%**	**-**	**-**
Summer On-Peak	3,155	7.7%	5.56	6.9%
Summer Mid-Peak	3,294	6.3%	3.08	7.6%
Summer Off-Peak	4,654	6.3%	3.74	5.6%
Winter Mid-Peak	9,791	7.9%	4.44	8.6%
Winter Off-Peak	7,920	7.5%	3.04	6.4%

Table 4: Participant Energy and Demand Gross Savings by Time-of-use period

Table 4 also shows the energy and demand savings by SCE time-of-use period. To compare the savings within each time-of-use period, the energy and demand savings of the participants relative to their own baseline is plotted in Figure 2. The participants' annual energy usage was 7.2% better than baseline, while their summer on-peak demand savings were 9.8% better than baseline. "Better than baseline" means that the buildings are more energy efficient than the baseline efficiency levels established for this study. Numerically, a building that is 20% better than baseline uses 20% less energy than it would have used if built to baseline efficiency levels.

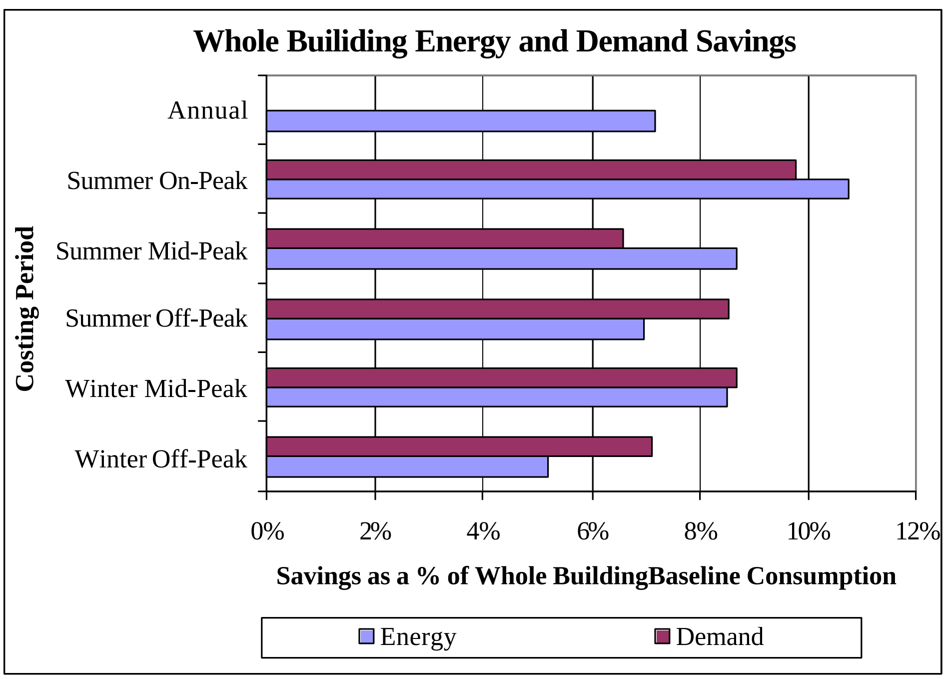
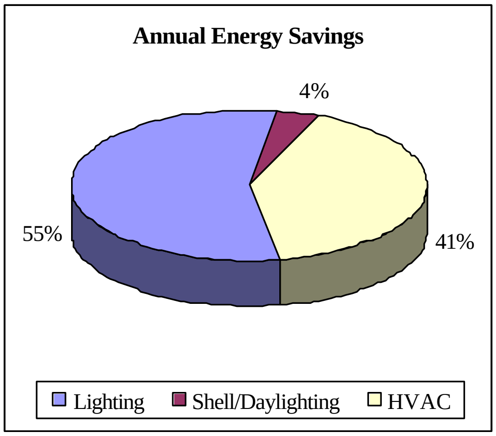


Figure 2: Gross Energy and Demand Savings Relative to Whole Building Baseline

Energy and demand savings were also estimated for lighting, shell/daylighting, and HVAC end-uses. Figure 3 shows the composition of the annual energy savings and the summer on-peak demand savings for program participants.



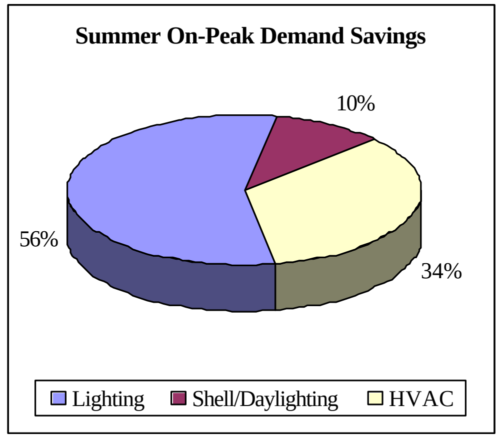


Figure 3: Composition of Gross Savings

Table 5 shows the energy savings by end-use for each of the time-of-use periods. Table 6 shows the demand savings by end-use for each of the time-of-use periods.

Period	Lighting	Shell/ Daylighting	HVAC
Annual	**15,944**	**1,077**	**11,791**
Summer On-Peak	1,873	247	1,035
Summer Mid-Peak	1,844	174	1,276
Summer Off-Peak	1,895	230	2,528
Winter Mid-Peak	6,354	233	3,203
Winter Off-Peak	3,977	192	3,751

Table 5: End-Use Gross Energy Savings by Time-of-use period (MWh)

Period	Lighting	Shell/ Daylighting	HVAC
Summer On-Peak	**3.11**	**0.56**	**1.89**
Summer Mid-Peak	1.52	0.17	1.38
Summer Off-Peak	1.84	0.29	1.61
Winter Mid-Peak	2.97	0.19	1.27
Winter Off-Peak	1.42	0.18	1.43

Table 6: End-Use Gross Demand Savings by Time-of-use period (MW)

Net Savings

As discussed in a prior section, a relatively simple difference of differences approach was used to calculate the net-to-gross ratio. In the difference of differences methodology, the net-to-gross ratio was calculated by comparing (a) the gross savings relative to baseline of the program participants and (b) the gross savings relative to baseline of the non-participants.

Table 7 summarizes the net-to-gross ratio calculated using the difference of differences approach in the 1996 evaluation. The table shows the estimated net savings for both annual energy and summer peak demand that was calculated for the 1998 evaluation using the net-to-gross ratio calculated from the 1996 evaluation.

	Net-to-Gross Ratio	**Net Savings**
Annual Energy (MWh)	62.3%	17,951
Summer Peak Demand (MW)	52.0%	2.89

Table 7: Difference of Differences Net-to-gross Ratio[5]

[5] The statistical precision that was calculated for the net-to-gross ratio in 1996 is not reported here because the statistical confidence can not be applied with the assumption that it would be the same if a net-to-gross ratio were calculated for the 1998 evaluation. The relative precision of the net-to-gross ratio that was calculated for the 1996 evaluation was ±22.0% for energy, and ±24.9% for demand.

Sample Design

Introduction

The key to effective sample design is to take advantage of the association between the target variables to be measured in the study and any supporting variables already known from the sampling frame. For example, the savings of each program participant measured in this project can be associated with the estimate of savings recorded in the program tracking system. Stratified sampling is used to ensure that the sample has the best mix of small and large sites, as defined by their energy savings. Ratio estimation is used to expand the sample data to the target population, taking advantage of the supporting information. Both stratified sampling and ratio estimation are well known and widely used in load research and DSM evaluation.

The principal questions addressed in sample design are:

- How big should the sample be, both overall and within different subsets of the target population?
- How much statistical precision can we expect from the sample?
- How should the sample be stratified to get the best statistical precision?

The usual approach is to estimate the variance of the estimated savings in the program tracking system. This approach is not appropriate for stratified ratio estimation since the statistical precision depends not on the variance of estimated savings but on the strength of the association between the measured savings and the tracking estimate of savings. The Model-Based Statistical Sampling (MBSS) approach is to develop a statistical model describing the relationship between these variables, and then use the parameters of this model to develop the sample design.

In this project the parameters of the MBSS model were estimated from the sample data collected in our prior evaluation of the 1996 program. Using the 1996 sample data, we estimated the MBSS model relating measured gross annual savings to the tracking savings. Table 8 shows the estimated parameters.

The error ratio and gamma were taken from the actual model parameters found in the 1996 NRNC study. The analysis was the actual energy saved and the explanatory variable was the tracking estimate of energy saved. The error ratio is a measure of the spread of the data around the trendline. It is analogous to the coefficient of variation. Gamma is a measure of the heteroscedastisity of the data. Heteroscedastisity is the tendency for the variation around the trendline to increase as the value of the stratification variable increases.

Model Parameter	Value
error ratio	0.67
gamma	0.62

Table 8: Model-Based Sampling Parameters for Participant Sample

Using these parameters, RLW Analytics designed the participant sample to achieve at least ±10 percent precision at the 90 percent confidence level for the participants' annual measured energy savings. We used the 99 sites that received incentive checks dated in 1997 and 1998 as a participant sample frame. Our analysis indicated that the participant sample size should be 49 sites, stratified by the tracking estimate of savings. Our analysis indicated that this sample design could give an anticipated precision of about ± 7.0 percent at 90 percent confidence, assuming that the parameters shown in Table 8 accurately describe the 1998 population.

The sample was stratified into 5 sampling strata and one certainty strata for a total of 6 strata by estimated annual energy savings. Sample size, population size, and stratum cutpoints are indicated in Table 9 below. It should be noted that the sample design provided a relatively small proportion of smaller projects (e.g., 7 out of 37 in stratum 1) and a larger proportion of larger projects (e.g., 7 out of 9 in stratum 5.) The 14 projects in stratum 6 where to be included with certainty, if possible.

Stratum	Maximum Energy Savings (kWh)	Poulation Size	Population Energy Savings (kWh)	Sample Size
1	49,931	37	749,232	7
2	128,248	18	1,510,265	7
3	231,366	12	2,099,351	7
4	317,345	9	2,486,196	7
5	439,311	9	3,433,190	7
6	5,000,000	14	17,243,790	14
TOTAL		**99**	**27,522,024**	**49**

Table 9: Stratified Sampling Plan for Participants

Sample Design vs. Actual Sample

Table 10 shows the participant sample design and the actual participant sample. As the table shows, stratum one has one less sample point than designed and stratum two has one more sample point than designed. With this small deviation from the plan, the actual sample was consistent with the sample design. In particular, we were able to obtain the cooperation of all 14 large projects in the certainty stratum. Our success in following the sample design gives strong assurance that the sample is representative of the program.

Stratum	Design	Actual
1	7	6
2	7	8
3	7	7
4	7	7
5	7	7
6	14	14
Total	**49**	**49**

Table 10: Participant Sample Design and Actual Sample

Data Collection

The data collection effort was one of the largest portions of the project. Six on-site surveyors worked with a recruiter for about 10 weeks to collect on-site and telephone survey data on 49 buildings.

RLW contracted with a Southern California engineering firm to facilitate the data collection. ASW, based in Tustin, CA, conducted the recruiting and completed the majority of the on-site surveys.

Recruiting

Experienced ASW staff was responsible for the customer recruiting effort. Special effort was made to use staff that was experienced in construction and development in order to ensure that the professionals being contacted did not feel that they were speaking with someone who did not understand the basic issues in the field. The approach proved to be a tremendous success.

Table 11 summarizes the recruiting effort. A conversion rate of 90% was achieved. Only 6% of the sites refused to participate in the study. This is a reflection of both the effectiveness of the recruiter, and the good reputation enjoyed by Edison in this market.

In the table, “completed” means that the site was successfully recruited and audited. “No contact” means that attempts to contact a decision-maker at the site failed. “Refused” indicates that the site was eliminated for one or more of the following reasons:

A. The customer was no longer doing business, the new owners were not interested in participating in the study.
B. A jail facility did not want to participate due to security reasons.

One site was dropped because the store was no longer open for business.

Disposition	Participants
Completed	49
No Contact	1
Refusal-A	3
Refusal-B	1

Table 11: Recruiting Disposition

On-Site Surveys

The primary data source for the DOE-2 models was the on-site survey. The survey form was designed so that the surveyors could make key modeling decisions on model zoning and equipment/space association while in the field. The form was designed to follow the logical progression of an on-site survey process. The form started out with a series of interview questions. Conducting the interview first helped orient the surveyor to the building and allowed time for the surveyor to establish a rapport with the customer. Once the interview was completed, an inventory of building equipment was conducted. The survey started with the HVAC systems, and progressed from the roof and/or other mechanical spaces into the conditioned spaces. This progression allowed the surveyor to establish the linkages between the HVAC equipment and the spaces served by the equipment.

Interview Questions.

The interview questions were used to identify building characteristics and operating parameters that were not observable by the surveyor during the course of the on-site survey. The interview questions covered the following topics:

Building functional areas. Functional areas were defined on the basis of operating schedules. Subsequent questions regarding occupancy, lighting, and equipment schedules, were repeated for each functional area.

Occupancy history. The occupancy history questions were used to establish the vacancy rate of the building during 1998-99. The questions covered occupancy, as a percent of total surveyed floor space, and HVAC operation during the tenant completion and occupancy of the space. Responses to these questions were used to understand building start-up behavior during the model calibration process.

Occupancy schedules. For each functional area in the building, a set of questions were asked to establish the building occupancy schedules. First, each day of the week was assigned to one of three daytypes: full occupancy, partial occupancy, and unoccupied. This was to cover buildings that did not operate on a normal Monday through Friday work week. Holidays and monthly variability in occupancy schedules were identified.

Daily schedules for occupants, interior lighting, and equipment/plug loads. A set of questions was used to establish hourly occupancy, interior lighting, and miscellaneous equipment and plug load schedules for each functional area in the building. Hourly schedules were defined for each daytype. A value, which represents the fraction of the maximum occupancy and/or connected load was entered for each hour of the day. The entry of the schedule onto the form was done graphically.

Daily schedules of kitchen equipment. A set of questions were asked to establish hourly kitchen equipment schedules for each functional area in the building. Hourly schedules were defined for each daytype. A value which represented the equipment-operating mode (off, idle, or low, medium or high volume production) was entered for each hour of the day. The entry of the schedule onto the form was done graphically.

Operation of other miscellaneous systems. General questions on the operation of exterior lighting systems, interior lighting controls, window shading, swimming pools, and spas were covered in this section.

Operation of the HVAC systems. A series of questions were asked to construct operating schedules for the HVAC systems serving each area. Fan operating schedules, and heating and cooling setpoints was entered. Additional questions were used to define the HVAC system controls. The questions were intended to be answered by someone familiar with the operation of the building mechanical systems. The questions covered operation of the outdoor air ventilation system, supply air temperature controls, VAV system terminal box type, chiller and chilled water temperature controls, cooling tower controls, and water-side economizers.

Building-wide water use. A series of questions were used to help calculate the service hot water requirements for the building.

Refrigeration system. The operation of refrigeration systems utilizing remote condensers, which are common in groceries and restaurants, was covered in this section. The systems were divided into three temperature classes, (low, medium and high) depending on the compressor suction temperature. For each system temperature, the refrigerant, and predominant defrost mechanism was identified. Overall system controls strategies were also covered.

Building Characteristics

The next sections of the on-site survey covered observations on building equipment inventories and other physical characteristics. Observable information on HVAC systems, building shell, lighting, plug loads, and other building characteristics were entered, as described below:

Built-up HVAC systems. Make, model number, and other nameplate data were collected on the chillers, cooling towers, heating systems, air handlers, and pumps in the building. Air distribution system type, outdoor air controls, and fan volume controls were also identified.

Packaged HVAC systems. Equipment type, make, model number, and other nameplate data were collected on the packaged HVAC systems in the building.

Zones. Based on an understanding of the building layout and the HVAC equipment inventory, basic zoning decisions were made by the surveyors according to the following criteria:

- ***Unusual internal gain conditions***. Spaces with unusual internal gain conditions, such as computer rooms, kitchens, laboratories were defined as separate zones.
- ***Operating schedules***. Occupant behavior varies within spaces of nominally equivalent use. For example, retail establishments in a strip retail store may have different operating hours. Office tenants may also have different office hours.
- ***HVAC system type and zoning***. When the HVAC systems serving a particular space were different, the spaces were sub-divided according to HVAC system type. If the space was zoned by exposure, the space was surveyed as a single zone, and a “zone by exposure” option was selected on the survey form.

For each zone defined, the floor area and occupancy type was recorded. Enclosing surfaces were surveyed, in terms of surface area, construction type code, orientation, and observed insulation levels. Window areas were surveyed by orientation, and basic window properties were identified. Interior and exterior shading devices were identified. Lighting fixtures and controls were identified and inventoried. Miscellaneous equipment and plug loads were also inventoried. Zone-level HVAC equipment, such as baseboard heaters, fan coils, and VAV terminals were identified and entered on the form.

Refrigeration systems. Refrigeration equipment was inventoried separately, and associated with a particular zone in the building. Refrigerated cases and stand-alone refrigerators were identified by case type, size, product stored, and manufacturer. Remote compressor systems were inventoried by make, model number, and compressor system type. Each compressor or compressor rack was associated with a refrigerated case temperature loop and heat rejection equipment such as a remote condenser, cooling tower, and/or HVAC system air handler. Remote condensers were inventoried by make, model number, and type. Nameplate data on fan and pump horsepower were recorded. Observations on condenser fan speed controls were also recorded.

Cooking equipment. Cooking equipment was inventoried separately and associated with a particular zone in the building. Major equipment was inventoried by equipment type (broiler, fryer, oven, and so on), size, and fuel type. Kitchen ventilation hoods were inventoried by type and size. Nameplate data on exhaust flowrate and fan horsepower were recorded. Each piece of kitchen equipment was associated with a particular ventilation hood.

Hot water/Pools. Water heating equipment was inventoried by system type, capacity, and fuel type. Observations on delivery temperature, heat recovery, and circulation pump horsepower were recorded. Solar water heating equipment was inventoried by system type, collector area, and collector tilt and storage capacity. Pools and spas were inventoried by surface area and location (indoor or outdoor). Filter pump motor horsepower was recorded. Pool and spa heating systems were inventoried by fuel type. Surface area, collector type, and collector tilt angle data for solar equipment serving pools and/or spas was recorded.

Miscellaneous exterior loads. Connected load, capacity, and other descriptive data on elevators, escalators, interior transformers, exterior lighting, and other miscellaneous equipment were recorded.

Meter Numbers. Additional data were collected in the field to assist in the billing data account matching and model calibration process. Meter numbers were recorded for each meter serving the surveyed space. If the meter served space in addition to the surveyed space, the surveyor made a judgment on the ratio of the surveyed space to the space served by the meter.

Establishing Component Relationships

In order to create a DOE-2 model of the building from the various information sources contained in the on-site survey, relationships between the information contained in the various parts of the survey needed to be established. In the interview portion of the form, schedule and operations data were cataloged by building functional area. In the equipment inventory section, individual pieces of HVAC equipment: boilers, chillers, air handlers, pumps, packaged equipment and so on were inventoried. In the zone section of the survey, building envelope data, lighting and plug load data, and zone-level HVAC data were collected. The following forms provided the information needed by the software to associate the schedule, equipment, and zone information.

System/Zone Association Checklist. The system/zone association checklist provided a link between each building zone and the HVAC equipment serving that zone. Systems were defined in terms of a collection of packaged equipment, air handlers, chillers, towers, heating systems, and pumps. Each system was assigned to the appropriate thermal zones in accordance with the observed building design.

Interview "Area" / Audit "Zone" Association Checklist. Schedule and operations data gathered during the interview phase of the survey were linked to the appropriate building zone. These data were gathered according to the building functional areas defined previously. Each building functional area could contain multiple zones. The association of the functional areas to the zones, and thereby the assignment of the appropriate schedule to each zone was facilitated by this table.

Engineering Models

An automated process was used to develop basic DOE-2 models from data contained in the on-site surveys, Title 24 compliance forms, program information and other engineering data. The modeling software took information from these data sources and created a DOE-2 model. The data elements used, default assumptions, and engineering calculations are described for the Loads, Systems, and Plant portions of the DOE-2 input file as follows.

Loads

Schedules were created for each zone in the model by associating the zones defined in the on-site survey with the appropriate functional area, and assigning the schedule defined for each functional area to the appropriate zone. The software created hourly schedules on a zone-by-zone basis for:

- Occupancy
- Lighting
- Electric equipment
- Gas equipment (primarily kitchen equipment)
- Solar glare
- Window shading
- Infiltration

Occupancy, lighting, and equipment schedules. Each day of the week was assigned to a particular daytype, as reported by the surveyor. Hourly values for each day of the week were extracted from the on-site database according to the appropriate daytype. These values were modified on a monthly basis, according to the monthly building occupancy history.

Solar and shading schedules. The use of blinds by the occupants was simulated by the use of solar and shading schedules. The glass shading coefficient values were modified to account for the use of interior shading devices.

Infiltration schedule. The infiltration schedule was established from the fan system schedule. Infiltration was scheduled “off” during fan system operation, and was scheduled “on” when the fan system was off.

Shell materials. A single-layer, homogeneous material was described which contains the conductance and heat capacity properties of the composite wall used in the building. The thermal conductance and heat capacity of each wall and roof assembly was taken from the Title 24 documents, when available. If the Title 24 documents were not available, default values for the conductance and heat capacity were assigned from the wall and roof types specified in the on-site survey, and the observed R-values. If the R-values were not observed during the on-site survey and the Title 24 documents were not available, an “energy-neutral” approach was taken by assigning the same U-value and heat capacity for the as-built and Title 24 simulation runs.

Windows. Window thermal and optical properties from the building drawings or Title 24 documents (when available) were used to develop the DOE-2 inputs. If these documents were not available, default values for the glass conductance were assigned according to the glass type specified in the on-site survey. If the glass type was not observed during the on-site survey and the Title 24 documents were not available, an "energy-neutral" approach was taken by assigning the same U-value and shading coefficient for the as-built and Title 24 simulation runs.

Lighting kW. Installed lighting power was calculated from the lighting fixture inventory reported on the survey. A standard fixture wattage was assigned to each fixture type identified by the surveyors. Lighting fixtures were identified by lamp type, number of lamps per fixture, and ballast type as appropriate.

Lighting controls. The presence of lighting controls was identified in the on-site survey. For occupancy sensor and lumen maintenance controls, the impact of these controls on lighting consumption was simulated as a reduction in connected load, according to the Title 24 lighting control credits. Daylighting controls were simulated using the "functions" utility in the load portion of DOE-2. Since the interior walls of the zones were not surveyed, it was not possible to use the standard DOE-2 algorithms for simulating the daylighting illuminance in the space. A daylight factor, defined as the ratio of the interior illuminance at the daylighting control point to the global horizontal illuminance was estimated for each zone subject to daylighting control. Typical values for sidelighting applications were used as default values. The daylight factor was entered into the function portion of the DOE-2 input file. Standard DOE-2 inputs for daylighting control specifications were used to simulate the impacts of daylighting controls on lighting schedules. The default daylight factors were adjusted during model calibration.

Equipment kW. Connected loads for equipment located in the conditioned space, including miscellaneous equipment and plug loads, kitchen equipment and refrigeration systems with integral condensers were calculated. Input data were based on the "nameplate" or total connected load. The nameplate data were adjusted using a "rated-load factor," which is the ratio of the average operating load to the nameplate load during the definition of the equipment schedules. This adjusted value represented the hourly running load of all equipment surveyed. Equipment diversity was also accounted for in the schedule definition.

For the miscellaneous equipment and plug loads, equipment counts and connected loads were taken from the on-site survey. When the connected loads were not observed, default values based on equipment type were used.

For the kitchen equipment, equipment counts and connected loads were taken from the on-site survey. Where the connected loads were not observed, default values based on equipment type and "trade size" were used. Unlike the miscellaneous plug load schedules, the kitchen equipment schedules were defined by operating regime. An hourly value corresponding to "off", "idle", or "low," "medium," or "high" production rates were assigned by the surveyor. The hourly schedule was developed from the reported hourly operating status and the ratio of the hourly average running load to the connected load for each of the operating regimes.

For the refrigeration equipment, refrigerator type, count, and size were taken from the on-site survey. Equipment observed to have an "integral" compressor/condenser that is, equipment that rejects heat to the conditioned space, were assigned a connected load per unit size.

Source input energy. Source input energy represented all non-electric equipment in the conditioned space. In the model, the source type was set to natural gas, and a total input energy was specified in terms of Btu/hr. Sources of internal heat gains to the space that were not electrically powered include kitchen equipment, dryers, and other miscellaneous process loads. The input rating of the equipment was entered by the surveyors. As with the electrical equipment, the ratio of the rated input energy to the actual hourly consumption was calculated by the rated load factor assigned by equipment type and operating regime.

Heat gains to space. The heat gains to space were calculated based on the actual running loads and an assessment of the proportion of the input energy that contributed to sensible and latent heat gains. This in turn depended on whether or not the equipment was located under a ventilation hood.

Spaces. Each space in the DOE-2 model corresponded to a zone defined in the on-site survey. In the instance where the "zoned by exposure" option was selected by the surveyor, additional DOE-2 zones were created. The space conditions parameters developed on a zone by zone basis were included in the description of each space. Enclosing surfaces, as defined by the on-site surveyors, were also defined.

Systems

This section describes the methodology used to develop DOE-2 input for the systems simulation. Principal data sources include the on-site survey, Title 24 documents, manufacturers' data, and other engineering references as listed in this section.

Fan schedules. Each day of the week was assigned to a particular daytype, as reported by the surveyor. The fan system on and off times from the on-site survey was assigned to a schedule according to daytype. These values were modified on a monthly basis, according to the monthly HVAC operating hour adjustment. The on and off times were adjusted equally until the required adjustment percentage was achieved. For example, if the original schedule was "on" at 6:00 hours and "off" at 18:00 hours, and the monthly HVAC adjustment indicated that HVAC operated at 50% of normal in June, then the operating hours were reduced by 50% by moving the "on" time up to 9:00 hours and the "off" time back to 15:00 hours.

Setback schedules. Similarly, thermostat setback schedules were created based on the responses to the on-site survey. Each day of the week was assigned to a particular daytype. The thermostat setpoints for heating and cooling, and the setback temperatures and times were defined according to the responses. The return from setback and go to setback time was modified on a monthly basis in the same manner as the fan-operating schedule.

Exterior lighting schedule. The exterior lighting schedule were developed from the responses to the on-site survey. If the exterior lighting was controlled by a time clock, the schedule was used as entered by the surveyor. If the exterior lighting was controlled by a photocell, a schedule, which follows the annual variation in daylength, was used.

System type. The HVAC system type was defined from the system description from the on-site survey. The following DOE-2 system types were employed:

- Packaged single zone (PSZ)
- Packaged VAV (PVAVS)
- Packaged terminal air conditioner (PTAC)
- Water loop heat pump (HP)
- Evaporative cooling system (EVAP-COOL)
- Central constant volume system (RHFS)
- Central VAV system (VAVS)
- Central VAV with fan-powered terminal boxes (PIU)
- Dual duct system (DDS)
- Multi-zone system (MZS)
- Unit heater (UHT)
- Four-pipe fan coil (FPFC)

Packaged HVAC system efficiency. Manufacturers' data were gathered for the equipment surveyed based on the observed make and model number. A database of equipment efficiency and capacity data was developed from an electronic version of the ARI rating catalog. Additional data were obtained directly from manufacturers' catalogs, or the on-line catalog available on the ARI website (www.ari.org). Manufacturers' data on packaged system efficiency is a net efficiency, which considers both fan and compressor energy. DOE-2 requires a specification of packaged system efficiency that considers the compressor and fan power separately. Thus, the manufacturers' data were adjusted to prevent "double-accounting" of fan energy, according to the procedures described in the 1995 Alternate Compliance Method (ACM) manual.

Pumps and fans. Input power for pumps, fans and other motor-driven equipment was calculated from motor nameplate hp data. Motor efficiencies as observed by the surveyors were used to calculate input power. In the absence of motor efficiency observations, standard motor efficiencies were assigned as a function of the motor hp, RPM and frame type. A rated load factor was used to adjust the nameplate input rating to the actual running load. For VAV system fans, custom curves were used to calculate fan power requirements as a function of flow rate in lieu of the standard curves used in DOE-2, as described in the 1995 ACM manual.

Refrigeration systems. Refrigeration display cases and/or walk-ins were grouped into three systems defined by their evaporator temperatures. Ice cream cases were assigned to the lowest temperature circuit, followed by frozen food cases, and all other cases. Case refrigeration loads per lineal foot were taken from manufacturers' catalog data for typical cases. Auxiliary energy requirement data for evaporator fans, anti-sweat heaters, and lighting were also compiled from manufacturers' catalog data. Model inputs were calculated based on the survey responses. For example, if the display lighting was surveyed with T-8 lamps, lighting energy requirements appropriate for T-8 lamps were used to derive the case auxiliary energy input to DOE-2.

Compressor EER data were obtained from manufacturers' catalogs as a function of the suction temperatures corresponding to each of the three systems defined above. These data were used to create default efficiencies for each compressor system. Custom part-load curves were used to simulate the performance of parallel-unequal rack systems.

Service hot water. Service hot water consumption was calculated based on average daily values from the 1995 ACM for various occupancy types. Equipment capacity and efficiency were assigned based on survey responses.

Exterior lighting. Exterior lighting input parameters was developed similarly to those for interior lighting. The exterior lighting connected load was calculated from a fixture count, fixture identification code and the input wattage value associated with each fixture code.

Plant

This section describes the methodology used to develop DOE-2 input for the plant simulation. Principal data sources included the on-site survey, Title 24 documents, manufacturers' data, program data, and other engineering references.

Chillers. The DOE-2 input parameters required to model chiller performance included chiller type, full-load efficiency and capacity at rated conditions, and performance curves to adjust chiller performance for temperature and loading conditions different from the rated conditions. Chiller type was assigned based on the type code selected during the on-site survey. Surveyors also gathered chiller make, model number, and serial number data. These data were used to develop performance data specific to the chiller installed in the building. Program data and/or manufacturers' data were used to develop the input specifications for efficiency.

Cooling towers. Cooling tower fan and pump energy was defined based on the nameplate data gathered during the on-site survey. Condenser water temperature and fan volume control specifications were derived from the on-site survey responses.

Model Calibration

An integral part of DOE-2 model development was the model calibration process. Monthly energy consumption and demand from the DOE-2 models was compared to billing data for the same period to assess the reasonableness of the models. Changes were made to a fixed set of calibration parameters until the models matched the billing data. The goal of the calibration process was to match billing demand and energy data within ± 10 percent on a monthly basis. The overall model calibration process consisted of the following steps:

1. Review and format billing data. Billing data as received from Edison was reformatted as required by the model calibration software.
2. Select relevant accounts. For many of the sites, a number of accounts were provided. Account information such as customer name, address, business type, and meter number was compared to the onsite survey information. The list of accounts that seemed to best match the surveyed space was selected.
3. Assign surveyed to metered space percentage. During the onsite survey, the surveyors were asked to assess the ratio of the space surveyed to the space

served by the building meter(s). Billing data records were adjusted to reflect portion of the metered data that applied to the modeled space.

4. Run model. The as-built model was run with actual 1998 and 1999 weather data applicable to the particular site, using the occupancy as reported by the surveyors. Annual simulations for both years were done, and the modeled consumption and demand was aggregated to correspond to the meter read dates from the billing data. The 1999 calibration covered billing data and simulated energy consumption for the first six months of the year. The actual year weather data was provided by SCE.
5. Review kWh and kW comparison. The modeled and metered consumption and demand for each billing period was compared using a graphical data visualization tool. An example output screen from the calibration tool is shown in Figure 4.
6. Reject unreasonable or faulty billing data. Some of the billing data received was incomplete or not well matched to the modeled space. In these cases, the billing data were rejected, and the models were not calibrated.
7. Make adjustments to calibration variables. A fixed set of calibration variables was provided to the modeling calibration team. The calibration parameters, and the range of acceptable adjustments are shown in Table 12. The modelers adjusted the calibration parameters until the modeled results matched the metered results within ± 10 percent for each billing period. This was an iterative process, involving changing the model inputs, repeating the simulation, and reviewing the results. At each iteration, the changes made to the model and the impacts of the change on the model vs. billing data comparison were entered into a calibration log file.

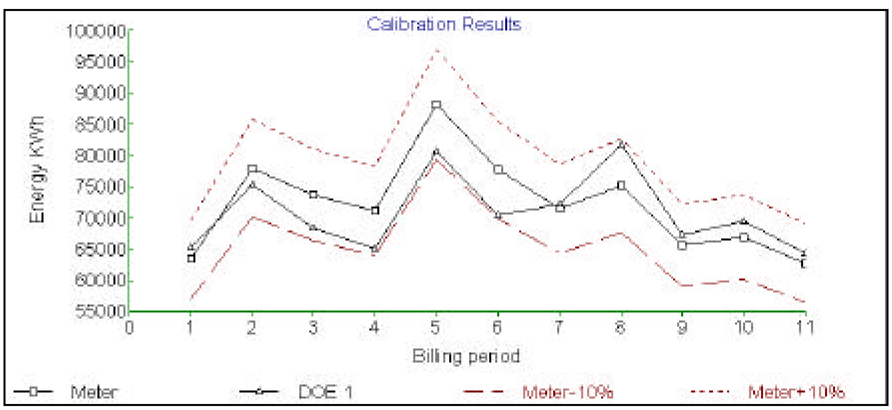


Figure 4: Example Calibration Tool Screen

Calibration Parameter	**Adjustment range**
Monthly schedule multiplier	.2 – 2
Lighting diversity multiplier	.2 – 2
Plug load diversity multiplier	.2 – 5
Plug load internal heat gains multiplier	.2 – 5
Heating thermostat setpoint	± 5°F
Cooling thermostat setpoint	± 5°F
DHW water use multiplier	.1 – 10

Minimum outside air ratio	.1 - .7, if no additional information
Refrigeration compressor efficiency	± 20%
Heating supply air temp control	discrete choices
Direct evaporative system effectiveness	0.2 - 0.8
Indirect evaporative system effectiveness	0.2 - .07
Heat pump defrost control	discrete choices
Daylight factor	look at hourly reports to verify correct operation
Building azimuth	± 45 degrees

Table 12: Model Calibration Parameters and Acceptable Adjustment Range

In some cases, it was not possible to calibrate the models. When billing data were not available, the modeled results were examined for reasonableness, in terms of annual energy consumption (kWh/SF) by building type and end-use percentage of total consumption. Even when billing data were available, some of the models resisted reasonable attempts to achieve calibration. Rather than making unreasonable adjustment to the models, the models were left uncalibrated or partially calibrated. During calibration, the models were run with actual year weather data provided by SCE from 23 local weather stations located throughout the Edison service territory.

The results of the model calibration process are shown in Figure 5. Billing data records that were well-matched to the surveyed space were obtained for 27 sites. Of these, the modelers were able to successfully calibrate 21 models. We were unable obtain useful billing data for 11 sites, due primarily to lack of access to the billing meter during the on-site survey. The remaining sites were either additions or one of several buildings served by a single meter, where the surveyed space was not well-matched to the space served by the billing meter.

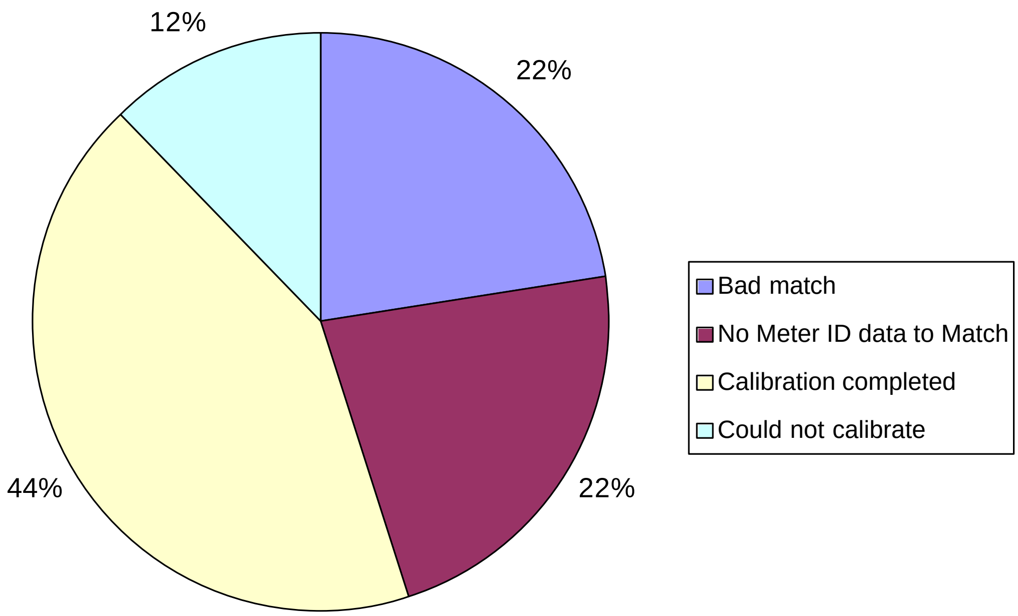


Figure 5: Model Calibration Results

Model Review and Quality Control

The onsite survey data entry program contained numerous quality control (QC) checks designed to identify invalid building characteristics data during data entry. Once the data were entered, the models were run and the results were reviewed by the surveyor/modeler and senior engineering staff. A building characteristics and model results summary report was created for each site. The model results were compared to a set of QC criteria as shown in Table 13. Data falling outside of the QC range were validated during the QC process.

Building Parameter	Range	Definition
Lighting Power Density	0.9 - 1.9	building wide average
Equipment Power Density	0.1 - 5	building wide average
Cooling Ratio	95 - 200%	capacity from annual run / capacity from sizing run
Cooling EER	8 - 14	capacity weighted cooling efficiency
Wall-U	0.5 - 0.033	area weighted average, includes air film
Roof-U	0.5 - 0.033	area weighted average, includes air film
Win-U	0.3 - 0.88	area weighted average, includes air film
Win-Shading Coefficient	0.35 - 0.88	area weighted average
Win Area	0 - 70%	Percentage of gross wall area associated w/windows, expressed as a true percentage 0 –100
Sky-U	0.3 - 0.9	area weighted average of glazing contained in roof
Sky-Shading Coefficient	0.35 - 0.88	area weighted SC for all horizontal glazing
Sky-Area	0 - 10%	Percentage of gross roof area associated with sky light, expressed as a true percentage 0 –100
LTG Occupancy Sensors	0 - 50%	Percentage of lighting watts controlled by occupancy sensors, expressed as a true percentage 0 –100
LTG Daylighting controls	0 - 50%	Percentage of lighting watts controlled by daylighting sensors, expressed as a true percentage 0 –100
Measures only savings relative to program expectations	50% - 150%	measures-only savings / program expectations
Total savings (all sites)	0% - 50%	Savings expressed as a percentage of baseline energy consumption

Table 13: Model Quality Control Criteria

Modeling results were also reviewed by Edison engineering staff. A meeting was held in San Dimas to review results for sites falling outside of the QC range. A number of modeling and data problems were identified during the Edison staff review, adding an additional level of QC to the overall process. These problems were fixed, thus improving the overall accuracy of the modeling process.

Parametrics

Once the models were calibrated and quality checked, a batch process was used to create a series of parametric simulation runs. These runs were used to simulate gross savings on a whole-building and measure-class basis. The parametric runs performed for this study are listed below:

As-Built Parametric Run.

Once the models were completed, checked for reasonableness, and/or calibrated, the as-built parametric run was done. Monthly schedule variations resulting from partial occupancy and building startup were eliminated, and the models were run using long-term average weather data from the CEC CTZ long term average weather data files.

Baseline Parametric Run.

Key building performance parameters were reset to a baseline condition to calculate gross energy savings for participants on an end-use basis. The California Building Energy Efficiency Standard (Title 24) was the primary reference for establishing baseline performance parameters. Title 24 specifies minimum specifications for building attributes such as:

- Opaque shell conductance
- Window conductance
- Window shading coefficient
- HVAC equipment efficiency
- Lighting power density

Title 24 applied to most of the building types covered in the programs covered under this evaluation, with the exception of:

- Hospitals
- Unconditioned space (including warehouses)

Incentives were also offered by the programs for building attributes not addressed by Title 24. In situations where Title 24 does not address building types or equipment covered under the program, baseline parameters equivalent to those used for the program baseline efficiencies were used.

Envelope

Opaque shell U-values were assigned based on Title 24 requirements as a function of climate zone and heat capacity of the observed construction. For windows, Title 24 specifications for maximum relative solar heat gain were used to establish baseline glazing shading coefficients. Fixed overhangs were removed from the baseline building. Glass conductance values as a function of climate zone were applied. For skylights, shading coefficients and overall conductance was also assigned according to climate zone.

Mechanical

Baseline specifications for HVAC equipment efficiency were derived from the Title 24 requirements as a function of equipment type and capacity. Maximum power specifications for fans were established based on Title 24 requirements, which address fan systems larger than 25 hp. Specific fan power was held energy neutral (as built W/CFM = baseline W/CFM) for fan systems under 25 hp. Additionally, all systems larger than 2500 CFM (except for hospitals) were simulated with economizers in the baseline run. All VAV fan systems larger than 50 hp were simulated with inlet vane control. All variable-volume pumps were simulated with throttling valve control.

HVAC system sizing

HVAC system sizing for the as-built case was determined by direct observation of the nameplate capacities of the HVAC equipment. The installed HVAC system capacity was compared to the design loads imposed on the system to determine a sizing ratio for the as-built building. Once established, the sizing ratio was held constant for each subsequent DOE-2 run. A separate sizing run was done prior to the baseline and parametric runs. The peak cooling system size was calculated using the equipment sizing algorithms in DOE-2. The system capacity was reset using the calculated peak cooling capacity, and the as-built sizing ratio. A new system size was calculated for the baseline run and each parametric run.

Lighting

The Title 24 area category method was used to set the baseline lighting power for each zone as a function of the observed occupancy. Task lighting and exit signs were not included in the baseline lighting calculation. A lighting power density appropriate for corridor/restroom/support areas was assigned according to the portion of each space allocated to these areas. All lighting controls were turned off for the baseline simulation.

Additional Parametric Runs

Once the as-built and baseline building models were defined, an additional set of parametric runs were done to estimate the program impact on the lighting, HVAC, and shell / daylighting end-uses. The baseline model was returned to the as-built design in a series of steps outlined as follows:

1. Lighting - measures only. Baseline lighting power densities and controls (except daylighting) for incented measures only were returned to their as-built condition.
2. All Lighting . All baseline lighting power densities and controls (except daylighting) were returned to their as-built condition.
3. Daylighting plus shell - measures only. Run 2 above, plus baseline envelope and daylighting controls for incented measures only returned to their as-built condition.
4. All Daylighting plus shell. Run 2 above, plus all baseline envelope and daylighting controls returned to their as-built condition.
5. HVAC - measures only. Run 4 above, plus HVAC for incented measures only parameters returned to their as-built condition.
6. All HVAC. Run 4 above, plus all HVAC parameters returned to their as-built condition. This run is equivalent to the full as-built run.

Estimated Savings

This section presents the energy and demand savings estimates of all program participants. Savings findings for the whole building as well as for lighting, shell/daylighting, and HVAC end-uses are reported. In addition to the

Some definitions are helpful to clarify the discussion.

Baseline — A consistent standard of energy efficiency against which all buildings were measured. This was defined as the output of a DOE-2.1E simulation of a building using Title 24 required equipment efficiencies (where applicable) run using the operating schedule found by the on-site surveyor. Where Title 24 did not apply (e.g. hospitals), the baseline that was defined by the program for estimating the program savings was used.

As Built — A DOE-2.1E simulation of a building using all equipment and operating parameters as found by an on-site surveyor.

Savings — The difference between baseline and as built. Positive savings indicate that the building was more efficient – used less energy -- than its base case.

"Better than baseline" — The as built simulation showed less energy consumption than the baseline simulation – more efficient than the base case. Positive savings.

"Worse than baseline" — The as built simulation showed more energy consumption than the baseline simulation – less efficient than the base case. Negative savings.

Time-of-use period — SCE defined time periods for reporting energy and demand usage. See Table 14 for description of each period.

Period	Dates	Days / Times
Summer On-peak	June 4 to September 30	Weekdays 11 am to 5 pm
Summer Mid-peak	June 4 to September 30	Weekdays 7 am to 11 am and 5 pm to 10 pm
Summer off-peak	June 4 to September 30	Weekdays 10 pm to 7 am. All day weekends and holidays
Winter Mid-peak	October 1 to June 3	Weekdays 7 am to 8 pm
Winter Off-peak	October 1 to June 3	Weekdays 8 pm to 7 am. All day weekends and holidays.

Table 14: Time-of-use periods

SCE Coincident Hours The month, day, and hour coinciding with the peak demand upon the utility for each billing period.

The engineering analysis was conducted using Typical Meteorological Year (TMY) data, so the system load information for 1998 could not be used directly. This is because TMY weather data is a 30-year average, resulting in different load profiles for each building than would have been obtained using 1998 weather data. RLW Analytics used the following methodology developed in the 1994 SCE/PG&E NRNC study to determine the appropriate peak hour under TMY weather:

1. Every DOE-2.1 model (run with actual weather data) for a given utility was compared to the system load profile and the model that was most correlated to the system profile was selected as representative for the utility. This was done using a stepwise regression procedure set to include the DOE-2.1 model with the largest F statistic in the regression first. This is analogous to selecting the DOE-2.1 model that was most correlated to the system load profile.
2. The selected DOE-2.1 model was run using TMY weather.
3. The peak hour for each of the five costing periods was determined from the peak hours of this model.

The peak day and hour are shown for each costing period in Table 3-1.

Period	Coincident Month/Day/Hour
Summer On-peak	8/9/17
Summer Mid-peak	8/31/19
Summer off-peak	7/15/17
Winter Mid-peak	5/19/17
Winter Off-peak	6/3/18

Table 15: Coincident Hours for Each Billing Period

Methodology

This project used a statistical methodology called Model-Based Statistical Sampling or MBSS™. MBSS has been used for many evaluation studies to select the sites or projects to be studied and to extrapolate the results to the target population. MBSS has been used for previous Edison projects such as the 1994 and 1996 New Construction Evaluations, in addition to projects completed for NEES, Northeast Utilities, Consolidated Edison, The New York Power Authority, Wisconsin Electric, Sierra Pacific Power Company, and Washington Power and Light among others. MBSS was used in the end-use metering component of the 1992 evaluation of PG&E's CIA program. A complete description of MBSS methodology is available.[6]

The Sample Design chapter earlier in this report describes the sample designs used in this study. Therefore this section will describe the methods used to extrapolate the results to the target population. Three topics will be described: (a) case

[6] *Methods and Tools of Load Research, The MBSS System, Version V*. Roger L. Wright, RLW Analytics, Inc. Sonoma CA, 1996.

weights, (b) balanced stratification to calculate case weights, and (c) stratified ratio estimation using case weights.

Case Weights

We will use the following problem to develop the idea of case weights. Given observations of a variable *y* in a stratified sample, estimate the population total *Y*.

Note that the population total of *y* is the sum across the *H* strata of the subtotals of y in each stratum. Moreover each subtotal can be written as the number of cases in the stratum times the mean of *y* in the stratum. This gives the equation:

$$Y = \sum_{h=1}^{H} N_h m_h$$

Motivated by the preceding equation, we estimate the population mean in each stratum using the corresponding sample mean. This gives the conventional form of the stratified-sampling estimator, denoted $\hat{Y}$, of the population total *Y:*

$$\hat{Y} = \sum_{h=1}^{H} N_h \bar{y}_h$$

With a little algebra, the right-hand side of this equation can be rewritten in a different form:

$$\begin{aligned} \hat{Y} &= \sum_{h=1}^{H} N_h \bar{y}_h \\ &= \sum_{h=1}^{H} N_h \left(\frac{1}{n_h} \sum_{k \in s_h} y_k \right) \\ &= \sum_{k=1}^{n} \left(\frac{N_h}{n_h} \right) y_k \end{aligned}$$

Motivated by the last expression, we define the ***case weight*** of each unit in the sample to be $w_k = \frac{N_h}{n_h}$. Then the conventional estimate of the population total can be written as a simple weighted sum of the sample observations:

$$\hat{Y} = \sum_{k=1}^{n} w_k y_k$$

The case weight w_k can be thought of as the number of units in the population represented by unit *k* in the sample. The conventional sample estimate of the population total can be obtained by calculating the weighted sum of the values observed in the sample.

Table 20 shows an example[7]. In this example, the population of program participants has been stratified into five strata based on the annual savings of each project shown in the tracking system. For example, the first stratum consists of all projects with annual savings less than 101,978 kWh. The maximum kWh in each stratum is called the stratum cut point. There are 339 projects in this stratum and they have a total tracking savings of 8,038,527 kWh. The estimate of gross impact was obtained from the measured savings found in a sample of 85 projects. Column five of Table 16 shows that the sample contains 62 projects from the first stratum. Each of these 62 projects can be given a case weight of 339 / 62 = 5.47.

Stratum	Max kWh	Population Size	Total KWh	Sample Size	Case Weight
1	101,978	339	8,038,527	62	5.47
2	278,668	61	10,949,421	9	6.78
3	441,916	35	12,598,315	8	4.38
4	816,615	22	13,654,171	3	7.33
5	4,000,000	12	17,469,244	3	4.00
Total		469	62,709,678	85	

Table 16: Stratification Example

Balanced Stratification

Balanced stratification is another way to calculate case weights. In this approach, the sample sites are sorted by the stratification variable, tracking kWh, and then divided equally among the strata. Then the first stratum cutpoint is determined midway between the values of the stratification variable for the last sample case in the first stratum and the first sample case in the second stratum. The remaining strata cutpoints are determined in a similar fashion. Then the population sizes are tabulated within each stratum. Finally the case weights are calculated in the usual way.

Table 17 shows an example[8]. In this case the sample of 85 sites has been equally divided among five strata, so there are 17 sites per stratum. Then the stratum cutpoints shown in column two were calculated from the tracking estimates of kWh for the sample sites. Next the population sizes shown in column three were calculated from the stratum cutpoints. The final step was to calculate the case weights shown in the last column. For example, the case weight for the 17 sites in the first stratum is 136 / 17 = 8.

Stratum	Max kWh	Population Size	Total KWh	Sample Size	Case Weight
1	7,948	136	417,368	17	8.00

[7] This is an example only. The numbers presented here are not relevant to the study findings.

[8] This is only an example. The numbers presented are not relevant to the study findings.

2	22,361	84	1,211,832	17	4.94
3	63,859	84	3,605,867	17	4.94
4	202,862	73	8,146,886	17	4.29
5	2,883,355	92	49,327,725	17	5.41
Total		469	62,709,678	85	

Table 17: Balanced Stratification

Stratified Ratio Estimation

Ratio estimation is used to estimate the population total Y of the target variable y taking advantage of the known population total X of a suitable explanatory variable x. The ratio estimate of the population total is denoted $\hat{Y}_{ra}$ to distinguish it from the ordinary stratified sampling estimate of the population total, which is denoted as $\hat{Y}$.

Motivated by the identity $Y = B\,X$, we estimate the population total Y by first estimating the population ratio B using the sample ratio $b = \bar{y}/\bar{x}$, and then estimating the population total as the product of the sample ratio and the known population total X. Here the sample means are calculated using the appropriate case weights. This procedure can be summarized as follows:

$$
\begin{aligned}
\hat{Y}_{ra} &= b\,X \quad \text{where} \\
b &= \frac{\bar{y}}{\bar{x}} \\
\bar{y} &= \frac{1}{\hat{N}}\sum_{k=1}^{n} w_k\, y_k \\
\bar{x} &= \frac{1}{\hat{N}}\sum_{k=1}^{n} w_k\, x_k \\
\hat{N} &= \sum_{k=1}^{n} w_k
\end{aligned}
$$

The conventional 90 percent confidence interval for the ratio estimate of the population total is usually written as

$$
\begin{aligned}
\hat{Y}_{ra} &\pm 1.645\sqrt{V\left(\hat{Y}_{ra}\right)} \quad \text{where} \\
V\left(\hat{Y}_{ra}\right) &= \sum_{h=1}^{H} N_h^2\left(1-\frac{n_h}{N_h}\right)\frac{s_h^2(e)}{n_h} \\
s_h^2(e) &= \frac{1}{n_h-1}\sum_{k\in s_h}\left(e_k-\bar{e}_h\right)^2 \\
e_k &= y_k - b\,x_k
\end{aligned}
$$

We can calculate the relative precision of the estimate $\hat{Y}_{ra}$ using the equation

$$rp = \frac{1.645\sqrt{V\left(\hat{Y}_{ra}\right)}}{\hat{Y}_{ra}}$$

MBSS theory has led to an alternative procedure to calculate confidence intervals for ratio estimation, called model-based domains estimation. This method yields the same estimate as the conventional approach described above, but gives slightly different error bounds. This approach has many advantages, especially for small samples, and has been used throughout this study.

Under model-based domains estimation, the ratio estimator of the population total is calculated as usual. However, the variance of the ratio estimator is estimated from the case weights using the equation

$$V\left(\hat{Y}_{ra}\right) \quad = \quad \sum_{k=1}^{n} w_k \left(w_k - 1\right) e_k^2$$

Here w_k is the case weight discussed in Section 6.5.1 and e_k is the sample residual $e_k = y_k - b\,x_k$. Then, as usual, the confidence interval is calculated as

$$\hat{Y}_{ra} \quad \pm \quad 1.645\sqrt{V\left(\hat{Y}_{ra}\right)}$$

and the achieved relative precision is calculated as

$$rp = \frac{1.645\sqrt{V\left(\hat{Y}_{ra}\right)}}{\hat{Y}_{ra}}$$

The model-based domains estimation approach is often much easier to calculate than the conventional approach since it is not necessary to group the sample into strata. In large samples, there is generally not much difference between the case-weight approach and the conventional approach. In small samples the case-weight approach seems to perform better. For consistency, we have come to use model-based domains estimation in most work.

This methodology generally gives error bounds similar to the conventional approach. Equally, the model-based domains estimation approach can be derived from the conventional approach by making the substitutions:

$$\begin{aligned} \bar{e}_h &\approx 0 \\ s_h^2(e) &\approx \frac{1}{n_h} \sum_{k \in s_h} e_k^2 \end{aligned}$$

In the first of these substitutions, we are assuming that the within-stratum mean of the residuals is close to zero in each stratum. In the second substitution, we have replaced the within-stratum variance of the sample residual e, calculated with $n_h - 1$ degrees of freedom, with the mean of the squared residuals, calculated with n_h degrees of freedom.

Model-based domains estimation is appropriate as long as the expected value of the residuals can be assumed to be close to zero. This assumption is checked by examining the scatter plot of y versus x. It is important to note that the assumption affects only the error bound, not the estimate itself. $\hat{Y}_{ra}$ will be essentially unbiased as long as the case weights are accurate.

Gross Savings Expansions

Each building in the sample was modeled as described in the Engineering Models section. Baseline, as built, and savings estimates were developed for every building in the sample. The sample of baseline, as built, and savings estimates was projected to the participant population using model-based statistical methods described above.

Gross Energy Savings

Whole Building

SCE's whole building gross energy savings were 28,813 MWh. The relative precision of the estimate was ±6.7%. This represents a gross realization rate of 104.7% of verified annual savings. Table 18 shows the estimated savings by time-of-use period.

Period	Energy Savings (MWh)	Relative Precision (+/-)
Annual	**28,813**	**6.7%**
Summer On-Peak	3,155	7.7%
Summer Mid-Peak	3,294	6.3%
Summer Off-Peak	4,654	6.3%
Winter Mid-Peak	9,791	7.9%
Winter Off-Peak	7,920	7.5%

Table 18: Whole Building Energy Savings by Time-of-use period

Figure 6 shows the savings of participants relative to the whole building baseline usage.

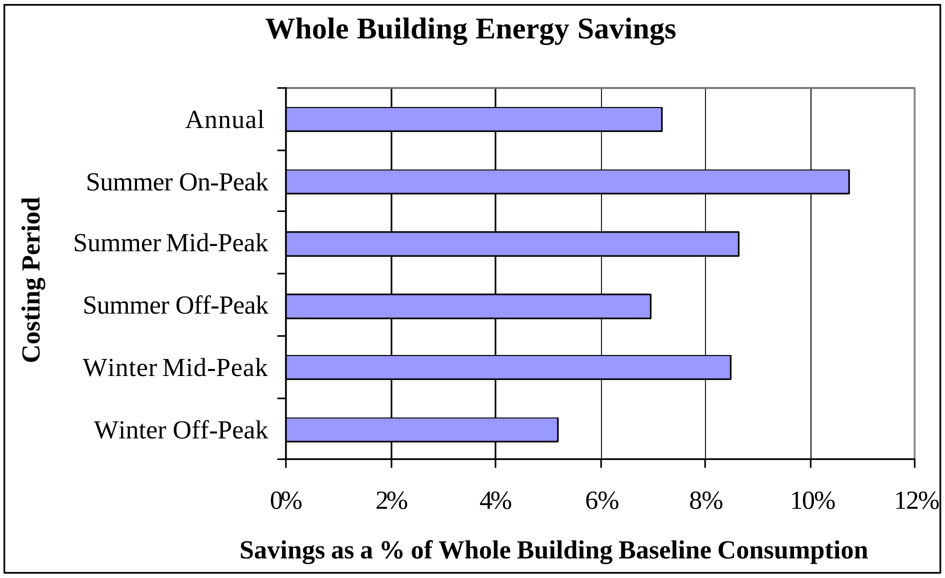


Figure 6: Participant Energy Savings Relative to Whole Building Baseline

As Figure 6 shows, the participants were 7.2% better than whole building baseline on average overall. The level of efficiency relative to the baseline remains fairly constant throughout the year, with the summer on-peak savings relative to baseline usage being the largest of all costing periods.

End-Use Savings

Three end-uses were examined as part of this study, lighting, HVAC, and shell / daylighting. The savings for all sites in the sample were projected to the population to arrive at the total savings estimate. Note that the sum of the end-use savings may not add exactly to 1 due to rounding. In the first of the figures describing the end-use savings, the percentages are calculated as the savings due to each end use relative to the whole building baseline. The percentage scale in the figures is an indicator of the contribution to overall savings of each end-use.

In addition to the previously described figures, there is an additional figure provided in the lighting and HVAC end-use sections. The second figure in those sections contains percentages that represent the measures-only savings for each end use relative to that specific end use baseline usage. The percentage scale in these figures is an indicator of the contribution to each overall end use savings of the rebated measures in that end use.

Figure 7 shows the breakdown of annual energy savings by end-use.

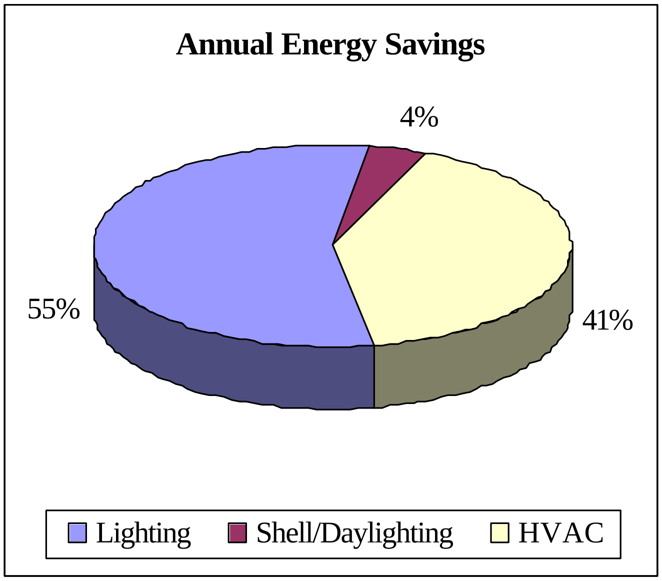


Figure 7: Composition of Energy Savings

Lighting

The lighting end-use accounted for 55.3% of the annual energy savings of the participants, or 15,944 MWh. Table 19 shows the savings and relative precision by time-of-use period.

Period	Energy Savings (MWh)	Relative Precision (+/-)
Annual	**15,944**	**11.4%**
Summer On-Peak	1,873	13.1%
Summer Mid-Peak	1,844	11.4%
Summer Off-Peak	1,895	10.2%
Winter Mid-Peak	6,354	12.7%
Winter Off-Peak	3,977	11.0%

Table 19: Lighting Energy Savings by Time-of-use period

Figure 8 shows all of the lighting savings relative to whole building baseline consumption by time-of-use period.

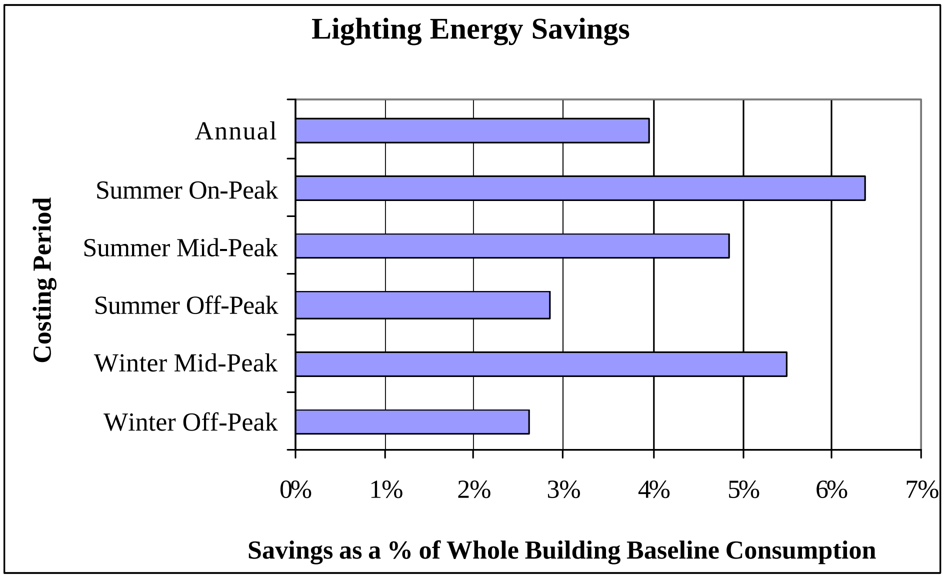


Figure 8: Lighting Energy Savings Relative to Whole Building Baseline Usage

Figure 9 shows the measures only lighting savings relative to lighting baseline consumption.

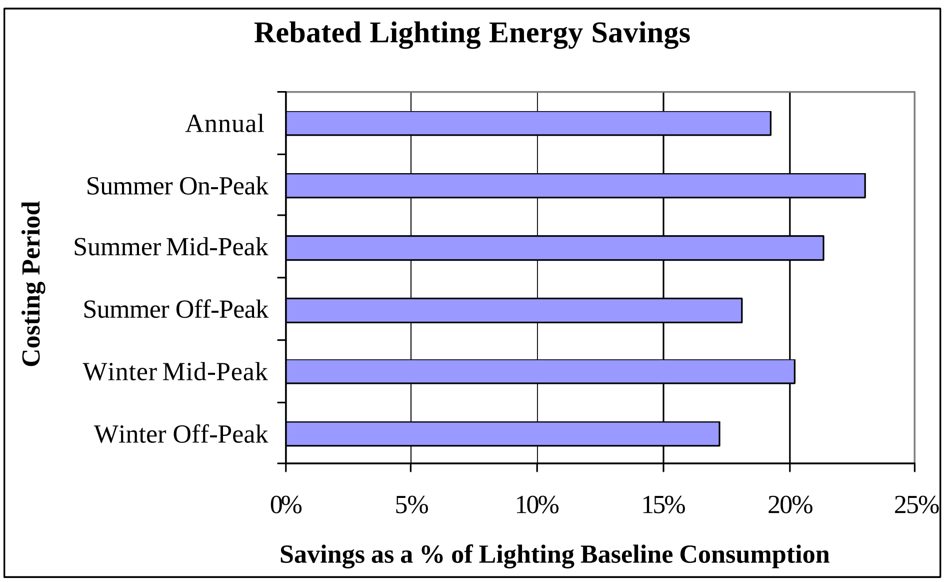


Figure 9: Lighting Measures Only Savings Relative to Lighting Baseline Usage

HVAC

The HVAC end-use accounted for 40.9% of the participants' savings, or 11,791 MWh. Table 20 shows the savings and relative precision by time-of-use period.

Period	Energy Savings (MWh)	Relative Precision (+/-)
Annual	**11,791**	**9.0%**
Summer On-Peak	1,035	8.4%
Summer Mid-Peak	1,276	8.6%
Summer Off-Peak	2,528	8.6%
Winter Mid-Peak	3,203	9.6%
Winter Off-Peak	3,751	10.6%

Table 20: HVAC Energy Savings by Time-of-use period

Figure 10 shows the HVAC savings relative to whole building baseline consumption by time-of-use period.

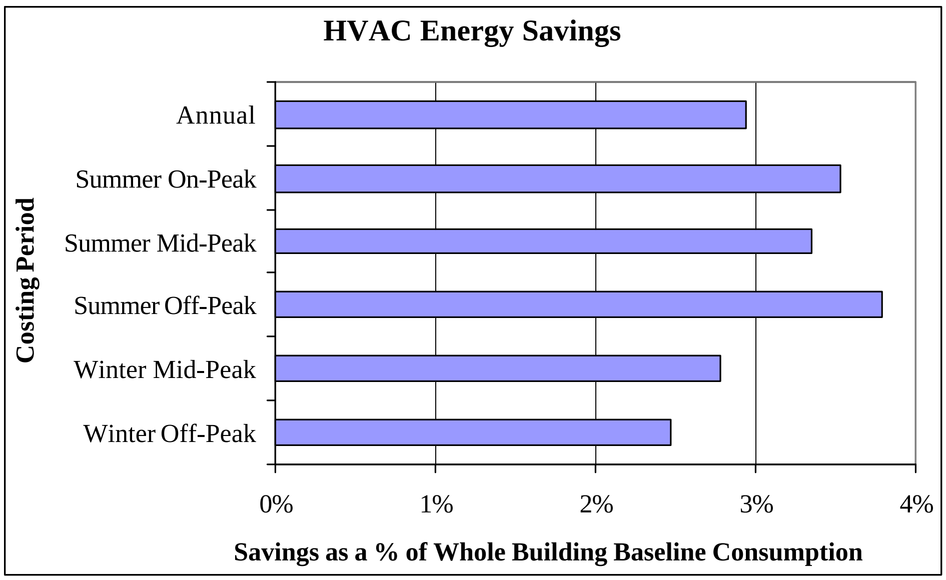


Figure 10: HVAC Energy Savings Relative to Whole Building Baseline

Figure 11 shows the measures only HVAC savings relative to HVAC baseline consumption.

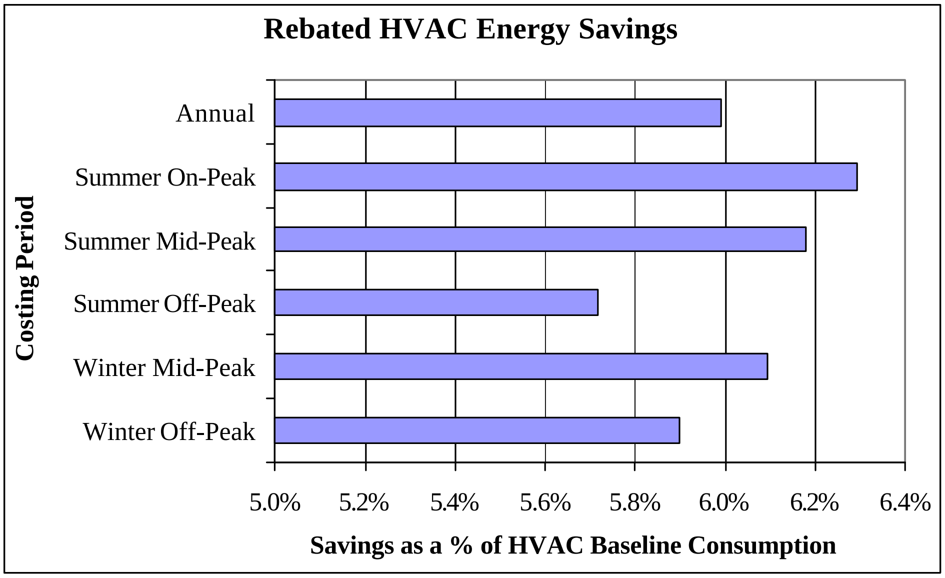


Figure 11: HVAC Measures Only Savings Relative to HVAC Baseline Usage

Shell & Daylighting

The shell / daylighting control end-use accounted for 3.7% of the participant savings, or 1,077 MWh. Table 21 shows the savings and relative precision by time-of-use period.

Period	Energy Savings (MWh)	Relative Precision (+/-)
Annual	**1,077**	**9.0%**
Summer On-Peak	247	7.7%
Summer Mid-Peak	174	10.9%
Summer Off-Peak	230	9.3%
Winter Mid-Peak	233	11.0%
Winter Off-Peak	192	11.2%

Table 21: Shell & Daylighting Energy Savings by Time-of-use period

Figure 12 shows the participant shell & daylighting savings relative to whole building baseline consumption by time-of-use period.

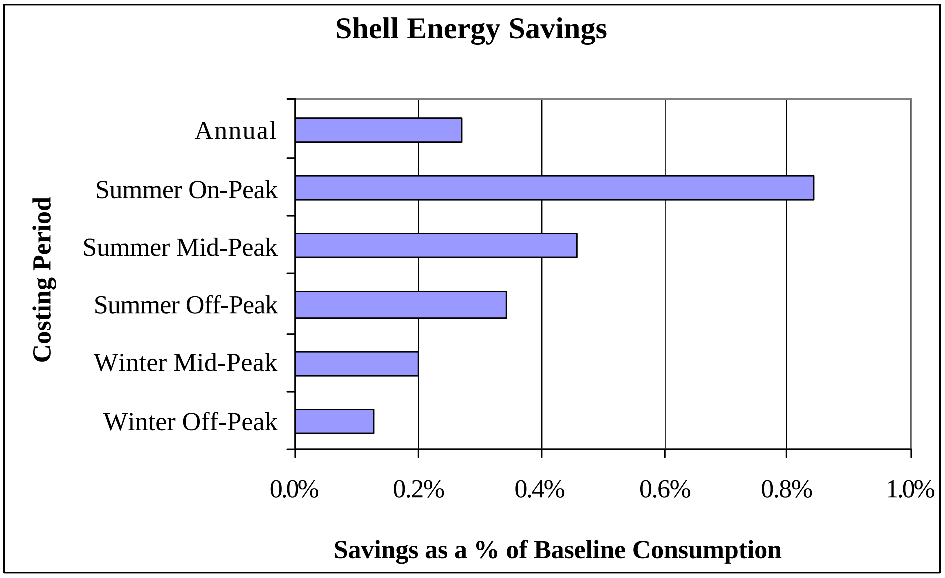


Figure 12: Shell & Daylighting Energy Savings Relative to Whole Building Baseline

Gross Demand Savings

Whole Building

SCE's whole building summer on-peak gross demand savings was 5.56 MW. The relative precision of the estimate was ±6.9%. This represents a gross realization rate of 93.1% of verified summer on-peak demand savings. Table 22 shows the estimated savings by time-of-use period.

Period	Demand Savings (MW)	Relative Precision (+/-)
Summer On-Peak	5.56	6.9%
Summer Mid-Peak	3.08	7.6%
Summer Off-Peak	3.74	5.6%
Winter Mid-Peak	4.44	8.6%
Winter Off-Peak	3.04	6.4%

Table 22: Whole Building Demand Savings by Time-of-use period

Figure 13 shows the savings of participants expressed as a percentage of their whole building baseline demand.

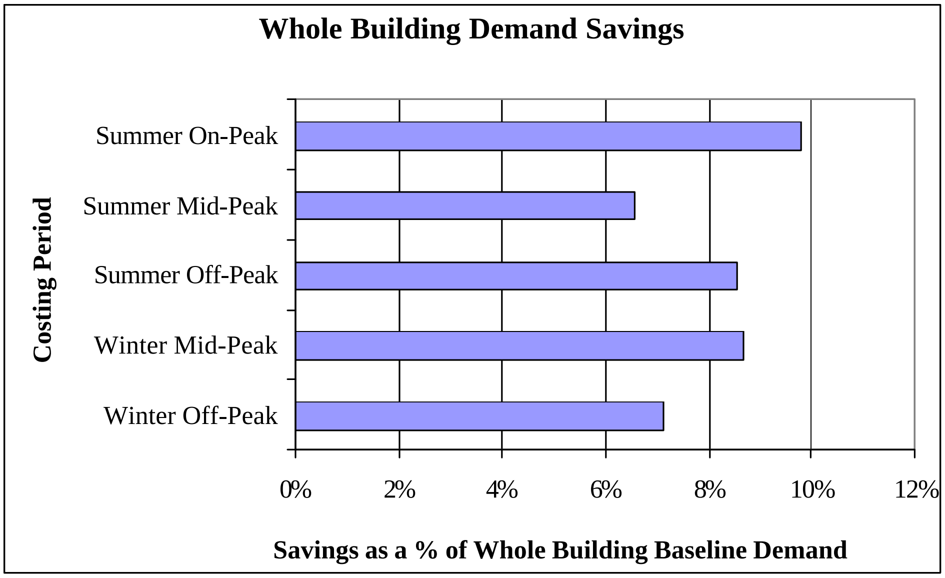


Figure 13: Whole Building Demand Savings Relative to Whole Building Baseline

As the figure shows, the participants were 9.8% better than whole building baseline during the summer on-peak period. The level of efficiency relative to the baseline remains fairly constant throughout the year.

End-Use Demand Savings

Three end-uses were examined as part of this study, lighting, HVAC, and shell / daylighting. Those sites that had savings were projected to the population to arrive at the total savings estimate. Note that the sum of the end-use savings may not add exactly to 1 due to rounding. In each of the figures describing end-use savings, the percentages are calculated as the savings due to each end use relative to the whole building baseline. The percentage scale in the figures is an indicator of the contribution to overall savings of each end-use.

In addition to the previously described figures, there is an additional figure provided in the lighting and HVAC end-use sections. The second figure in those sections contains percentages that represent the measures-only savings for each end use relative to that specific end use baseline usage. The percentage scale in these figures is an indicator of the contribution to each overall end use savings of the rebated measures in that end use.

Figure 14 shows the breakdown of summer peak demand savings by end-use.

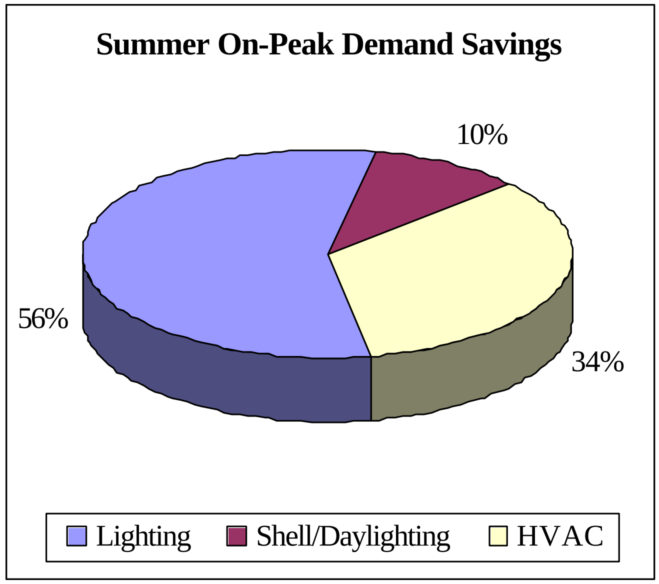


Figure 14: Composition of Summer Peak Demand Savings

Lighting

SCE's lighting end-use gross demand savings was 3.11 MW and accounted for 55.9% of the summer on-peak demand savings for participants. The relative precision of the estimate was ±11.7%. Table 23 shows the estimated savings by time-of-use period.

Period	Demand Savings (MW)	Relative Precision (+/-)
Summer On-Peak	3.11	11.7%
Summer Mid-Peak	1.52	13.5%
Summer Off-Peak	1.84	7.1%
Winter Mid-Peak	2.97	11.9%
Winter Off-Peak	1.42	9.0%

Table 23: Lighting Summer On-Peak Demand Savings by Time-of-use period

Figure 15 shows the savings of participants expressed as a percentage of their whole building baseline demand.

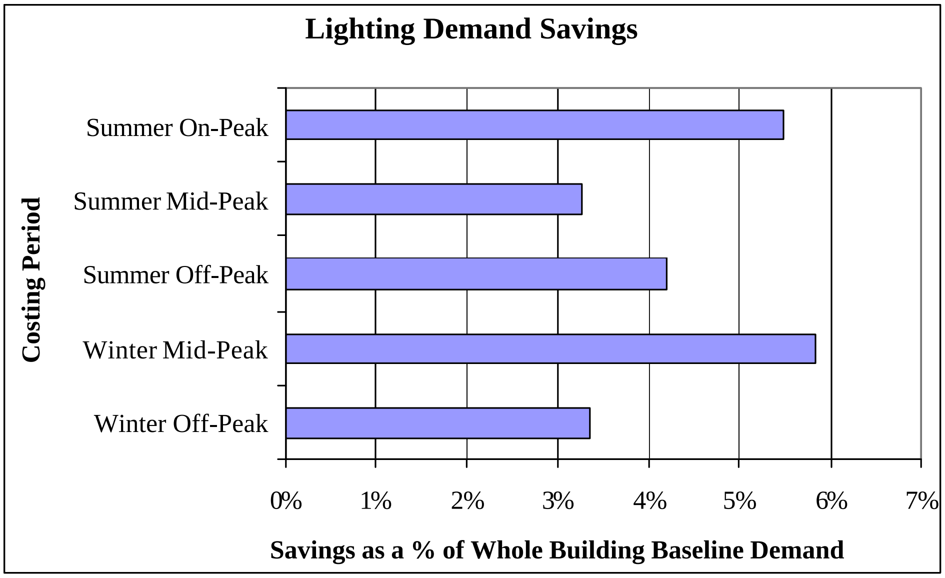


Figure 15: Lighting Summer On-Peak Demand Savings Relative to Whole Building Baseline

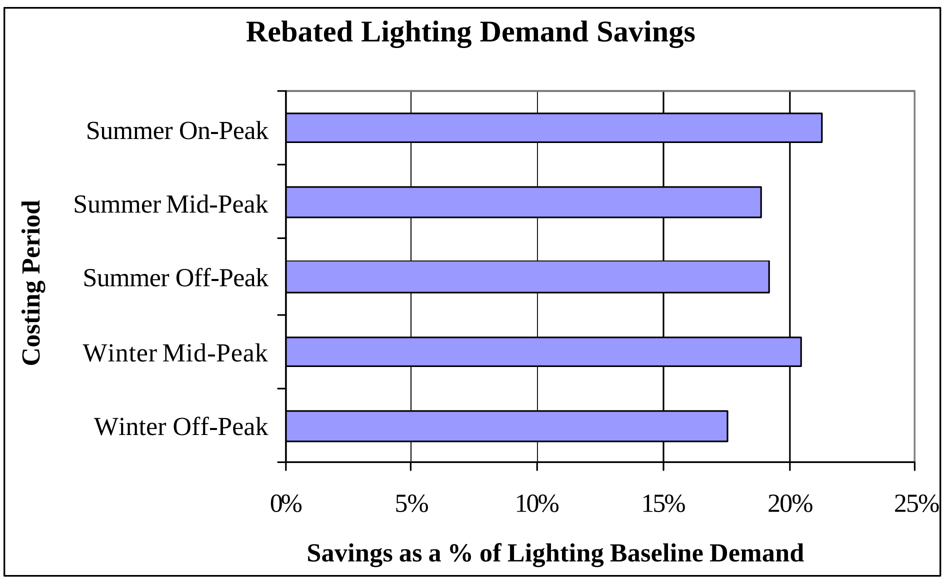


Figure 16: Lighting Measures Only Savings Relative to Lighting Baseline

HVAC

The HVAC end-use accounted for 34.0% of the summer on-peak demand savings of the participants, or 1.89 MW. The relative precision of the estimate was ±9.4%. Table 24 shows the estimated savings by time-of-use period.

Period	Demand Savings (MW)	Relative Precision (+/-)
Summer On-Peak	1.89	9.4%
Summer Mid-Peak	1.38	11.4%
Summer Off-Peak	1.61	10.9%
Winter Mid-Peak	1.27	11.2%
Winter Off-Peak	1.43	10.6%

Table 24: HVAC Summer On-Peak Demand Savings by Time-of-use period

Figure 17 shows the savings expressed as a percentage of the whole building baseline demand.

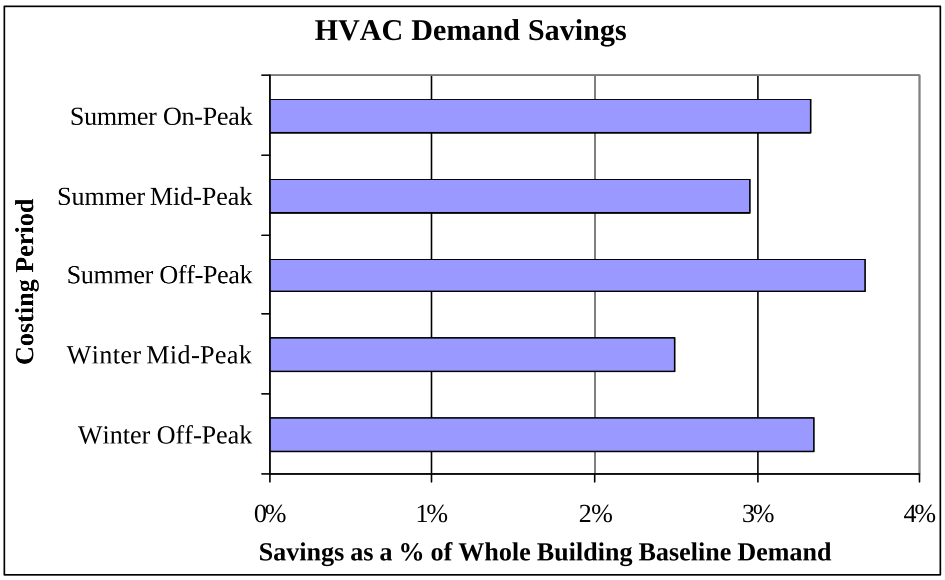


Figure 17: HVAC Summer On-Peak Demand Savings Relative to Whole Building Baseline

Figure 18 shows the measures only HVAC savings relative to the HVAC baseline demand.

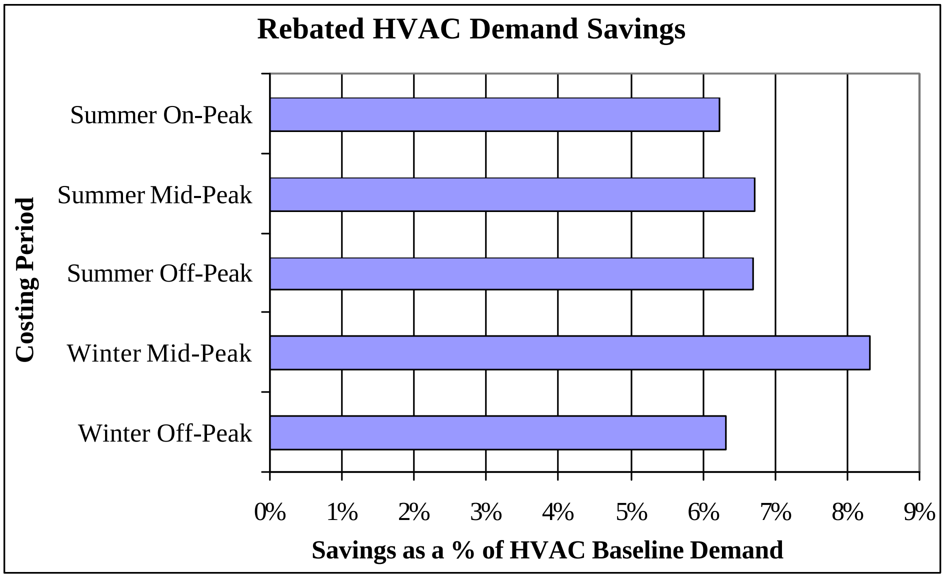


Figure 18: HVAC Measures Only Savings Relative to HVAC Baseline

Shell & Daylighting

The shell and daylighting control end-use accounted for 10.1% of the summer on-peak demand savings of the participants, or 0.56 MW. The relative precision of the estimate was ±11.1%. Table 25 shows the estimated savings by time-of-use period.

Period	Demand Savings (MW)	Relative Precision (+/-)
Summer On-Peak	0.56	11.1%
Summer Mid-Peak	0.17	22.0%
Summer Off-Peak	0.29	16.8%
Winter Mid-Peak	0.19	19.5%
Winter Off-Peak	0.18	34.1%

Table 25: Shell & Daylighting Summer On-Peak Demand Savings by Time-of-use Period

Figure 19 shows the savings of participants expressed as a percentage of their baseline demand.

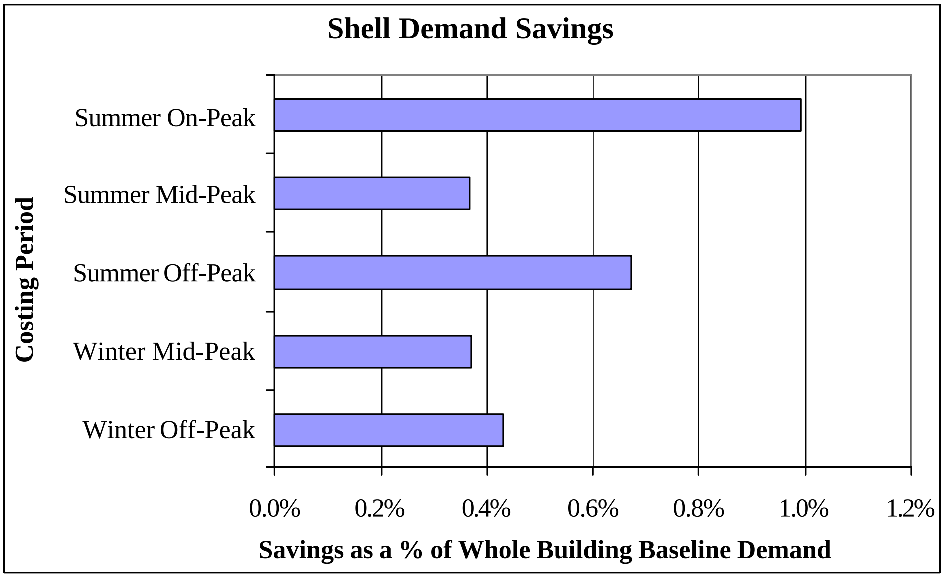


Figure 19: Shell & Daylighting Summer On-Peak Demand Savings Relative to Whole Building Baseline

Net Savings

A simple "difference of differences" estimation approach to net savings was done for the 1996 study. This method estimated net savings by comparing the savings of the participants in the sample to a "matched" sample of non-participants. The savings of the non-participant group were assumed to be the savings of the participants in the absence of the program. In this methodology, spillover among the non-participants was assumed to be offset by free-ridership among the participants but no attempt was made to measure either spillover or free-ridership. In accordance with a waiver filed and approved June 16, 1999, the results from the 1996 study were used for the 1998 NRNC study

The following table summarizes the 1996 findings from the difference of differences analysis. Table 26 shows the estimated net savings and net-to-gross ratio for both annual energy and summer peak demand savings. The net savings are the measured savings for the 1998 evaluation after the net-to-gross ratio was applied to the gross savings.

	Net-to-Gross Ratio	Net Savings
Annual Energy (MWh)	62.3%	17,951
Summer Peak Demand (MW)	52.0%	2.89

Table 26: Difference of Differences Net-to-gross Ratios

Parameters for Future Sample Designs

In order to lay groundwork for future sample designs, we used the 1998 sample data for annual energy savings to develop new estimates for the MBSS parameters. Table 27 compares the values of the parameters that were assumed in the sample design (estimated from the 1996 sample data) to the values estimated from the current sample.

The error ratio is the primary factor determining the statistical precision. The table shows that the error ratio was found to be slightly smaller than the assumed value. This indicates that the association between the measured annual savings and tracking savings was slightly stronger than expected, thereby giving slightly better statistical precision than anticipated.

The gamma parameter is used to construct the sample design. The value of gamma was found to be slightly smaller than assumed, indicating slightly less heteroscedasticity than expected. The difference is not material.

Model Parameter	Assumed Value	Estimated Value
error ratio	0.67	0.65
gamma	0.62	0.55

Table 27: Model-Based Sampling Parameters for Future Samples

Comparison Between the 1998 and 1996 Findings

Realization Rates

Table 28 compares the principle results between the 1998 and 1996 evaluation studies. The program savings estimates are the tracking savings in the two years. This shows that the 1998 program was smaller than the 1996 program.

The gross savings and realization rates are the results of the engineering analysis for the two programs. The gross realization rate for energy was found to be 116% in 1996 and 104.7% in the current study. In other words, the tracking savings in 1996 understated the measured savings by about 16% whereas the tracking savings in 1998 understated the measured savings by 4.7%. This suggests that the tracking estimates have become more accurate.

In the case of demand, the gross realization rate was found to be 115% in 1996 and 93.1% in 1998. In other words, the tracking savings in 1996 understated the measured savings by about 15% whereas the tracking savings in 1998 overstated the measured savings by about 7%.

		1996 Program Year	1998 Program Year
Energy (MWh)	Program Savings Estimate (MWh)	36,836	27,522
	Gross Savings (MWh)	42,730	28,813
	Gross Realization Rate	116.0%	104.7%
	Net to Gross Ratio	62.3%	62.3%
	Net Savings (MWh)	26,621	17,951
	Net Realization Rate	72.3%	65.2%
Demand (MW)	Program Savings Estimate (MWh)	8.81	5.97
	Gross Savings (MWh)	10.13	5.56
	Gross Realization Rate	115.0%	93.1%
	Net to Gross Ratio	52.0%	52.0%
	Net Savings (MWh)	5.27	2.89
	Net Realization Rate	59.8%	48.4%

Table 28: Comparison of Results between 1996 and 1998 Evaluations

Table 28 also shows the net to gross ratio in the two years. Following the waiver the 1998 net to gross ratio was taken to be equal to the 1996 net to gross ratio. The net savings were obtained by multiplying the gross savings that was measured in each of the two years by the net to gross ratio. The differences reflect the differences in the gross savings. Finally the net realization rate was calculated by dividing the net savings by the program savings estimate in each of the two years. The net realization rate is also equal to the gross realization rate times the net to gross ratio.

Reasons for the Change

Why did the gross realization rates change so greatly, particularly for demand, from 1996 to 1998? There are three possible causes:

- A change in the mix of building types in the two years,
- A change in the procedure for estimating the savings of each project, i.e., of calculating the tracking estimates of savings, and
- A change in the mix of measures and end uses.

We do not believe the first factor was a strong contributor to the change. With some exceptions, the mix of building types seemed to be generally the same between the two years. However, the 1998 program did include some building types not previously seen, such as a few refrigerated warehouses and perhaps more process loads.

The procedure for determining the program estimates of the savings was also a contributing factor. In the 1996 program, about half of the savings was associated with Design for Excellence projects in which the savings was estimated using a performance approach. In the remaining 1996 projects, the savings were calculated following a prescriptive approach that used unit energy savings (UES) tables. In the 1998 program, the 1996 UES tables were used to estimate the savings of virtually all of the projects. In other words, almost none of the 1998 projects were Design for Excellence projects.

The third possible explanation for the drop in the gross realization rate is a change in the end uses and measures addressed in the program. Table 29 compares the measured end-use savings in three categories: lighting, shell / daylighting, and HVAC categories. The energy and demand savings from shell / daylighting were essentially unchanged in the two years. But there was a substantial shift from lighting to HVAC in the measured energy savings from 1996 to 1998.

The shift in the energy savings from lighting to HVAC coincides with a new policy introduced in the 1998 program to increase the threshold for lighting measures. To the extent that the realization rate is higher for lighting than for HVAC, this shift could have contributed to the drop in the realization rate.

However, in the case of demand savings, the shift from lighting to HVAC is not observable in Table 29. This may be because HVAC measures provide relatively less on-peak savings compared to lighting measures. Much of the savings of HVAC measures come from improved part-load efficiency. Consequently, the shift from lighting to HVAC yielded less demand savings than energy savings.

It is important to note that the shift from lighting to HVAC was designed to reduce free ridership in the program, i.e., to increase the actual net to gross ratio from 1996 to 1998. This would indicate that the decision to use the 1996 net to gross ratio for the 1998 program may have been conservative. That is, the actual net to gross ratio and the resulting net savings may be understated.

% of Savings by Use	Lightin	Shell Daylightin	HVA
1998	55%	4%	41%
1996	70%	3%	27%
% of Savings by Use	**Lightin**	**Shell Daylightin**	**HVA**
1998	56%	10%	34%
1996	58%	9%	33%

Table 29: Comparison of Savings by End Use in the 1998 and 1996 Programs

Other Observations

The methodology used for this study has proven to be successful. The sample design provided highly reliable estimates of gross savings. In fact, the achieved statistical precision was almost identical to the anticipated precision. Indeed, in retrospect, the waiver to use a statistical sample rather than attempt a 100% audit proved to be wise. The sampling approach led to almost complete coverage of the largest projects and provided Sefficient use of the data collection resources.

The engineering audit and simulation tools developed by the RLW Team in prior NRNC evaluation studies have also proved to be very effective. RLW Analytics, AEC and ASW were able to collect and analyze large amounts of detailed data quickly using these tools. To be sure, this was not an inexpensive endeavor, but it has produced buildings characteristics and energy use information that is also very valuable for studies of market transformation, new construction energy codes, and other market research.

Given the quality of the audits and simulations, the waiver allowing more limited use of billing data also seems to have been sound. The validity of the engineering models would only have been reduced by calibrating the models to inappropriate billing data – e.g., sites for which there is a poor correspondence between the space affected by the project and the space served by the meter. These sites accounted for 22% of all the sites. Moreover, in the 1994 and 1996 studies, we found that calibration had a very small effect on the measured gross savings.

In retrospect, the third element of the waiver also seems to have been conservative since steps were taken to reduce free ridership in the 1998 program.

Finally, several additional aspects of the evaluation methodology should also be mentioned. These innovations were introduced in the 1996 evaluation as a response to lessons learned from the 1994 evaluation. The 1998 experience confirmed the validity of these observations:

- **The use of the same staff to survey buildings and build engineering models**. This approach allowed RLW Analytics, ASW and AEC to build much better models because the data was collected with a full understanding of the needs of the models. Also, because the person who developed the model was on-site, a much better "reality check" could be done using the judgement of the engineer.
- **Building the engineering model shortly after the site visit**. In the 1994 study, several months passed before the modeling staff could review the field

data, greatly increasing the chance that errors could not be adequately corrected. In the 1996 and 1998 studies, the initial models were built within days or weeks of the site visit. This, combined with the point above, greatly improved the quality of the models because the building was much fresher in the mind of the modeler.

- **A single, experienced construction professional was used to recruit and survey design professionals and building owners**. The use of someone who understood the industry was the primary reason that such a high participation rate was observed. This also helped with survey completion and data quality because the respondents felt as though the surveyor understood the subject matter and could speak on their level.
- **More active involvement by the study sponsors**. This study was truly a collaborative process between the SCE team and the RLW Analytics, ASW, AEC team. The active involvement of many talented people at SCE, the Heschong Mahone Group, and the involvement of members of the CADMAC New Construction subcommittee greatly contributed to the smooth flow of the project and to the quality of the final results.

Most of the cost and effort in this study involved the data collection and engineering model building tasks. Several steps were taken in those areas to improve the cost effectiveness of the study:

- **"Codify" engineering judgement**. A major innovation was the inclusion of less experienced auditors on the team. This led to substantial reductions in cost. Initially we were concerned that there might be a concomitant loss of quality. But with strong training and the tools that have been developed, these less experienced auditors were able to provide the high quality of data required in this project. This was possible because we have been able to capture much of the engineering judgement in the software itself, so that lower cost staff can be used in the data collection.
- **Improvements in the model building software**. The data entry, model building, and calibration modules of the software were more fully integrated to increase the throughput and reduce the human intervention needed to turn survey data into DOE models. This also contributed to the effectiveness of the less experienced auditors.

One final suggestion can be offered:

- **Revision of the CADMAC protocols on sampling**. To the extent that CADMAC sponsored regulatory studies like this one continue after January 1, 1998, a revision of the sampling protocols would benefit future studies. The wisdom of the CADMAC committee was evident in their approval of the waiver to allow this study's variance from the protocols. The results of the study show that this sampling approach is effective in capturing the required information at a significantly lower cost than would be required by a sample complying with the current protocol.

SOUTHERN CALIFORNIA EDISON PRE-1998 NON-RESIDENTIAL NEW CONSTRUCTION EVALUATION

FINAL APPENDIX

December 16, 1999

Study ID# 572

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SCE-06

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Appendix A. CADMAC Protocols Table 6

Southern California Edison
Study ID# 572

	Energy		Demand	
	Participant Group	Comparison Group	Participant Group	Comparison Group
	(per sqft in kwh/sqft/year)		*(per sqft in w/sqft)*	
Energy Usage				
Base Usage	401,986,930	na	56,755	na
Base usage per sqft	45.55	na	6.43	na
Impact Year Usage	373,173,695	na	51,194	na
Impact Year Usage per sqft	42.28	na	5.80	na
Gross Load Impact	28,813,235	na	5,561	na
Gross Load Impact per sqft	3.26	na	0.63	na
Net Load Impact	17,950,645	na	2,892	na
Net Load Impact per sqft	2.03	na	0.33	na
% Load Impact	7.2%	na	9.8%	na
% Load Impact per sqft	7.2%	na	9.8%	na
Gross Realization Rate	104.7%	na	93.1%	na
Net Realization Rate	65.2%	na	48.4%	na
Net-to-Gross Ratios				
Load Impacts	62.3%	na	52.0%	na
Load Impact per sqft	62.3%	na	52.0%	na
Square Footage				
Pre-Installation	8,825,484	na	8,825,484	na
Post-Installation	8,825,484	na	8,825,484	na
90% Precision				
Base Usage	11.8%	na	9.6%	na
Base usage per sqft	11.8%	na	9.6%	na
Impact Year Usage	12.7%	na	11.9%	na
Impact Year Usage per sqft	12.7%	na	11.9%	na
Gross Load Impact	6.7%	na	10.1%	na
Gross Load Impact per sqft	6.7%	na	10.1%	na
Net Load Impact	na	na	na	na
Net Load Impact per sqft	na	na	na	na
80% Precision				
Base Usage	9.2%	na	7.5%	na
Base usage per sqft	9.2%	na	7.5%	na
Impact Year Usage	9.9%	na	9.3%	na
Impact Year Usage per sqft	9.9%	na	9.3%	na
Gross Load Impact	5.2%	na	7.9%	na
Gross Load Impact per sqft	5.2%	na	7.9%	na
Net Load Impact	na	na	na	na
Net Load Impact per sqft	na	na	na	na

Measure Counts	Measure counts are not applicable to the design of this program

TABLE 6 CONTINUED

Population by Building Type	
Category	**Total**
C&I Storage	2.0%
Community Center	1.0%
Fire/Police/Jails	2.0%
General C&I	11.1%
Grocery	11.1%
Libraries	1.0%
Medical/Clinical	4.0%
Office	11.1%
Other	1.0%
Religious Worship, Auditorium, Convention	5.1%
Restaurant	11.1%
Retail	26.3%
School	12.1%
Theater	1.0%
Grand Total	100.0%

Appendix B. CADMAC Protocols Table 7

Southern California Edison
Study ID# 572

A. OVERVIEW INFORMATION

1. Study title and study ID number

Impact Evaluation of Southern California Edison's Pre-1998 Non-residential New Construction Programs. Study ID Number 572.

2. Program and year

SCE Pre-1998 Non-residential New Construction Program Carryover.

3. End uses measures

The study was directed primarily to the total load of the affected space. Lighting, shell measures, and HVAC were also examined.

4. Methods and models used

This study used an integrated combination of model-based statistical sample design, onsite audits, site-specific DOE-2 engineering models calibrated to billing data, short-term metering, econometric analysis and statistical expansion. See report body for methodological discussion.

5. Participant and comparison group definitions

Participants were sites that received a rebate during the 1997 and 1998 program year. A non-participant sample was not used. The net-to-gross ratio from the 1996 study was used in accordance with the retroactive waiver approved June 16, 1999 and included in the appendix.

6. Analysis sample sizes

Commercial gross analysis: 49 buildings.

B. DATABASE MANAGEMENT

1. Data quality checks

Strict quality control measures were carried out throughout the data collection phase of the project. They consisted of a number of range, consistency, and sanity checks on the collected data, as well as random spot-checks on auditors in the field. These procedures are discussed in detail in the report section on engineering models and data collection.

2. Data collected but not used

None.

C. SAMPLING

1. Sampling procedures and protocols

The participant sample was stratified by the program estimate of savings. Model based statistical sampling (MBSS™) methods were used to construct the strata and choose the sample sizes. See the report section on sample design.

2. Survey information

See report text and answer D 3 below.

3. Statistical descriptions

Standard descriptive statistics are misleading for a stratified ratio estimation since weighting is necessary to obtain meaningful results and the methods described in the report are needed to evaluate statistical precision. The report provides statistical results for all key variables that are properly expanded to the population, together with suitable error bounds at the 90% level of confidence.

D. DATA SCREENING AND ANALYSIS

1. Outliers, missing data, and weather adjustment

The following section discusses the methodology used in the 1996 evaluation. The net-to-gross ratio from the 1996 study was used to calculate the net savings for this study, thus the discussion was included in the appendix.

The full sample was retained throughout the analysis. Studentized residuals were used to identify outliers. A site was considered to be an outlier if its studentized residual was greater than three in absolute value. A separate indicator variable was used to represent each such outlier in the model. The coefficient of this indicator variable indicated how much the dependent variable deviated from its expected value for the particular outlier. The statistical significance of these indicator variables were used to identify outliers that were statistically significant.

Sites that refused to participate in the study were replaced using a randomly drawn sample of backup sites. The level of refusal was rather low, as discussed earlier in this report.

Weather adjustment was handled in the engineering modeling. The model calibration used actual weather concurrent with the available billing data. Then all models were run using typical meteorological weather data. In this way the gross savings determined by the engineering models reflected normal weather conditions expected in each climate zone.

2. Control for background variables

The experimental design provided two types of control: (a) engineering models which provided 'same-building' comparisons, and (b) the net-to-gross analysis which compared the results of the engineering models for the participant and non-participant subsamples. The engineering models provided the first 'line of defense' against biased findings. The engineering models were used to compare the 'as-built' building to the 'baseline' building. Here the baseline referred to a building that just complied with Title 24 code. The engineering models were normalized for weather. The occupancy schedules were based on the onsite information describing the normal occupancy of the building on a daily and monthly basis.

This led to our estimates of weather-normalized gross savings. The net-to-gross analysis, in turn, compared the gross savings found from the engineering models for the participant and non-participant subsamples. The net to gross analysis used econometric techniques to estimate the naturally occurring level of efficiency that would have been built in the absence of the program. The econometric analysis included additional explanatory variables to control for self-selection bias and other differences between participants and non-participants.

All of these procedures were designed to get a reliable, unbiased estimate of the net impact of the programs. In particular, the experimental approach was designed to control for the effect of changes in economic or political activity. Increased operating hours would increase the gross savings for both the participants and non-participants but be controlled for in the net savings.

3. Screening procedures

The tables below summarize the screening procedures used to arrive at the final analysis datasets. In the case of the onsite audits, 49 buildings were recruited for the audit.

5. Specification of Models

The "Engineering Models" section of the report describes the DOE-2 engineering models used to estimate the gross savings. The "Commercial-Net Savings" section of the report describes the econometric models that were used in the net to gross analysis.

Heterogeneity:	The DOE-2 engineering models were designed to represent the heterogeneity of sites in the program. The models were designed to represent all building types, functional zones and equipment types encountered in the sample sites. The econometric models were designed to explain the variation in efficiency choice from one site to another.

Time series variation: In the gross analysis, time series variation was controlled by the simulation methodology. The gross savings were calculated by simulating the building with and without the energy efficiency measures but holding other equipment and schedules fixed as observed. Time-series variation was not an issue in the net-to-gross regression analysis since all observations reflected the same time period. In other words, the regression modeling addressed variation from one same site to another, but not from one time point to another.

Self selection: Self selection was addressed in the net-to-gross analysis by developing a logistics model for the probability of participating, and then using the resulting double inverse Mills ratios as added explanatory variables in the efficiency choice models. The statistical significance and effect of the inverse Mills ratios were estimated and reported.

Omitted factors: Two factors might be discussed: the use of Title 24 documentation and billing data. The study sought to use both Title 24 documentation and billing data to the extent practical. When either Title 24 documentation or billing data was available, it was used to improve the accuracy of the engineering models. This approach allowed us to maintain the full sample even when these data were unavailable.

- The evaluation of the 1994 program clearly demonstrated the difficulty of obtaining Title 24 documentation, especially for the non-participants. In order to avoid high refusal rates and the concomitant risk of nonresponse bias, we only insisted on Title 24 documentation for sites that used the tailored lighting approach or the performance-based approach to Title 24 compliance.

Billing data was used to calibrate each individual engineering model whenever possible. However, as described elsewhere, the available billing data did not always reflect the space affected by the new construction. In some of these cases, we sought to supplement the billing data with our own metering. Nevertheless, some of the sites did not have actual usage data. In such cases we trusted that the engineering models were accurate without calibration. To confirm this assumption, we compared the gross savings determined before and after calibration for the sites with billing data or our metering. This analysis confirmed that the pre-calibration models were very accurate.

Net impacts: The combination of statistical sampling, onsite surveys, site-specific engineering models, econometric analysis, and statistical expansion was carefully designed to provide an unbiased and statistically reliable estimate of net program savings. In particular, the decision-maker survey was designed to isolate self-selection bias and the long-run impact of the program on design practice. The model was specified to include any observable and statistically significant effects of the program on the energy efficiency of both participants and non-participants.

6. Errors in measuring variables

In the onsite surveys and engineering modeling we sought to obtain an accurate representation of each individual sample site. Past experience suggested that serious errors could arise from failing to model the space in the building actually affected by the new construction, or by failing to accurately describe some of the equipment and schedules of use. The present study addressed these problems by improved training and communication with the auditors, earlier retrieval and review of program files, having the auditors themselves responsible for the data entry and modeling, and having the auditors develop the model for a site soon after completing its survey. The engineering team met with PG&E's program managers and reviewed the site-specific models in detail. We also redesigned the decision-maker survey, streamlined the process used to recruit each site and complete the decision maker survey, and assigned the responsibility for the whole process to a single, very competent person. All of these measures resulted in much more accurate data going into the econometric analysis than in the prior study.

7. Autocorrelation

Does Not Apply. All regression analysis was cross-sectional.

8. Heteroscedasticity

Heteroscedasticity – the tendency of larger projects to have greater variation – was addressed in both the sample design and efficiency-choice regression models.

The MBSS methodology used in the sample design addressed heteroscedasticity by modeling the variation in savings as a function of the tracking estimate of savings or the square footage of each site and then using an efficiently stratified sampling plan to increase the probability of selecting large sites. This ensures that the sample is effectively focused where the savings are greatest, while retaining an unbiased representation of small and large projects alike.

The efficiency-choice regression models were specified to minimize the danger of heteroscedastisity by defining the dependent variable as the gross savings as a fraction of the baseline energy use. This specification is closely related to the weighted-least-square methodology resulting from the assumption that the residual variation in gross savings is proportional to the baseline energy use of each site. Graphical scatter plots of the studentized residuals were examined to confirm the absence of Heteroscedasticity. In addition, a statistical test of homogeneity of variance was carried out to measure the statistical significance of differences in the variance of the residuals grouped by building type and by the level of efficiency predicted by the model..

9. Collinearity

Multicollinearity is generally a less serious problem in a cross sectional analysis than in a time series analysis. Our methodology was designed to protect against the type of problem that might arise in a cross sectional analysis. Extreme multicollinearity can cause computational problems. Several of the indicator variables used in the regression models were perfectly collinear. This occurred, for example, if a respondent who failed to answer a given question also failed to answer a second question. In this case the missing-response indicators would be perfectly collinear. The SPSS software used in the analysis identifies and reports these instances and automatically drops one of the variables from the analysis. The software also provides a warning if the multicollinearity is strong enough to affect the numerical accuracy of the estimated coefficients. In practice there was no indication of a serious problem with numerical accuracy.

When explanatory variables have strong but not extreme multicollinearity, it is important to guard against obtaining biased results. Omitted-variable bias can arise if one of the correlated variables is dropped from the model. We guarded against this possibility by systematically comparing the estimated coefficients of our various models and looking for other indicators such as large shifts in statistical significance.

10. Influential data points

We followed diagnostic procedures recommended by Belsley, Kuh and Welsh.[1] Our key indicator of an influential observation was the studentized residual, which can be related to the t-distribution. We also examined normal probability plots, partial-regression leverage plots for each explanatory variable, and other case-specific measures of influence. When an influential observation was identified, we included an indicator variable in the analysis that was 1 for the influential observation and 0 for all other cases in the sample. We retained this variable if it was statistically significant in the final model.

11. Missing data

See answer D.1. above.

12. Precision

In each regression model, we used standard logistics or least-squares techniques to calculate the standard error and statistical precision of each coefficient. We used the standard MBSS statistical techniques described in the Gross Savings chapter to expand to the econometric estimates for each sample site to the population and to measure the statistical precision of the results.

[1] D. A. Belsley, E. Kuh and R. E. Welsch, *Regression Diagnostics*, Wiley, 1980.

Appendix C. SCE NRNC Retroactive Waiver Request

SOUTHERN CALIFORNIA EDISON COMPANY
RETROACTIVE WAIVER REQUEST FOR
THE FIRST-YEAR IMPACT EVALUATION OF THE
PRE-1998 NONRESIDENTIAL NEW CONSTRUCTION PROGRAM
CARRYOVER
(Study ID #572)
Approved June 16, 1999

Summary of Request

In 1998, SCE paid rebates to 99 customers who had received rebate offers from the Company's Nonresidential New Construction Program before 1998, but whose construction was not completed until 1998. This waiver requests deviations from the Protocols for the first-year impact evaluation of this 1998 Nonresidential New Construction Program activity. The first two parts of this request are very similar to the deviations previously requested by SCE and approved by CADMAC for SCE's 1994 and 1996 Nonresidential New Construction Programs. The third is based on use of the information developed in those previous studies. The following variations are requested:

1. Achieve the requisite precision and confidence levels with a reduced sample size of 49 participants.
2. Require the use of billing data only for sites for which reliable data are available and the metered area corresponds well to the area affected by the program.
3. Use the net-to-gross ratio adopted for the 1996 Nonresidential New Construction Program rather than developing a new one from new comparison group data.

The table below summarizes basic information about the program.

Program Summary

1998 Nonresidential New Construction Program (DSM Carryover)

Number of Participants	99
Administrative Costs	$ 500,000
Incentive Costs	$ 1,874,000
Total Program Costs	$ 2,374,000
Resource Benefits, net	$ 8,056,000
Earnings	$ 964,000

Parameter 1: Sample Size Requirement

Protocol Requirement

Table C-8, Participant Item 1, which refers to Table 5, Section C on required sample sizes Table 5 requires that: 1) a sample must be randomly drawn and be sufficiently large to achieve a minimum precision of plus/minus 10% at the 90% confidence level, based on total annual energy use; and 2) the sample must be an attempted census if the number of participants is less than 350, with a minimum of 150 participants being required.

Waiver Alternative

Permit a smaller sample size, based on model-based sampling, that is designed meet the precision requirements specified in Table 5 with a lower sample size than Table 5 requires. The sample size will be based on precision for energy savings estimates, rather than annual energy use, since estimating energy savings is the objective of the study.

Rationale

The draft sample design for this project indicates that SCE can meet the required precision level applied to estimated energy savings with a sample size of 42, and that with a sample size of 49, a precision level of plus/minus 7% can be achieved. SCE proposes to use a participant sample size of about 49.

Because of the rigorous and costly methods of data collection and analysis used in these studies to accurately estimate energy savings for each site, it is important to control costs by keeping the sample as small as it can be while meeting precision requirements. Since a smaller sample size, if carefully designed, can meet the precision requirements laid out by the Protocols, requiring larger sample sizes would raise measurement costs and customer burden without adequate justification.

Parameter 2: Requirement for Use of Billing Data

Protocol Requirement

Table C-8, Item 3, The End Use Consumption and Load Impact Model requires that billing data be used as the primary determinant of energy usage. In partial contradiction, Table C-8 Comparison Group Item 1 appears to make use of billing data optional, but states that "If used, a minimum of nine months of billing data are required for both participants and nonparticipants."

Waiver Alternative

Use available billing data for calibration when it is reliable and the metered area corresponds well to the area affected by the program.

Rationale

For impact evaluations of new construction programs that use detailed engineering simulation models to determine whole building energy use and measure savings, billing data are used to check the accuracy of the models through a calibration process. The billing data are not used in the traditional sense of a billing analysis.

Experience, including experience on the 1994 and 1996 evaluations, has shown that the usefulness of billing data for calibration purposes is often limited because:

- The building area served by the billing meter and the participant area of the building often do not coincide.
- Billing data are often difficult to match to customer sites, even with meter numbers from the site.
- There are typically other energy uses in the building, such as escalators or outdoor lighting, which have little impact on energy savings but which show up on the billing meter.
- Occupancy of the building may vary substantially from month to month during the initial years of its life, leading to erratic billing meter readings.

In the 1994 Nonresidential New Construction Program Impact Evaluation, intense efforts were made to obtain billing data for surveyed sites. Even so, billing data could not be located for 28% of the surveyed sites, and another 21% of the sites did not have billing data that matched the surveyed building areas. Of the billing data that were gathered, 5% of the sites had so many missing records as to render the data useless for calibration purposes. Another 12% of the building models simply would not calibrate to the billing data due to unknowns about either the building or the constituents of the billing data. This left 34% of the building models which were successfully calibrated to within plus/minus 10% on a monthly basis.

Because of these calibration problems, SCE proposes to use billing data for calibration only when they are available for the customer site and when there is a strong correspondence between the metered areas and the area affected by the program.

It should be noted that even when buildings have adequate billing data, the model calibration remains an exercise in judgment. Matching the model outputs to the billing data ensures that the estimates of overall energy usage are more accurate, but it is impossible to know the degree to which the savings estimates are more accurate than before the calibration.

In the 19994 evaluation, a set of 103 calibrated model savings estimates were compared to their pre-calibrated savings estimates. There was a very strong correlation between the pre- and post-calibration savings estimates and only an average of 2% difference between the estimates. The calibrated model savings were slightly smaller. These results indicate that the effect of calibration was small relative to the statistical precision of the final results.

Parameter 3: Requirement for Use of A New Comparison Group to Develop a Net-to-Gross Ratio

Protocol Requirement

Table C-8, Nonparticipant, requires that a comparison group of nonparticipants be used to develop a net-to-gross ratio. Table 5 implies that alternative methods of analysis can be used to develop a net-to-gross ratio using participant or nonparticipant information. These include a simple difference-of-differences approach or an econometric analysis of differences between participants and nonparticipants in their energy efficiency choice and program participation.

Waiver Alternative

Use the 60% net-to-gross ratio developed from the simple difference-of-differences approach in the first-year impact evaluation of the 1996 nonresidential new construction program.

Rationale

In 1996, SCE used both difference-of-differences and econometric approaches to estimate the net-to-gross ratio. In 1994, SCE used an econometric approach. The most justifiable econometric net-to-gross ratios developed in these two studies were between 60 and 70%, although alternative specifications varied widely. The 60% net-to-gross ratio produced by the difference-of-differences approach was finally agreed upon in the case management process for the second earnings claim for the 1996 program.

At this point, there are two previous SCE studies providing evidence on the likely level of the net-to-gross ratio, with no result lower than the 60% adopted for 1996. The previous PG&E and SDG&E studies of their nonresidential new construction programs have found net-to-gross ratios above 60%. Therefore, there seems to be little likelihood that using the 1996 study results will create an over-estimate. Using the previous ratio reduces the burden on nonparticipating customers of being included in a lengthy evaluation study, takes advantage of numerous studies already done, produces a conservative estimate for earnings purposes, and eliminates the need for regulatory review and contention over a new net-to-gross analyis.

In addition, this year, three of the large sites participating in the program are unique (a jail, an aquarium, and an airport). There are no adequate comparison group counterparts for these sites. So for these sites, a net-to-gross ratio derived from other participants in 1998 or from earlier studies would be necessary in any case.

Table A
Summary of Retroactive Waiver for Study #553
Retention Measurement Requirements - Table 9A

Parameter	Protocol Requirements	Waiver Alternative	Rationale
TableC-8, Participant Item 1, which refers to Table 5, Section C	Sample size must be an attempted census and have a minimum sample size of 150, if the program has less than 350 participants.	Permit a smaller sample size that is designed to meet the Protocol precision requirements of plus/minus 10% with 90% confidence.	The program only has 99 participants. The precision requirements can be more than met with a sample of 49, reducing study cost and customer burden.
TableC-8, Participant Item 3, and Comparison Group Item 1	Item 3 requires use of billing data as primary determinant of usage. Item 1 says if billing data are used, a minimum of nine months are required.	Use available billing data for calibration when the metered area corresponds well to the area affected by the program.	Calibration is impossible for a large fraction of sites because the metered area does not correspond well to the program-affected area, and for several other reasons that render billing data unavailable or not meaningful for developing good estimates of energy savings.
Table 5, Sections C and D; TableC-8, Comparison Group	The comparison group sample will be drawn using the same criteria for participants. Comparison group usage (A) includes customers who installed applicable measures	Do not use a new comparison group for 1998. Instead, use the 60% net-to-gross ratio derived by the difference-of-differences approach in the study of the 1996 program.	Counterparts for some major, unique sites could not be identified for a 1998 comparison group. In addition, several previous studies have established this as the lower bound of reasonable estimates. Using it reduces respondent burden, cost, and the need for regulatory review.

Appendix D. On-Site Survey Instrument

General Information

Site ID # [ ]

Surveyor Name:	Building Name:

Date:	Primary Contact:	Phone:

Building Address:	
City	Zip

Interview Questions

The following interview questions will be used to help us identify unobservable aspects of your building. These aspects include occupancy history, schedules, and heating and cooling controls. Answers to these questions will be coupled with data collected from our walk-through audit to produce a model which simulates the annual energy use of the building.

Building Overview

Q1. Characterize the building type according to the standard CEC building types.

Enter type code____________

Q2. What is the overall building floor area? ____________SF

Q3. What is the floor area of the applicable new construction?

( ) same as overall building floor area ____________SF

Q4. Have there been any significant changes in building use, occupancy patterns, operating hours, or additions/removal of large electrical loads that may affect energy consumption since the building was built?

List changes:

Q5. How many individual tenants (businesses) occupy this building? __________________

Q6. Do the majority of tenants have their own electric meter? Y N

The remainder of this survey deals with the applicable new construction (treated space for participants, 1998 new construction that would have been eligible for the program for non-participants)

Q7. What was the method used for Title 24 compliance?

Envelope (ENV):	Component ( )	Overall envelope ( )	Performance ( )	
Mechanical (MECH):	Prescriptive ( )	Performance ( )		
Lighting (LTG):	Complete building ( )	Area category ( )	Tailored ( )	Performance ( )

Q8. Which statement best describes the operation of the building?

( ) The entire building operates on *basically* the same schedule.
( ) There are areas of the building (departments, tenants, etc.) that have *substantially* different operational schedules.

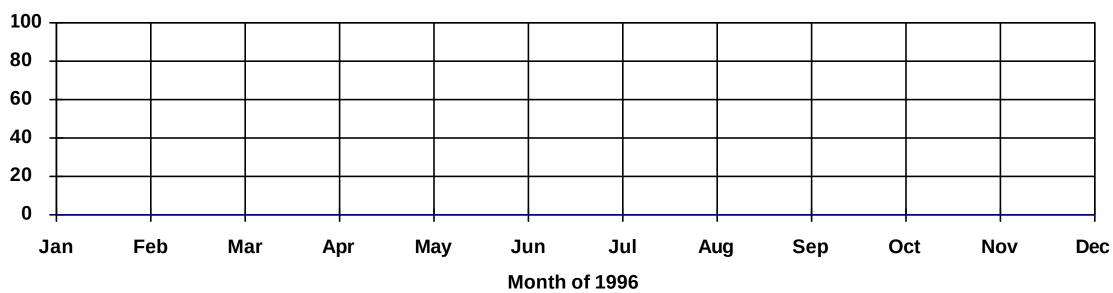
Q9. If different operational schedules exist, divide the building into areas with differing schedules, and provide a name for each area:

1. ________________________
2. ________________________
3. ________________________
4. ________________________
5. ________________________

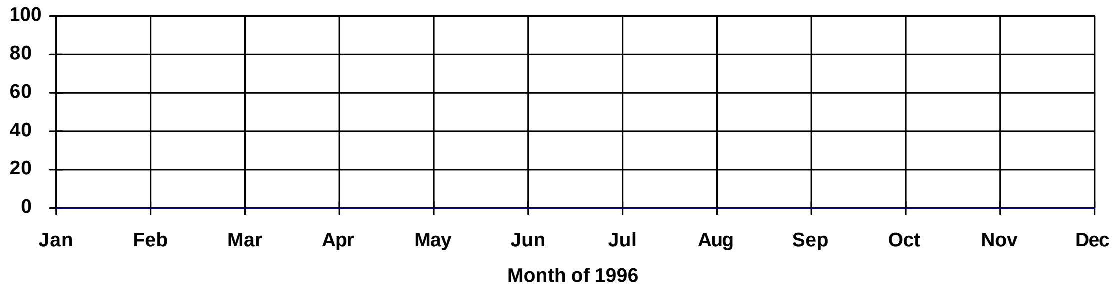
Building-Wide Occupancy History

The following questions are designed to help us understand how the vacancy rate of the building has changed over time. The period we are concerned with is the year 1998.

Q10. Draw a line that indicates the percentage of the building that was occupied (% of floor area) for 1998.



Q11. Draw a line that indicates the percentage of the building that was conditioned (% of floor area) during 1998.



( ) Building-Wide (fill out only one page)	**- or -**	**Area #___ and Area Name ______________________** (fill out one page per area)

Schedules

The following questions will help us establish schedules for the building.

Q12. What would be the best way to group the days of the week to describe the operation of this area? One of the three operation levels must be assigned to each day of the week.

	M	Tu	W	Th	F	Sa	Su	Holiday
Full operation:	( )	( )	( )	( )	( )	( )	( )	( )
Light operation:	( )	( )	( )	( )	( )	( )	( )	( )
Closed:	( )	( )	( )	( )	( )	( )	( )	( )

Q13. Are there any months that this area has higher or lower than normal operating hours? Indicate months of increased or decreased operating hours. Normal (100%) is assumed for blank entries.

	Lighting % of Normal	HVAC % of Normal	Equip and Process % of Normal
Jan	____%	____%	____%
Feb	____%	____%	____%
Mar	____%	____%	____%
Apr	____%	____%	____%
May	____%	____%	____%
Jun	____%	____%	____%
Jul	____%	____%	____%
Aug	____%	____%	____%
Sep	____%	____%	____%
Oct	____%	____%	____%
Nov	____%	____%	____%
Dec	____%	____%	____%

Q14. Which holidays are observed (check all that apply)

( ) New Years day ( ) MLK day ( ) Presidents' day ( ) Memorial day

( ) July 4th ( ) Labor day ( ) Columbus day ( ) Veteran's day

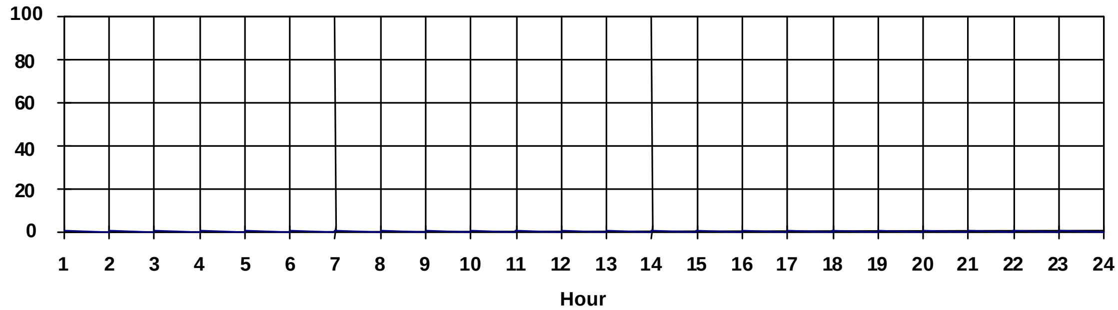
( ) Thanksgiving ____ days ( ) Christmas _____ days

Note: Holidays for 1998:

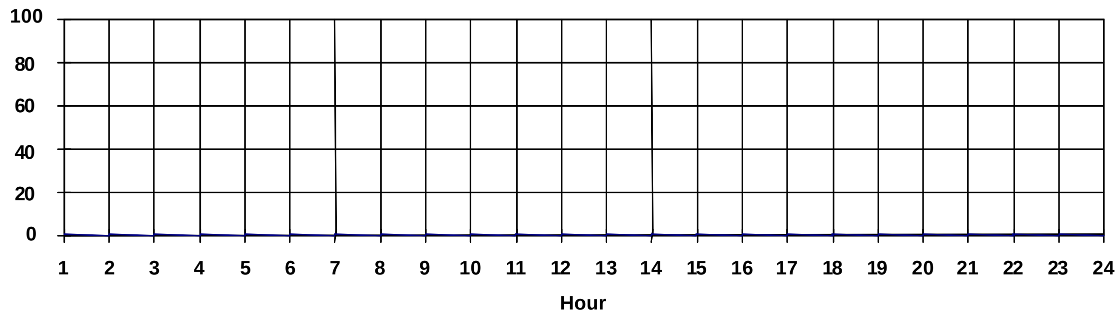
Holiday	Day/Date	Holiday	Day/Date
New Years day	Mon, Jan 1	Labor day	Mon Sep 2
MLK day	Mon Jan 15	Columbus day	Mon Oct 14
Presidents' day	Mon Feb 19	Veteran's day	Mon Nov 11
Memorial day	Mon May 27	Thanksgiving	Thur Nov 28
July 4^{th}	Thur Jul 4	Christmas	Wed Dec 25

( ) Building-Wide	**- or -**	**Area #___ and Area Name _______________________**
(fill out only one page)		(fill out one page per area)

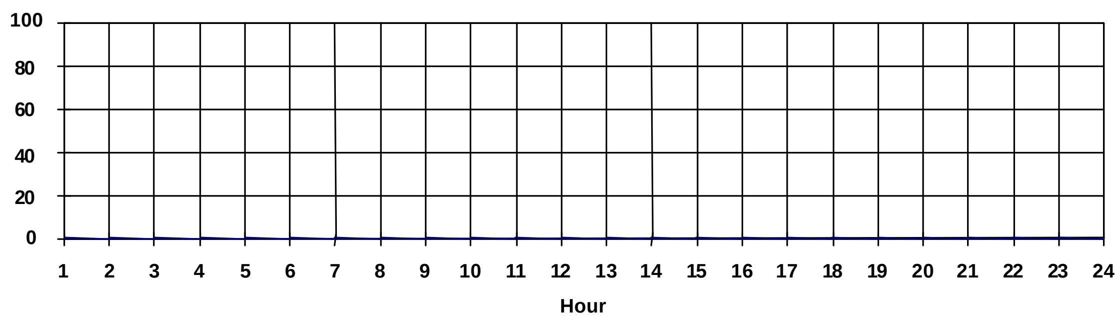
Q15. Draw a line that describes the ***occupancy*** schedule for a ***full operation day***. (1 and 24 should be the same.)



Q16. Draw a line that describes the ***occupancy*** schedule for a ***light operation day***.

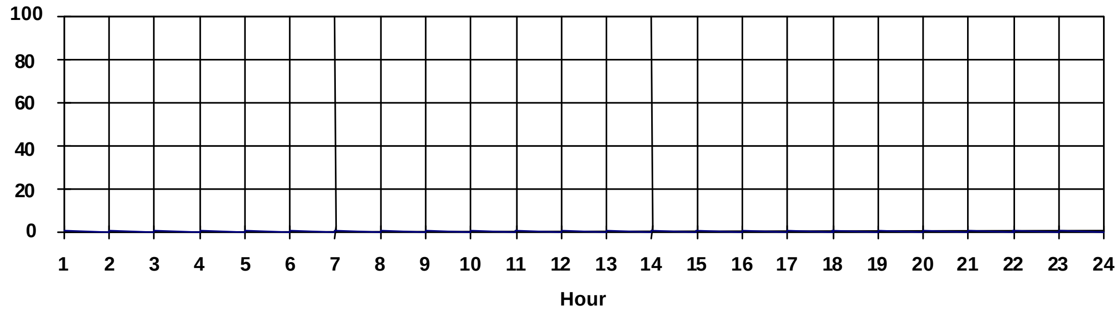


Q17. Draw a line that describes the ***occupancy*** schedule for a ***closed operation day***.

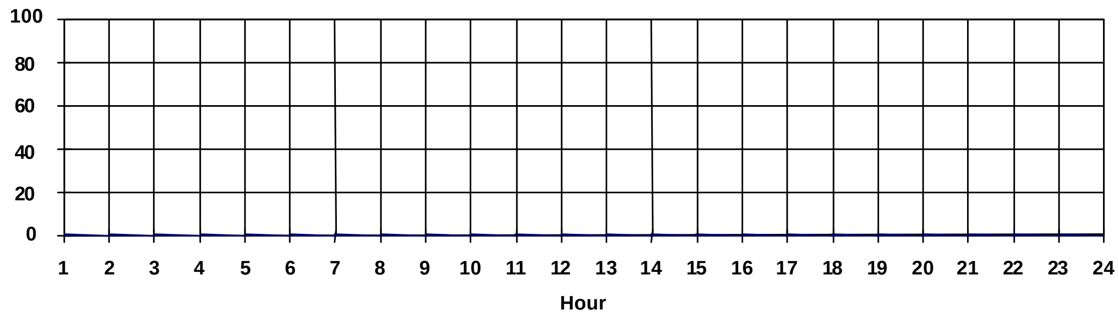


( ) Building-Wide	**- or -**	**Area #___ and Area Name ______________________**
(fill out only one page)		(fill out one page per area)

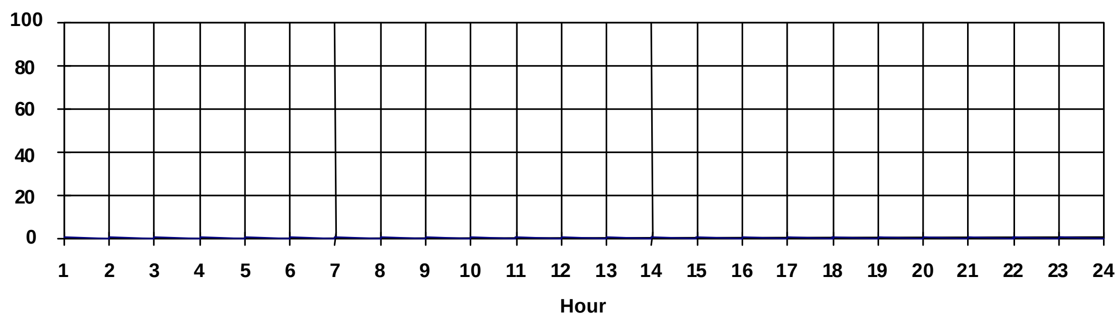
Q18. Draw a line that describes the schedule of use for ***interior lighting*** for a ***full operation day***.



Q19. Draw a line that describes the schedule of use for ***interior lighting*** for a ***light operation day***.



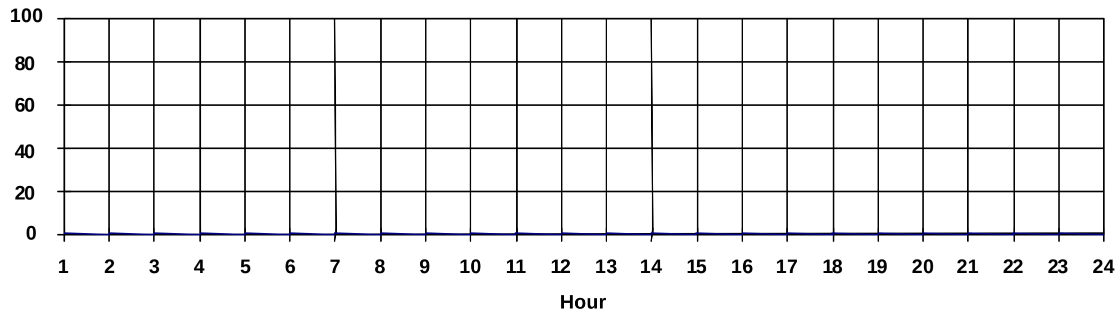
Q20. Draw a line that describes the schedule of use for ***interior lighting*** for a ***closed operation day***.



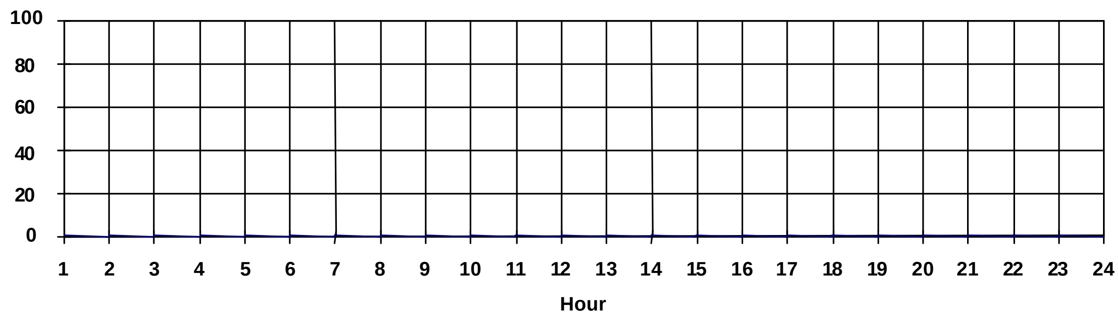
( ) Building-Wide	**- or -**	**Area #___ and Area Name ______________________**
(fill out only one page)		(fill out one page per area)

Miscellaneous equipment and plug loads refer to any electrical equipment located in the conditioned space which is not lighting or HVAC

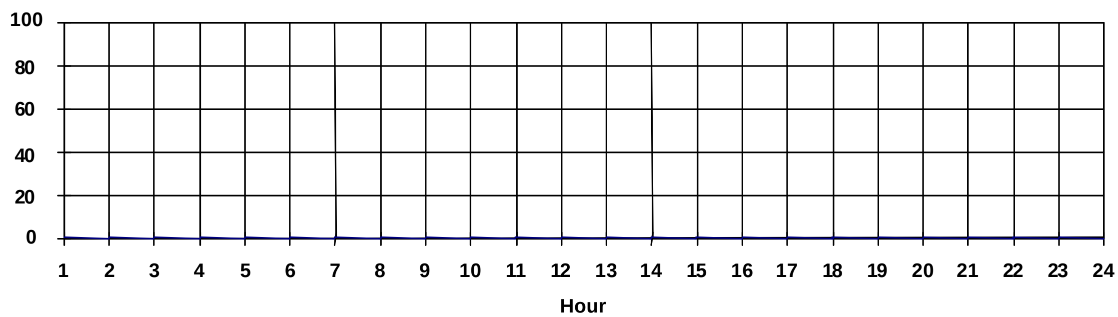
Q21. Draw a line that describes the schedule of use for ***miscellaneous equipment and plug loads*** for a ***full operation day***.



Q22. Draw a line that describes the schedule of use for ***miscellaneous equipment and plug loads*** for a ***light operation day***.



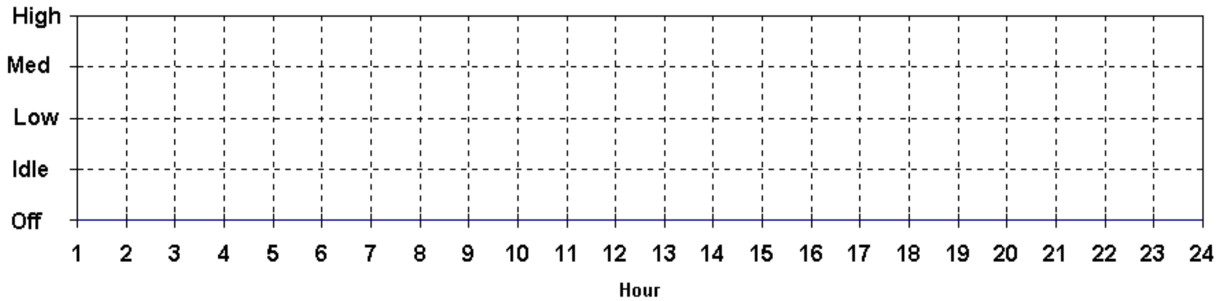
Q23. Draw a line that describes the schedule of use for ***miscellaneous equipment and plug loads*** for a ***closed operation day***.



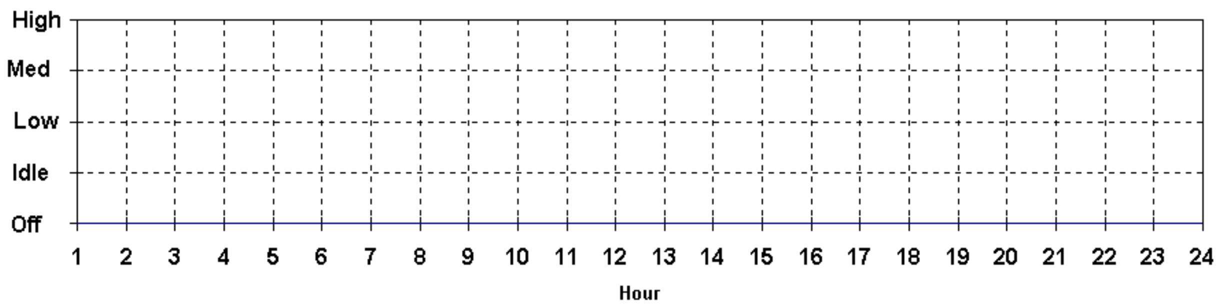
( ) Building-Wide (fill out only one page)	**- or -**	**Area #___ and Area Name ______________________** (fill out one page per area)

Kitchen Operation

Q24. If the area has a commercial kitchen, draw a line that describes the schedule of use for ***kitchen equipment*** for a ***full operation day***. (1 and 24 should be the same.)



Q25. If the area has a commercial kitchen, draw a line that describes the schedule of use for ***kitchen equipment*** for a ***light operation day***.



( ) Building-Wide	**- or -**	**Area #___ and Area Name ______________________**
(fill out only one page)		(fill out one page per area)

HVAC Fan System Operation

Q26. Draw a line that describes the air handler fan operation for a ***full operation day***. ( ) DK

on																								
off																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

Q27. Draw a line that describes the air handler fan operation for a ***light operation day***. ( ) DK

on																								
off																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

Q28. Draw a line that describes the air handler fan operation for a ***closed operation day***. ( ) DK

on																								
off																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

( ) Building-Wide - or - (fill out only one page)	**Area #___ and Area Name ______________________** (fill out one page per area)

Room Thermostat Setpoints

Q29. Enter the values and draw a line that describes the room temperature thermostat setpoints for a ***full operation day***. DK ( )

Unocc CSP																									
Occ CSP																									
Occ HSP																									
Unocc HSP																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

Q30. Enter the values and draw a line that describes the room temperature thermostat setpoints for a ***light operation day***. DK ( )

Unocc CSP																									
Occ CSP																									
Occ HSP																									
Unocc HSP																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

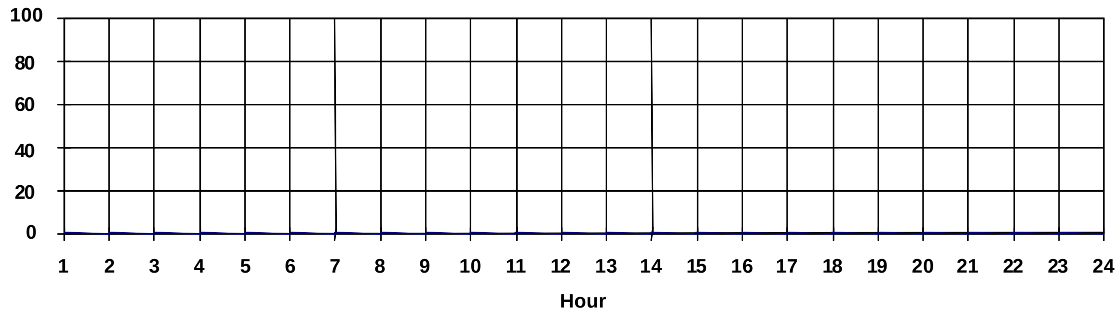
Q31. Enter the values and draw a line that describes the room temperature thermostat setpoints for a ***closed operation day***. DK ( )

Unocc CSP																									
Occ CSP																									
Occ HSP																									
Unocc HSP																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

Exterior Lighting

Q32. How are the exterior lights controlled? ( )Time clock ( )Photocell ( )Both ( )Neither ( )DK

Q33. If the exterior lights are controlled with a time clock, draw a line that describes the *average* time clock schedule throughout the year. (1 and 24 should be the same.)



Window Shading

Q34. If there are shades or blinds on windows, which ***best*** describes their general use?

( ) Always open
( ) Always closed
( ) Operated by occupants to control comfort
( ) Open when space is occupied, closed otherwise

Swimming Pools

Q35. If the building has a heated swimming pool, what water temperature is maintained? ________°F

Q36. If the building has a heated swimming pool, is a pool cover used? Y N

Q37. If a cover is used, at what time is it normally put on the pool? _____ (military time, blank if DK)

Q38. If a cover is used, at what time is it normally removed from the pool? _____ (military time)

Spas

Q39. If the building has a spa, what water temperature is maintained? ________°F

Q40. If the building has a spa, is a cover used? Y N

Q41. If a cover is used, at what time is it normally put on the spa? _____ (use military time)

Q42. If a cover is used, at what time is it normally removed from the spa? _____ (use military time)

Central HVAC Design and Control

The following questions will help us to understand how the HVAC systems operate in the building. (These questions are designed to be answered by someone familiar with the operation of the building mechanical and control systems.)

Q43. What is the minimum cooling supply air temperature setpoint ______°F ( )DK

Q44. If system is VAV, what type of terminal boxes are used (check all that apply):

( )non-powered (standard) VAV boxes ( )fan-powered induction-type VAV boxes ( )DK

Q45. What is the condenser water setpoint temperature ______°F ( )DK

Q46. If the building has chillers and cooling towers, is the system equipped with a water-side economizer? Y N DK

Q47. If yes, what type of water-side economizer is used?

( ) Strainer cycle ( ) Thermosyphon ( ) Plate-frame heat exchanger ( ) DK

Q48. Circle the months of the year when the water-side economizer system is typically used:

J F M A M J J A S O N D DK

Q49. Is the heating system turned off (locked out) on a seasonal basis? ( ) Yes ( ) No

Q50. If yes, indicate the months when the heating system is typically available:

J F M A M J J A S O N D DK

Q51. List the building control strategies used, and whether they are implemented by a building energy management system (EMS):

Control Strategy	EMS?	M?
On/off scheduling of air handlers or AC systems		
Room temperature setpoint control		
Supply air reset based on ( ) outside temperature, ( ) zone temperature		
Optimum fan startup ( )		
Condenser water setpoint ( ) fixed, ( ) reset on outdoor temperature		
Outdoor air (economizer) control ( ) temp, ( ) enthalpy ( ) CO_2		
Chilled water reset based on ( ) outside temperature, ( ) zone temperature		
DDC of supply air flow rate based on terminal flow rate requirements ( )		
Peak demand limiting (explain)		
Lighting sweeps		
Daylighting controls		
Occupancy sensor controls		
Other (list)		

Refrigeration System

Q52. Does the building have a refrigeration system with remote condensers? Y N
If no, skip the remaining questions pertaining to refrigeration systems.

Q53. What is the minimum condensing temperature setpoint? ______°F, Q54. For each circuit temperature, what type of defrost is typically used?

a. Low temp (Ice cream) ( )electric ( )hot gas ( )time off ( )DK

b. Med temp (Frozen food) ( )electric ( )hot gas ( )time off ( )DK

c. High temp (All others) ( )electric ( )hot gas ( )time off ( )DK

Commissioning

Commissioning is a process of ensuring that the building systems perform according to their design intent, and meet the needs of the occupants. Commissioning can also be viewed as "quality assurance." It is a process that ensures that the contractor delivers a building that "works" the way the architect or engineer designed it. Commissioning is generally coordinated through an independent commissioning agent.

Q55. Was there a formal commissioning process for the building's HVAC and lighting control systems, with a designated owner's representative, such as a commissioning agent, to lead it?

☐ Yes
☐ No [Go to Q59]
☐ Don't Know [Go to Q59] If respondent cannot answer questions, identify who can:

Name: ______________________ Company: ______________________

Title: _______________________ Phone: _____________

Q56. If so, who performed the commissioning activities? (check all that apply)

☐ Mechanical contractor
☐ Electrical contractor
☐ T&B contractor
☐ Engineer
☐ Architect
☐ Independent commissioning agent
☐ Other (describe): ____

Q57. How much in total would you estimate the commissioning process added to the cost of the project? $ _________________

Q58. Which of the following quality assurance procedures or commissioning services, if any, were used on this project? [Read all]

☐ Quality assurance review of design documents
☐ Delivery of building systems documentation
☐ Training of building operators
☐ Testing of building system performance
☐ Other (describe): ____
☐ None/done only on an as needed basis

Q59. On a scale of 1 to 5, with 1 being extremely unfavorable and 5 being extremely favorable, how would you view Southern California Edison as a potential provider of commissioning services?

[1-5] ______ Comment: ____

Q60. Who is responsible for regularly scheduled building O&M? [Read all]

☐ In-house staff
☐ Outside contractor
☐ Combination of both

Q61. Have you had any equipment or system operating problems that caused thermal discomfort or excessive energy consumption?

☐ Yes [Describe]: ____
☐ No
☐ Don’t Know

To assist modeling, use the following list to prompt respondent and identify whether any operational problems have occurred:

Problem	**System(s) affected (Lighting, HVAC etc.)**
HVAC system under or oversized	
Insufficient or excess air flow	
Faulty control sensors	
Improper control sensor installation or location	
Insufficient sensor points for control and/or monitoring	
Improper EMS or control system programming	
Control systems "locked out" (left in manual position)	
Faulty valve or damper linkage or actuators	
Loose fan belts and / or improper alignment	
Improper ductwork installation	
Leaky valves or pipe fittings	
Defective major components (compressors, pumps, fans, etc.)	
Refrigerant leakage	
Fouled evaporative cooler media	
Water treatment problems (corrosion or bacterial growth)	
Other (list)	

Built-Up HVAC Systems

(Do not enter backup or stand-by equipment)

Chillers/ Large Split DX

	CH-1	M?	CH-2	M?	CH-3	M?
Equipment Name						
Location						
Quantity						
Manufacturer						
Model Number						
Serial Number						
Size (tons)						
Type code						
Full-load efficiency (kW/ton)						
Air-Cooled Cond. Fan hp						

Towers/ Evaporative Condensers

	T-1	M?	T-2	M?	T-3	M?
Equipment Name						
Location						
Quantity						
Manufacturer						
Model Number						
Total Fan hp						
Fan Control	1-Sp / 2-Sp / Pony / VSD		1-Sp / 2-Sp / Pony / VSD		1-Sp / 2-Sp / Pony / VSD	
Total Spray Pump hp						

Heating System

	HS-1	M?	HS-2	M?	HS-3	M?
Equipment Name						
Location						
Quantity						
Manufacturer						
Model Number						
Capacity (if elec) kW						
Type	Steam / HW / Furnace / Duct Htr		Steam / HW / Furnace / Duct Htr		Steam / HW / Furnace / Duct Htr	
Fuel	Electric / Other		Electric / Other		Electric / Other	

Built-Up HVAC Systems (cont.)

(Do not enter backup or stand-by equipment)

Central Air Handlers

Name	AH-1	M?	AH-2	M?	AH-3	M?
Equipment Name						
Location						
Quantity						
Type	Sngl Duct /Dual Duct/ Multi-Zone		Sngl Duct /Dual Duct/ Multi-Zone		Sngl Duct /Dual Duct/ Multi-Zone	
Evaporative System Type	None / Direct / Ind / Ind-Dir		None / Direct / Ind / Ind-Dir		None / Direct / Ind / Ind-Dir	
Supply Fan Type	CV / 2-Spd / VAV		CV / 2-Spd / VAV		CV / 2-Spd / VAV	
Supply Fan Control	CV / Cycles / VSD/ Discharge / Inlet		CV / Cycles / VSD/ Discharge / Inlet		CV / Cycles / VSD/ Discharge / Inlet	
Supply Fan Flow Rate (cfm)						
Supply Fan Motor HP						
motor efficiency						
Return/ Relief Fan HP						
motor efficiency						
OA Control	Fixed / Temp / Enthal		Fixed / Temp / Enthal		Fixed / Temp / Enthal	
OA Fraction						

Pumps

Pump	**Name**	**HP**	Motor effic %	M?	**Control**	M?	**Location**	**Loop**	**Use**
P-1					CV / 2-spd / VSD			CHW / Cond / HW	Pri / Sec
P-2					CV / 2-spd / VSD			CHW / Cond / HW	Pri / Sec
P-3					CV / 2-spd / VSD			CHW / Cond / HW	Pri / Sec
P-4					CV / 2-spd / VSD			CHW / Cond / HW	Pri / Sec
P-5					CV / 2-spd / VSD			CHW / Cond / HW	Pri / Sec
P-6					CV / 2-spd / VSD			CHW / Cond / HW	Pri / Sec
P-7					CV / 2-spd / VSD			CHW / Cond / HW	Pri / Sec
P-8					CV / 2-spd / VSD			CHW / Cond / HW	Pri / Sec

Packaged HVAC Systems

	AC-1	M?	AC-2	M?	AC-3	M?
Equipment Name						
Location						
Quantity						
Type Code						
Manufacturer						
Model No. (outdoor - all)						
Model No. (indoor if split)						
Cooling Capacity (ton)						
Efficiency	EER SEER		EER SEER		EER SEER	
Supply CFM						
Heating Fuel	Elec / Other		Elec / Other		Elec / Other	
Heating Capacity (kBtuh)						
Heating COP						
Evap Condenser	Yes / No		Yes / No		Yes / No	
Evaporative System Type	None / Direct / Ind / Ind-Dir		None / Direct / Ind / Ind-Dir		None / Direct / Ind / Ind-Dir	
Supply Fan Type	CV / 2-Spd / VAV		CV / 2-Spd / VAV		CV / 2-Spd / VAV	
Supply Fan Control	CV / Cycles / VSD Discharge / Inlet		CV / Cycles / VSD Discharge / Inlet		CV / Cycles / VSD Discharge / Inlet	
Supply Fan HP						
Return/Relief Fan HP						
OA Control	Fixed / Temp / Enthal		Fixed / Temp / Enthal		Fixed / Temp / Enthal	
OA Fraction						

Zone 1 2 3 4 5

Name ______________________ Zone Multiplier ________ HVAC zoning by exposure? Y N

Exterior Surfaces

Name	**Assembly Name**	Type Code	**R-value (or)**	**U-value (Btu/hr-SF-F)**	**HC (Btu/SF-°F)**	**Orient**	**H (ft)**	**W (ft)**	M?
S-1						N S E W H			
S-2						N S E W H			
S-3						N S E W H			
S-4						N S E W H			
S-5						N S E W H			
S-6						N S E W H			

Windows

Name	**Assembly Name**	Type Code	**SC**	**U-value**	**Orient**	**H (ft)**	**W (ft)**	**Qty**	**Int. Shade Code**	**% shade**	**Ext. Shade Code**	**OH Off (ft)**	**OH Proj (ft)**	M?
W-1					N S E W H									
W-2					N S E W H									
W-3					N S E W H									
W-4					N S E W H									
W-5					N S E W H									
W-6					N S E W H									

Zone-Level HVAC Equipment (Not Central, Not Packaged)

Name	**Type Code**	**Quantity**	Fan Hp	**Heat Source**	kW (If elec. heat)
ZS-1				**None / Elec. / Other**	
ZS-2				**None / Elec. / Other**	
ZS-3				**None / Elec. / Other**	
ZS-4				**None / Elec. / Other**	
ZS-5				**None / Elec. / Other**	

Space 1 2 3 4 5 6 7 8 9 10

Name ________________ Occupancy Code _______ LPD Measure? ❑

Floor Area ____________ SF % Corridor/Restroom/Support Area _______ % Space Multiplier ___

Lighting

Name	**Fixture Code**	Ballast M?	**Fixture Count**	Mounting	**Control Code**	**% fix ctrl**	**% ctrl oper**	Control M?
L-1				Rec / Sus / Task				
L-2				Rec / Sus / Task				
L-3				Rec / Sus / Task				
L-4				Rec / Sus / Task				
L-5				Rec / Sus / Task				
L-6				Rec / Sus / Task				
L-7				Rec / Sus / Task				
L-8				Rec / Sus / Task				
L-9				Rec / Sus / Task				
L-10				Rec / Sus / Task				
L-11				Rec / Sus / Task				
L-12				Rec / Sus / Task				

Miscellaneous Equipment and Plug Loads

Define typical value for zone ( ) Use typical value ( ) Use typ value and define extraordinary loads ( )
Define for this space only ( )

Name	**Equip. Code**	**Count**	kW/ Unit or	Motor HP or	kBtuh Input	Under Hood?
E-1						Y / N
E-2						Y / N
E-3						Y / N
E-4						Y / N
E-5						Y / N
E-6						Y / N
E-7						Y / N

Refrigeration

Zone: 1 2 3 4 5 ____

Refrigerated Cases

Name	Type Code	Size	Qty	Prod Code	Comp Loc
RF-1					Int / Rem
RF-2					Int / Rem
RF-3					Int / Rem
RF-4					Int / Rem
RF-5					Int / Rem
RF-6					Int / Rem
RF-7					Int / Rem
RF-8					Int / Rem

Compressors / Compressor Racks

Name	Make	Model	Comp Code	Temp.	Ht. Recov. to AHU
CR-1				L / M / H	Y / N
CR-2				L / M / H	Y / N
CR-3				L / M / H	Y / N
CR-4				L / M / H	Y / N
CR-5				L / M / H	Y / N
CR-6				L / M / H	Y / N
CR-7				L / M / H	Y / N
CR-8				L / M / H	Y / N

Refrigeration Control Panel Make____________________ Model No._______________________-

Refrigeration Condenser

Name	Make	Model	Type	Fan Hp	Pump Hp	Fan Speed Control
RC-1			Air / Water			1Sp / 2Sp / Pony / VSD
RC-2			Air / Water			1Sp / 2Sp / Pony / VSD
RC-3			Air / Water			1Sp / 2Sp / Pony / VSD
RC-4			Air / Water			1Sp / 2Sp / Pony / VSD
RC-5			Air / Water			1Sp / 2Sp / Pony / VSD
RC-6			Air / Water			1Sp / 2Sp / Pony / VSD
RC-7			Air / Water			1Sp / 2Sp / Pony / VSD
RC-8			Air / Water			1Sp / 2Sp / Pony / VSD

Foodservice

Zone: 1 2 3 4 5 _____

Kitchen Equipment

Appliance Name	**Qty**	**Type Code**	**Fuel**	**kW or**	Volts / Amps or	**kBtuh Input or**	Trade Size	Hood
K-1			Elec. / Other		/			Y / N
K-2			Elec. / Other		/			Y / N
K-3			Elec. / Other		/			Y / N
K-4			Elec. / Other		/			Y / N
K-5			Elec. / Other		/			Y / N
K-6			Elec. / Other		/			Y / N
K-7			Elec. / Other		/			Y / N
K-8			Elec. / Other		/			Y / N
K-9			Elec. / Other		/			Y / N
K-10			Elec. / Other		/			Y / N
K-11			Elec. / Other		/			Y / N
K-12			Elec. / Other		/			Y / N

Hoods

Name	Type	Size (sf)	Flow (cfm)	Fan hp	Makeup Air Source
H-1	Canopy / Island Canopy / Backshelf				Cond / Uncond
H-2	Canopy / Island Canopy / Backshelf				Cond / Uncond
H-3	Canopy / Island Canopy / Backshelf				Cond / Uncond
H-4	Canopy / Island Canopy / Backshelf				Cond / Uncond
H-5	Canopy / Island Canopy / Backshelf				Cond / Uncond
H-6	Canopy / Island Canopy / Backshelf				Cond / Uncond

Hot Water

Conventional Water Heating Equipment

Name	**Location**	**Type Code**	Cap (gal)	**Fuel**	Pump hp	M?
WH-1				Elec / Other		
WH-2				Elec / Other		
WH-3				Elec / Other		
WH-4				Elec / Other		

Solar Water Heating Equipment (collect only if electric backup)

Name	Location	System Type Code	Collector Area (SF)	Tilt (deg, horiz =0)	Storage Cap (gal)	M?
SWH-1						
SWH-2						
SWH-3						

Pools/ Spas (collect only if electric heater)

Name	**Location**	**Surface Area (SF)**	**Filter Motor hp**	**Heating System**
PS-1	Outside / Inside			None / PH-___
PS-2	Outside / Inside			None / PH-___
PS-3	Outside / Inside			None / PH-___
PS-4	Outside / Inside			None / PH-___

Pool/Spa Heating System (collect only if electric heater)

Name	**Location**	**Fuel Code**	Solar Collector Type	Collector Area (SF)	Tilt (deg, horiz =0)	Heat Recovery	M?
PH-1		Elec / Other	Glazed / Unglazed			Y / N	
PH-2		Elec / Other	Glazed / Unglazed			Y / N	
PH-3		Elec / Other	Glazed / Unglazed			Y / N	
PH-4		Elec / Other	Glazed / Unglazed			Y / N	

Miscellaneous

Vertical Transportation

Name	**Type**	**Qty**	**Motor hp**	Elevator Number of Floors	Width (ft)	Escalator Rise (ft)	Run (ft)
VT-1	Elev / Esc						
VT-2	Elev / Esc						
VT-3	Elev / Esc						
VT-4	Elev / Esc						

Exterior Lighting

Name	**Fixture Code**	**Count**	M?
XLT-1			
XLT-2			
XLT-3			
XLT-4			
XLT-5			
XLT-6			

Miscellaneous Exterior Electric Loads

Name	Equip Code	Quantity	**kW/unit or**	**Hp/unit**
MC-1				
MC-2				
MC-3				
MC-4				
MC-5				
MC-6				

Billing Meters

Meter Number (kWh meters only not kVAR)	**TOU?**	**Surveyed Space kWh / Metered Space kWh (%)**	**Meter Location**
	Y / N		
	Y / N		
	Y / N		
	Y / N		

❑ Some or all meter information not available

System / Zone Association Checklist

Systems	1	2	3	4	5	Zonal HVAC only	Uncond
Packaged HVAC							
AC-1							
AC-2							
AC-3							
AC-1b							
AC-2b							
AC-3b							
AC-1c							
AC-2c							
AC-3c							
AC-1d							
AC-2d							
AC-3d							
Central Systems							
Air Handlers							
AH-1							
AH-2							
AH-3							
AH-1b							
AH-2b							
AH-3b							
Chillers / AC Compressors							
CH-1							
CH-2							
CH-3							
CH-1b							
CH-2b							
CH-3b							
Towers / Evap. Condensers							
T-1							
T-2							
T-3							
T-1b							
T-2b							
T-3b							
Heating Systems							
HS-1							
HS-2							
HS-3							
HS-1b							
HS-2b							
HS-3b							
Pumps							
P-1							
P-2							
P-3							
P-4							
P-5							
P-6							
P-7							
Zone 1							
Zone 2							
Zone 3							
Zone 4							
Zone 5							
Zone 1b							
Zone 2b							
Zone 3b							
Zone 4b							
Zone 5b							

Check 'Zonal HVAC only' if zone is conditioned only by baseboard, radiant, or unit heaters, or unit ventilators.

Interview "Area" / Audit "Zone" Association Checklist

Areas	1	2	3	4	5
Zone 1					
Zone 2					
Zone 3					
Zone 4					
Zone 5					
Zone 1b					
Zone 2b					
Zone 3b					
Zone 4b					
Zone 5b					

Space/Zone Association

	Zone									
Space	Z 1	Z 2	Z 3	Z 4	Z 5	Z 1b	Z 2b	Z 3b	Z 4b	Z 5b
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
1b										
2b										
3b										
4b										
5b										
6b										
7b										
8b										
9b										
10b										
1c										
2c										
3c										
4c										
5c										
6c										
7c										
8c										
9c										
10c										

Sketch of Building Floor Plan

Be sure to include dimensions, North arrow, and zone and HVAC equipment locations