Customer Energy Efficiency Program
Measurement and Evaluation Program

IMPACT EVALUATION OF PACIFIC GAS & ELECTRIC COMPANY AND SOUTHERN CALIFORNIA EDISON 1994 NONRESIDENTIAL NEW CONSTRUCTION PROGRAMS

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Measurement and Evaluation
Customer Energy Efficiency Policy & Evaluation Section
Pacific Gas and Electric Company
San Francisco, California

Disclaimer of Warranties and Limitation of Liabilities

As part of its Customer Energy Efficiency Programs, Pacific Gas and Electric Company (PG&E) has engaged consultants to conduct a series of studies designed to increase the certainty of and confidence in the energy savings delivered by the programs. This report describes one of those studies. It represents the findings and views of the consultant employed to conduct the study and not of PG&E itself.

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1. EXECUTIVE SUMMARY

This report presents the evaluation of the 1994 Commercial New Construction programs of Pacific Gas & Electric and Southern California Edison. The programs' impact on peak demand and energy use are presented according to five costing periods specified by the utilities.

Both gross and net savings are determined for the total load savings for each utility, as well as the savings resulting from four separate groups of program measures. Also, the study design is reviewed, with recommendations for future studies.

1.1 IMPACT FINDINGS

The PG&E program resulted in a gross summer on-peak demand savings of 19.7 MW and an annual energy savings of 81,350 MWH. The gross realization rate of the PG&E program was 103 percent for summer on-peak demand and 107 percent for annual energy. The net summer on-peak demand savings resulting from the PG&E program was 14.2 MW and the net annual energy savings was 68,334. The net realization rates of the PG&E program were 82 percent for demand and 100 percent for energy.

The SCE program's gross summer on-peak demand savings was 10.3 MW and the gross annual energy savings was 67,850 MWH. The gross realization rate of this program was 66 percent for summer on-peak demand and 98 percent for annual energy. The net summer on-peak demand savings from the SCE program was 6.4 MW and the net annual energy savings was 43,424 MWH. The program's net realization rate was 46 percent for summer on-peak demand and 72 percent for annual energy.

Table 1-1 shows the gross savings by costing period for both utilities. Table 1-2 summarizes the net savings.

	PG&E Participants		**SCE Participants**	
	KW	**KWH**	**KW**	**KWH**
Summer On-Peak	19,680	13,030,000	10,270	6,502,000
Summer Part-Peak	18,670	10,920,000	6,073	8,103,000
Summer Off-Peak	12,890	20,560,000	7,853	10,150,000
Winter Part-Peak	12,730	19,470,000	7,870	22,310,000
Winter Off-Peak	6,652	17,360,000	6,435	20,790,000
Total Annual		81,350,000		67,850,000

Table 1-1: Gross Savings by Costing Period

	PG&E Participants		**SCE Participants**	
	KW	**KWH**	**KW**	**KWH**
Summer On-Peak	14,170	10,945,200	6,367	4,161,280
Total Annual		68,334,000		43,424,000

Table 1-2: Net Savings

Figure 1-1 and Figure 1-2 compare the participant and non-participant gross demand savings expressed as a percentage of the baseline consumption. Here and elsewhere, the baseline is the consumption of the buildings under the California State Energy Code (Title 24), or under the program's baseline assumptions for buildings or measures not covered under Title 24. So, for example, 1- Figure 1 shows that the summer on-peak demand of PG&E participants was about 19% lower than it would have been if the buildings just complied with Title 24, whereas the summer on-peak demand of non-participants in PG&E's service area was about 9% lower.

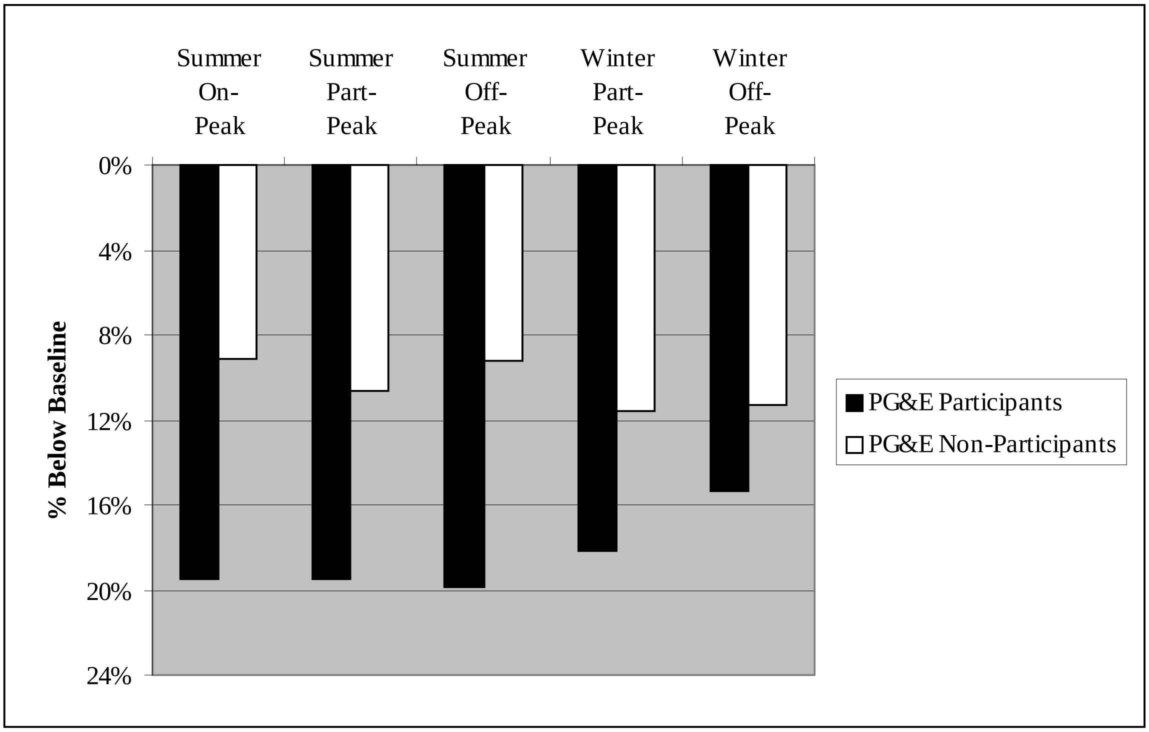

Figure 1-1: PG&E Gross kW Savings as a Percentage of Baseline

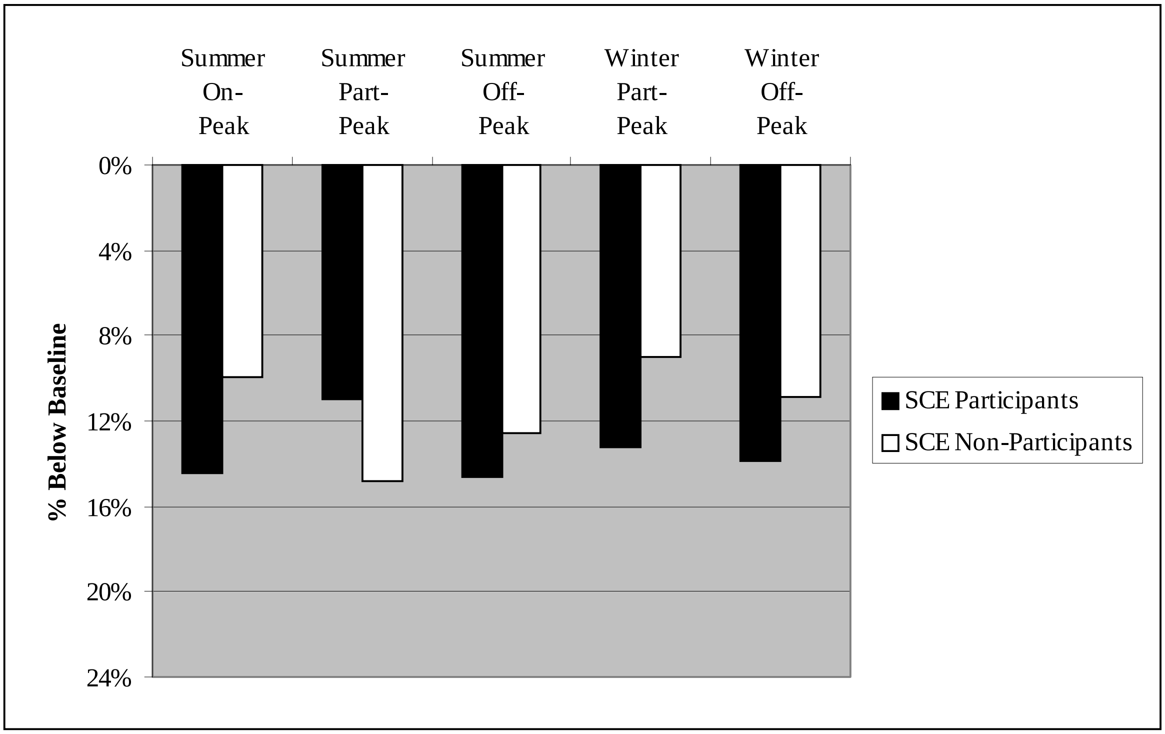

Figure 1-2: SCE Gross kW Savings as a Percentage of Baseline

Figure 1-3 and Figure 1-4 show the gross energy savings for participants and non-participants as a percentage of the baseline energy consumption.

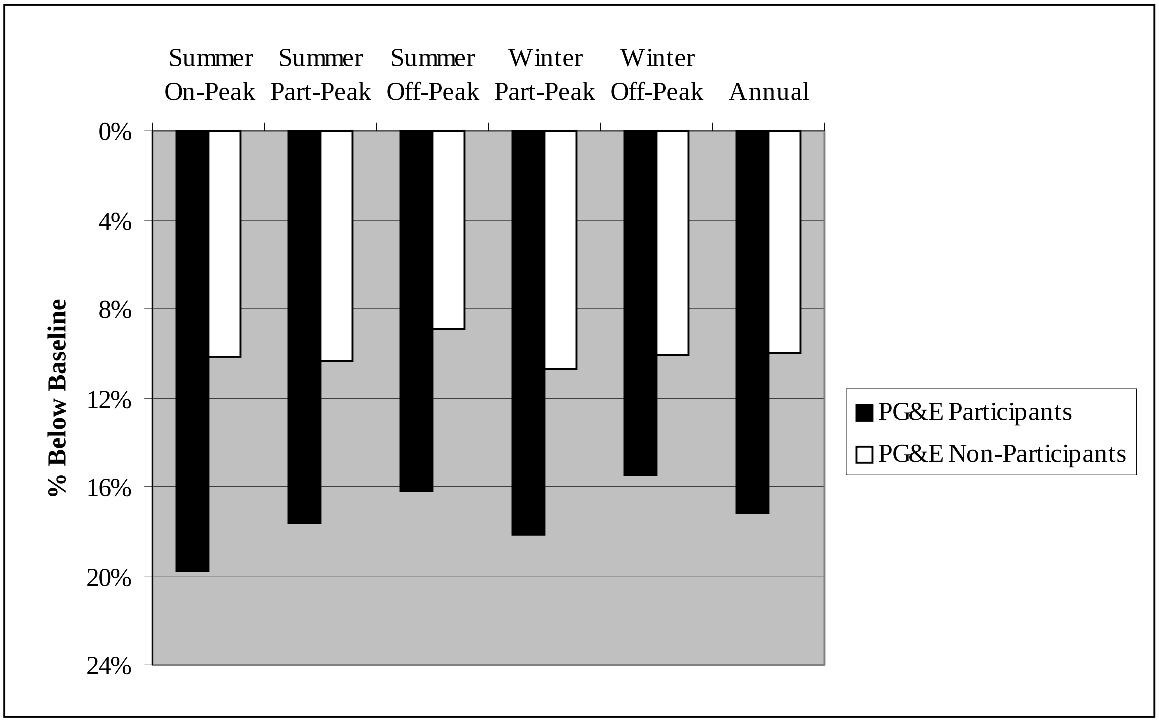

Figure 1-3: PG&E Gross kWh Savings as a Percentage of Baseline

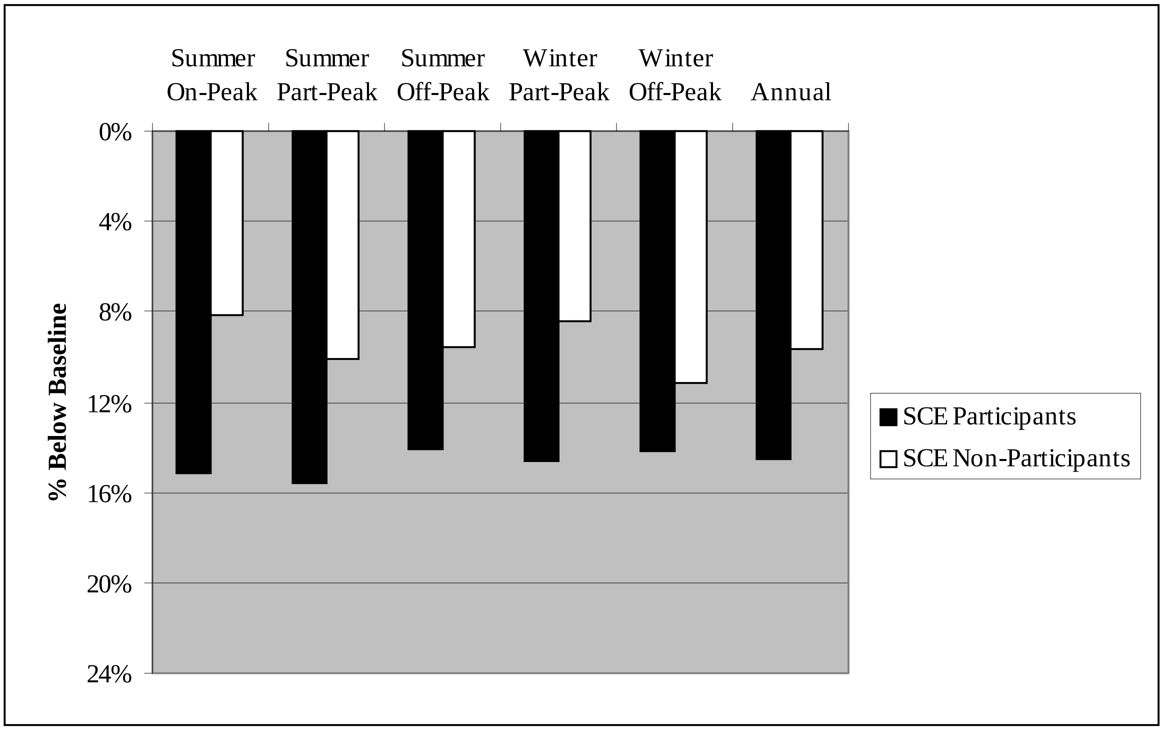

Figure 1-4: SCE Gross kWh Savings as a Percentage of Baseline

The econometric net-to-gross analysis found no statistically significant spillover effects. Table 1-3 shows the estimates of free-ridership for demand and energy. For PG&E, the free-ridership amounted to

28 percent of gross demand savings and 16 percent of gross energy savings. SCE's free-ridership was 38 percent of gross demand savings and 36 percent of gross energy savings.

	PG&E Participants		**SCE Participants**	
	KW	**KWH**	**KW**	**KWH**
Summer On-Peak	5,510	2,084,800	3,902	2,340,720
Summer Part-Peak	5,227	1,747,200	2,307	2,917,080
Summer Off-Peak	3,609	3,289,600	2,984	3,654,000
Winter Part-Peak	3,564	3,115,200	2,990	8,031,600
Winter Off-Peak	1,862	2,777,600	2,445	7,484,400
Total Annual		13,016,000		24,426,000

Table 1-3: Estimates of Free-Ridership

Throughout this evaluation, the Title 24 baseline was based on the actual building schedules found in the onsite audits. By contrast, at the time of building design, Title 24 uses assumed schedules. An analysis was done to compare the energy and demand of the building under the actual building schedules and the assumed Title 24 building schedules. These comparisons showed that the Title 24 schedules accurately estimated summer on-peak demand, but significantly underestimated the annual energy use of the building. Figure 1-5 shows the actual peak demand and energy consumption using both actual building schedules and assumed Title 24 building schedules.

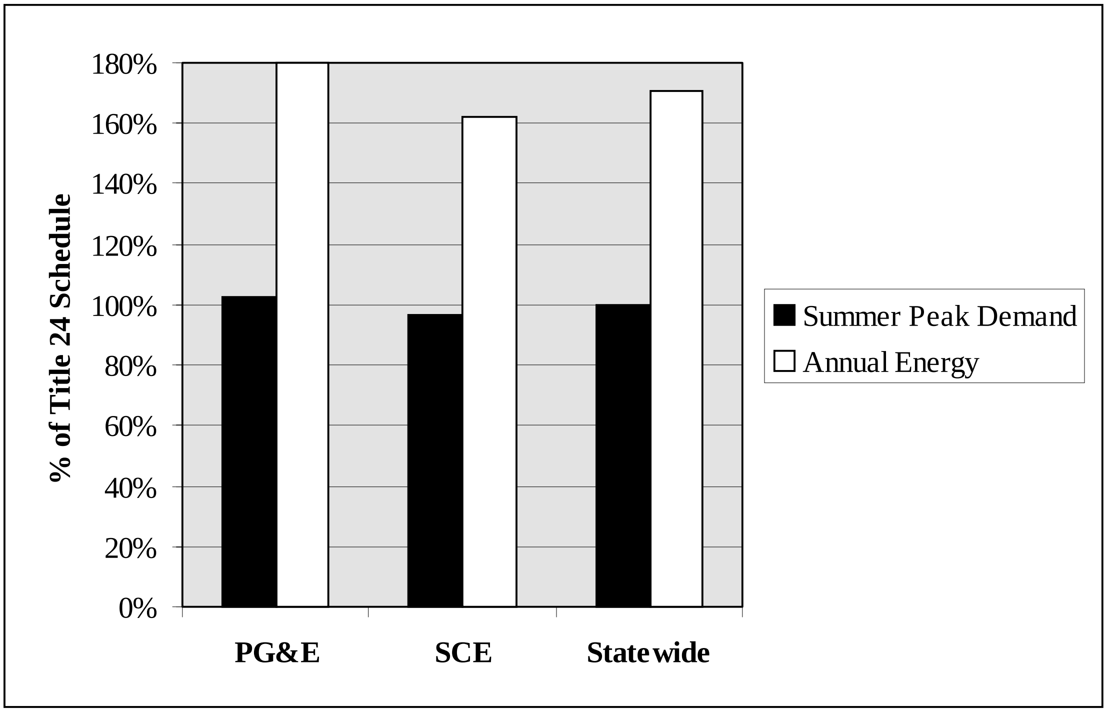

Figure 1-5: Comparison of Actual to Assumed Title 24 Building Schedules

The preceding findings can be summarized as follows:

- The energy and demand of program participants was found to be substantially lower than nonparticipants. In other words, the energy efficiency of participants exceeded the energy efficiency of nonparticipants.
- The energy and demand of program nonparticipants was found to be substantially lower than the Title 24 baseline. In other words, the energy efficiency of nonparticipants exceeded the Title 24 standard.
- The energy of buildings under the Title 24 baseline was found to be substantially higher with actual schedules than with the schedules assumed by Title 24 at the design stage. In effect, the actual operating hours were found to be longer than the operating hours assumed by the standard Title 24 schedules.

1.2 REFRIGERATED WAREHOUSES

A special study was carried out to evaluate the impact of PG&E's refrigerated warehouses Program. A census was attempted of the 16 facilities participating in the program, and all but five facilities participated in this evaluation. Engineering models of each facility were constructed from a combination of program documents and on-site surveys. Standard engineering algorithms were used to evaluate the gross impacts of the program, and a default 0.75 net to gross value was adopted in accordance with the protocols.

The gross energy impact in the refrigerated warehouse program was 14,852 MWH and the demand impact was 3.34 MW. Overall, the program achieved approximately 91 percent of the expected kWh savings and 134 percent of the expected demand savings. The realization rates can be improved in the future by incorporating a seasonal adjustment factor to the energy savings calculations for facilities with variable loading, and by adhering more strictly to the program minimum specifications at all facilities. The net energy savings was 11,139 MWH and the net demand impact was 2.50 MW.

1.3 OTHER FINDINGS

This study proposed many departures from methodology used in the past, some of which proved to be very effective and some of which proved problematic. The following aspects of the 1994 Commercial New Construction evaluation were quite successful and should be duplicated in future studies:

- The use of experienced surveyors and engineers for on-site audits of sample buildings proved to provide the study with accurate, compete building data for use in DOE modeling.
- The use of DOE models to estimate building savings provided a powerful, flexible tool with which to conduct the study. The use of DOE models allowed the study to investigate specific measures and to answer questions about statewide Title 24 compliance levels.
- The use of targeted end-use metering greatly illuminated the performance of various technologies and was very valuable in ensuring the proper construction of the DOE models. The individual sites that were monitored also benefited from the detailed site report that highlighted additional savings opportunities for the site.

There were some other aspects of the study that, while appearing logical at the outset, proved to be problematic in the execution of the study. Those aspects included:

- The delay of the study to collect extensive billing data may have done more harm than good. Only a fraction of the billing data proved to be useful and had a relatively small impact on the results, while the delay made surveying decision makers and obtaining permission for on-site audits more difficult. Future studies should consider a delay of several months after the program to allow normal occupancy patterns to develop, but should not wait for large amounts of billing data to be available.

- The use of the Dodge New Construction database as a sample frame led to ambiguities in the identity and location of program participants. The available site data in Dodge also proved to be a less reliable predictor of savings than the traditional program tracking data. This led to somewhat poorer precision than expected. Future studies should use the tracking estimates of savings as stratification and explanatory variables in impact analysis.
- The collection of Title 24 documentation proved to be frustrating. It was discovered that many companies viewed this documentation as proprietary and refused to release it, or had relegated it to dead storage. Local building departments with whom the data was on file, would not release it without the consent of the building owner. As a result, very little Title 24 documentation was collected. If the acquisition of Title 24 documents is determined to be important, the utilities should consider requiring the submission of complete Title 24 documents as part of program eligibility.

2. OVERVIEW OF STUDY DESIGN

This section presents an overview of the structure of the study. A basic familiarity with the approach used to conduct the study will provide a context for the reader in interpreting the findings. Detailed methodological discussion is reserved for chapters 8 through 12.

The flow of work in this study is shown in Figure 2-1 below. The following discussion summarizes each of the tasks in the flowchart.

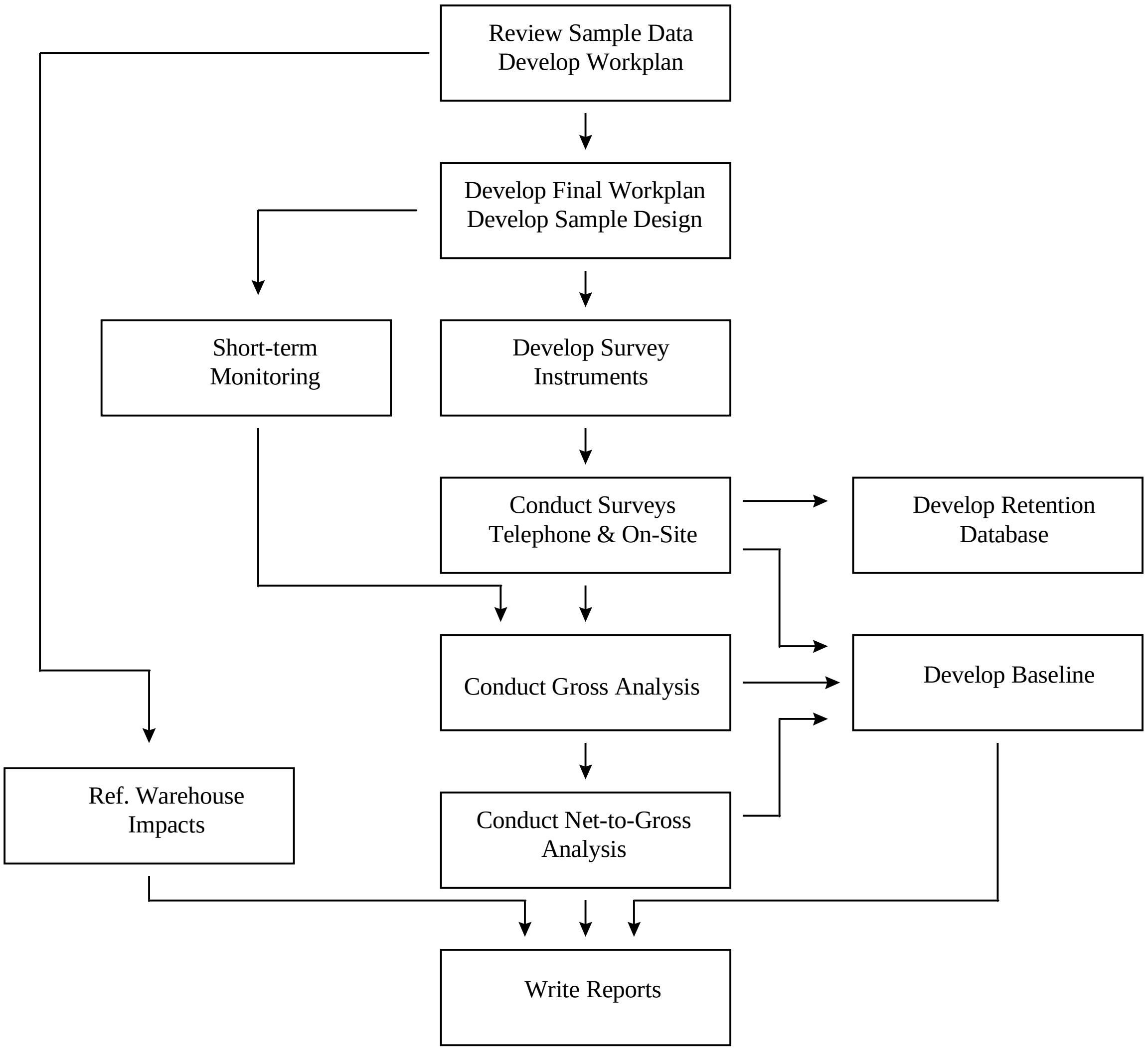

Figure 2-2-1: Flow Diagram of Study

2.1 REVIEW OF SAMPLE DATA AND KICKOFF MEETING.

The data review and the kickoff meeting provided the team with a very clear understanding of objectives, data resources, priorities, concerns, potential problems and their resolution, schedules, and deliverables. This step provided the necessary context for the effective development of the survey instruments.

2.2 DEVELOP FINAL STUDY RESEARCH PLAN AND SAMPLING PLAN.

The purpose of this task was to review the research objectives and finalize the overall project workplan as well as the sampling plan for selecting representative projects. The primary approach to the sample design used a single sampling plan for all three segments of the market - participants, non-participants, and partial participants - drawn from both PG&E and SCE service areas. The sampling frame was developed from the F. W. Dodge new construction database for 1992, 1993 and 1994 permitted projects.

The sampling plan was nested to provide samples for four different data-collection initiatives. Following a stratified sampling plan, a sample of 600 interviews was selected for the Decision-Maker Telephone Survey. A sample of 355 buildings was selected for the on-site audits and automated DOE-2 modeling. In a sub-sample of 100 of these 355 buildings, more detailed calibration-level models were hand built and calibrated to energy data. Finally, short-term monitoring was used in 30 buildings to provide the best practical field measurement of operating conditions.

2.3 TELEPHONE AND ON-SITE SURVEY INSTRUMENTS

An integrated approach was followed to combine the decision-maker Survey for the net-to-gross analysis and the recruiting for the on-site audits. The first component was a customer recruiting script that sought the building owner’s approval for the on-site audit and his or her participation in the Decision-Maker Survey. A second, shorter recruiting instrument recruited other participants for the Decision-Maker Survey. This effort began with the contact information taken from the Dodge data and continued until the appropriate customer contacts were identified.

The third telephone survey instrument was the actual Decision-Maker Survey. The team designed a telephone survey instrument specifically for the Decision-Maker Survey. The survey instrument was intended for building owners/developers, design professionals, and others involved in major decisions regarding non-residential new construction. This instrument collected data regarding:

- The degree of program participation -- pure non-participants, partial participants[1], full participants
- The specific nature of influences on key design decisions
- Whether their design decisions would have been taken in the absence of the program.

The Decision-Maker Survey also provided information on baseline and Title 24 compliance issues against which program impacts was assessed.

The on-site survey was used to obtain an independent, realistic, observation of the energy conservation measure conditions and performance. The on-site survey instrument was designed to provide the information needed to simulate energy use and demand for each building by a minimum of five different scenarios. For maximum validity, the field data collection was aimed at directly observable data. Special attention was paid to Title 24 specifications and program measures throughout the building. The on-site visits also helped to assess the suitability of each site for potential short-term metering, and where appropriate, supporting spot wattage measurements.

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[1] Those sites that were influenced by the program but did not actually participate.

2.4 CONDUCT TELEPHONE AND ON-SITE SURVEYS

2.4.1 Telephone Surveys

The team conducted the decision analysis survey as a computer assisted telephone interviewing (CATI) survey. The instrument required about 20 minutes per respondent to administer.

2.4.2 On-Site Audits

A vital step in the process of collecting quality data is training. The team conducted three days of training to prepare auditors for data collection. The first one and a half days were dedicated to classroom training. The remaining time consisted of practice surveys of two facilities, followed by reviews of the visits and questions and answers.

The auditors were selected and trained to maintain professional standards and minimize customer inconvenience. In order to assist in conducting a thorough and accurate site visit, the auditor reviewed all available site information prior to the site visit. Once on site, the auditor began with the personal interview because personal interaction during the interview tends to foster the customer's trust and confidence. Subsequently, detailed information was collected from the utility meters, the heating system and cooling equipment, the storeroom, and the remaining equipment inventories.

Strict quality control measures were implemented during the data collection phase of the project. They consisted of a number of range, consistency, and sanity checks on the colleted data, as well as random spot-checks on auditors in the field and follow-up contact with the surveyed sites. These procedures are discussed in detail in chapter 10.

2.5 SHORT TERM MONITORING

Short-term monitoring was carried out on a sub-sample of 30 buildings to allow end-use calibration to improve the accuracy of the DOE-2 models relative to those calibrated to billing data. The short-term monitoring data was used to develop information about the building such as:

- Chilled water temperature
- Water pump kW (Chiller, Hot Water, Condenser)
- Water pump minimum flow ratio
- Economizer setpoint
- Approach temperatures
- Condensing temperatures
- Fan kW and control strategy
- Refrigeration head pressure setpoint

2.6 GROSS IMPACT ANALYSIS

Based on the California protocols and the requirements of the project, the gross impact analysis was conducted using the DOE-2 building energy simulation program. The DOE-2 program is well suited to analyzing the impacts of most measures included in the new construction programs. DOE-2 is a very flexible modeling tool, allowing the calculation of energy and demand savings for lighting, lighting controls, shell measures, HVAC efficiency improvements, many HVAC control measures, and grocery store refrigeration systems.

In order to perform DOE-2 simulations of 347 sites under multiple baseline scenarios within the time and budget constraints of this project, an automated process that integrates the on-site data collection and DOE-2 modeling effort was used. The data collection and modeling process is outlined below:

1. Collection of appropriate building information during the on-site survey. Competent, well-trained surveyors focused on collecting key building data. Based on past experiences, the surveyors were trained to focus on essential information, and not waste time on superfluous data collection.
2. Entry of the on-site survey data into an electronic database, with extensive quality control procedures, including double key entry, range, internal consistency, and reasonableness checks.
3. Use of computerized tools to calculate model input parameters from the on-site survey databases and automatically generate as-built DOE-2 input files.
4. Model fine-tuning and calibration by an experienced DOE-2 engineer.
5. Use of computerized tools to automatically perform the required parametric runs and store the results in an electronic database.

The automated process outlined above was used to develop the input files from the on-site surveys for all buildings in the sample. In this project, electronic data records of on-site surveys were automatically queried, and calculations of as-built and baseline energy end-use consumption was automatically performed for the sample of 407 buildings at the 355 sites.

Results obtained from the automated process were verified using “enhanced” models for a sub-sample of 100 buildings. These hand-built models included models of performance-based program participants available from PG&E and SCE, as well as models of prescriptive program participant buildings built by an experienced DOE-2 engineer. The findings from the enhanced models were fed back into the machine built models to improve the accuracy of the machine built models. For example, the enhanced models discovered that the machine built models under-predicted the nighttime lighting loads. This information allowed the evaluation team to adjust the nighttime lighting in the machine built models to more accurately reflect the buildings’ performance.

Model calibration to billing data was used to provide a reasonableness check on the model results, when billing data was available. Our engineers are well acquainted with the hazards of calibrating building energy simulation models to billing data[2]. Good engineering judgment based on years of modeling experience was used when adjusting model parameters, including reasonable assumptions on diversity and load factors, thermostat setpoint, system operating schedules and so on. Calibration procedures focused on high influence parameters such as outside air fraction, economizer operation, fan schedules and so on that may be difficult to observe during an on-site survey.

In consultation with the PG&E project manager, guidelines were established for model calibration. Models were calibrated to ±10 percent agreement on monthly whole-building energy consumption, where possible. As expected, some buildings did not have adequate billing data to perform the calibration due to meter number mismatches, multiple accounts, and so on. In these cases, good modeling guidelines, as well as annual energy usage intensity (EUI) range checks were used in lieu of calibration to billing data.

A second round of calibrations was performed on a sub-sample of 30 sites where we collected short-term monitored data. The short-term monitoring was used to improve the end-use consumption estimates in all building models, thus improving estimates of energy savings for the entire sample. Data gathered from short-term monitoring was used to define key simulation model inputs, thus limiting the variables available for adjustment during calibration. This ensured that building systems were modeled as they

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[2] Model calibration guidelines are discussed in detail in the Engineering Methods Handbook, Vol. 1.

actually operated. The methodology allowed the analysis to quickly compare model outputs to measured data, thus facilitating the calibration process. Experience has shown that great improvements in the accuracy of simulation models on an end-use basis result from the calibration to end-use metering.

2.7 NET-TO-GROSS AND SPILLOVER ANALYSIS

Gross impact analysis measures the difference between whole building energy consumption of the as-built building to whole building energy consumption of that building as it just meets Title 24 minimum requirements. Net program impact, as defined in the Protocols, is the savings attributable to the utility DSM program. Programs may also impact efficiency improvements in buildings for which no rebate was paid under the program.

This analysis followed a combination of the conditional demand analysis (CDA) and calibrated-engineering (CE) model approaches to measuring the net impacts of the programs. The analysis was fully consistent with the Protocols and provided impact estimates that flow from statistical models and for which tests of statistical validity can be applied. The approach used defensible, published statistical theory and empirical methods to estimate adjustments for free-ridership and spillover.

2.8 NONRESIDENTIAL BASELINE

The naturally occurring energy use baseline for each building in the Study was determined as a byproduct of the data collection, gross analysis, and net analysis tasks. The tasks were combined to estimate the Nonresidential baseline for each building in the on-site sample. With this methodology, baseline measures can be developed for various aggregations of buildings in the study. For easy comparison and maximum utility, baseline energy use was expressed as a percentage of Title 24 reference consumption for these principal measure categories:

- Building Envelope
- Lighting
- Mechanical Systems.

These measure baselines are reported both statewide and by service territory.

2.9 REFRIGERATED WAREHOUSE PROGRAM

For the Refrigerated Warehouse Program evaluation, a combination of engineering algorithms and simulations were used. The team used a set of basic engineering algorithms and spreadsheet calculations for analyzing refrigeration plant improvements, which are covered in the second volume of the Engineering Methods in DSM Handbook[3]. Where more complex dynamic refrigeration systems and loads were encountered, the TRNSYS general purpose simulation program was used. The TRNSYS program allows for custom development of refrigeration equipment simulation modules, along with a library of component modules suitable for modeling refrigerated warehouses and refrigeration plants.

2.10 MEASURE RETENTION PANEL AND DATABASE

The persistence retention sample is comprised of all participants in the on-site survey sample. Those measures responsible for the first 50 percent of overall savings were eligible for inclusion in the retention sample. During the on-site audits, eligible equipment with estimated lives greater than three years were

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[3] Engineering Methods for Estimating the Impacts of Demand-Side Management Programs, Vol. 2: Fundamental Equations for Residential and Nonresidential End-Uses. EPRI TR-100984 V2

documented. This sample formed a Measure Retention Panel, which conforms to the requirements of Table 9A of the Protocols. Customer data and measure-specific data from the program application tracking system was combined with data collected through the telephone and on-site surveys to create a comprehensive database that will facilitate future analysis by PG&E or other contractors. Data specified for inclusion in the database contains all relevant information necessary to conduct follow-up persistence studies.

2.11 ANALYSIS OF RESULTS FOR REGULATORY FILINGS

The team provided an interim report that documented the survey research and preliminary observations of the impact analysis and the net-to-gross studies. The report consisted of an informal presentation of interim results to the PG&E and SCE Project Managers. A final draft report, which documents the findings of the complete project, was provided for review and comment by PG&E and key stakeholders in the evaluation. The Final Report (this document) incorporates the consolidated comments made by PG&E and SCE reviewers.

3. GROSS IMPACT FINDINGS

3.1 METHODOLOGY

3.1.1 Definitions

To clarify the discussion, a few terms are defined below that are used throughout the remainder of the report.

As-Built Model	The output of a DOE-2.1 model run using the building equipment efficiencies and schedules as found during an on-site audit of the building.
Baseline	The output of a DOE-2.1 model run with the building's equipment set to Title 24 efficiency standards. The actual building schedules were used, *not* Title 24 assumed schedules.
Realization Rate	The realization rate was calculated as the estimated annual energy savings divided by the utility's program estimate of total savings for the 1994 program.
Savings	The difference between the results of the As-Built and Baseline models. Positive Savings means that the As-Built consumption was less than the baseline consumption. All references to demand savings in this report are to system coincident peak savings during the costing period.
Title 24 Baseline	The output of a DOE-2.1 model run with the building's equipment set to Title 24 efficiency standards *and* Title 24 assumed schedules.

3.1.2 Methodology

A DOE-2.1 model was constructed for each surveyed building. The energy use was summed by costing period for each utility and reported as the total use per costing period. The building's hourly demand during the system peak hour for each costing period was reported as the demand in the model output.

Model-Based Statistical Sampling (MBSS™) techniques were used to expand the sample savings to the populations of interest, participants and non-participants. For participants, the population was comprised of 1994 program participants. For non-participants, the population was comprised of all new construction within the utility's service territory listed in the F.W. Dodge new construction database and on which construction started in 1993.

The explanatory variable used in the ratio expansion was the estimated program savings for participants and the square footage listed in the Dodge database for non-participants.

The engineering analysis was conducted using Typical Meteorological Year (TMY) data, so the system load information for 1995 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 1995 weather data. RLW Analytics used the following methodology to determine the appropriate peak hour under TMY weather:

1. Every DOE-2.1 model (run with 1995 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. The PG&E proxy for the peak day and hour was an office building and the SCE proxy was a retail store.

	PG&E Peak	SCE Peak
Summer On-Peak	July 18 2 p.m.	August 9 5 p.m.
Summer Part-Peak	July 5 12 p.m.	August 31 7 p.m.
Summer Off-Peak	July 29 2 p.m.	July 15 5 p.m.
Winter Part-Peak	December 21 9 am	May 19 5 p.m.
Winter Off-Peak	January 1 10 am	June 3 6 p.m.

Table 3-1: PG&E and SCE System Peak Hours

3.1.3 Costing Periods

Both demand and energy impacts were estimated for five utility defined costing periods. Table 3-2 shows the definitions of the costing periods for each utility.

Costing Period	PG&E	SCE
Summer On-Peak	May 1 to October 31: Noon to 6 p.m. on weekdays	June 4 to Sept 30 : noon to 6 p.m. on weekdays
Summer Part-Peak	May 1 to October 31: 8:30 am to Noon and 6 p.m. to 9:30 p.m. on weekdays	June 4 to Sept 30 : 8am to noon and 6 p.m. to 11 p.m. on weekdays
Summer Off-Peak	May 1 to October 31: 9:30 p.m. to 8:30 am weekdays, and all Saturday, Sunday, and holidays	June 4 to Sept 30 : 11 p.m. to 8am on weekdays and all day Saturday, Sunday, and holidays
Winter Part-Peak	November 1 to April 30: 8:30 am to 9:30 p.m. on weekdays	Oct 1 to June 3 : 8 am to 9 p.m. on weekdays
Winter Off-Peak	November 1 to April 30: 9:30 p.m. to 8:30 am on weekdays, and all Saturday, Sunday, and holidays	Oct 1 to June 3 : 9 p.m. to 8am on weekdays and all day Saturday, Sunday, and holidays

Table 3-2: Definition of Costing Periods

3.2 GROSS KW IMPACT

Table 3-3 shows the total reduction in demand during the system peak hour in each of the five costing periods. PG&E realized maximum load reduction during the summer on-peak period, totaling 19.6 MW. SCE realized maximum load reduction during the summer on-peak costing period, totaling 10.2 MW.

The gross realization rates for summer on-peak demand for PG&E and SCE were 103 percent and 66 percent, respectively. The PG&E estimated demand savings is 19.2 MW and the SCE estimated savings is 15.6 MW.

Table 3-3 shows error bounds for all results. Throughout this report, error bounds were calculated at the 90% level of confidence. For example, the demand savings for PG&E participants was 19,680 ± 7,901 kW, so the 90% confidence interval was from 19,680 - 7,901 kW to 19,680 + 7,901 kW, that is, from 11,779 to 27, 581 kW at the 90% level of confidence.

	PG&E Participants			SCE Participants		
	Total	Error Bound		Total	Error Bound	
Summer On-Peak	19,680	±	7,901	10,270	±	2,537
Summer Part-Peak	18,670	±	7,454	6,073	±	1,752
Summer Off-Peak	12,890	±	6,554	7,853	±	1,750
Winter Part-Peak	12,730	±	5,289	7,870	±	1,837
Winter Off-Peak	6,652	±	3,398	6,435	±	1,208

Table 3-3: System Peak Hour kW Savings by Costing Period

Figure 3-1 and Figure 3-2 show the gross kW savings as a percentage of the baseline demand for participants and non-participants. In percentage of baseline terms, the participants in both PG&E's and SCE's greatest demand reduction came in the summer off-peak period. The savings were 19.9 percent and 14.6 percent, respectively. The non-participant savings relative to baseline ranged from a high of 11.6 percent during the winter partial-peak period to 9.1 percent during the summer on-peak period for PG&E. For SCE, the non-participant savings were the greatest during the summer partial-peak, at 14.8 percent, and were lowest during the winter partial-peak, at 9.0 percent. During the summer partial peak period, the SCE non-participants' system coincident peak demand was less then the participants' peak demand.

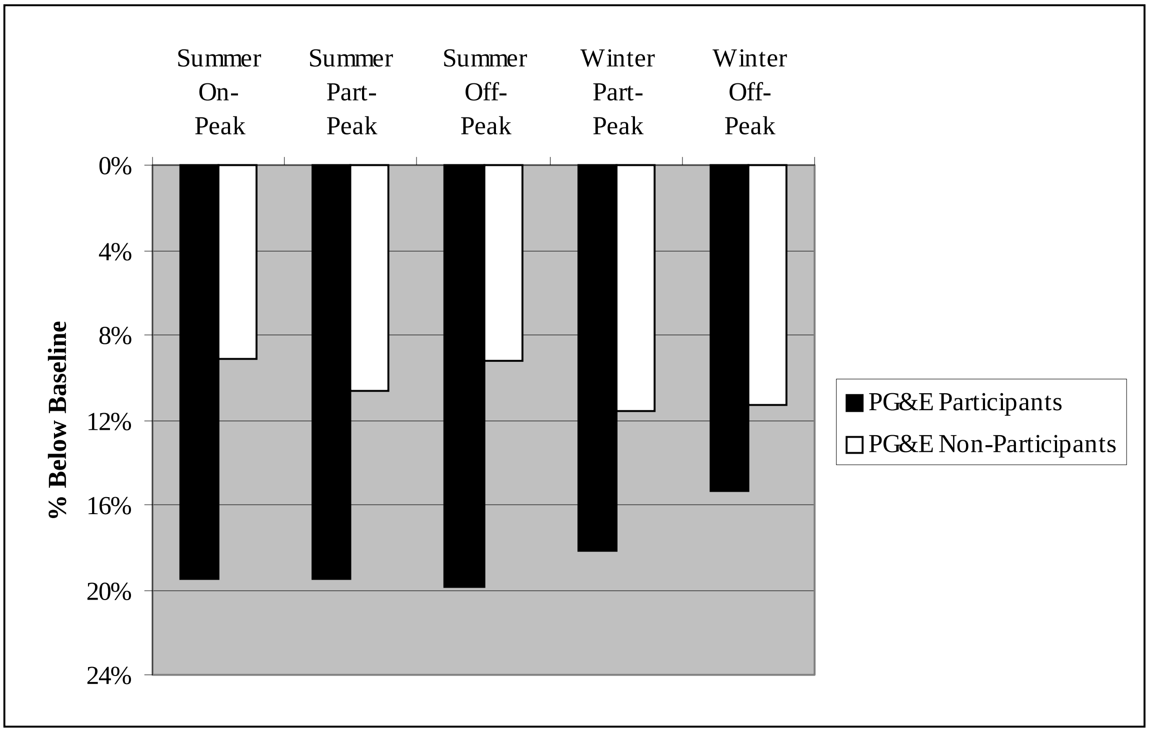

Figure 3-1: PG&E Demand Savings as a Percentage of Baseline Demand

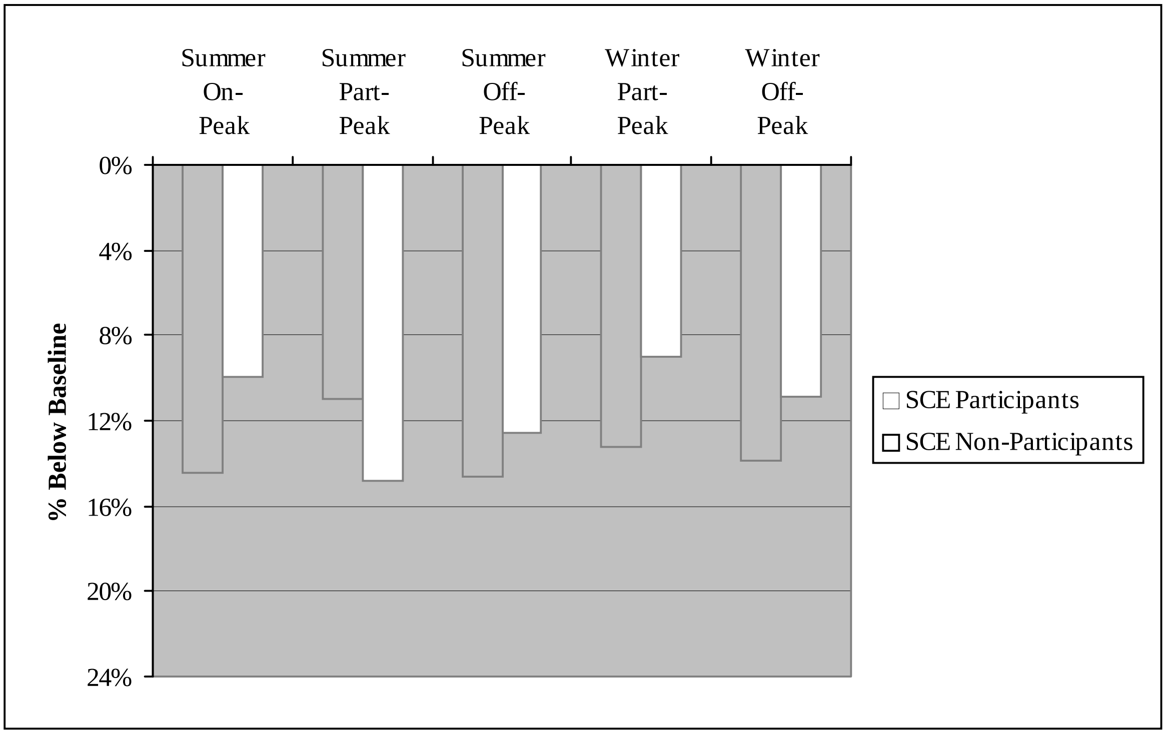

Figure 3-2: SCE Demand Savings as a Percentage of Baseline

3.3 GROSS KWH IMPACT

3.3.1 Findings

Table 3-4 shows the energy savings for each costing period and for the entire year. PG&E saved the most energy during the summer off-peak period, while SCE had the largest kWh savings during the winter partial peak period.

The gross realization rates for annual energy were 107 percent for PG&E and 98 percent for SCE. The program estimates of annual energy savings are 75,676 MWH for PG&E and 68,979 MWH for SCE.

	PG&E Participants		SCE Participants	
	Total	**Error Bound**	**Total**	**Error Bound**
Summer On-Peak	13,030,000	± 5,473,000	6,502,000	± 1,545,000
Summer Part-Peak	10,920,000	± 3,867,000	8,103,000	± 1,657,000
Summer Off-Peak	20,560,000	± 7,272,000	10,150,000	± 2,159,000
Winter Part-Peak	19,470,000	± 7,735,000	22,310,000	± 4,934,000
Winter Off-Peak	17,360,000	± 6,460,000	20,790,000	± 4,943,000
Annual	81,350,000	± 29,980,000	67,850,000	± 14,190,000

Table 3-4: kWh Savings by Costing Period

Figure 3-3 and Figure 3-4 show the kWh savings as a percentage of the baseline consumption. As a percentage of the baseline, PG&E participants realized the greatest savings during the summer on-peak period and SCE participants realized the greatest savings during the summer partial-peak period. The savings were 19.7 percent for PG&E and 15.6 percent for SCE. For the entire year, PG&E participants saved 17.2 percent relative to the baseline, while SCE participants saved 14.6 percent relative to the baseline.

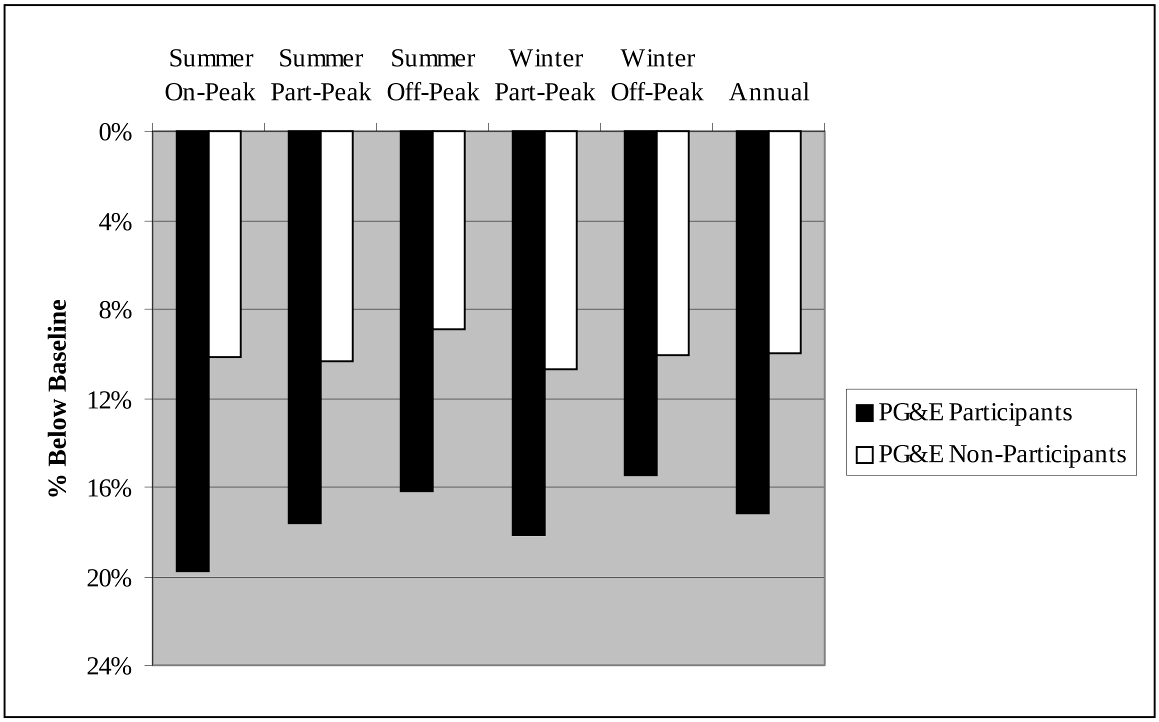

Figure 3-3: PG&E kWh Savings as a Percentage of Baseline

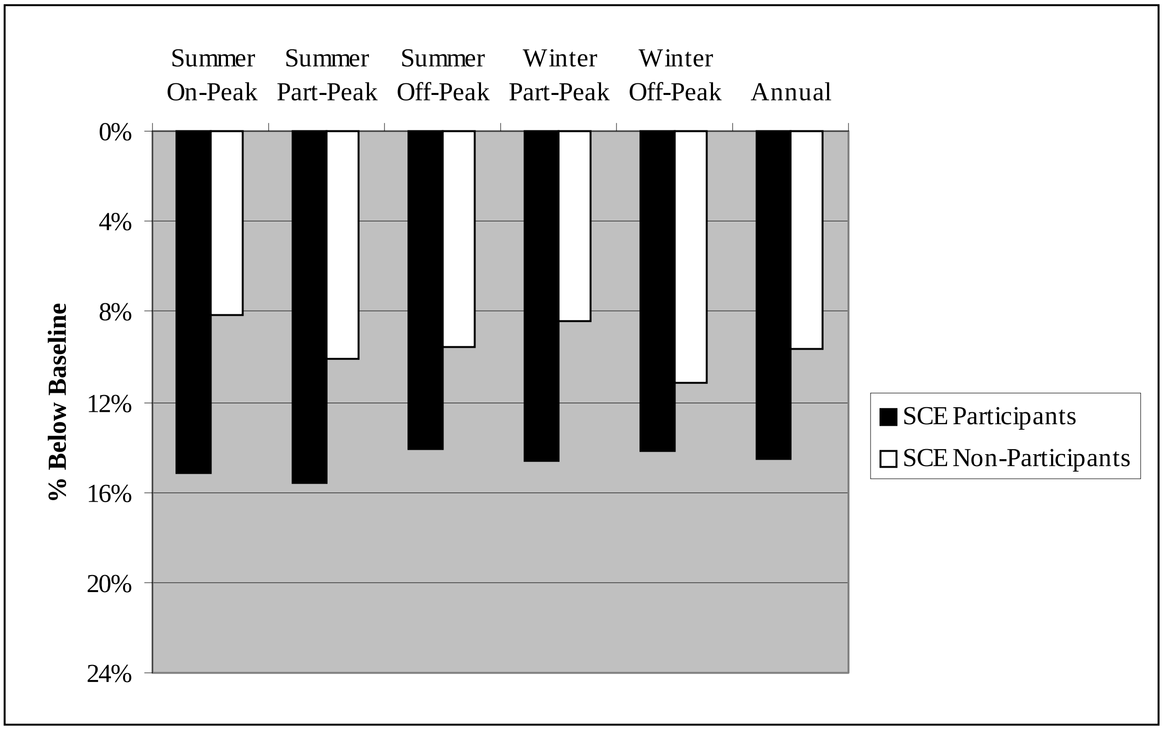

Figure 3-4: SCE kWh Savings as a Percentage of Baseline

3.4 COMPARISON OF SAVINGS TO TITLE 24 SCHEDULES

The building consumption was measured using the Title 24 assumed schedules to investigate their accuracy. The California Energy Commission (CEC) sets standard analysis rules for building compliance purposes. All of the analysis in this report uses actual building operating schedules rather than the standard Title 24 analysis schedules. This section compares the building energy use under actual operating schedules and the Title 24 standard schedules used for compliance.

The assumed Title 24 schedules appeared to accurately estimate the summer on-peak demand. However, the assumed schedules significantly underestimated annual energy use of the buildings. Table 3-5 shows the estimated summer on-peak As-Built demand and As-Built annual energy use for both PG&E and SCE program participants.

	PG&E	**SCE**	**Statewide**
Actual Schedule - Demand	81,300	61,000	n/a
Title 24 Schedule - Demand	79,300	62,900	n/a
Ratio	1.025	0.969	0.997
Actual Schedule - Energy	392,600,000	398,100,000	790,700,000
Title 24 Shedule - Energy	218,300,000	245,400,000	463,700,000
Ratio	1.798	1.622	1.705

Table 3-5: Comparison of Consumption with Actual and Assumed Title 24 Schedules

Figure 3-5 shows the comparison of actual schedules to Title 24 schedules graphically. It is easy to see that the Title 24 schedules accurately predict the summer peak demand but significantly underpredict annual energy use. This implies that the schedules used in the Title 24 compliance analysis do not capture all of the operating hours of the buildings.

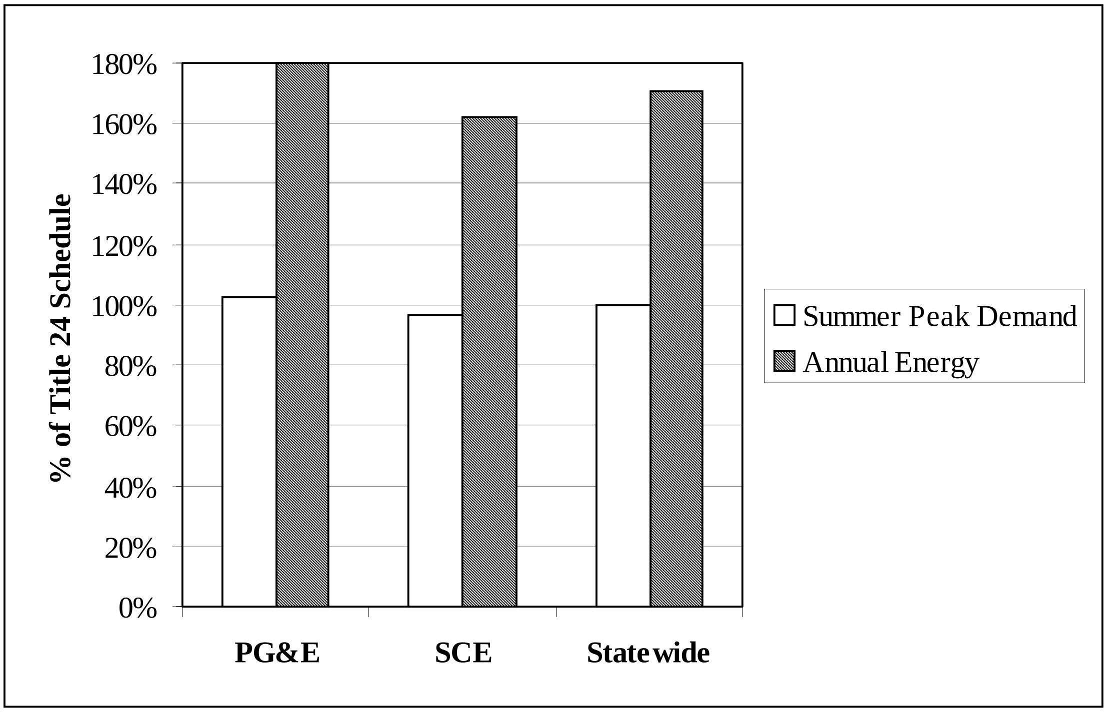

Figure 3-5: Actual Building Energy use as a Percentage of Title 24 Assumed Energy Use

3.5 STATEWIDE BASELINE

As a separate exercise for CADMAC, the statewide baseline energy use was calculated to determine the level of compliance with Title 24 standards. Considering all nonresidential new construction but not counting the effect of the program, the summer peak demand was 8.2 percent below the baseline demand and annual energy use was 8.1 percent below the baseline. Here, as elsewhere in this report, baseline refers to the level of energy and demand that the buildings would have had if they had been built exactly according to Title 24 standards but were used following the schedules found in the onsite audits. In other words, excluding the program impacts, the buildings were found to be about 8 percent more efficient than the Title 24 baseline. This is shown, along with data for the PG&E and SCE service territories, in Figure 3-6.

In order to take advantage of all available data, the nonparticipants and participants were combined in this analysis. The baseline was calculated by adding the non-participant savings to the portion of participant savings attributable to free-ridership and dividing by the baseline for non-participants and participants. This is show in the equation below.

$$Sav_{\%} = (NP_{sav} + (P_{sav} * FR)) / (NP_{base} + P_{base})$$

These results were not used directly in the impact evaluation. However, the naturally occuring level of efficiency addressed in the net to gross analysis, and thereby included in the estimates of the net program impacts.

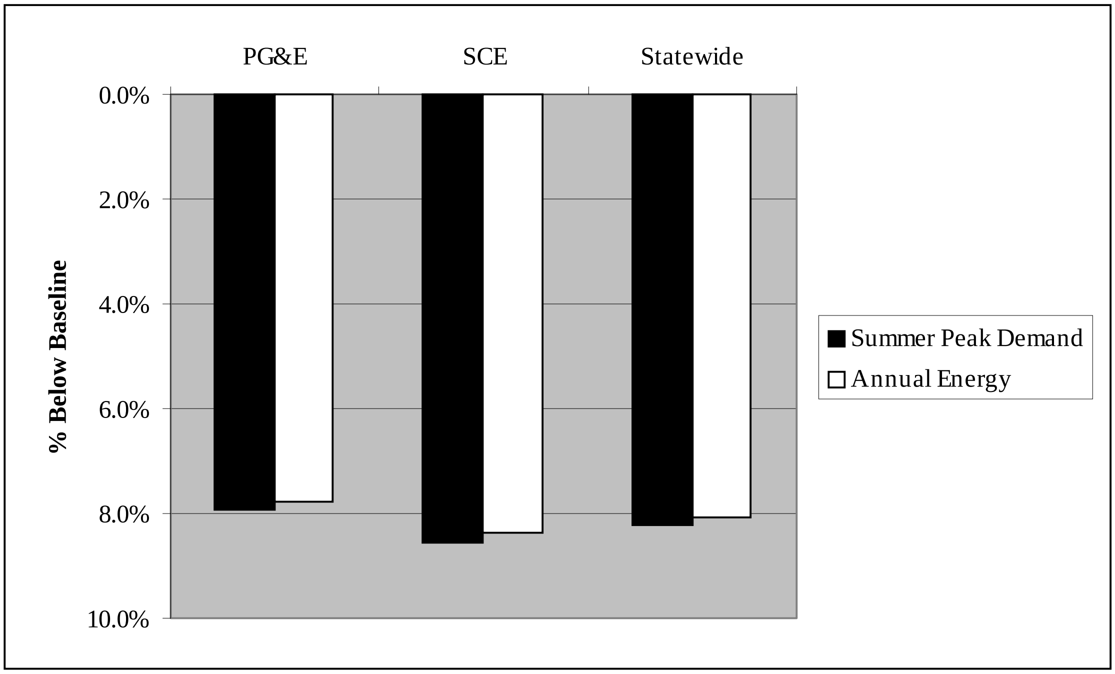

Figure 3-6: Statewide Savings as a Percentage of Baseline

3.6 EXHIBIT 1

Table 3-6 and Table 3-6 show the gross impact findings in the format of Exhibit 1, as required by Contract Z54004796.

Costing Period	Avg KW Savings	Avg KW Savings Coincident with System Maximum in Period	KW Adjustment factor	KWH Savings	KWH Adjustment Factor	Annual KWH Savings	Average Load KW
Summer On-Peak	16,452	19,680	100%	13,030,000	16%	13,030,000	66,881
Summer Partial Peak	11,818	18,670	95%	10,920,000	13%	10,920,000	55,325
Summer Off-Peak	7,615	12,890	65%	20,560,000	25%	20,560,000	39,422
Winter Partial Peak	11,701	12,730	65%	19,470,000	24%	19,470,000	52,602
Winter Off-Peak	6,478	6,652	34%	17,360,000	21%	17,360,000	35,388

Table 3-6 : PG&E Gross Impact Exhibit 1

Costing Period	Avg KW Savings	Avg KW Savings Coincident with System Maximum in Period	KW Adjustment factor	KWH Savings	KWH Adjustment Factor	Annual KWH Savings	Average Load KW
Summer On-Peak	8,210	10,270	100%	6,502,000	10%	6,502,000	45,894
Summer Partial Peak	8,769	6,073	59%	8,103,000	12%	8,103,000	47,378
Summer Off-Peak	3,759	7,853	76%	10,150,000	15%	10,150,000	23,000
Winter Partial Peak	13,407	7,870	77%	22,310,000	33%	22,310,000	78,239
Winter Off-Peak	7,757	6,435	63%	20,790,000	31%	20,790,000	46,907

Table 3-7 : SCE Gross Impact Exhibit 1

4. NET IMPACT FINDINGS

4.1 METHODOLOGY

4.1.1 Definitions

To clarify the discussion in this chapter, the following definitions are offered.

Spillover	The difference in savings between those buildings identified in the Decision-maker Survey as partial-participants and those identified as pure non-participants.
Free-ridership	The amount of savings that a building would have achieved in the absence of the program.
Net Savings	Gross savings minus free-ridership plus spillover.
Net-to-Gross ratio	Net savings divided by gross savings.
Partial participant	Heard about the program and interacted with utility during design but elected not to participate.

4.1.2 Estimating Spillover

The hypothesis behind the spillover analysis was that the design of some buildings might be affected by the program even though the buildings do not actually participate in the program. For example, a building might participate in the program through much of the design process but drop out at the end perhaps because of limited time or because the building fails to meet the level of efficiency required by the program.

In order to estimate spillover, the Decision-maker Survey was used to classify non-participants as partial-participants or pure non-participants. A respondent was considered a partial participant only if they indicated that they had heard about the program (Q25), and had interaction with the utility staff during the design phase (Q27), and considered participating in the program (Q28).

Once the non-participants were categorized, the gross savings and Title 24 baseline consumption were both expanded to the population of all new construction in each utility's service area. These results were used to calculate the savings of each category as a percentage of the baseline consumption. Standard stratified ratio estimation techniques were used to calculate the statistical precision of these results. Finally, the percentage savings of the partial participants was compared to the percentage savings of the pure non-participants, and the statistical significance of the difference was determined using the standard two-sample hypothesis test.

4.1.3 Estimating Free-Ridership

The output of the net-to-gross econometric analysis was an estimate of what a building would have done in the absence of the program. This was expressed as savings as a percentage of the baseline consumption of the building. This was converted into net savings in kWh and kW by the following formula:

net savings = gross savings - (baseline consumption * econometric estimate)

The net savings were then expanded using the same procedure as was used for the gross savings. The difference between the gross savings and the net savings is the free-ridership.

4.2 SPILLOVER

Table 4-1 shows the number of projects in each of the samples used in the spillover analysis. About 22 percent of the non-participants were classified as partial participants using the criteria discussed in Section 4.1.2.

	PG&E	SCE	Total
Pure Non-Participants	61	74	135
Partial Participants	18	19	37
Total Non Participants	79	93	172

Table 4-1: Sample Sizes by Category of Non-Participant

Table 4-2 summarizes the spillover results for the summer on-peak demand savings. The table shows the savings as a percentage of the baseline consumption. The results for SCE were consistent with the spillover hypothesis, but the PG&E results were contrary to the hypothesis.

In the case of SCE, pure non-participants had average savings of 10 percent relative to the Baseline, whereas partial participants had larger savings of 14 percent. The difference between savings experienced between these two groups was 4 percent. The SCE results were consistent with the hypothesis that the SCE program had increased the savings of the partial participants.

For PG&E, the findings were reversed. The partial participants had a lower level of savings than the pure non-participants did, contrary to expectation. The explanation could be that PG&E's partial participants declined to participate because they were aware that their buildings would not pass PG&E's program criteria. This negative self-selection might have led the partial participants to have a lower level of savings than the pure non-participants. In other words, PG&E might have successfully marketed its program to all qualified buildings, those with high levels of savings.

	PG&E		SCE	
	Savings	**Err Bnd**	**Savings**	**Err Bnd**
Pure Non-Participants	9%	4%	10%	9%
Partial Participants	5%	10%	14%	8%
Difference	-4%	11%	4%	13%
t-stat		-0.60		0.50

Table 4-2: Summer On-Peak Savings by Category of Non-Participant

Table 4-2 also shows the error bound for the estimated savings. For example, the 90 percent confidence interval for the savings of PG&E pure non-participants is 9% ± 4%. For PG&E's partial participants the confidence interval is 5% ± 10%. The wide confidence intervals indicate that the partial participant results are not statistically significant. In fact, the confidence interval for the difference between PG&E's partial participants and pure non-participants is -4% ± 11%, or from -15% to + 7%. In other words, we cannot conclude whether the difference is negative or positive. Table 4-2 also shows the t-statistic, which is the standard way to measure the statistical significance of the difference between the savings in the two PG&E samples. The t-statistic is equal to the difference in the savings multiplied by

1.645 and divided by the corresponding error bound. Since the t-statistic is small (e.g., less than 1.645 in absolute value), the difference is not statistically significant. This is true for both PG&E and SCE.

Table 4-3 shows the results for total annual savings. These results are virtually identical to the summer on-peak results shown in Table 4-2. Again the findings for SCE are consistent with the hypothesis of spillover, the findings for PG&E contradict the hypothesis, but neither set of findings are statistically significant. Because of the poor statistical significance, the spillover impacts were not quantified further for either utility.

	PG&E		**SCE**	
	Savings	**Err Bnd**	**Savings**	**Err Bnd**
Non-Participants	10%	4%	10%	7%
Partial Participants	5%	8%	14%	5%
Difference	-5%	9%	4%	9%
t-stat		-0.87		0.86

Table 4-3: Total Annual Savings by Category of Non-Participant

4.3 FREE-RIDERSHIP

Free-ridership is the difference between the participants' gross and net savings. PG&E's free-ridership was estimated to be 5,510 kW, or 28 percent for demand and 13,016,000 kWh, or 16 percent for annual energy. SCE's free-ridership was 3,902 kW, or 38 percent for demand and 24,426,000 kWh, or 36 percent for annual energy. See Table 4-4.

The net-to-gross analysis constructed models for only the summer on-peak demand and the annual energy savings, so only those results are shown in this chapter.

	PG&E Participants	**SCE Participants**
Summer On-Peak kW	5,510	3,902
Total Annual kWh	13,016,000	24,426,000

Table 4-4: Free-Ridership Estimates for kW and kWh

4.4 NET IMPACT

4.4.1 kW Impact

Table 4-5 shows the net demand savings for each costing period. The net demand savings for both utilities during the summer on-peak period was 14.1 MW for PG&E and 6.3 MW for SCE. The net realization rate for peak demand savings was 82 percent for PG&E and 46 percent for SCE. The net program estimates of demand savings were 17.3 MW and 13.8 MW for PG&E and SCE, respectively. The net-to-gross ratio for peak demand was 72 percent for PG&E and 62 percent for SCE.

	PG&E Participants		SCE Participants	
	Total	**Error Bound**	**Total**	**Error Bound**
Summer On-Peak Demand	14,170	± 6,356	6,367	± 1,573

Table 4-5: Net kW Savings

By definition, non-participant net savings must be zero. All of the non-participant savings must be free-ridership because the savings were achieved in the absence of the program. The PG&E participants net savings relative to the baseline is 14.1 percent. The SCE participant demand reduction is 8.9 percent.

4.4.2 kWh Impact

The net annual energy savings are shown in Table 4-6. PG&E's annual net savings were 68,334 MWH for the year and SCE's annual savings was 43,424 MWH.

The net realization rates were 100 percent and 72 percent for PG&E and SCE, respectively. The net program estimates of energy savings were 68,000 MWH for PG&E and 60,702 MWH for SCE. The net-to-gross ratio for PG&E was 84 percent and the net-to-gross ratio for SCE was 64 percent.

	PG&E Participants		SCE Participants	
	Total	**Error Bound**	**Total**	**Error Bound**
Annual Energy	68,334,000	± 28,331,201	43,424,000	± 12,109,352

Table 4-6: Net kWh Savings by Costing Period

The PG&E participants' annual net energy savings was 14.4 percent relative to the baseline consumption, SCE participants' annual net savings was 9.3 percent.

5. MEASURE LEVEL GROSS IMPACTS

Four groups of measures were selected for analysis: shell, lighting, HVAC, and refrigeration. The following sections detail the demand and energy savings attributable to each of these measure categories.

Many of the impact findings presented in this chapter are not statistically different from zero. Generally, this is due to small samples for each of the individual measure analyses. The lack of statistical significance of the measure-level runs in no way impacts the significance of the total load estimates presented earlier. A side effect of the lack of statistical significance is that the sum of the measure-level estimates will not exactly equal the total load estimate. For example, the total gross savings for PG&E participants from chapter 3 were 81,400 MWH. The sum of the measure-level estimates in this chapter is 81,345 MWH. Also, because there are negative savings estimates, the percentages will not sum to 100 percent.

5.1 METHODOLOGY

The analysis methodology is the same as for the total load gross impacts from the previous chapter. Each measure was isolated by calculating the change in energy use over successive runs of the DOE model for each site. The measure level impacts were calculated using the following five model runs:

1. Baseline model
2. Baseline with shell measures set to As-Built
3. Baseline with shell and lighting measures set to As-Built
4. Baseline with shell, lighting, and HVAC measures set to As-Built
5. As-Built model

The difference between run 1 and run 2 provided the shell measure impacts. The difference between run 2 and run 3 provided the lighting measure and lighting / shell interaction impacts. The difference between run 3 and run 4 generated the HVAC measure and HVAC / lighting and HVAC / shell interaction impacts. The difference between run 4 and run 5 provided the refrigeration measure and interaction impacts. Other impacts were negligible.

5.2 SHELL MEASURES

Shell measure impacts were not statistically different from zero for most costing periods, with the exception of SCE participant energy savings. The shell measures accounted for approximately 2 percent of SCE participants' total annual savings.

5.2.1 kW Impact

The impact of the shell measures is very small for both PG&E and SCE. This was due to low participation using these measures. In almost all of the costing periods, the shell measure impacts are not significantly different from zero. The only costing period for which the savings are non-zero for PG&E is the winter partial peak. For SCE, the periods where the shell measure impact is statistically significant are the summer on-peak, the summer off-peak, and the winter off-peak.

	PG&E Participants		**SCE Participants**	
	Total	**Error Bound**	**Total**	**Error Bound**
Summer On-Peak	815	± 1,191	563	± 323
Summer Part-Peak	22	± 883	(112)	± 122
Summer Off-Peak	246	± 601	192	± 171
Winter Part-Peak	315	± 308	561	± 462
Winter Off-Peak	358	± 567	90	± 84

Table 5-1: Shell Measures kW Impact by Costing Period

Figure 5-1 and Figure 5-2 show the shell measure savings as a percentage of baseline demand for participants and non-participants. For the summer on-peak period, only the SCE participants are significantly different than zero, at 0.8 percent below the Baseline demand. In other costing periods, the only statistically significant difference from zero for non-participants is for PG&E during the summer off-peak period. No SCE non-participants had non-zero shell measure savings.

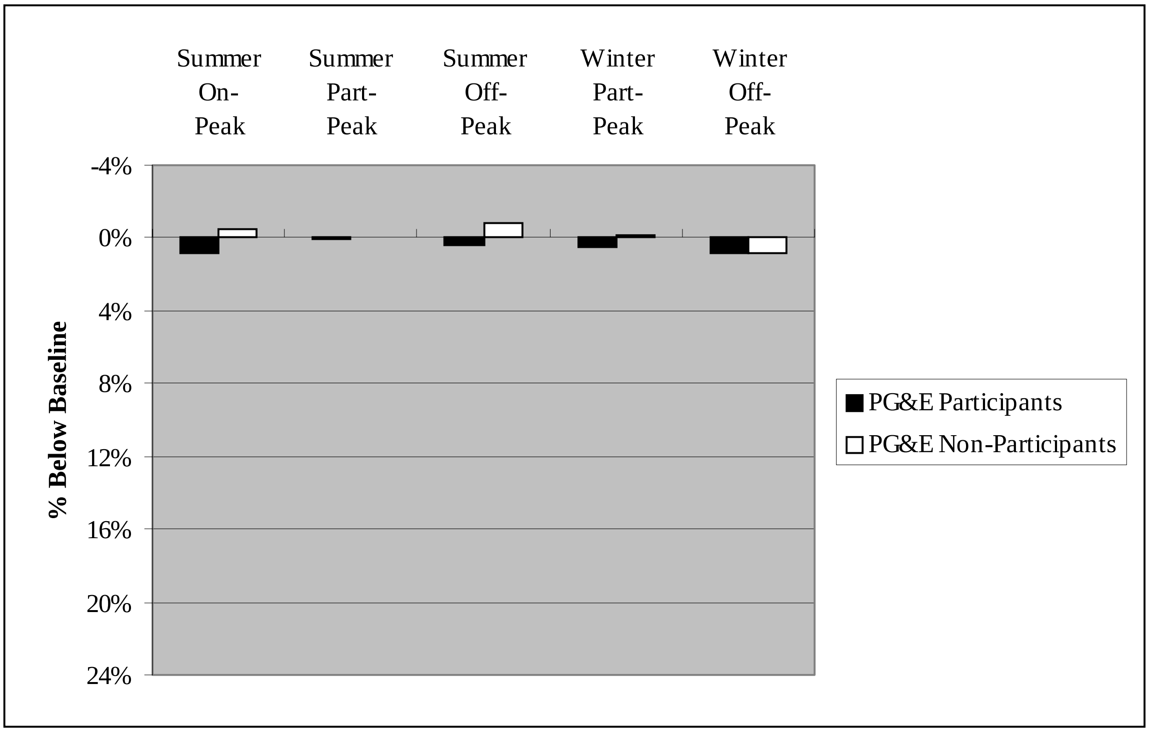

Figure 5-1: PG&E Shell Measures as a Percentage of Baseline Demand

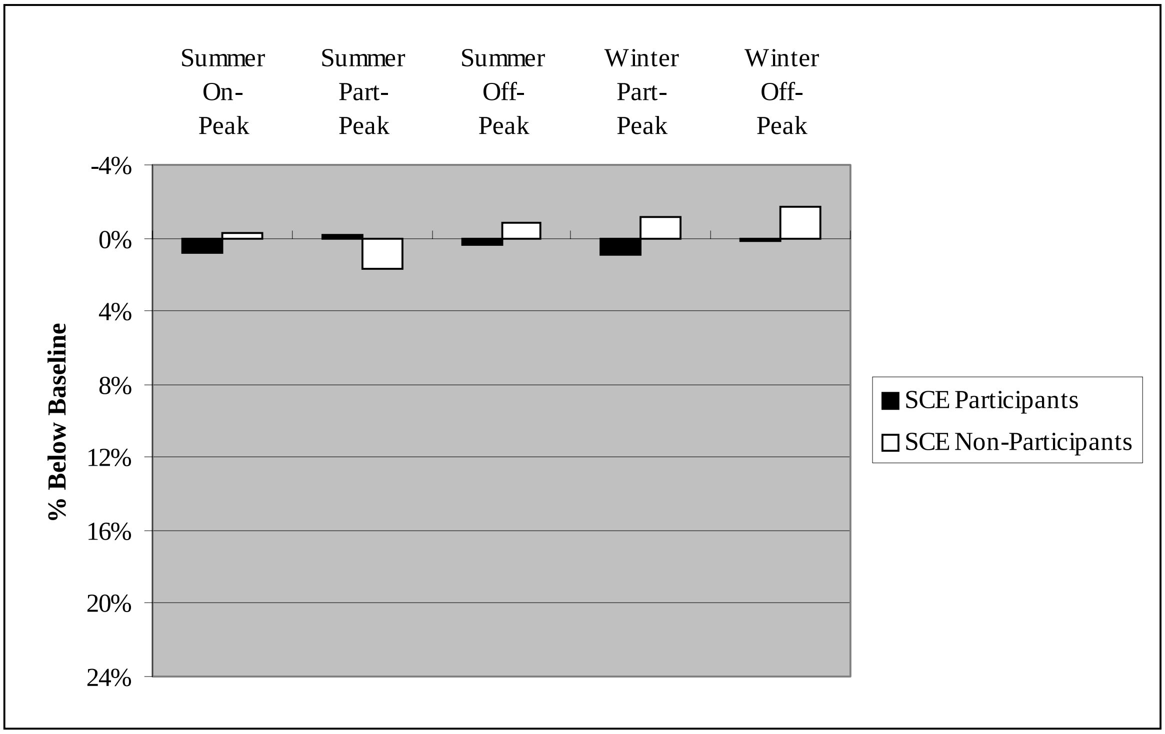

Figure 5-2: SCE Shell Measures as a Percentage of Baseline Demand

5.2.2 kWh Impact

For PG&E participants, the shell measures did not produce statistically significant savings during any costing period. The SCE savings totaled 1,378 MWH for the year and were statistically different from zero. The shell measures accounted for about 2 percent of SCE total energy savings. The SCE savings were roughly constant throughout the year.

	PG&E Participants			SCE Participants		
	Total	Error Bound		Total	Error Bound	
Summer On-Peak	177,500	±	642,600	318,400	±	124,700
Summer Part-Peak	(91,730)	±	598,500	297,300	±	116,800
Summer Off-Peak	283,900	±	929,800	237,700	±	118,800
Winter Part-Peak	264,900	±	488,500	263,500	±	145,400
Winter Off-Peak	376,700	±	509,100	261,300	±	141,300
Annual	1,011,000	±	2,962,000	1,378,000	±	501,900

Table 5-2: Shell Measures kWh Impact

Figure 5-3 and Figure 5-4 show the estimates for both participants and non-participants. All non-participant estimates are not statistically different from zero. Only the SCE participant savings are significant and represent annual savings of 0.3 percent relative to the Baseline.

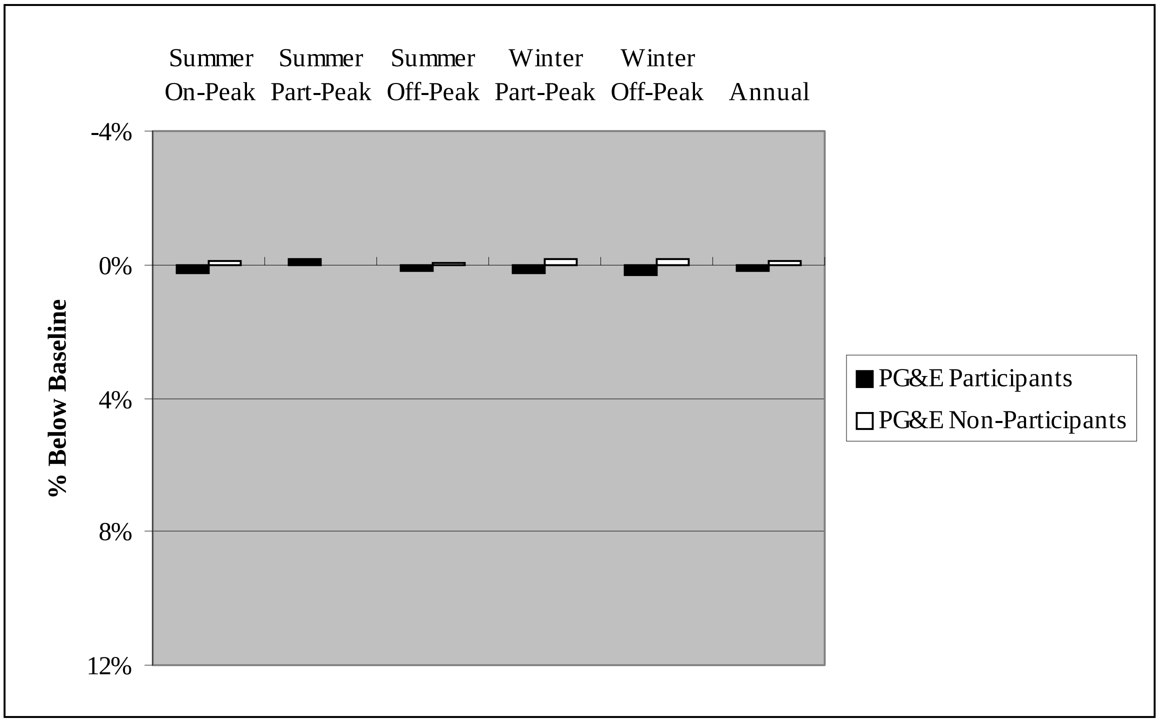

Figure 5-3: PG&E Shell Measure kWh Savings as a Percentage of Baseline Energy

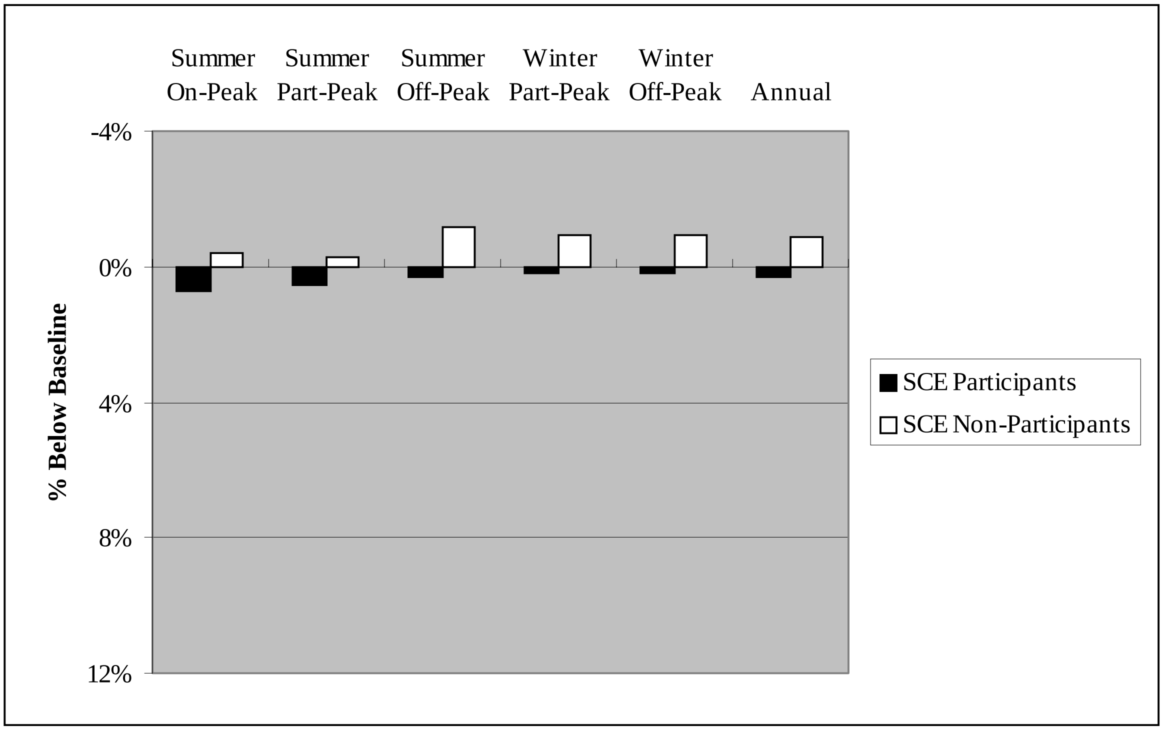

Figure 5-4: SCE Shell Measure kWh Savings as a Percentage of Baseline Energy

5.3 LIGHTING MEASURES

Lighting measures accounted for the greatest share of both demand reduction and energy savings in each of the utility's programs. For PG&E, lighting measures represented 12.2 MW in system peak demand savings and 63,780 MWH energy savings. This accounted for 62 percent of demand reduction and 78.4 percent of the energy savings. The lighting measures' demand and energy savings at SCE totaled 8.6 MW and 63,160 MWH, which was 84 percent and 93 percent of total savings, respectively.

5.3.1 kW Impact

The lighting measures had the greatest load reduction impact for both PG&E and SCE. The lighting measures accounted for 62 percent of PG&E's summer on-peak demand reduction and 84 percent of SCE's reduction. Table 5-3 shows the lighting measure impact estimate and error bound for each of the costing periods.

	PG&E Participants			**SCE Participants**		
	Total	**Error Bound**		**Total**	**Error Bound**	
Summer On-Peak	12,200	±	5,508	8,624	±	2,207
Summer Part-Peak	12,350	±	5,386	6,976	±	1,770
Summer Off-Peak	7,081	±	3,642	6,859	±	1,852
Winter Part-Peak	10,740	±	4,697	7,079	±	1,757
Winter Off-Peak	5,193	±	2,924	5,705	±	1,439

Table 5-3: Lighting Measure kW Savings by Costing Period

The lighting measure savings, expressed as a percentage of the total load Baseline demand, is shown for both participants and non-participants in Figure 5-5 and Figure 5-6. The non-participants had lower demand relative to the Baseline for several of the costing periods.

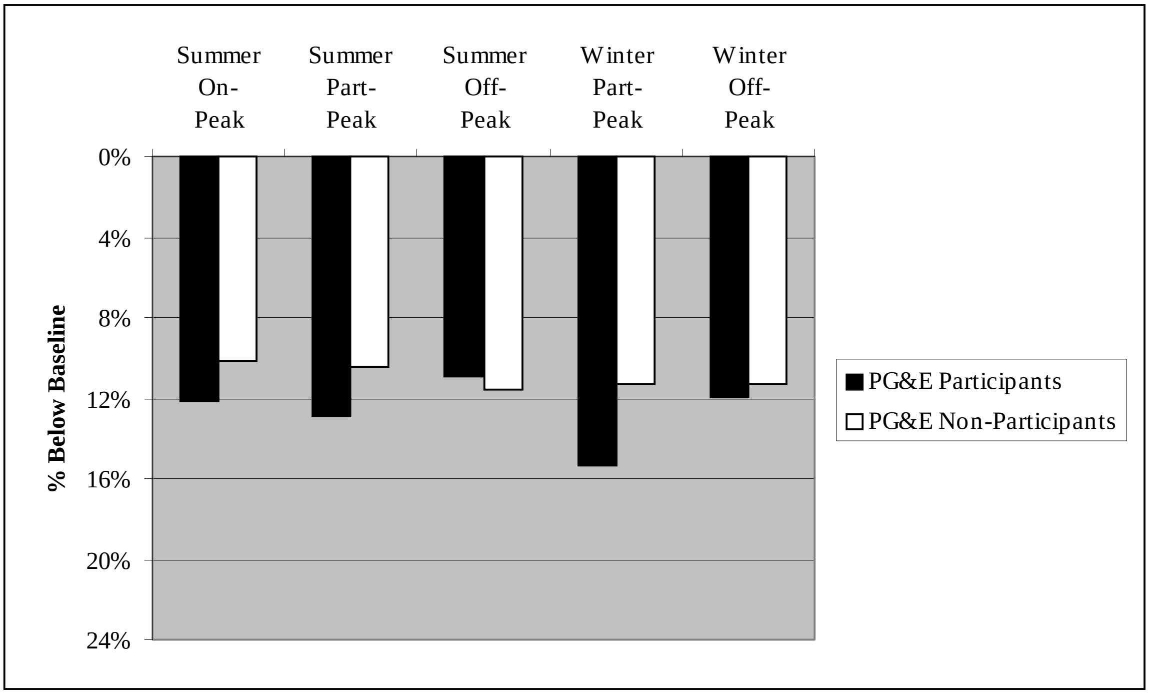

Figure 5-5: PG&E Lighting kW Savings as a Percentage of Baseline Demand

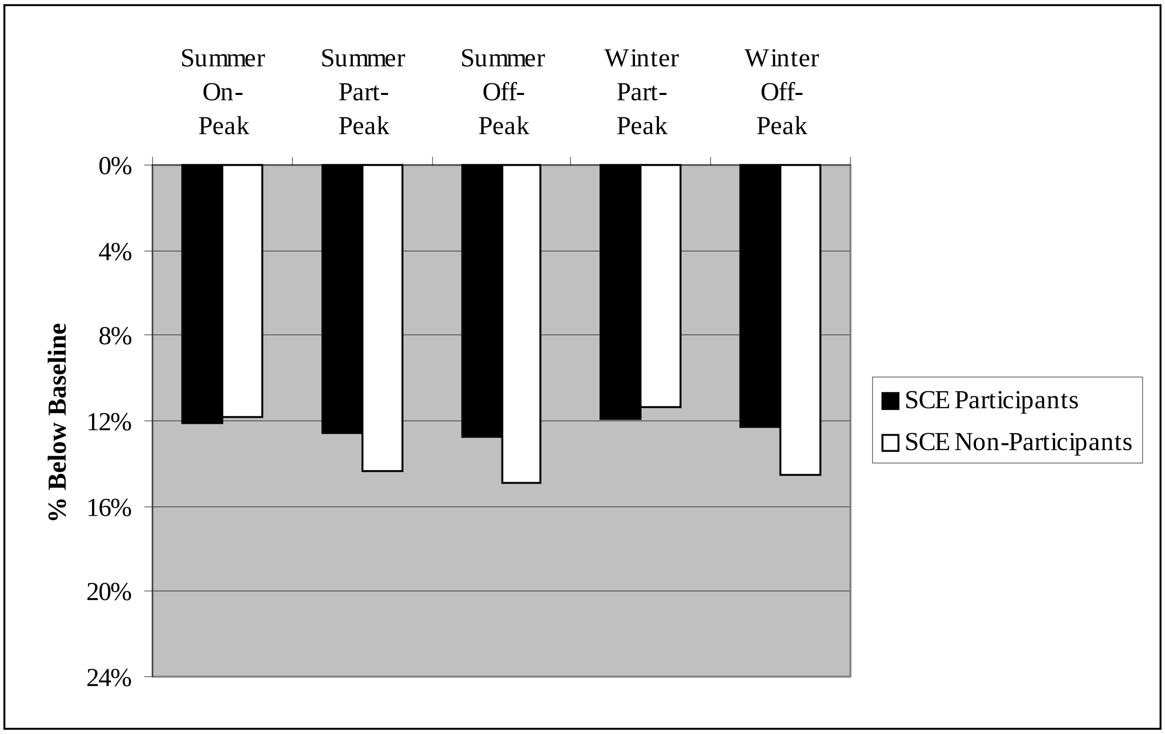

Figure 5-6: SCE Lighting kW Savings as a Percentage of Baseline Demand

5.3.2 kWh Impact

The lighting measures had the greatest energy savings for both PG&E and SCE. The lighting measures accounted for 78.4 percent of PG&E's energy savings and 93 percent of SCE's savings. Table 5-4 shows the lighting measure impact estimate and error bound for each of the costing periods.

	PG&E Participants		SCE Participants	
	Total	**Error Bound**	**Total**	**Error Bound**
Summer On-Peak	8,584,000	± 3,892,000	5,593,000	± 1,222,000
Summer Part-Peak	8,520,000	± 3,467,000	6,755,000	± 1,445,000
Summer Off-Peak	15,990,000	± 6,028,000	9,796,000	± 2,322,000
Winter Part-Peak	16,060,000	± 6,714,000	21,450,000	± 4,486,000
Winter Off-Peak	14,620,000	± 5,401,000	19,570,000	± 4,839,000
Annual	63,780,000	± 24,820,000	63,160,000	± 13,830,000

Table 5-4: Lighting kWh Savings by Costing Period

The lighting energy savings are expressed as a percentage of baseline energy consumption in Figure 5-6 and Figure 5-7. Savings relative to the Baseline are shown for both participants and non-participants. The participants consumed less energy for lighting in all costing periods than did the non-participants.

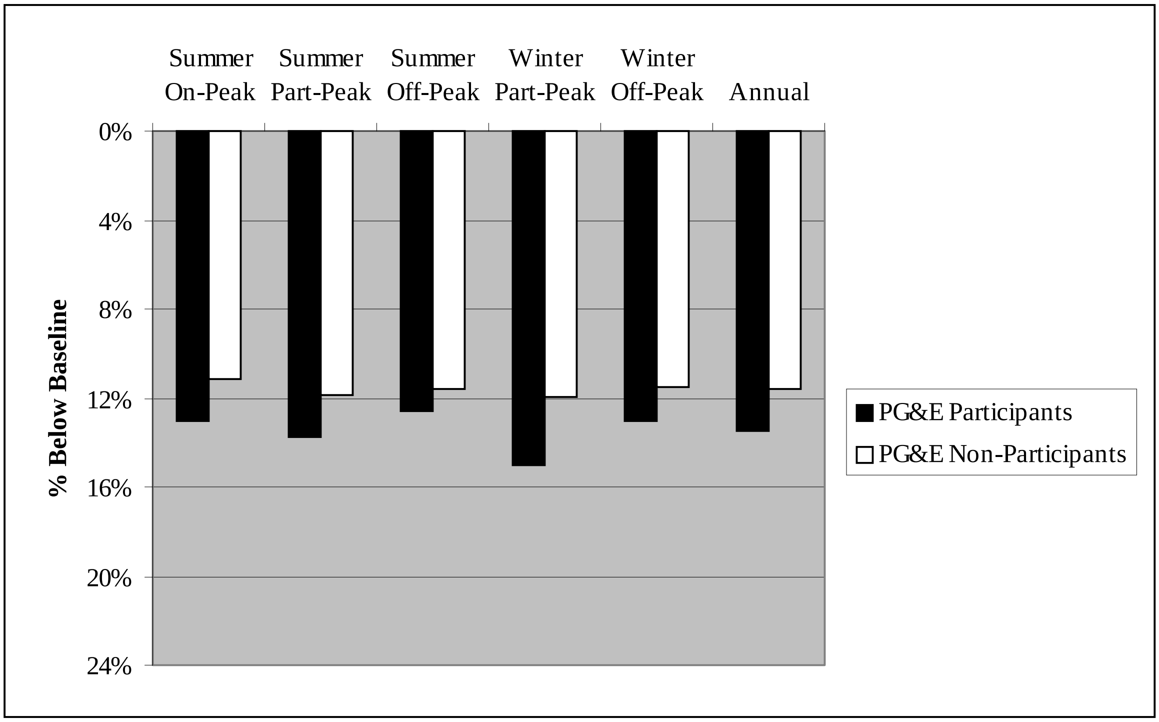

Figure 5-7: PG&E Lighting kWh Savings as a Percentage of Baseline Energy

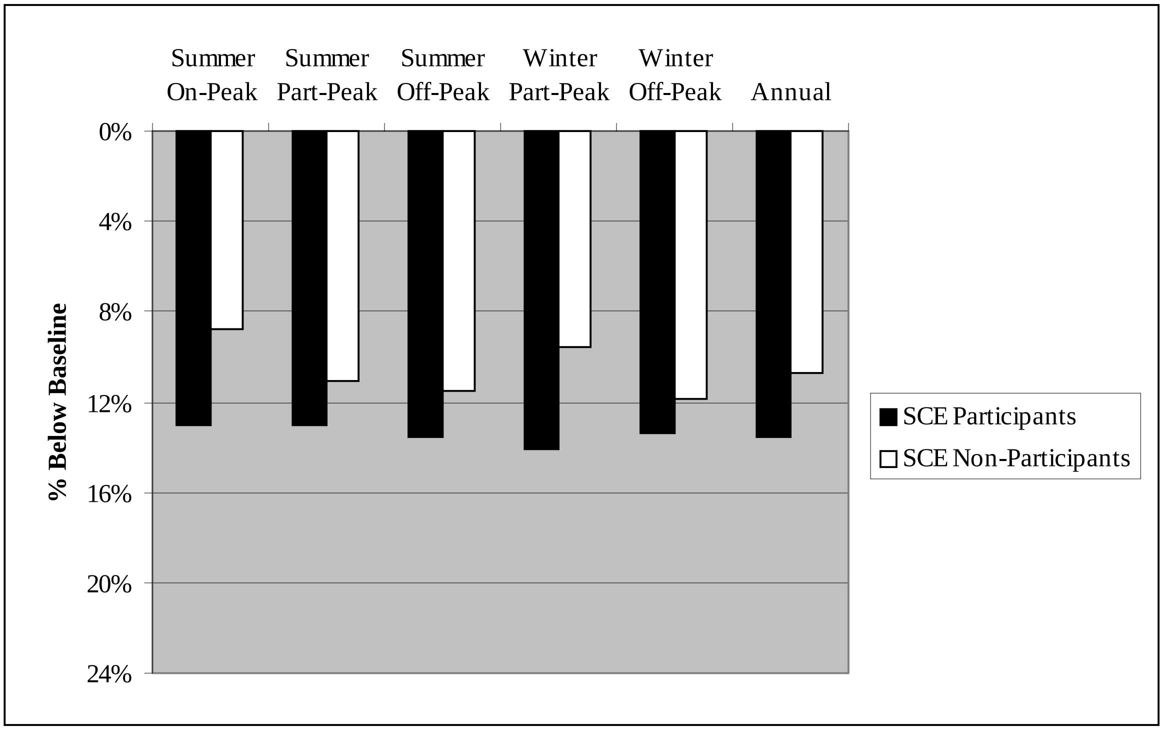

Figure 5-8: SCE Lighting kWh Savings as a Percentage of Baseline Energy

5.4 HVAC MEASURES

HVAC measures accounted for the second largest share of both demand reduction and energy savings in each of the utilities programs. For PG&E, HVAC measures represented an 8.1 MW reduction in system peak demand savings and 17,850 MWH energy savings. This accounted for 41.3 percent of demand reduction and 21.9 percent of the energy savings. The HVAC measures' demand and energy savings at SCE totaled 2.3 MW and 6,369 MWH, which was 22.2 percent and 9.3 percent of the total savings, respectively.

5.4.1 kW Impact

The HVAC measures were the second largest contributor to demand reductions for both PG&E and SCE. The PG&E HVAC measures accounted for a summer on-peak demand savings of 8.1 MW, which was 41.3 percent of the total demand reduction. The SCE measures accounted for a summer on-peak demand savings of 2.3 MW, which was 22.2 percent of the total demand reduction.

	PG&E Participants			SCE Participants		
	Total	Error Bound		Total	Error Bound	
Summer On-Peak	8,139	±	4,253	2,382	±	1,136
Summer Part-Peak	6,977	±	3,681	(12)	±	1,235
Summer Off-Peak	6,575	±	3,588	1,401	±	483
Winter Part-Peak	1,482	±	1,285	313	±	1,081
Winter Off-Peak	1,046	±	641	663	±	801

Table 5-5: HVAC Measures kW Impact

Figure 5-8 and Figure 5-9 show the HVAC measures savings as a percentage of the baseline demand for each costing period. The PG&E participant savings were greater than the non-participant savings for all periods. This was also the case with SCE. The SCE participant savings are statistically different from zero for only the summer on-peak and summer off-peak periods. None of the non-participant estimates are statistically different from zero.

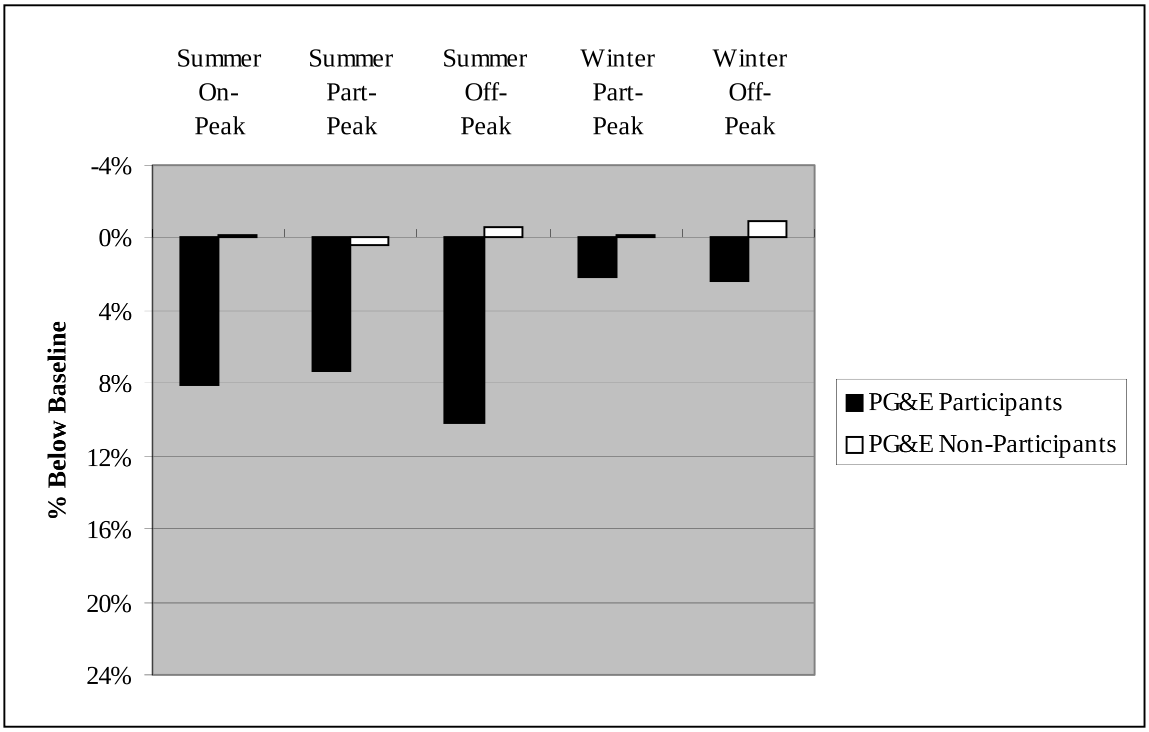

Figure 5-9: PG&E HVAC Measures kW Impact as a Percentage of Baseline

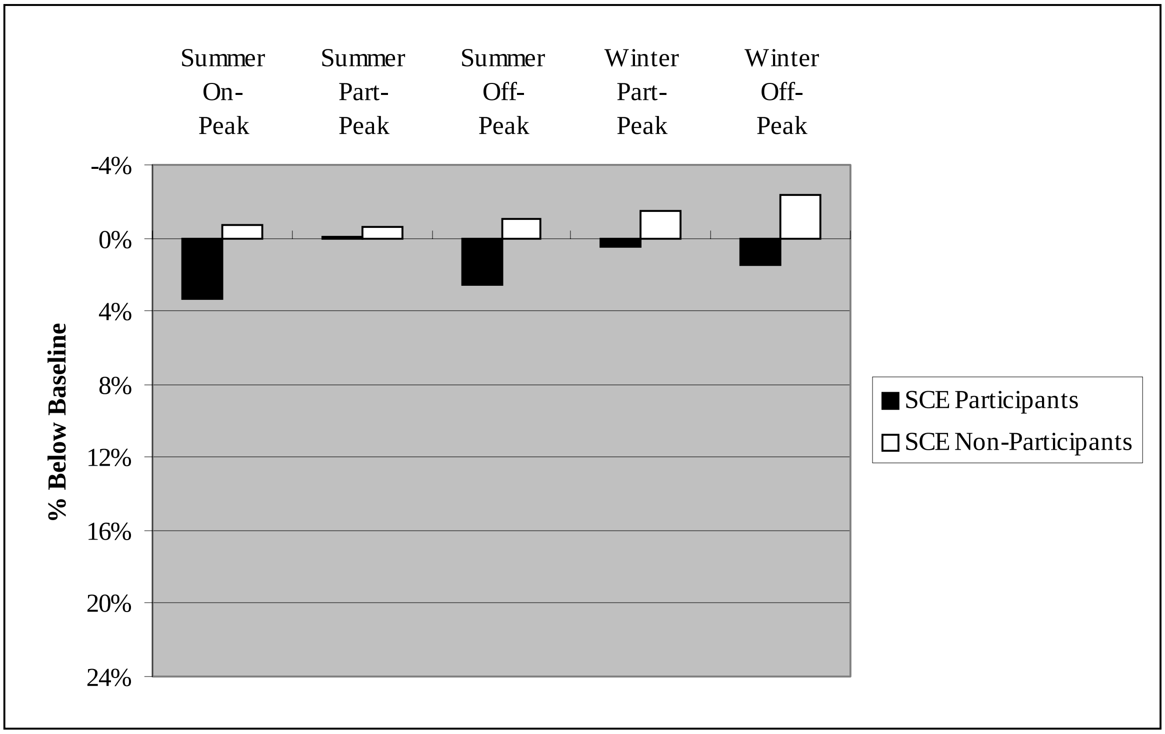

Figure 5-10: SCE HVAC Measures kW Impact as a Percentage of Baseline

5.4.2 kWh Impact

The HVAC measures were the second largest contributor to energy savings for both PG&E and SCE. The PG&E HVAC measures accounted for annual savings of 17,850 MWH, which is 21.9 percent of the total energy savings. The SCE measures saved 6,369 MWH of energy annually, which was 9.3 percent of the total savings. The winter SCE energy savings are not statistically different from zero.

	PG&E Participants		SCE Participants	
	Total	**Error Bound**	**Total**	**Error Bound**
Summer On-Peak	4,672,000	± 2,662,000	1,639,000	± 626,000
Summer Part-Peak	2,725,000	± 1,650,000	1,748,000	± 791,800
Summer Off-Peak	4,776,000	± 2,825,000	1,024,000	± 993,300
Winter Part-Peak	3,272,000	± 2,036,000	1,085,000	± 2,025,000
Winter Off-Peak	2,406,000	± 1,723,000	873,800	± 2,235,000
Annual	17,850,000	± 10,230,000	6,369,000	± 5,783,000

Table 5-6: HVAC Measures kWh Savings

Figure 5-10 and Figure 5-11 show energy savings relative to the baseline for participants and non-participants.

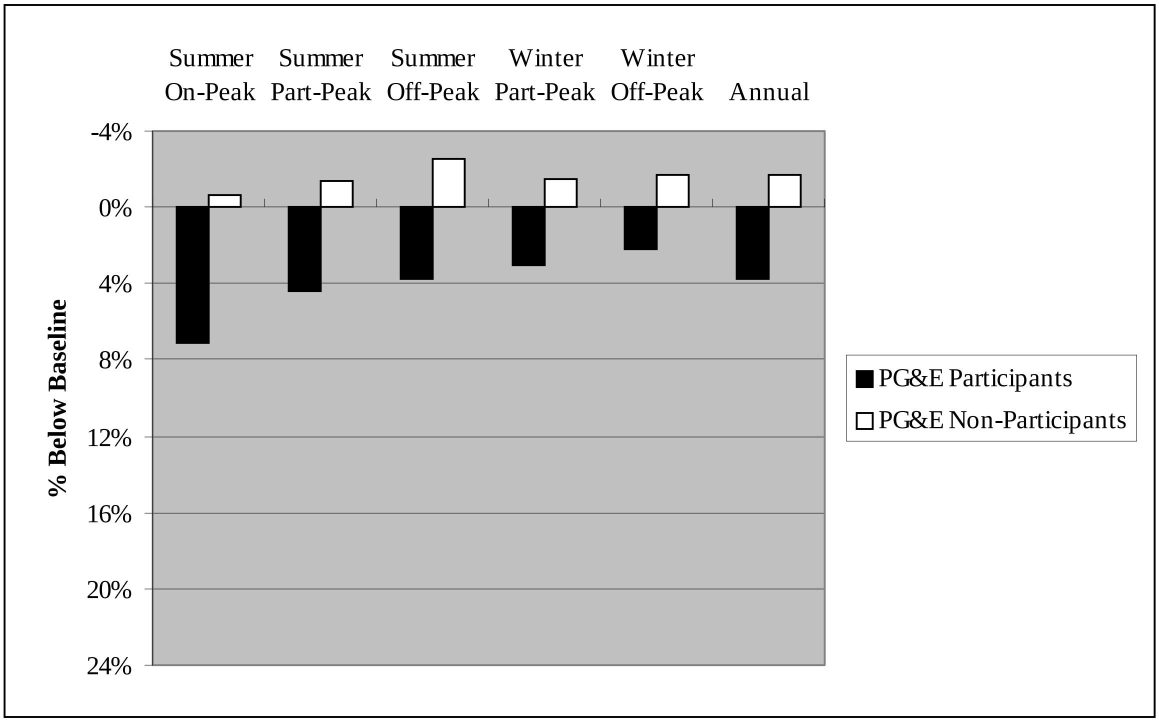

Figure 5-11: PG&E HVAC Measures kWh Savings as a Percentage of Baseline

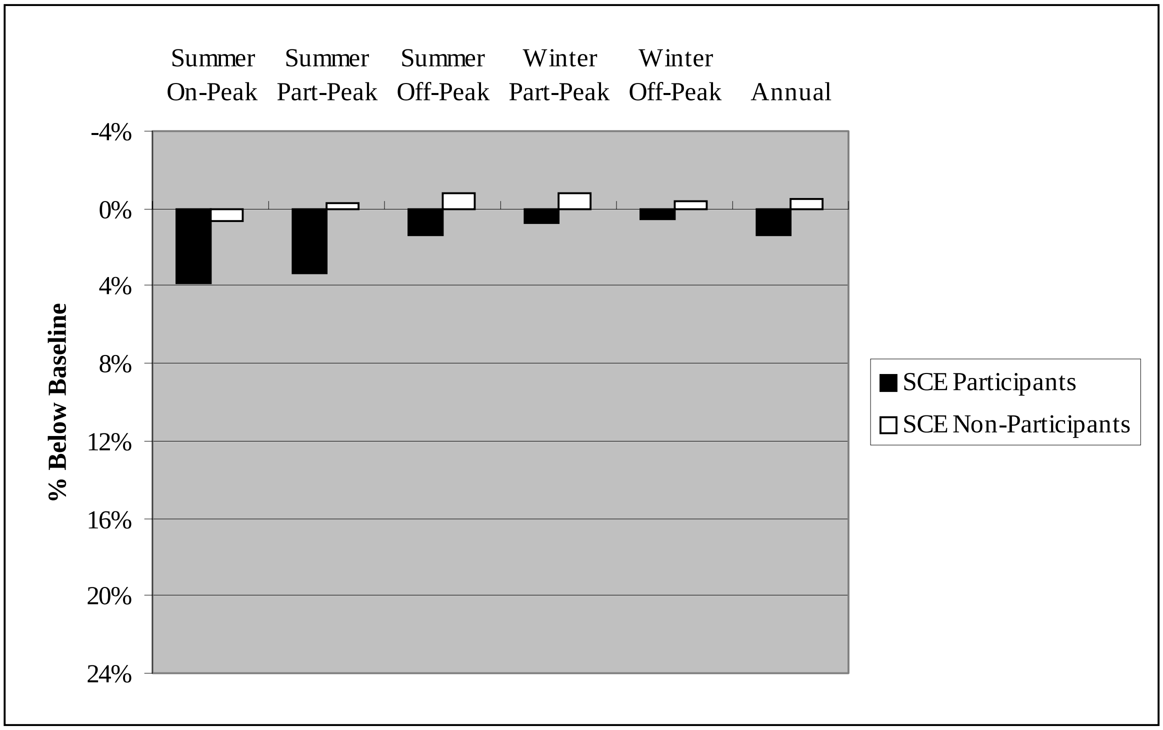

Figure 5-12: SCE HVAC Measures kWh Savings as a Percentage of Baseline

5.5 REFRIGERATION MEASURES

Refrigeration measure savings were statistically different from zero for only the summer periods for SCE, where the savings was negative. This is not surprising, as SCE did not pay rebates for refrigeration measures. PG&E participant refrigeration measure savings were not statistically different from zero for any period.

5.5.1 kW Impact

Table 5-7 shows the estimates of refrigeration savings for PG&E and SCE participants.

	PG&E Participants			SCE Participants		
	Total	Error Bound		Total	Error Bound	
Summer On-Peak	(1,477)	±	1,592	(1,301)	±	572
Summer Part-Peak	(678)	±	954	(777)	±	436
Summer Off-Peak	(1,014)	±	1,155	(600)	±	332
Winter Part-Peak	194	±	309	(83)	±	580
Winter Off-Peak	55	±	270	(23)	±	627

Table 5-7: Refrigeration Measures kW Impact

Figure 5-12 and Figure 5-13 show the refrigeration measures savings as a percentage of the baseline demand for each costing period. The PG&E non-participant savings were statistically different from zero for only the summer partial peak period. The SCE non-participant savings were statistically significant for the summer periods only.

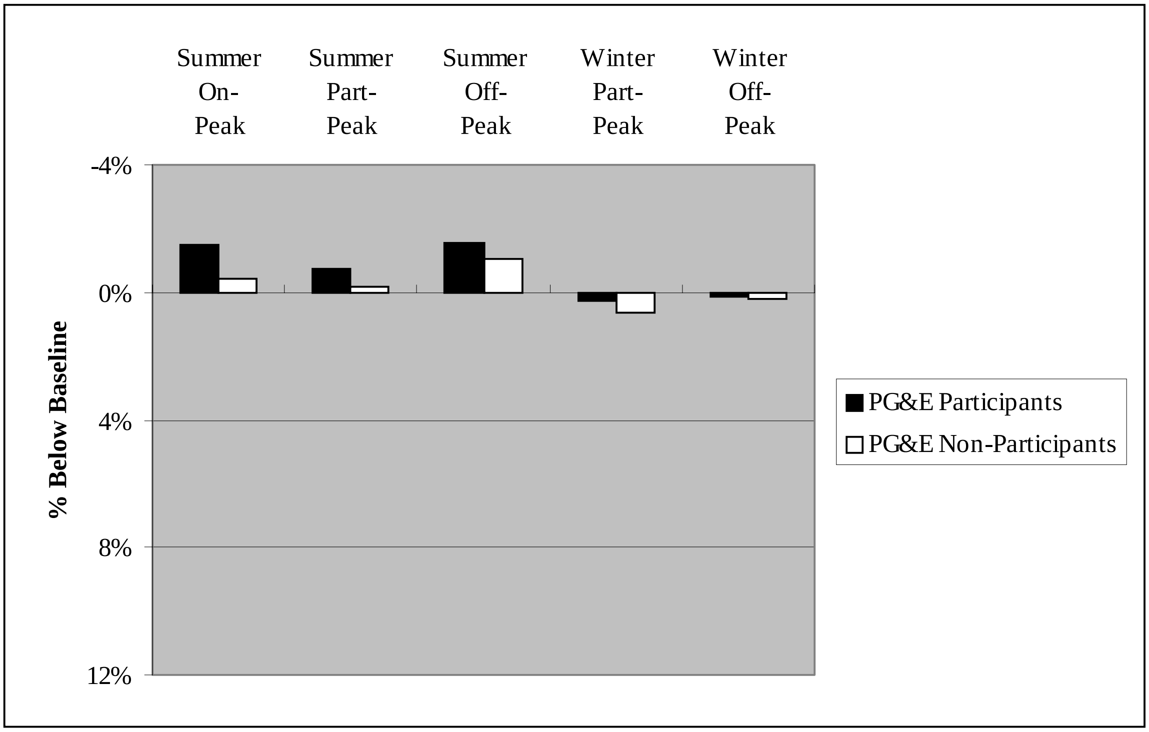

Figure 5-13: PG&E Refrigeration Measures kW Impact as a Percentage of Baseline

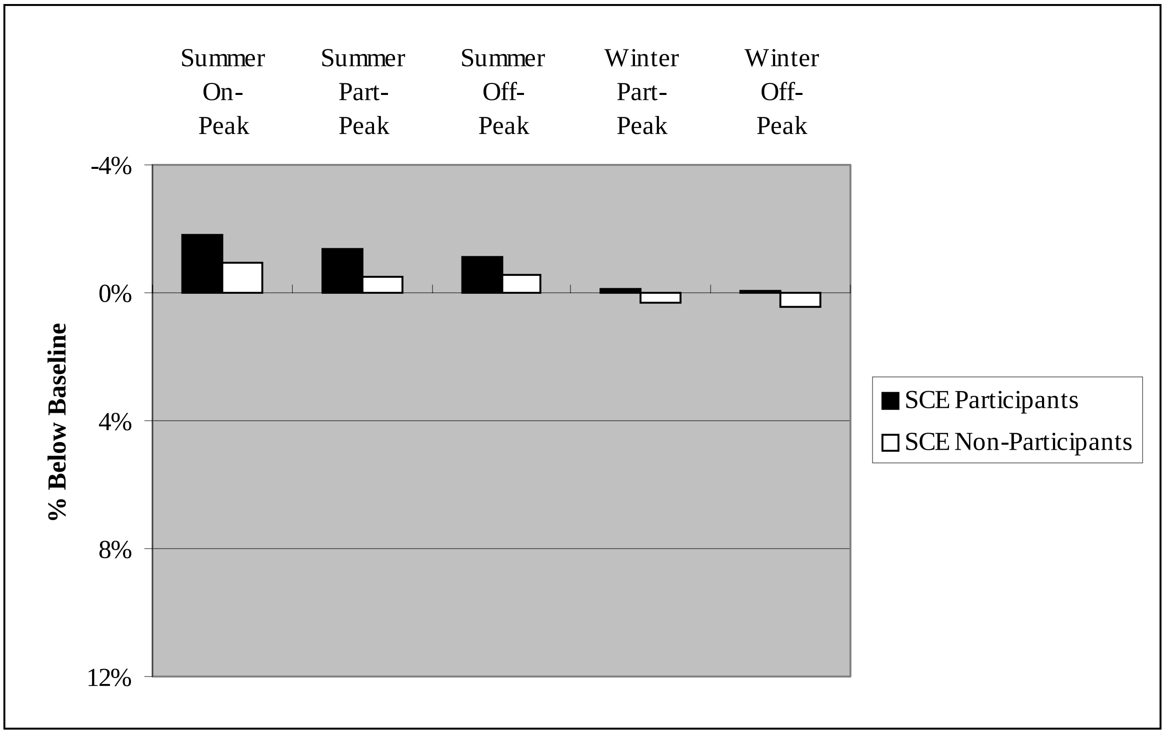

Figure 5-14: SCE Refrigeration Measures kW Impact as a Percentage of Baseline

5.5.2 kWh Impact

The refrigeration measures were statistically different from zero for only the SCE summer periods, where they were negative. The savings estimates for participants are shown in table 5-8.

	PG&E Participants			SCE Participants		
	Total	Error Bound		Total	Error Bound	
Summer On-Peak	(398,900)	±	527,700	(1,048,000)	±	465,700
Summer Part-Peak	(235,200)	±	403,300	(697,700)	±	338,400
Summer Off-Peak	(494,200)	±	982,800	(908,200)	±	639,700
Winter Part-Peak	(130,600)	±	683,300	(493,600)	±	1,112,000
Winter Off-Peak	(37,050)	±	731,300	81,490	±	2,034,000
Annual	(1,296,000)	±	3,167,000	(3,067,000)	±	4,099,000

Table 5-8: Refrigeration Measures kWh Savings

Figure 5-14 and Figure 5-15 show refrigeration savings expressed as a percentage of the Baseline energy use for both participants and non-participants. The only non-participant savings estimates that are statistically significant are the SCE summer on-peak, SCE summer partial peak, and SCE winter partial peak.

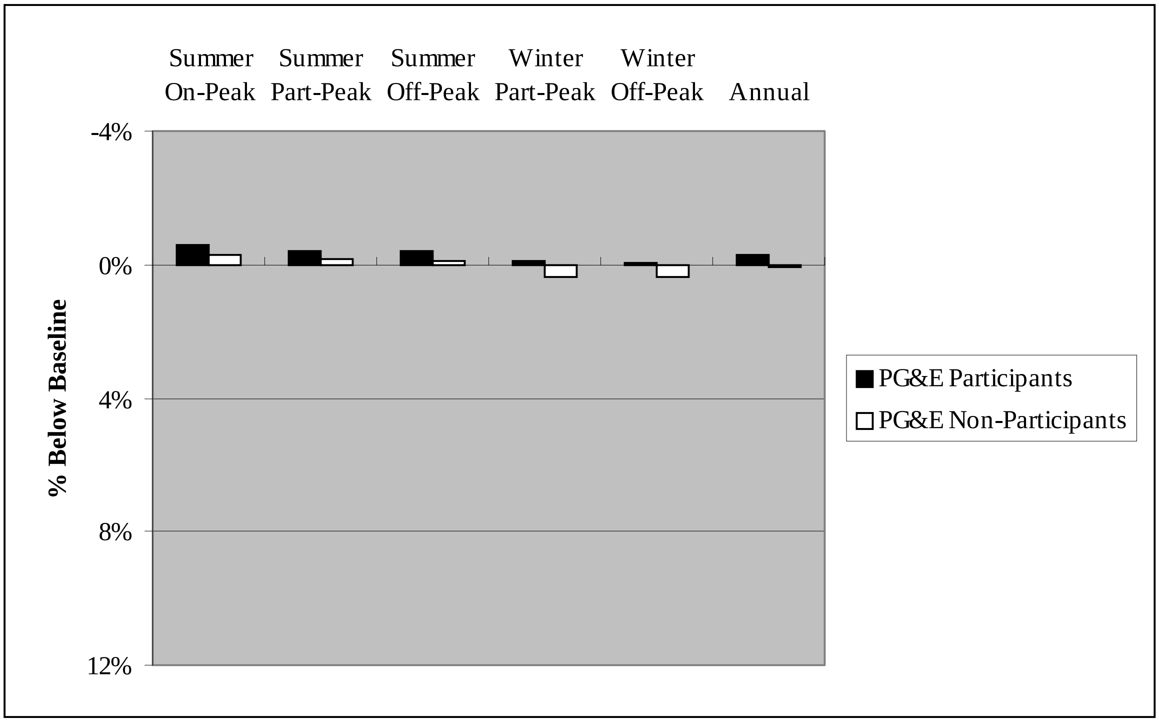

Figure 5-15: PG&E Refrigeration Measures kWh Savings as a Percentage of Baseline

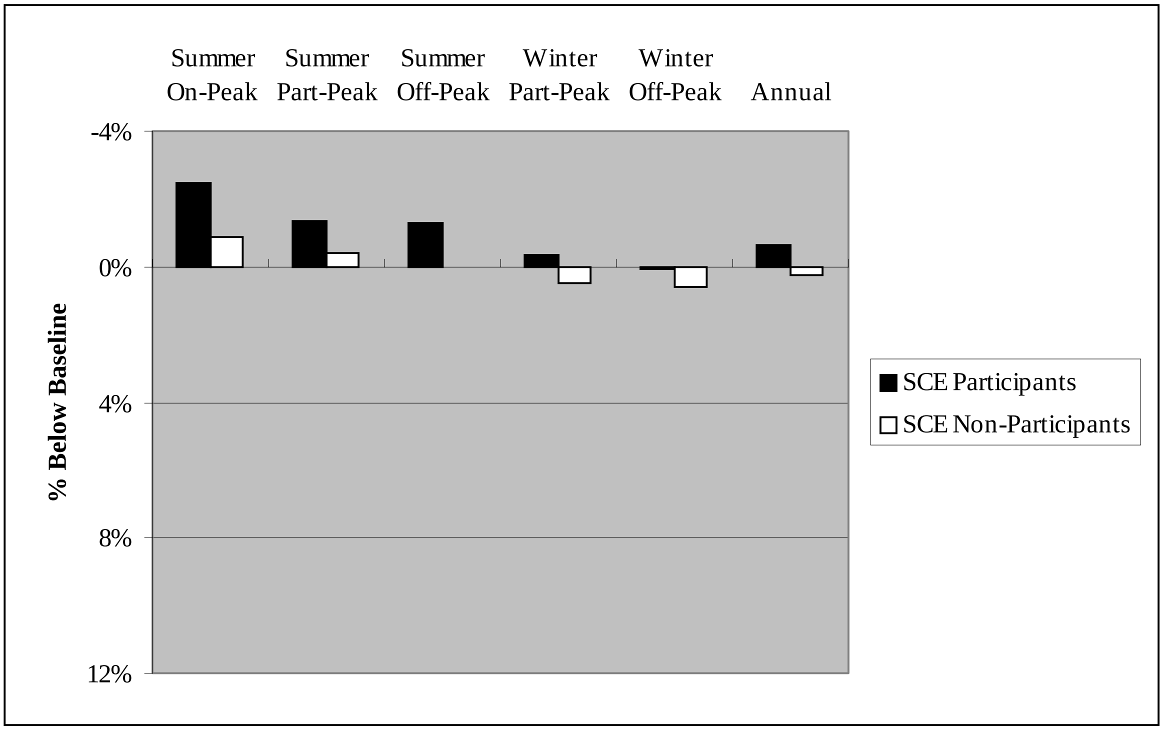

Figure 5-16: SCE Refrigeration Measures kWh Savings as a Percentage of Baseline

5.6 MEASURE SAVINGS PER SQUARE FOOT

Table 5-9 shows the demand and annual energy savings per square foot for PG&E and SCE participants for each of the four measures. The total PG&E participant square footage was 26.7 million ft^2 and the SCE participant square footage was 18.7 million ft^2. The demand savings is presented in watts per square foot and the energy savings is in kWh per square foot per year.

	PG&E Participants		SCE Participants	
	Total	**Error Bound**	**Total**	**Error Bound**
Shell Measures				
Peak Demand	0.03	± 0.04	0.03	± 0.02
Annual Energy	0.04	± 0.11	0.07	± 0.03
Lighting Measures				
Peak Demand	0.46	± 0.21	0.46	± 0.12
Annual Energy	2.39	± 0.93	3.38	± 0.74
HVAC Measures				
Peak Demand	0.30	± 0.16	0.13	± 0.06
Annual Energy	0.67	± 0.38	0.34	± 0.31
Refrigeration Measures				
Peak Demand	(0.06)	± 0.06	(0.07)	± 0.03
Annual Energy	(0.05)	± 0.12	(0.16)	± 0.22

Table 5-9 : Measure Demand Savings per Square Foot

6. PROCESS FINDINGS

6.1 DRIVERS OF PARTICIPATION

Maximum likelihood estimation methods were used to estimate the participation decision equations. Model runs were completed on variations of the initial decision equation. The final estimated participation decision equation has a log-likelihood value of -146.72 and correctly predicts the participation decision for 68% of the buildings. This 68% concordance falls within the range of prior studies, which reported concordances as low as 62% and as high as 80%.[4]

The preliminary models included:

- Climate zone variables
- Building type variables
- Building square footage
- Building weekly occupancy load
- Type of ownership for the building
- The circumstances under which the building was built
- The number of tenants in the building
- Whether occupants are separately metered
- The degree of input the owner had in the design process
- The importance of first cost versus operating cost and the investment criteria that were used
- The significance of energy costs for the businesses that will occupy the building
- The importance of energy efficiency in the choice of fuel.

All of the variables were tried in the models. Based on the coefficient values and t-tests for these runs, variables were dropped or combinations of discrete answer choices were combined into one dummy variable. For example, rather than having investor-owned and developer-owned dummy variables enter the model separately, these answer choices were combined into one variable. The final model specification includes only those variables that have an impact on the participation decision.

Table 6-1 shows the coefficient and t-ratio for each variable. From this table, it can be seen that the probability of participation varies by climate zone. Overall, restaurants and miscellaneous buildings, simple payback criteria, and the importance of energy efficiency in fuel choice positively influenced program participation. Further, buildings owned by the developer/investor have a lower probability of participation.[5]

The inverse Mill's ratio for participants and non-participants was calculated from the results of this equation to correct for self-selection bias in the net savings equations.

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[4] Pacific Gas and Electric Company, *Commercial New Construction Impact Evaluation Study*, October 22, 1993; Southern California Edison Company, *Design for Excellence Commercial New Construction Incentive Program Impact Evaluation*, November 12, 1993.

[5] This variable was not statistically significant at the 10% level but was retained in the model because the t-ratio was greater than one.

Variable	Coefficient (t-ratio)
Constant	-0.343 (-1.628)
Square Feet (000)	0.005*** (2.531)
Restaurant Building	1.483** (2.153)
Miscellaneous Building	0.761*** (2.513)
Climate Zones 5 and 6	-1.315*** (-4.075)
Climate Zones 8 through 10	-0.977*** (-4.150)
Climate Zones 12 and 13	-0.475** (-2.091)
Climate Zone 14-East	-0.886** (-1.970)
Simple Payback Criteria	0.477*** (2.599)
Owned by Developer/Investor	-0.330 (-1.455)
Energy Efficiency Very Important	0.340* (1.724)
Log Likelihood = -146.7232, n=256 *** = significant, α=0.01; ** = significant, α=0.05; * = significant, α=0.10	

Table 6-1: Participation Decision Model

6.2 STUDY DESIGN ISSUES

This section discusses what has been learned from this project about the design of an evaluation study of commercial new construction. The current project has suggested a number of important issues that should be explored in future projects:

- **Billing Data**. How important is billing data? In particular, is it worth delaying the study to collect a full year of billing data for each site?
- **Dodge New Construction Data**. How useful is Dodge new construction data as a sampling frame?
- **Choice of Sample Sizes**. What can be said about the sample sizes needed for future projects?
- **Title 24 Documentation**. Is it practical to require Title 24 documentation?
- **Decision Maker Surveys**. Are the decision-maker surveys worthwhile? How can they be improved?
- **On-Site Audits**. How successful were the field auditing procedures? How can they be improved?

- **DOE-2 Modeling**. Are site-specific DOE-2 models an appropriate tool for evaluation? How comprehensive are machine-built models? Is it necessary to calibrate the machine-built models using hand-built models?
- **End Use Metering**. How valuable is end-use metering? How is it best incorporated into this type of study?
- **Partial Participation**. How is this best defined?

6.2.1 Billing Data

This study was designed to measure the savings of new construction projects that received rebates during 1994. In principle, the study could have been started in the beginning of 1995 since the projects must be finished when the rebates are paid. In fact, the study was delayed more than a year in order to ensure the availability of twelve months of billing data for each project.

There are several important disadvantages of delaying the study. Delay complicates data collection. This affects both the decision-maker survey and the on-site audits. A substantial lapse between completion of the project means that it is harder to locate the key decision-maker, harder to enlist his or her cooperation, and harder for the decision-maker to accurately recall the project and the more subtle aspects of the design process. Therefore, the delay tends to increase the non-response rate and to compromise the accuracy of the answers.

In the case of the on-site audits, the validity and statistical reliability of the results depend crucially on accurately identifying the space affected by the project. A delay of a year or more makes it harder for the facility manager to identify the correct space and to distinguish the desired project from other activities. The delay also is likely to make it harder to get permission for the on-site audit. On the other hand, a delay of several months after completion improves that likelihood that the affected space is fully occupied and that the operating patterns have stabilized after the construction.

Although the project was delayed 12 months to ensure that billing data was available to calibrate engineering models, the billing data turned out to be less valuable than initially assumed. Only about half of the new construction projects were individual new buildings. The remaining projects were about equally divided between renovation projects and additions. In renovations and additions, the available billing data often includes usage from the original building which can not be separated from the energy usage of the affected area. The same thing can happen if a new building is added to a multi-building facility, e.g., a campus. The billing data can reflect the total use of all of the buildings on the campus, whereas the actual interest is in the single new building.

In fact, there was a fairly poor correspondence between the available billing data and the actual space affected by the program. When the billing data and modeled space are not in agreement, calibration will actually distort the model rather than improve it. Therefore the project team decided to calibrate only those sites where the billing data was complete and appeared to be associated with the space described by the model. In other words, the billing data was only used when it was believed that it would improve the accuracy of the model.

Finally, the primary purpose of evaluation is program improvement. The more timely the evaluation study, the greater its impact on future program design and implementation. Therefore a delay of a year or more reduces the benefit of the evaluation study.

Figure 6-1 summarizes the results of the calibration to the billing data. About 34 percent of the sites were calibrated successfully to within ±10 percent of the monthly billing data. For 28 percent of the sites, the billing data was not provided by the utility, either because the relevant accounts could not be located, the meter number and account number could not be obtained from the customer, or the available billing data did not correspond to the affected site. About one-fifth of the sites had billing data that did not match the audited space.

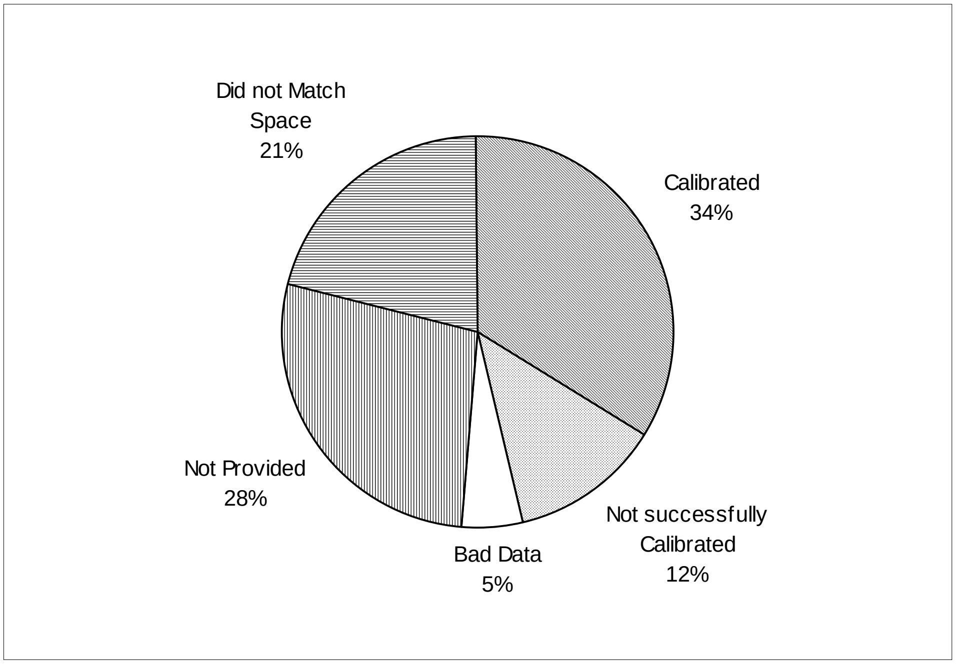

Figure 6-1: Calibration of Models to Billing Data

To summarize, suitable billing data was available for 46 percent of the sites, and 34 percent of these were successfully calibrated. However, 54 percent of the sites had missing, bad or unmatched billing data and could not be calibrated. This makes it questionable whether a project of this sort should be delayed just to get billing data.

6.2.2 Dodge New Construction Data

This study used Dodge new construction data as the principal sampling frame. A Dodge database was developed listing new construction projects started in 1992-1994. These data were carefully cleaned to select projects within the areas served by PG&E and SCE. Out-of-scope projects such as highway construction were deleted.

A stratification variable designed to measure the size of each project was constructed from the project square footage and expected cost reported by Dodge. When square footage was reported, it was used as the stratification variable. However, many of the sites had missing square footage. A regression model was used to quantify the relationship between the square footage and the expected project cost of each project. Separate models were estimated for different geographical regions. These models were used to estimate the square footage when it was missing in the Dodge data.

Then the participants in the 1994 PG&E and SCE New Construction programs were matched to the Dodge sites. This matching work was carried out manually because the Dodge project name, description, and address was often different than the participant name and address appearing in the tracking data provided by each utility. A ZIP code would have simplified the matching, but it was not available in the Dodge database. Whenever possible, the analyst chose a Dodge project that appeared to correspond to the tracking information, but a matching Dodge project was not found for about 20% of the participants appearing in the tracking data. Failure to achieve a match could have been due to a number of factors:

- The Dodge data may omit some new construction projects.
- The participant project may have been started prior to 1992 but completed in 1994.
- The project name and address appearing in Dodge may have been incomplete or inaccurate and therefore not recognized as the participant project.

The Dodge data was used to develop a sample design that was stratified by utility service area, Dodge building type and Dodge square footage (constructed as described above). The same sample design was used to select both the participant and non-participant primary samples and prioritized lists of replacement sites.

This approach was designed to provide comparable samples of participants and non-participants. By using the same Dodge data for both participants and non-participants, it was hoped to minimize differences in the samples that might invalidate or introduce a bias into comparisons between the participants and non-participants.

It is difficult to assess the success of this approach. The participant and non-participant samples were well matched in terms of building type and size, thus achieving the primary goal. However, the approach was much more labor intensive and it is not clear that it produced a sample that was significantly better than a sample drawn from the program tracking data.

Stratum	Max kWh	Population Size	Total kWh	Ideal Sample	Actual Sample
1	101,978	339	8,038,527	18	62
2	278,668	61	10,949,421	18	9
3	441,916	35	12,598,315	18	8
4	816,615	22	13,654,171	18	3
5	4,000,000	12	17,469,244	12	3
Total		469	62,709,678	84	85

Table 6-2: Ideal Stratification of PG&E Participants

In addition, stratification by Dodge square footage does not appear to have been as effective as stratification by the estimated savings appearing in the tracking data. Consider the PG&E participants. Table 6-2 shows the ideal stratification using the tracking kWh savings. The last two columns compare the ideal sample with the actual sample. Ideally, the sample should be equally allocated to each of the five strata, subject to the limitation of the population size. By contrast to the ideal sample, the actual sample contained too many small projects and too few large projects. This did not introduce a bias in the sample but it did reduce the statistical precision compared to what might have been achieved.

Table 6-3 shows the sampling fractions corresponding to the ideal and actual sample. The ideal sampling fractions increase steadily starting at 0.05 and rising to 1.00. In effect, the ideal sample design draws an increasing proportion of larger projects that have a greater impact on the total savings of the program and account for more statistical variation in the savings. However, the actual sampling fractions range from a low of 0.14 to a high of 0.25, with no obvious increasing trend as the project size increases. In effect, the actual sampling fractions are similar to simple random sample.

Stratum	**Population Size**	**Ideal Sample**	**Sampling Fraction**	**Actual Sample**	**Sampling Fraction**
1	339	18	0.05	62	0.18
2	61	18	0.30	9	0.15
3	35	18	0.51	8	0.23
4	22	18	0.82	3	0.14
5	12	12	1.00	3	0.25
Total	469	84	0.18	85	0.18

Table 6-3: Sampling Fractions

How did this happen? The samples were efficiently stratified by Dodge square footage to provide a systematic increase in the sampling fraction for projects with higher Dodge square footage. It was expected that this would yield a higher sampling fraction for program participants with higher kWh savings. However, there turned out to be a poor correlation between the Dodge estimates of square footage and the tracking estimates of kWh savings. The poor correlation could be due to several factors:

- The Dodge square footage may have been inaccurately recorded or poorly estimated from the preliminary regression models. The primary input into the regression models was the estimated cost of the project recorded in the Dodge data.
- The Dodge square footage may be poorly related to the square footage actually affected by the program.
- The tracking estimates of kWh reflect many factors other than square footage affected by the program, such as the type of measures installed.
- The Dodge project may have been incorrectly matched to the participant site.

It should be emphasized that these factors would not introduce a bias into the results, but would reduce the statistical precision compared to what might have been achieved.

6.2.3 Choice of Sample Sizes

In planning a project of this type, the sample size must be chosen to meet the desired level of statistical precision. In commercial sampling, stratified ratio estimation generally yields more reliable results with smaller samples. With stratified ratio estimation, the expected statistical precision is determined by a parameter called the error ratio that measures the strength of association between the stratification variable and the analysis variable.

In the present project, the participant samples were post-stratified and weighted using the estimated kWh savings shown in the program tracking systems. To estimate the sample size needed in future projects, the sample data were used to calculate the error ratio between the tracking estimate of kWh savings and the gross kWh base use and savings measured for each site from this study. Table 6-4 shows the results.

For the program participants, the error ratios were in the range 0.74 to 1.43. The average error ratio was about 1.0, which reflects a conservative planning assumption.

	Error Ratio		**Gamma**	
Participants	**Base**	**Savings**	**Base**	**Savings**
PGE	1.43	0.99	0.59	0.47
SCE	0.74	1.02	0.47	0.44
Non-Part	**Base**	**Savings**	**Base**	**Savings**
PGE	1.84	2.05	0.97	0.97
SCE	0.90	3.06	0.56	0.72

Table 6-4: Sample design parameters estimated from this study

The non-participant samples were post-stratified and weighted using the Dodge square footage estimated in the Dodge database of new construction that was used as the primary sampling frame. In this case, an error ratio was calculated between the Dodge square footage and the measured gross kWh base use and savings. For non-participants, savings reflect the difference between the building as actually built and the Title 24 baseline. Table 6-4 also shows these results. These error ratios were generally much higher, ranging from 0.90 to 3.06. This indicates the relatively poor utility of Dodge square footage as a stratification variable. In this case, the error ratios for base use were somewhat smaller than the error ratios for savings, indicating that Dodge square footage was more strongly associated with base use than savings.

Table 6-4 also reports the estimated values of a second, more technical parameter called gamma. This parameter is used to actually construct the strata boundaries. Gamma is usually expected to fall between zero and one. If gamma is relatively large then large projects are selected with increasing sampling fractions, whereas if gamma is small, all projects are selected with about the same sampling fraction. Using the data developed in this study, the estimated values of gamma ranged from 0.44 to 0.97. It appears that an assumed value of 0.6 would be appropriate for planning a new study.

Returning to the error ratios, these parameters can be used to predict the expected relative precision or to choose the desired sample size. For a large population, the following equation is used to predict the expected relative precision at the 90 percent level of confidence:

$$rp = 1.645 \frac{er}{\sqrt{n}}$$

For example if the error ratio is assumed to be 0.80 and the sample size is 80 projects, then the expected relative precision would be about ±15 percent:

$$rp = 1.645 \frac{0.8}{\sqrt{80}} = 0.15$$

This equation can be easily solved to determine the required sample size *n* required for any desired level of relative precision *rp*. For example, suppose we are planning a study of non-participant savings and want results with a relative precision of ±20 percent. Then, assuming that the error ratio is 2.5, the required sample size would be about 423 sites:

$$n = \left(\frac{1.645 \times er}{rp} \right)^2 = \left(\frac{1.645 \times 2.5}{0.20} \right)^2 = 423$$

The model parameters were examined for non-participants using the reported Dodge project value rather than square footage as the explanatory variable. The model parameters were found to be approximately equivalent to those found for square footage. Because square footage has an understood relationship to energy consumption, it was retained as the explanatory variable.

6.2.4 Title 24 Documentation

In this study, a concerted effort was made to collect Title 24 documentation for each site. The intent was to use the Title 24 documentation to improve the accuracy of the models and baseline assumptions. In practice, it turned out to be very difficult to collect this documentation.

The following steps were taken to obtain Title 24 documentation:

- Obtain the documentation from the program files for participants
- Request it during the recruitment survey
- Request it during the decision maker survey
- Attempt to obtain it while scheduling the on-site audit or during the audit
- Employ a specialist to follow up on all leads
- Contact building departments

Despite all of these attempts, the documentation was not received for almost 70 percent of the sites. The results are summarized in Figure 6-2. In almost half of the cases, all of the contacts either refused or were unable to provide the documentation. The best contacts were the architects and engineers, but the documents were often archived or in dead files. It was hoped to get the documentation from local building departments, but this was found to require the permission of the owner or architect and engineer.

One can not be certain, but it would seem that a shorter delay from the program implementation to the data collection effort would help to mitigate the difficulties in obtaining Title 24 documentation.

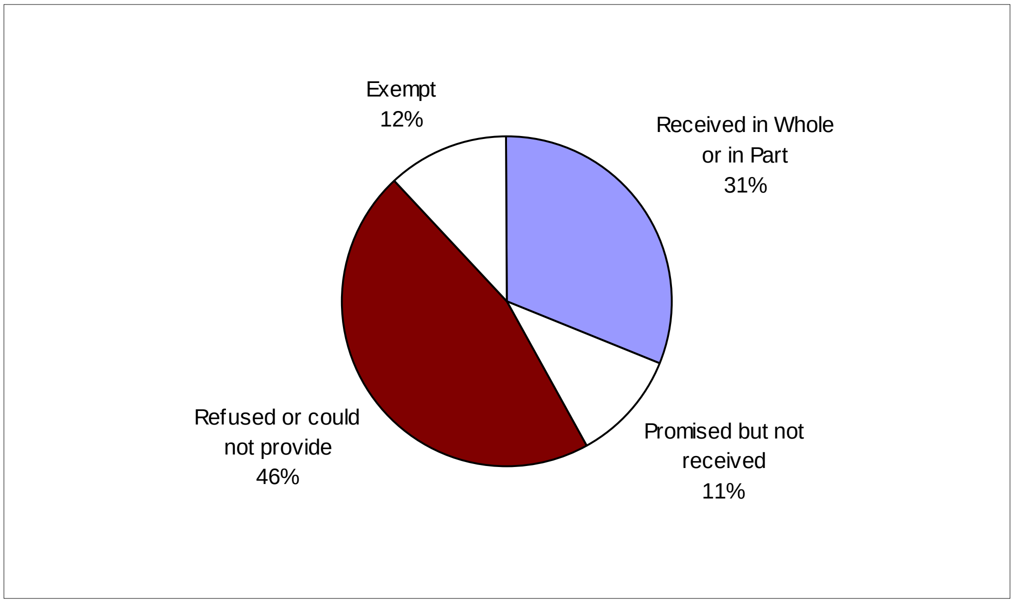

Figure 6-2: Results of Title 24 Collection

6.2.5 Decision Maker Surveys

The decision maker survey was primarily used to collect information needed for the net-to-gross analysis. A detailed questionnaire was used to collect information on the reasons behind equipment and efficiency choices, and how much influence the program had on these choices. This information was used to estimate free-ridership and spillover.

The Dodge database proved to be quite useful for identifying respondents for the decision maker survey. Dodge listed several key contact persons for each site, generally including the owner, developer, builder, architect, and engineer. Names and phone numbers were provided. Generally, the building owner was the primary contact but follow-ups were made with the other contacts provided by Dodge.

The decision maker survey presented several challenges:

- The survey coincided with the contacts for the on-site audit as well as the attempts to obtain the Title 24 documentation.
- Some of the contacts had changed
- Contacts were often difficult to reach, requiring up to eleven attempts
- The survey was long, about twenty minutes
- Some of the contacts were associated with multiple sites such as chain stores

With perseverance, the survey team contacted 625 of 833 possible respondents. 346 of these finished the entire survey, for a response rate of 55 percent. These 346 completed surveys gave usable decision-maker information for 220 sites.

The most significant problem encountered with the decision maker survey was the fact that only 220 sites were available for the net-to-gross analysis. The following recommendations should be considered for improving the quality of the decision-maker information in future studies and increasing the number of usable sites:

- Adapt a project schedule with sufficient time to allow completion of all decision-maker surveys prior to the start of the on-site audits. This would avoid needless completion of on-site audits at sites that refuse to participate in the decision maker survey.
- Limit the length of the survey. The twenty-minute survey used in this study appeared to be too long, contributing to the poor response rates.
- Use interviewers that are conversant in building technology. This will improve the response rate and respondent attitude but will also increase the cost of the survey.
- The survey should be managed to limit the burden on contacts with several chain-account sites in the study. Set up a separate procedure for chain accounts and other multi-site interviews and use an especially qualified interviewer for these sites.

6.2.6 On-Site Audits

The on-site auditing procedure was generally very successful. This study required on-site audits for the sample of 400 buildings that were widely distributed throughout California. A team of a dozen experienced auditors was assembled from the area and carefully trained and supervised. The audit instrument was highly structured and was designed specifically for the zoned DOE-2 modeling to be used in this study.

The schedule for completing these audits was very demanding. In the beginning, centralized scheduling was a bottleneck, so many of the auditors accepted the responsibility for their own scheduling. This improved the pace and the audits were completed on time.

A detailed, real-time, multi-step quality assurance program was carried out to maintain quality. All of the audit data had to pass stringent tests for completion and consistency. About 10 percent of the participants received follow-up calls to check whether the auditor was courteous and on time, and to determine the duration of the audit. The remaining participants received a thank you letter with a reply card for their reactions to the audit. Each of the field auditors was observed during one or more audits by a staff auditor/analyst from RLW Analytics. In addition, the short-term metering team checked the accuracy of the audit when they visited their thirty sites.

The main audit challenge was to ensure that the correct space was audited. If the site was a program participant, the desired space was the building or portion of the building actually affected by the program. This might be a single building in a group, or part of a building. If the site was a non-participant, we wanted the building or space actually corresponding to the Dodge project, regardless of whether it was new construction, renovation or addition.

Problems were occasionally encountered and had to be corrected. For example, in one case, there were three large buildings at one business location. One of the buildings participated in the 1993 program, while the remaining two participated in the 1994 program. Therefore the desired audit was for the two 1994 buildings. In practice, a careful review of the program documentation prior to the audit was necessary to ensure that the correct space was audited.

Some sites consisted of several individual buildings. In this project, the largest two buildings at the site were audited. The auditor prepared a list of each building and its square footage, and showed which buildings were actually audited.

The following recommendations are made for future projects:

- **Site Descriptions**. A summary of each site must be prepared prior to the audit to help the audit or identify the correct space and the measures affected by the program. This should include the available billing data if it is to be used.

- **Training**. Thorough auditor training is crucial. All forms and materials must be available at the time of training.
- **Quality Control**. The quality control program and tests must be established well ahead of time.
- **Data Entry**. When audit data are to be used to develop machine-built models as in this project, all audit information must be quantified and entered consistently in a computer readable database.

6.2.7 DOE-2 Modeling

This project employed site-specific DOE-2 building simulation models to determine the measured gross savings for each audit site. These models were the central tools of the impact evaluation. In effect, the models combined the on-site audit information describing building characteristics, equipment and schedules; and calculated the expected energy consumption and demand for each building in each costing period of interest. Whenever possible, the models were calibrated to the available billing data. Once calibrated, the models were run using Typical Meteorological Year (TMY) weather data.

These TMY models were run under two basic sets of assumptions.

1. **As Built**. These models described each building as it was actually found in the audit, reflecting the actual equipment, efficiencies, and schedules.
2. **Baseline**. These models described how each building would have been built if it had just met the Title 24 requirements for design and efficiency. If Title 24 did not apply, then the models were designed to reflect the baseline assumptions made in the new construction programs of PG&E and SCE. These models reflected the actual schedules found in the audit.

Added runs were carried out to measure the contribution to savings of several categories of measure.

The energy and demand outputs of the models were the primary determinants of all subsequent analysis of program savings. The gross savings of each site were calculated as the difference between the baseline consumption of the site and the as-built consumption of the site. The net savings for each site were determined by an econometric analysis of the gross savings, which compared the gross efficiency of the participants, non-participants, and partial participants. All results were extrapolated to the population using model-based survey sampling techniques.

An innovative feature of this study was the development of highly detailed, zoned DOE-2 models that were generated automatically from the survey data using specialized computer code. These machine-built models integrated information from the on-site survey, the Title 24 documents when they were available, manufacturer's catalogs, and engineering references. The primary information from the on-site audits was occupancy schedules, building characteristics, equipment inventories and operations, the identified measures, the HVAC and space zoning, and the association between equipment and spaces. The audit instrument was very structured and very detailed. Essentially all of the audit information was quantified and used in the machine-built models.

Special software was also developed to facilitate calibration. Each model was carefully calibrated to any billing data that was available and relevant. Every change made to a model was recorded by the calibration software and documented in the DOE-2 file.

To ensure the accuracy of the machine-built models, 103 of the models were subjected to further analysis, leading to the so-called hand-built models. The hand-built process focused on information not incorporated into the machine-modeling process. This included any notes made by the auditor, any additional information in the program files, additional manufacturer's data, and follow-up conversations with the auditor. The 8760-hour, simulated end-use consumption of each site was also subjected to a detailed graphical review. Both the as-built and baseline models were reviewed.

The hand-built review led to the identification and correction of several errors in the automatic model generator or the underlying audit data. These improvements included the following:

1. Inclusion of return-air fans for sites with packaged units.
2. Correcting excessively large motors for exhaust fans.
3. Correcting set points for cooling towers.
4. Correcting simulation of window wall AC units.
5. Correcting questionable task lighting.
6. Correcting the accounting for efficient motors.

The hand built process led to very rigorous testing of the model-generation software. There was almost constant dialog between the engineering teams responsible for the machine-built models and the hand-built models, thereby allowing rapid feedback. All of the significant improvements identified in the hand-built review were incorporated into the final version of the model-generation software. All 393 models were run through the final model-generation software.

The following conclusions about this process are offered:

- **Consistency of Results**. In some past uses of DOE-2 models, it has been difficult to maintain consistency in modeling practice. Modeling was as much art as science. The results would vary from one practitioner to another. The use of model-generation software eliminates site-to-site variation from modeling inconsistencies.
- **Level of Detail**. This is not the first study to use model-generation software. However, the audit form used in this study was designed to collect detailed information by space and equipment zone. The use of zones provides great flexibility in modeling relatively simple or very complex buildings. Most of the auditors were experienced DOE-2 modelers and understood how to define zones appropriately for each site. Consequently, we believe that these models reflect the most detailed information about buildings ever achieved in machine-built models.
- **Consistency of Syntax**. DOE-2 models can involve thousands of lines of computer code. The model-generation software ensures that this computer code has absolutely consistent syntax. This facilitates hand review of large numbers of models.
- **Accuracy of the Audit Data**. The model is only as good as the data that generates it. However, use of model-generation software helps to identify problems in the audit data. In effect, model-generation can become part of the quality assurance program.
- **Cost Effectiveness**. Once the model-generation software is built and tested, the generation of site-specific models proceeds very rapidly. A variety of ‘what-if’ parametric runs can be carried out quickly. Moreover, improvements and added levels of detail can be incorporated systematically. Thus the model-generation approach is very cost effective.
- **The Importance of Hand Review**. The hand-built review was a key contributor to the accuracy of the machine-built models. 103 of the 393 machine-built models were reviewed independently in depth. This greatly improved our confidence in the model-generator.
- **Synergy between Model-Generation and Hand Review**. Independent engineering teams were used for model-generation and hand-review. But a very high level of communication and cooperation was maintained. This ensured very rapid feedback and evaluation of suggestions from the hand review. Any problems that were identified were corrected across the full sample by

correcting the model-generation software itself and then rerunning the new software across the full sample.

6.2.8 End Use Metering

In this study, short-term end-use monitoring was used in thirty of the 393 sites. The main objective of the end-use monitoring was to measure important operating parameters that could not be readily observed in the on-site audit. The initial plan was to select the 30 sites on a sampling basis. In the end, it was deemed best to select the sites based on engineering judgment about what parameters were most important and what sites would be most informative to the overall model building effort.

Two factors were considered in this decision. First, the end-use monitoring sample was small. Thirty sites could not provide statistically meaningful representation of both the participants and non-participants from each of the two utilities across several building types. Second, it seemed better to focus the metering on particular technologies that were not readily observed or well understood rather than on a dominant but relatively thoroughly studied end use such as lighting. In short, the end-use monitoring was ultimately designed to contribute to the body of knowledge used for the machine-generated models.

The disadvantage of this approach, however, is that it is difficult to measure the value of the resulting information. With a statistical approach, a level of confidence can be placed on the results. The disadvantage of the statistical approach on the other hand is that a substantially larger end-use monitored sample would have been required.

On balance, the approach used here seemed to be very successful. The use of microloggers facilitated installation and kept the cost affordable. Moreover, the end-use monitoring validated certain key engineering parameters that otherwise would have been based purely on assumption. The thirty sites seem to have contributed more valuable information than would have been likely if they had been selected following a statistical sampling plan.

6.2.9 Partial Participants

This study used a conservative definition of partial participation for purposes of estimating the spillover effects. The method used was to rely on self-reporting of partial participation in the decision-maker survey. The respondents had to answer three questions in the affirmative to be considered a partial participant. They were:

1. Have you heard about the program?
2. Did you have interaction with the utility staff during the design phase?
3. Did you consider participating in the program?

The econometric analysis showed that the partial participant status was fairly insensitive to varying the criteria for partial participation (1, 2, 3, or 4 affirmative responses). This is more fully discussed in the net-to-gross methodology section.

This definition of partial participation may have excluded some legitimate partial participants such as chain stores, who will typically interact with the utility at the regional or corporate management level to make decisions affecting the construction of many facilities. An issue to be considered for future studies is the development of a precise definition of partial participation that is agreed on by the utilities, CEC staff, and CPUC staff.

7. INTRODUCTION

Short-term monitoring was done on a sample of 30 buildings as a means of improving the engineering models used in the analysis. Due to the fairly small sample of monitored sites (30) and the relatively large number of sample strata (> 100), the monitored data were not used to create a statistical adjustment on end-use consumption across all sites. The primary objective of the monitoring was to define building performance parameters that were important for creating the DOE-2 models that were not observable during an on-site survey. These important yet unobservable parameters tended to be concentrated in buildings with complex HVAC, refrigeration, and/or control systems. Additionally, the data were used to calibrate the engineering models of each monitored building. Since buildings with complex HVAC and/or refrigeration systems tended to be larger sites with large expected savings, the measurements and calibrated models were thereby targeted at a larger portion of the total expected savings. Lighting measurements were also included to investigate the accuracy of the self-reported lighting schedules.

7.1 SITE SELECTION

Sites were selected based on their HVAC and refrigeration system characteristics. A total of 30 sites were selected for short-term monitoring. Monitoring activities occurred in three waves, beginning in July 1996 and finishing in September 1996. The list of sites monitored is as follows:

Site ID Number	Building Type	SF	HVAC System Type
SCE 0031	Office	220,000	Built-up system w/ chiller
SCE 0043	Education	94,200	Built-up system w/ chiller and thermal energy storage
SCE 0025	Government	24,600	Multizone system with chiller
SCE 0044	Government	12,280	Large split DX system
SCE 0075	Government	26,200	Built-up system w/ chiller and thermal energy storage
SCE 0097	Retail	142,000	Large packaged systems
SCE 0117	Health	28,000	Built-up system w/ chiller
SCE 0138	School	87,000	Built-up system w/ chiller and thermal energy storage
SCE 0033	School	115,000	Packaged systems

Table 7-1: SCE - Round I Monitored SitesTable

Site ID Number	Building Type	SF	HVAC System Type
PGE 7427	Office	99,500	Packaged systems
PGE 7388	Health	106,170	Built-up system w/ chiller
PGE 7160	Office	455,000	Built-up system w/ chiller
PGE 7219	Grocery	67,000	Built-up DX system w/ refrigeration
PGE 7301	Retail	156,000	Packaged system w/ refrigeration
PGE 7262	Office	66,000	Built-up system w/ chiller
PGE 3146	Health	8,700	Built-up system w/ chiller
PGE 7379	Health	94,000	Built-up system w/ chiller

Table 7-2: PG&E - Round II Monitored Sites

Site ID Number	Building Type	SF	HVAC System Type
PGE 7381	Government	29,000	Packaged systems
PGE 4647	Office	124,400	Built-up system w/ chiller
PGE 4687	Office	510,000	Built-up system w/ chiller
PGE 7202	Government	48,300	Built-up system w/ chiller
PGE 4563	Office	152,000	Built-up system w/ chiller
PGE 7394	Office	140,000	Packaged systems
PGE 2839	Grocery	51,325	Built-up DX system w/ refrigeration
PGE 4086	Office/manufacturing	99,500	Built-up system w/ chiller
PGE 7323	Retail	89,800	Packaged systems
PGE 7434	Office	1,180,000	Built-up floor-by-floor system

Table 7-3: PG&E - Round III Monitored Sites

Site ID Number	Building Type	SF	HVAC System Type
SCE 0074	Retail	120,000	Built-up system w/ chiller
SCE 5669	Office	67,000	Large split DX system
SCE 2995	Education	47,000	Built-up system w/ chiller and thermal energy storage

Table 7-4: SCE - Round III Monitored Sites

7.2 MONITORING PLANS

7.2.1 Objectives

The overall objectives of the short-term monitoring activities were as follows:

1. Observe HVAC and refrigeration system performance parameters that are influential in determining equipment performance and measure savings, but are not observable during an on-site survey.
2. Confirm surveyor estimates of lighting operating hours and schedules.

7.2.2 Experimental Design

1. One-time (spot), post-construction measurements on selected HVAC and lighting circuits
2. Short term (3 week) post-construction time series monitoring of selected HVAC and lighting equipment

7.2.3 Data Products

The information developed from the short-term monitoring activities is listed in Table 7-5 below:

Equipment	**Data Product**
Chiller	Chilled water temperature setpoint Chiller sequencing
Chilled water pumps	Flow control type (constant/variable) Minimum flow ratio Chilled water pump kW
Hot water pumps	Flow control type (constant/variable) Minimum flow ratio Hot water pump kW
Condenser water pumps	Flow control type (constant/variable) Condenser water pump kW
Cooling towers	Minimum condensing temperature Approach temperature Fan control strategy Fan kW Pump kW

Air handlers, packaged equipment	Minimum supply temperature Supply air reset controls Economizer controls Minimum outdoor air fractions Economizer lockout control	Economizer high limit control Fan operating schedules Minimum fan flow ratio Supply fan kW Return fan kW
Zones	Cooling setpoint	
Refrigeration	Minimum head pressure setpoint Condenser loading and staging Condenser fan controls	
Lighting	Operating schedule Daylighting control response	
Thermal Energy Storage	Charging schedule Discharging schedule Initial and final storage temperatures	

Table 7-5: Information Developed From Short Term Monitoring Activities

7.2.4 Monitoring Procedure

The ENFORMA™ System (an integrated package of hardware and software designed to perform short-term end-use measurements and model calibration) was used to structure the short-term data collection process. A series of small, battery-powered data loggers were used to form a wireless distributed data logging system. Each data logger is capable of measuring a number of physical quantities, including temperature, humidity, pressure, on-off status, and current. An instrumentation plan was created by the software that was tailored to the characteristics of the building HVAC system. The data loggers were initialized and time synchronized by the software and were deployed on a 3-week basis by AEC engineers and local electrical contractors. At the conclusion of the monitoring period, the loggers were retrieved by the local contractors and sent to AEC for analysis. The ENFORMA™ software was used to automatically download and analyze the data.

The overall procedure is outlined as follows:

1. ***Describe the building***. The building HVAC and lighting system descriptions were entered into the ENFORMA™ software.

2. ***Develop monitoring plan***. Based on the HVAC system description, ENFORMA automatically created a monitoring plan.

3. ***Collect building performance data***. Small, battery-powered data loggers were deployed throughout the building to collect short-term data on building operations and HVAC and lighting system performance.

4. ***Calibrate the simulation model***. Measured data from ENFORMA were compared to simulation model inputs. Adjustments to simulation inputs were made to bring simulation results into agreement with measured data.

5. ***Calculate annual building performance***. Once the building model was calibrated, the calibrated model was used to calculate the annual performance of the building.

7.2.5 Typical Monitoring Points

One-time spot measurements of equipment kW were made along with the short-term time-series measurements. On constant load equipment, the spot measurements were made to assess the rated load factor, or the ratio of the actual running load to the nameplate connected load. Spot measurements were also combined with time-series current measurements to estimate time-series kW data. Typical time-series monitoring points specified by the ENFORMA™ software included those listed in Table 7-6.

Location	**Measurements Made**	**Comments**
Ambient	Temperature, relative humidity	
Packaged HVAC units	Total unit current, supply air temperature, return air temperature, mixed air temperature	Spot measurements of kW vs. Amps used to derive time-series kW data from current data.
Air Handlers	Supply fan current, return fan current, supply air temperature, return air temperature, mixed air temperature, fan motor RPM	Spot measurements of kW vs. Amps used to derive time-series kW data from current data. RPM data collected on variable-speed drive applications.
Chillers	Total unit current, chilled water inlet and outlet temperature, condenser water inlet temperature	Spot measurements of kW vs. Amps used to derive time-series kW data from current data.
Cooling towers/evap condensers	Fan and pump current, condenser water outlet or high pressure liquid outlet temperature	Temperatures may be redundant with chiller measurements.
Pumps	Pump current, shaft RPM	RPM data collected on variable-speed drives.
Refrigeration racks	Rack current, cooling water or high-pressure liquid inlet temperature	Temperatures may be redundant with condenser or tower measurements.
Lighting Panels	Lighting circuit current	Spot measurements of kW vs. Amps used to derive time-series kW data from current data.

Table 7-6: Typical Time Series Monitoring Points

7.3 RESULTS

Information on building operations gathered from the short-term monitoring were applied to each monitored building, thus improving the model for the particular building studied. Since the monitored data were applied to individual buildings, and not leveraged across a larger population of buildings, a comparison of model energy consumption with and without the short-term data was not done. However, a few examples of the comparisons between the surveyed and monitored building characteristics are presented.

7.3.1 Outdoor Air Fraction

A comparison between the measured and assumed values for minimum outdoor air fraction is shown in Figure 7-1. Overall, the modeling assumptions tended to over-predict the minimum outdoor air fraction slightly, but there is much variability from site to site. This result is somewhat counter-intuitive, indicating that the recent emphasis on indoor air quality has not caused widespread increases in building ventilation rates over Title 24 levels.

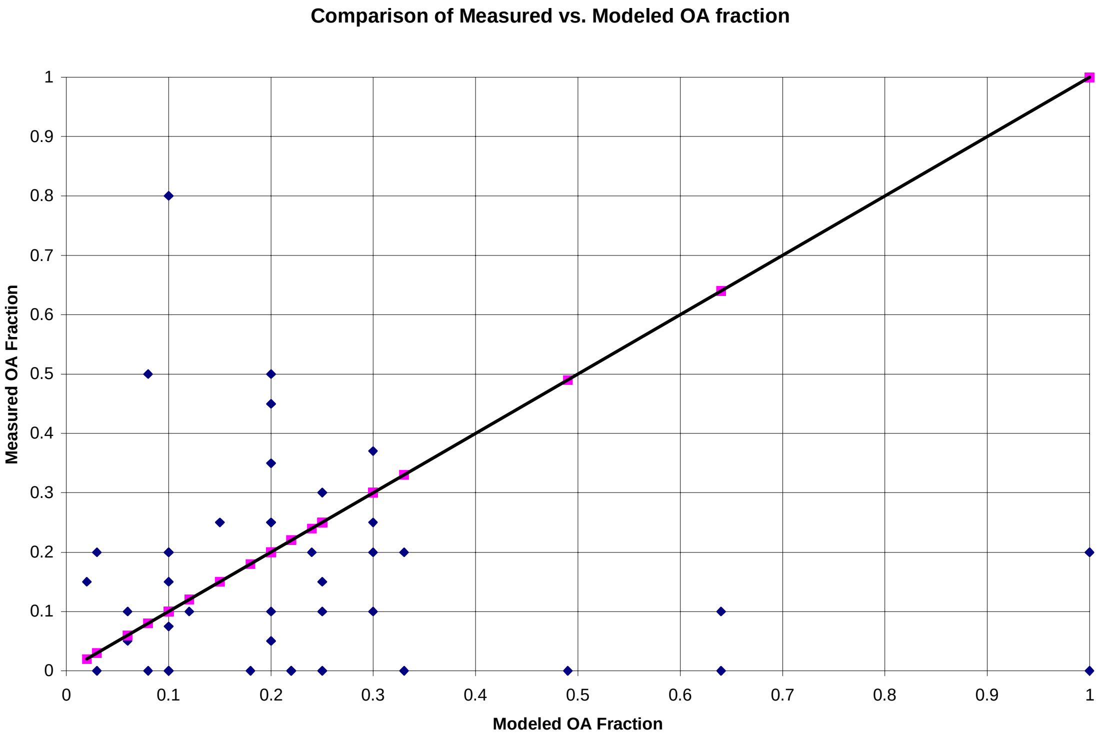

Figure 7-1: Measured vs. Modeled Outdoor Air Fraction

7.3.2 Supply Air Temperature

A comparison between the measured and assumed values for HVAC system minimum supply air temperature setpoint is shown in Figure 7-2. The survey was a relatively weak predictor of the actual supply air temperature. Although 55°F was a popular response, actual measured data varied from 45°F to 65°F. Some of the survey responses were quite high (70°F), and were reduced during the model calibration process

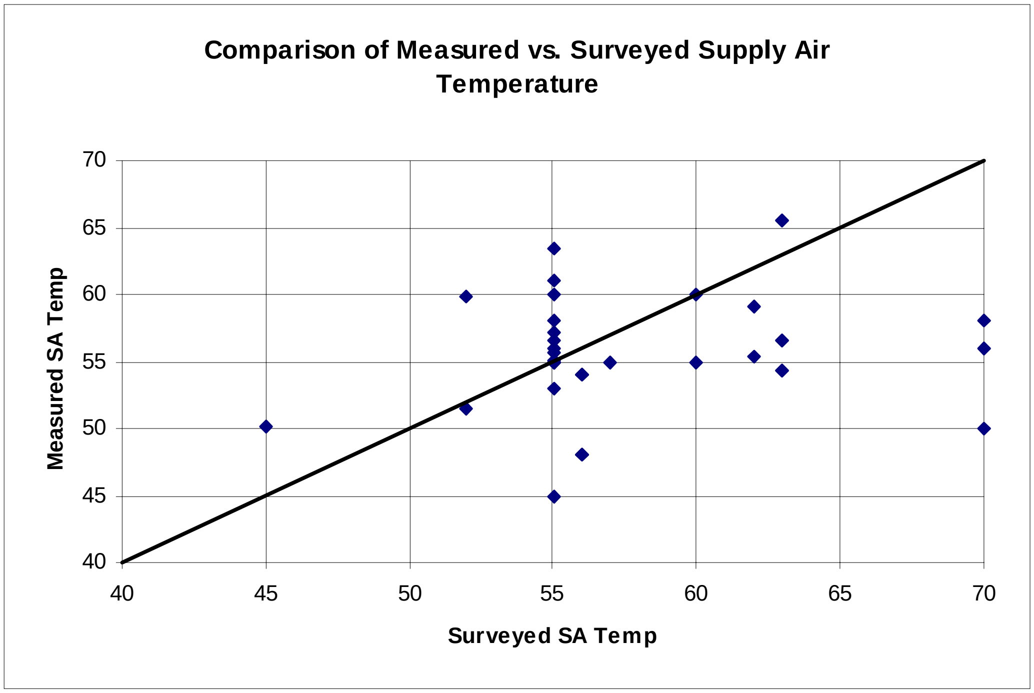

Figure 7-2: Measured vs. Surveyed Supply Air Temperature

7.3.3 Minimum Condenser Water Temperature

A comparison between the measured and assumed values for the chiller system minimum condenser water temperature setpoint is shown in Figure 7-3. The measured data are generally lower than the values reported by the surveyors. Since the condenser water temperature has a major influence on the chiller system efficiency, the monitored data indicate more efficient chiller operation than the data collected during the onsite survey.

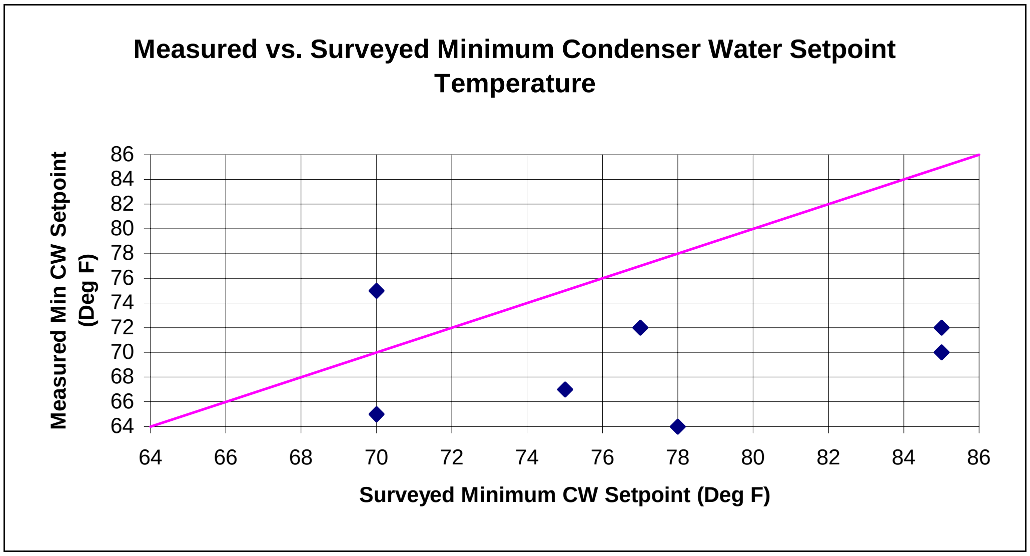

Figure 7-3: Condenser Water Setpoint Temperature

7.3.4 Lighting

Lighting schedules were monitored in eight of the buildings to assess the accuracy of the self-reported schedules. In general, the self-reported operating hours compared well to the monitored data. However, the surveyors tended to overpredict the “on-period” diversity, defined as the total connected load that was “on” during normal building operations, as shown in Figure 7-4.

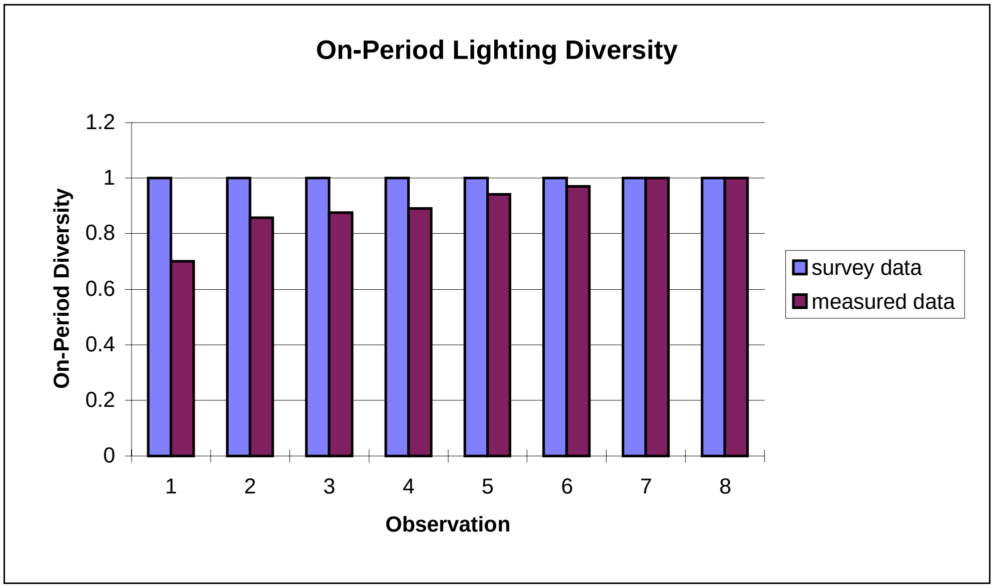

Figure 7-4: Lighting “on-period” diversity

In each of the sites monitored, the surveyors predicted that the lighting power would reach the full connected load during the day. Operation at 100 percent of the connected load was observed in only two of the eight buildings studied. In one building, only 70 percent of the connected load was observed to be operating during the day. The on-peak demand savings for sites with less than full daytime lighting operation are likely to be over-predicted.

Conversely, the surveyors tended to under-predict the “off period” diversity, as shown in Figure 7-5.

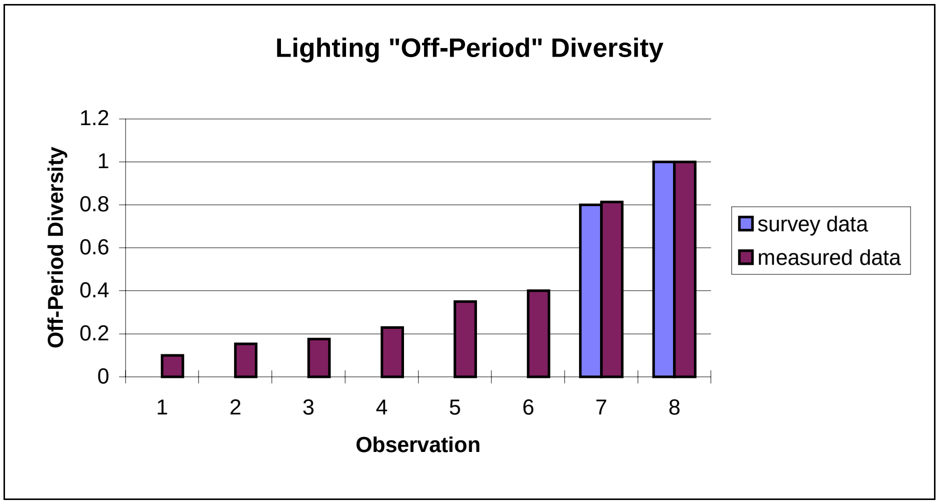

Figure 7-5: Lighting “off-period” diversity

The off-period diversity was surveyed as zero percent for six of the eight sites, but the monitored data indicate that 10 to 40 percent of the connected lighting continues to operate throughout the unoccupied period in these buildings. Increased nighttime operation generally tends to offset the reduced predicted daytime consumption.

7.3.5 Cross-Building Comparisons

In addition to improving the models of the buildings studied, cross-building comparisons of the monitored data were made to develop study-wide average values of key modeling parameters. The results of this analysis are summarized in Table 6-7 below:

Data Product	**Sample average**	**Coefficient of variation**	**Initial default value**	**Revised default value**	**Comments**
Tsupply - packaged systems	55°F	7.7%	55°F	55°F	
Tsupply - built-up systems	54°F	10.5%	55°F	54°F	Not much difference
Outdoor air fraction	0.20	116.4%			Wide variability
Minimum chilled water temperature	46°F	5.2%	44	46	Improved chiller efficiency from increased chilled water temperature
Fan rated load factor	0.78	16.2%	0.8	.78	

Pump rated load factor	0.84	22.8%	0.8	.84	Pumps motors are sized closer to the load
Cooling tower fan rated load factor	0.54	51.2%	0.8	.54	Cooling tower fans are substantially oversized.
Minimum condensing water temperature	69.5°F	6.9%	80°F	70°F	Improved chiller efficiency from reduced condenser water temperatures
Cooling tower approach temperature	10.3°F	25.7%	7°F	10°F	In line with program incentives for oversized condensers
Refrigeration system minimum condensing temperature	80°F	8.7%	82°F	80°F	Floating head pressure below 70°F not observed
Lighting “on” diversity	0.89	11.2%	None	Max of 0.9	Consistent with Title 24 schedules
Lighting “off” diversity	0.27	52.9%	None	Min of 0.1	Only sites unoccupied at night considered, 0.1 minimum value is conservative, wide fluctuation in observed values

Table 7-7: Analysis Results

7.4 BUILDING OPERATIONAL PROBLEMS DISCOVERED DURING SHORT-TERM MONITORING

During the course of the data gathering and analysis, a number of building operational problems were discovered. These problems can cause excessive energy consumption, reduced energy savings, and/or reduced occupant comfort. Operational problems identified from the short-term monitored data analysis include:

1. Inadequate outdoor ventilation air
2. Chilled water and/or supply air temperature setpoints not maintained in hot weather
3. Economizers not functional
4. Limited RPM modulation on variable speed drives
5. System control malfunctions that cause equipment to run when not needed, or prevent equipment from operating when needed
6. Poor staging of thermal energy storage systems and chillers, causing excessive on-peak demand

Many of these problems can be identified and repaired through a commissioning and O&M maintenance program, thus safeguarding the energy savings over the life of the measures. A summary of the problems found in each of the monitored buildings is shown in Table 7-8:

Site ID	**Problems Identified**
PGE1338	• High supply air temperature, comfort problems • Broken economizer, set at 100% OA
PGE2839	• No problems identified
PGE3146	• Broken economizer, set at 100% OA
PGE4086	• Chilled water pump runs when chiller turned off • Economizer not opening
PGE4563	• Tower locked out as chiller sequence changes, causing high condenser water temperatures and inefficient operation • Economizers not operating
PGE4647	• Pumps run when not needed • Erratic condenser water temperature control • Little or no outside air on some units, 50% on another
PGE4687	• Minimal modulation on VSD-equipped fans, reducing energy savings
PGE7160	• Chiller operation below outdoor lockout temperature • Heating between 4 AM and 1PM, 8PM and 11PM
PGE7202	• Chiller operates at night when fan coil units are off, cycling excessively • Hot water pump runs continuously • Outside air fan runs continuously
PGE7219	• No problems identified
PGE7262	• Air handling unit not maintaining supply air temperature, even with correct chilled water temperature, causing comfort problems
PGE7301	• One AC unit not providing enough cooling • Little or no outside air • No economizer operation
PGE7323	• Roof tope unit start-up times inconsistent • Economizers stuck at 100% outdoor air on some units
PGE7379	• Excessive chiller cycling • Economizer high limit temperature control set too high

Site ID	**Problems Identified**
PGE7381	• Unnecessary nighttime operation of air handlers • Economizers operational on only one of the four units monitored
PGE7394	• Cooling loads not met • VAV controls acting in reverse • Economizers not operating properly • Little or no outdoor air
PGE7427	• Little or no outside air
PGE7434	• No problems identified
SCE0025	• Simultaneous heating and cooling in Multi-zone unit • Little or no outside air at all times • No economizer operation
SCE0031	• Improper pump sequencing
SCE0033	• Compressor failure
SCE0043	• Main chiller and TES ice making chiller run together during on-peak period • Pumps run when not needed • Chilled water, supply air setpoints not maintained • Space temperatures not maintained • Cooling tower too small, condenser water temperature too high, causing chiller to shut down • Little or no outdoor air
SCE0044	• Insufficient capacity • Condensers located in very warm attic
SCE0074	• No problems identified
SCE0075	• Loads not met due to excessive supply air temperature • Economizer not working, 40% outside air at all times
SCE0097	• Morning purge cycle causing excessive cooling pull-down requirements • Excessive minimum outside air (25-40%)
SCE0117	• Frequent chiller cycling on weekends • Backup chiller operates when not needed, cycling frequently • Economizers not operating correctly • Little or no outdoor air

Site ID	Problems Identified
SCE0138	• Excessive fan operation • Non-TES chiller runs during weekend when chilled water pumps shut off • TES supplies cooling during off-peak period, main chiller only partly loaded
SCE2995	• Chiller and TES operate simultaneously during on-peak period • TES cools building during off-peak period • TES shuts off at night, more charging may be possible
SCE5669	• Rooftop units run all night, can be shut down • Little or no outdoor air • No economizer operation

Table 7-8: Summary of Building Operational Problems Identified

8. STATISTICAL METHODOLOGY

8.1 INTRODUCTION

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 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]

Chapter 9 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 weights, (b) balanced stratification to calculate case weights, and (c) stratified ratio estimation using case weights.

8.2 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:

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

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:

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

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

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 8-1 shows an example. In this example, the PG&E 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 5 of Table 8-1 shows that the sample contains 62 projects from the first stratum. Each of these 62 projects can be give 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 8-1: Calculating Case Weights

8.3 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 is a similar fashion. Then the population sizes are tabulated within each stratum. Finally the case weights are calculated in the usual way.

Table 8-2 shows an example. 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 sample 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
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 8-2: Balanced Stratification

8.4 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

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

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

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

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

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

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.

9. SAMPLE DESIGN

9.1 INTRODUCTION

The objective of the sample design was to provide a set of 355 projects for use in the telephone and on-site surveys (Task 4). The sample is representative of commercial new construction completed in 1994 in the PG&E and SCE electric service territories. A single integrated sampling plan was used for all three segments of the market - participants, non-participants, and partial participants - from both PG&E and SCE service areas. The sampling frame was developed from the F. W. Dodge new construction database for 1992, 1993 and 1994 permitted projects. Residential and industrial projects that would not qualify for the utilities programs were excluded.

The sample design was developed using RLW Analytic's Model-Based Statistical Sampling methodology (MBSS™). The sample was stratified by building type (office, retail, etc.) and square footage in order to balance program participants and non-participants and to oversample the major energy-savings projects. The participant sample for each utility meets the 90/10 criteria described in Table 5 of the Evaluation Protocols. The non-participant sample was expected to be approximately equal to the participant sample, thus also meeting the Evaluation Protocols. Once the final sample was recruited for the on-site audit, sub-samples were designated for the calibration-modeling sample and the short-term monitoring sample.

Table 9-1 summarizes the sample for each of the utilities. The recommended sample contains a total of 356 buildings. The sample includes a relatively large number of offices, retail buildings, and schools, since a large proportion of the new construction and the participants in the programs of both utilities are in these categories. A census was done for PG&E's 23 commercial refrigeration sites and 14 projects in the PG&E Refrigerated Warehouse program. The sample design satisfies the 90/10 criteria described in Table 5 of the Evaluation Protocols.

Type Category	PGE	SCE	Total
Government	8	16	24
Grocery	11	4	15
Hospital	11	8	19
Industrial	10	12	22
Miscellaneous	8	12	20
Office	51	20	71
Restaurant	5	4	9
Retail	26	32	58
School	24	42	66
Warehouse, Non Ref	25	12	37
Warehouse, Ref	14	0	14
Grand Total	194	162	355

Table 9-1: Sample Sizes by Building Type

9.2 SAMPLE DESIGN TASKS

The sample design was developed in the following thirteen steps. Each step is described in detail in the following sections.

Task 2.1. **Acquire Dodge data–**Acquire the F. W. Dodge new construction database for 1992, 1993 and 1994.

Task 2.2. **Assign to service areas–**Exclude projects outside the PG&E and SCE service areas. Assign the remaining projects to SCE or PG&E.

Task 2.3. **Acquire program tracking data–**Acquire PG&E and SCE program tracking data describing 1994 new construction program participants. Identify the special projects to include as a census, e.g., participants in PG&E's Refrigerated Warehouse program.

Task 2.4. **Identify probable participants–**Identify Dodge projects that appear to correspond to program participants.

Task 2.5. **Drop out-of-scope projects–**Identify and eliminate out-of-scope projects such as residential and industrial.

Task 2.6. **Estimate square footage–**Use the Dodge data on project value to estimate the square footage of projects with missing square footage.

Task 2.7. **Group by building type–**Group the Dodge projects by building type (office, retail, etc.) and construction type (new, addition, renovation) and compare the participants to the non-participants.

Task 2.8. **Develop the sample design–**Develop the sample design, stratifying by building type and square footage. Estimate the expected precision of the sample design, using a measure of variability (error ratio) for each building type developed from related studies.

Task 2.9. **Describe the sample–**Summarize the distribution of the sample by building type and stratum.

Task 2.10. **Select the sample–**Identify the most relevant time period, i.e., buildings in the 1993 Dodge database. Exclude non-participant projects outside of the chosen period. Select the primary and backup samples for both participants and non-participants following the sample design.

Task 2.11. **Utility review–**Sort the sample by PG&E division and city. Create a suitable form to collect available utility information for the non-participants. Provide the primary and backup samples to the PG&E Project Manager for review and approval by PG&E and SCE customer service representatives.

Task 2.12. **Screen the sample for multiple-site contacts–**Use the Dodge contact information to screen the sample lists for multiple-site contacts.

Task 2.13. **Finalize the sample–**Keypunch the information collected from the utilities. Establish the information needed in subsequent tasks from the Dodge data, the program tracking data (where applicable) and from the utility customer service representatives. Pass the information on to Aspen for use in Task 4.

The following subsections provide more detailed information on each of the preceding twelve subtasks of Task 2.

9.2.1 Task 2.1: Acquire Dodge data

At the beginning of the PG&E/SCE 1994 New Construction Program Evaluation, RLW requested and received a “DMP Backservice” database from F.W. Dodge of all permitted commercial and industrial new construction projects in California, for calendar years 1992, 1993, and 1994. F.W. Dodge, a subsidiary of the McGraw-Hill Construction Information Group, has been in business for over 100 years and is considered to be the most complete source of construction-related information in the nation. Dodge’s primary clients are general contractors, subcontractors, building product and equipment manufacturers, materials suppliers/distributors/dealers, and design professionals. Because these firms typically use the data for market forecasting and sales lead development, the data is not as suitable for utility load research as might be hoped. Dodge’s primary products are customized reports based on their extensive databases that are provided to clients on-line, by fax, or on paper media. For this project, historical data was retrieved, and the Custom Services Administration Manager in F. W. Dodge’s Hightstown, New Jersey prepared a customized dataset.

To ensure that no projects or associated data were overlooked, RLW requested and received the following:

1. All projects listed for California between 1/1/92 and 12/31/94.
2. All projects with “Stage Code=Start” (i.e. a project on which work will begin within 60 days)
3. All “Project Value” dollar amounts
4. All “Primary Structure Codes”, except Single Family Residential
5. All “Addition/Alteration Codes” (e.g. New, Additions, etc., except “specialty equipment”)
6. All other project related data including location, square footage, owner/developer/architect/ engineer contact data, construction methods, equipment, etc.

Dodge also provided:

- A detailed data dictionary describing the definitions of the fields
- Marketing material describing the full range of F.W. Dodge information services

RLW requested, however Dodge was unable to provide:

- A mapping of Dodge project type designations to SIC codes
- A mapping of project locations by zip code.

The base dataset included the number of projects shown in Table 9-2.

Year	Number of Projects
1992	7,469
1993	9,433
1994	11,408
Total	28,310

Table 9-2: Full Dodge Data

The following information is included in the database:

- Project description
- Project location – street address, city and county but not ZIP

- Building type – office, hospital, etc.
- Project value in dollars
- Number of stories and number of buildings in the project
- Floor area in square feet
- Construction code – new, addition, renovation or various combinations thereof
- Owner code – public, federal, college, private

The Dodge database also provides up to four sets of contact information, typically for the owner, architect, developer, and engineering consultant. Each contact includes the name and address of the firm, a contact person, phone number, and code describing the type of contact (owner, architect, etc.).

9.2.2 Task 2.2: Assign to service areas

The objective of this task was to classify each Dodge project by service territory: PG&E, SCE, or other. We started with a list of ZIP codes served by SCE. An analogous list of ZIP codes served by PG&E was developed using the service addresses of PG&E commercial customers. Unfortunately, the Dodge database did not include ZIP codes but only city locations. Therefore we used a table relating ZIP codes to cities in order to classify each city by service territory. Then the city associated with each Dodge project was used to classify the Dodge project by service territory. In practice, the classification was only approximate since many cities did not fall into a unique service territory. However, any errors did not have a material effect on the validity of the findings.

9.2.3 Task 2.3: Acquire program tracking data

Both utilities provided program tracking data for participants in their 1994 commercial new construction programs. The PG&E data identified 484 unique sites. The information included participant name and address, control number, as well as rebate dollars, savings and (sometimes) the affected square feet for the following end uses: lighting, cooling, glazing, motors, refrigeration, and thermal energy storage. The SCE data identified 272 program participants (sites). The data included participant information and measures information. SCE's measure codes identified lighting, HVAC, and motor measures as well as comprehensive design participants.

The Scope of Work specified that a census should be attempted for participants in PG&E's Refrigerated Warehouse program as well as projects that included commercial refrigeration and non-HVAC motors. PG&E's tracking data identified 14 participants in the Refrigerated Warehouse program, and 23 projects with commercial refrigeration. There were no SCE projects in these two categories.

The tracking data also identified 44 PG&E projects. However, the program tracking data did not distinguish between motors used for HVAC and other motor applications. Therefore it was not possible to attempt a census of PG&E projects with non-HVAC motors. Instead these projects were included in the general sample design. In the case of SCE, no rebates were given for non-HVAC motors in the new construction programs being evaluated.

9.2.4 Task 2.4: Identify probable participants

The purpose of this task was to identify Dodge projects that appeared to correspond to program participants. This was necessary to ensure that the participant portion of the sample would meet the 90/10 criteria described in Table 5 of the Evaluation Protocols.

The matching was done manually by comparing the name and location of each participant to the project descriptions and locations in the Dodge data. Probable matches were obtained for 272 of the 484 PG&E participants and for 154 of the 272 SCE participants. Considering both programs, probable matches were obtained for 56% of all participants.

An analysis was carried out to look for any special differences between the participants that were matched and those that were not found in the Dodge data. No significant differences were found. Therefore the matched participants were assumed to be representative of all participants.

It is easy to understand why it was difficult to match participants to Dodge records. The Dodge data is based on information provided at the start of construction. The project description and location is often inexact. The program tracking data reflects information collected through the utility program, often near the end of construction. The project or customer name, address and even the city may be different in the two databases. Or the project may have been started prior to 1992.

We judge that up to half of the participants that were not found might actually appear in the Dodge data, perhaps with a different address. However, it appears that the Dodge data may not contain 20% or more of the program participants. From this, we might assume that Dodge is missing 20% or more of all new construction. This may lead to moderate biases in some of the findings. For example, the program penetration may be somewhat overestimated and the spillover effects may be somewhat underestimated. However, there is no indication that the principle findings – gross and net saving – were affected.

9.2.5 Task 2.5: Drop out-of-scope projects

In this step, projects were dropped if they were outside of the target market of the commercial new construction programs. The approach was to examine the Dodge project categories and to compare them with the categories for the participants in the Dodge data. Categories such as bridge and highway construction were dropped immediately. The industrial category was retained because it was found to include participants.

9.2.6 Task 2.6: Estimate square footage

Square footage is useful as a stratification variable because it is typically correlated with savings and because it has a strong relationship to audit costs. However, square footage was found to be zero or missing in the Dodge database for about 30% of the projects retained from Task 2.5 and the correlation of square footage to savings was weaker in this project than is typically encountered. On the other hand, project value was provided for almost all projects and was found to be significantly correlated to square footage. In this task, missing values of square footage were estimated from regression equations relating square footage to project value. To take account of geographical variation, a separate regression equation was estimated for each county with sufficient data. In the following steps, square footage refers to a new field that is equal to the reported square footage when available, or the estimated square footage.

9.2.7 Task 2.7: Group by building type

The Dodge building type was found to contain more than fifty distinct categories. In this step, the Dodge categories were grouped into eleven distinct categories. Table 9-3 illustrates the Dodge categories included in each of our building types.

Type Categories		**Dodge Categories**	
Government	Government administration	Police & fire stations	Prisons, jails, detention home
	Libraries	Post offices	Space facilities
	Military facilities		
Grocery	Food product stores	Retail food stores	
Hospital	Hospitals	Nursing & convalescent	
Industrial	Food products manufacturing facilities	Manufacturing facilities, plants & other	
Miscellaneous	Air passenger terminals	Museums	Other service & maintenance
	Animal & fish plant facilities	Other recreational buildings	Stadiums
	Arenas, auditoriums, exhibit halls	Outdoor swimming pools	Theaters-indoor, fine arts buildings
	Campgrounds & resorts	Parking garages	Theaters-outdoor
	Funeral & interment facilities	Other passenger terminals	Worship facilities
	Hotels & motels	Religious educational buildings.	YMCA & YWCA
	Labs, testing, R&D		
Office	Clinics & medical offices	Financial services	Offices
	Communications facilities		
Restaurant	Restaurants & food service		
Retail	Auto & truck service & maintenance	Other stores	Shopping centers
School	Colleges & universities	Jr. & community colleges	Senior high schools
	Dorms & residence halls	Middle schools (Jr. high)	Special schools
	Gymnasiums & field houses	Primary schools (elementary)	Trade & vocational schools
Warehouse, Non Ref	Warehouses, not refrigerated		
Warehouse, Ref	Warehouses, refrigerated		

Table 9-3: Building Type Categories

9.2.8 Task 2.8: Develop the sample design

Separate sample designs were developed for each of the two utilities. Consider PG&E as an example. We started with the 272 probable participants in the Dodge data base found in Task 2.4 and made the assumption that all participants were equally likely to be matched to the Dodge data. Each of these participants was assigned a weight of 440/272 = 1.62 to reflect the number of participants in the program. Then the 272 projects were grouped by the building type categories established in Task 2.7 and sorted by the square footage estimated in Task 2.6.

In order to comply with the Evaluation Protocols, the MBSS™ methodology was used to develop an efficient sample design and to assess its likely statistical precision. The target variable of analysis, denoted y, was taken to be the energy use of the project. The primary stratification variable, the square footage of the project, was denoted *x*. A ratio model was formulated to describe the relationship between *y* and *x* for all units in the population, e.g., all PG&E program participants.

The MBSS™ ratio model consists of two equations called the primary and secondary equations:

$$\begin{aligned} y_k &= \beta\, x_k + \varepsilon_k \\ \sigma_k &= sd\left(y_k\right) = \sigma_0\, x_k^{\gamma} \end{aligned} \tag{9.1}$$

Here $x_k > 0$ is known throughout the population. *k* denotes the sampling unit, i.e., the project. In other notes, often *i* is used instead of *k*. $\{\varepsilon_1, \ldots, \varepsilon_N\}$ are independent random variables with zero expected value, and β, σ_0, and γ (gamma) are parameters of the model. The primary equation can also be written as

$$\mu_k = \beta x_k \tag{9.2}$$

This shows that under the MBSS ratio model, it is assumed that the expected value of y is a simple ratio or multiple of *x*. In other words, y_k is a random variable with expected value μ_k and standard deviation σ_k. Both the expected value and standard deviation generally vary from one unit to another depending on x_k, following the primary and secondary equations of the model. In statistical jargon, the ratio model is a (usually) heteroscedastic regression model with zero intercept.

One of the key parameters of the ratio model is the error ratio, denoted *er*. The error ratio is a measure of the strength of the association between *y* and *x*. The error ratio is suitable for measuring the strength of a heteroscedastic relationship and for choosing sample sizes. It is *not* equal to the correlation coefficient. It *is* somewhat analogous to a coefficient of variation except that it describes the association between two or more variables rather than the variation in a single variable.

Using the model discussed above, the error ratio, *er*, is defined to be:

$$er = \frac{\sum_{k=1}^{N} \sigma_k}{\sum_{k=1}^{N} \mu_k} = \frac{\frac{1}{N}\sum_{k=1}^{N} \sigma_k}{\frac{1}{N}\sum_{k=1}^{N} \mu_k} \tag{9.3}$$

Figure 9-1 gives some typical examples of ratio models with different error ratios. An error ratio of 0.2 represents a very strong association between *y* and *x*, whereas an error ratio of 0.8 represents a weak association.

As Figure 9-1 indicates, the error ratio is the principle determinant of the sample size required to satisfy the 90/10 criteria for estimating *y*. If the error ratio is small, then the required sample is corresponding small.

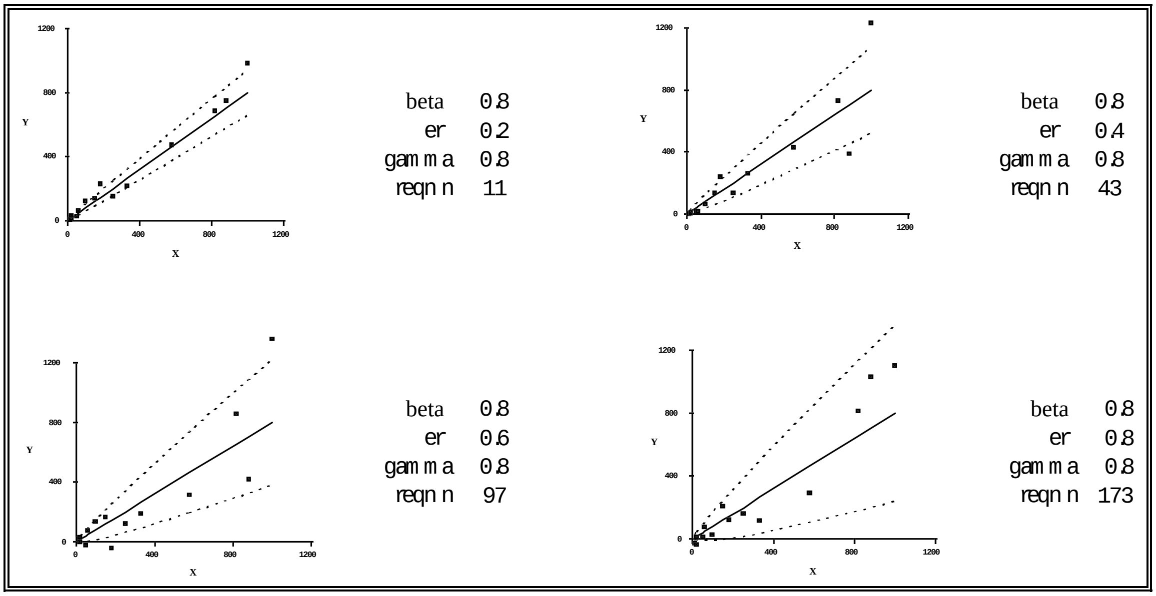

Figure 9-1: Examples of MBSS Ratio Models

In this application, we have assumed a separate ratio model (9.1) for each building type. We assessed the error ratio for each building type as shown in Table 9-4. These values were based on our professional judgment, reflecting RLW's experience in two recent projects (EPRI report forthcoming). It is also necessary to assess a second parameter called gamma in the ratio model (9.1). Gamma controls how the residual standard deviation varies with *x*. In technical terms, gamma controls the degree of heteroscedasticity specified in the model. All models had an assumed gamma of 0.8, which is midway between the expected range of gamma, 0.5 to 1.0, and is a good assumption in most utility applications. (Section 5.2.3 reports the values of the error ratios and gammas actually found in the present study.)

Building Type	*er*
Government	0.60
Grocery	0.40
Hospital	0.70
Industrial	0.50
Miscellaneous	0.80
Office	0.50
Restaurant	0.45
Retail	0.60
School	0.80
Warehouse, Non Ref	0.50
Warehouse, Ref	0.50

Table 9-4: Assumed Error Ratios

The next step was to choose a tentative sample size for the PG&E participant sample and allocate the sample to each building type. Based on the assumed ratio models, a procedure called Neyman allocation was used to calculate the most efficient allocation of the sample to building types.

Then, within each building type, we constructed strata based on square footage. Depending on the desired sample size, the number of strata varied from 1 to 4. Our MBSS software was used to construct stratum boundaries for each building type. For example, the first stratum in a particular building type might consist of all projects from 0 to 10,000 square feet. The stratum boundaries were constructed to group a larger number of projects into the lower strata and a smaller number in the higher strata. The stratum boundaries were constructed using MBSS stratification with a set gamma of 0.4. The value of gamma used to construct the strata was one-half of the value of gamma assumed in the models to reflect the higher cost of auditing larger sites. The MBSS software also determined whether the largest projects should be selected with certainty. When appropriate, a certainty stratum was constructed. The remaining sample was equally allocated to the remaining stratum. For example, 2 projects might be sampled from each of 3 strata for a total sample of 6.

Table 9-5 reports the number of strata and the stratum boundaries developed for the PG&E component of the sample design. The table reports the lower bound of each stratum. For example, in the government segment, two strata were used. Stratum 1 included projects from 0 to 31,342 square feet. Stratum 2 included projects above 31,342 square feet. As another example, the office segment had four strata: 0 - 20,969, 20,969 - 40,001, 40,001 - 216,001, and above 216,001. No stratification was used in the Refrigerated Warehouse category since a census was to be attempted. Table 9-6 shows the stratum boundaries developed for SCE.

Type Category \ Strata	1	2	3	4	5
Government	0	31,342			
Grocery	0	40,001			
Hospital	0	60,001	94,001		
Industrial	0	40,001			
Miscellaneous	0	19,176			
Office	0	20,969	40,001	216,001	
Restaurant	0	3,081			
Retail	0	25,399	68,066	121,769	
School	0	18,634	33,001	50,901	
Warehouse, Non Ref	0	17,961	56,421	92,001	370,001
Warehouse, Ref	0				

Table 9-5: Stratum boundaries for PG&E

Type Category \ Strata	1	2	3	4	5
Government	0	17,001	32,519	46,001	
Grocery	0	24,001			
Hospital	0	21,645			
Industrial	0	44,945	99,504		
Miscellaneous	0	15,201	20,111		
Office	0	10,001	21,297	25,001	47,664
Restaurant	0	6,507			
Retail	0	25,950	96,576	116,238	
School	0	30,939	72,628		
Warehouse, Non Ref	0	40,001	93,755		
Warehouse, Ref	0				

Table 9-6: Stratum boundaries for SCE

Next, the expected statistical precision was calculated using the assumed models and the planned sample design. The underlying methodology is the following. For any sample design being considered, let $\pi_k = \Pr(k \in s)$ be the inclusion probability for each unit *k,* i.e., the probability that the project falls into the sample under the proposed sample design. Let $\hat{Y}$ be the ratio estimator of the population total *Y*. Assume that the ratio model is accurate. Then the anticipated variance and the anticipated relative precision at the 90% level of confidence are defined to be, respectively:

$$\begin{aligned} AV\left(\hat{Y}\right) &= \sum_{k=1}^{N}\left(\pi_k^{-1}-1\right)\sigma_k^2 \\ rp &= \frac{1.645\sqrt{AV\left(\hat{Y}\right)}}{\sum_{k=1}^{N}\mu_k} \end{aligned} \tag{9.4}$$

By combining equations (9.1), (9.3), and (9.4), the anticipated relative precision can be written as:

$$rp = \frac{1.645\,er\sqrt{\sum_{k=1}^{N}\left(\pi_k^{-1}-1\right)x_k^{2\gamma}}}{\sum_{k=1}^{N}x_k^{\gamma}} \tag{9.5}$$

The MBSS software was used to calculate the anticipated relative precision within each building type using (9.5) and using the error ratios from Table 9-4 together with the square footage of the set of participants matched to the Dodge data. Then Excel was used to aggregate the results across all building types and to compare the expected precision to the 90/10 criteria. More than a dozen iterations of this procedure were carried out to develop the final sampling plans for both PG&E and SCE.

Following the Evaluation Protocols, the same sample design was planned for both the participant and non-participant portions of the Dodge data. Therefore, assuming that the participant matching of Task 2.4 was accurate, the final participant and non-participant samples were expected to be approximately equal.

9.2.9 Task 2.9: Describe the sample

The purpose of this section is to summarize the distribution of the sample by building type and square footage strata. A series of tables is given below, first for PG&E and then for SCE.

Table 9-7 shows the number of projects in the target population for each building category and each stratum of the sample design. Altogether, the target population had 2,547 projects. As discussed later in Task 2.10, the target population consists of 2,275 non-participants in the 1993 Dodge database plus the 272 program participants found in the 1992, 1993 and 1994 Dodge databases that were in the PG&E service territory and in the target building types. The strata were previously described in Table 9-5. The largest group of projects was in the office category.

Type Category \ Strata	1	2	3	4	5	Total
Government	88	27	0	0	0	115
Grocery	15	16	0	0	0	31
Hospital	65	5	8	0	0	78
Industrial	86	23	0	0	0	109
Miscellaneous	215	176	0	0	0	391
Office	527	229	87	14	0	857
Restaurant	24	82	0	0	0	106
Retail	181	43	23	27	0	274
School	193	104	63	53	0	413
Warehouse, Non Ref	77	50	6	9	1	143
Warehouse, Ref	30	0	0	0	0	30
Grand Total	1,501	755	187	103	1	2,547

Table 9-7: PG&E Population of Dodge Projects

Table 9-8 shows the distribution of the 272 PG&E program participants that were matched to the Dodge data. For example, out of a total of 14 participants in PG&E's Refrigerated Warehouse program, 11 were found in the Dodge database.

Type Category \ Strata	1	2	3	4	5	Total
Government	5	2	0	0	0	7
Grocery	5	5	0	0	0	10
Hospital	3	2	2	0	0	7
Industrial	8	4	0	0	0	12
Miscellaneous	17	12	0	0	0	29
Office	36	28	18	9	0	91
Restaurant	2	2	0	0	0	4
Retail	15	9	7	6	0	37
School	18	12	10	8	0	48
Warehouse, Non Ref	6	4	3	2	1	16
Warehouse, Ref	11	0	0		0	11
Grand Total	126	80	40	25	1	272

Table 9-8: PG&E Participants That Matched to Dodge Data

Table 9-9 summarizes the planned participant sample for PG&E. In the case of Government projects, for example, two participants were randomly selected from the five participants shown in Table 9-8 in stratum 1. In stratum 2 of government, we sought to recruit both participants into the sample. In the Refrigerated Warehouse program, we sought to include all 14 program participants into the sample. Table 9-9 includes the additional commercial refrigeration sites required for the attempted census of that program.

In general, the non-participant component of the sample was selected using the same sample design shown in Table 9-9. However, some strata of the office, hospital, retail, and non-refrigerated warehouse segments are larger than the participant sample. The number of participants in these strata limited the participant component of the sample. Moreover, following the Scope of Work, refrigerated warehouse projects were not included in the non-participant sample.

Type Category \ Strata	1	2	3	4	5	Total
Government	2	2				4
Grocery	5	4				9
Hospital	1	2	2			5
Industrial	4	2				6
Miscellaneous	2	2				4
Office	3	7	8	7		25
Restaurant	2	1				3
Retail	1	4	4	5		14
School	3	3	3	3		12
Warehouse, Non Ref	4	3	3	2	1	13
Warehouse, Ref	14					14
Grand Total	40	26	18	15	1	109

Table 9-9: PG&E Participant Sample

The following tables provide analogous information for the SCE sample design. Table 9-10 shows the number of projects in the target population for each building category and each stratum of the sample design. The strata were previously described in Table 9-6. Altogether, the target population had 2,289 projects that were in the SCE service territory and in the target building types. These consisted of 154 matched participants and 2,135 non-participants from the 1993 Dodge database. As with PG&E, the largest group of projects were in the office category.

Type Category \ Strata	1	2	3	4	5	Total
Government	27	38	8	10	0	83
Grocery	8	52	0	0	0	60
Hospital	31	24	0	0	0	55
Industrial	46	11	9	0	0	66
Miscellaneous	144	39	173	0	0	356
Office	192	163	91	164	56	666
Restaurant	48	66	0	0	0	114
Retail	276	99	15	25	0	415
School	193	101	42	0	0	336
Warehouse, Non Ref	102	18	11	0	0	131
Warehouse, Ref	7	0	0	0	0	7
Grand Total	1,074	611	349	199	56	2,289

Table 9-10: SCE Population of Dodge Projects

Table 9-11 shows the distribution of the 154 SCE program participants that were matched to the Dodge data. As previously noted, of all 272 SCE participants, 154 were successfully matched to the Dodge data.

Type Category \ Strata	1	2	3	4	5	Total
Government	5	4	3	3	0	15
Grocery	1	2	0	0	0	3
Hospital	3	2	0	0	0	5
Industrial	4	2	2	0	0	8
Miscellaneous	5	5	4	0	0	14
Office	15	8	9	5	5	42
Restaurant	3	2	0	0	0	5
Retail	9	6	4	5	0	24
School	14	9	8	0	0	31
Warehouse, Non Ref	3	2	2	0	0	7
Warehouse, Ref	0	0	0	0	0	0
Grand Total	62	42	32	13	5	154

Table 9-11: SCE Participants that Matched to Dodge Data

Table 9-12 summarizes the planned participant sample for SCE. In the case of Government projects, for example, two participants were randomly selected from the five participants shown in Table 9-11 in stratum 1. The same sample design shown in Table 9-12 was also used to select the non-participant component of the SCE sample.

Type Category \ Strata	1	2	3	4	5	Total
Government	2	2	2	2		8
Grocery	1	1				2
Hospital	2	2				4
Industrial	2	2	2			6
Miscellaneous	2	2	2			6
Office	2	2	2	2	2	10
Restaurant	1	1				2
Retail	4	4	4	4		16
School	7	7	7			21
Warehouse, Non Ref	2	2	2			6
Warehouse, Ref	0	0	0	0	0	0
Grand Total	25	25	21	8	2	81

Table 9-12: SCE Participant Sample

9.2.10 Task 2.10: Select the sample

The participant component of the sampling plan was selected from the participants that were matched to the Dodge database, shown in Table 9-8 and Table 9-11, following the sampling plans summarized in Table 9-9 and Table 9-12. The matched participants were sorted by building type and square footage stratum, and then assigned a priority within each stratum according to a random number. In strata with an adequate number of participants, a backup sample was designated for use in replacing refusals.

In this task we also sought to identify the most appropriate year of the Dodge data to use to select the non-participant component of the sample. Table 9-13 shows the number of matched participants according to the year that the building was started based on the Dodge data. Most commonly, a project that participated in the 1994 program was started in the preceding year, 1993. However, a substantial number of projects were started in either 1992 or 1994.

It was decided to exclude non-participating projects started in 1992 since some of these projects would not be covered by Title 24. Similarly projects started in 1994 were excluded to avoid a bias toward smaller, faster moving projects. Non-participant projects started in 1993 were thought likely to be most similar to 1994 program participants. So the non-participant component of the sample was selected from the 1993 Dodge projects, following the same sample design, using the procedure described in the first paragraph of this section.

Year	1992	1993	1994
PG&E	73	127	72
SCE	47	74	34

Table 9-13: Number of Matched Participants by Year Started

9.2.11 Task 2.11: Utility review

In this task, the sample was provided to each of the utilities for review. In addition, a form was designed to solicit information about any influence that the utility may have had on the design of the project. This information was useful in identifying partial participants.

9.2.12 Task 2.12: Screen the sample for multiple-site contacts

The Dodge database includes information on the building owner, designer, contractor, etc. We sorted the sample according to this information in order to identify multiple site contacts. The recruiting instrument developed in Task 3 was designed to collect information for multiple buildings from a single contact person.

9.2.13 Task 2.13: Finalize the sample

Based on the information collected in Tasks 2.11 and 2.12, the final primary sample and prioritized backups was determined. Multiple buildings were organized by contact person. The Dodge information and other supporting information were provided to Aspen for use in the recruiting and on-site data collection tasks.

10. OVERVIEW OF THE DATA COLLECTION EFFORT

There were six different data collection activities for the Commercial New Construction Project. Five of these activities are discussed in this chapter. The sixth, short-term monitoring is discussed in chapters 7 and 11. The five activities discussed here are:

- Recruiting On-site and Decision-Maker Contacts
- On-site Data Collection
- Quality Control of On-Site Survey Data
- Title 24 Capture
- Decision-Maker Survey

These activities produced the major part of the customer data used in the modeling and analysis phase.

10.1 RECRUITING

The purpose of the recruiting effort was to obtain a pre-qualified sample for the on-site and decision-maker surveys. Two recruiting instruments were developed: one for the on-site and decision-maker contact (if the same person) and one for the decision-maker contact if different from the on-site contact. All of these instruments were pre-tested prior to the beginning recruitment phase. This pre-testing ensured that no flaws existed in the structure and flow of questions in the survey. There were two drafts and a final version of the surveys.

Questions on the recruitment survey included:

- Pre-qualifying the Site for New/Renovation and Occupancy in 1994
- Ascertaining both the On-site and Decision-Maker Contacts
- Recruiting the On-site and Decision-Maker Contacts
- Requesting Title 24 Documentation and Construction Plans

A copy of the recruiting script is included in Appendix A.

The surveys were conducted from June 18 through August 30, 1996. The recruiters faced a number of challenges during the phase of the project including:

Identifying the correct contact. Numerous phone calls were often necessary to obtain the proper contact. Aspen made up to 8 phone calls to each site to obtain valid contact names.

Pre-qualifying the correct survey space. The Dodge record was often not the same as the utility billing address. This caused problems that at times even spilled over into the on-site phase, where additional pre-qualification was necessary.

On-site contacts were often difficult to contact. Aspen occasionally made as many as 11 calls without speaking to the valid on-site contact.

Discrepancies between Dodge and participant records. Approximately 38% of the SCE and 17% of the PG&E records were mismatched. This is a function of the Dodge data not having clearly defined names and addresses. Additional recruiting of approximately 11 sites was necessary in the scheduling phase to ensure that the proper participant contact was visited during the on-site survey.

Sample Staging: the use of primary and secondary samples. A total of 7 samples were supplied for each utility to Aspen's CATI center. The original intent was to obtain as many primary sample customers as possible, so the primary sample was loaded into the CATI system first. Six additional samples were then needed to obtain an adequately large sample for on-site surveying.

A total of 460 sites were recruited from over 1,500 supplied sample customers. Table 10-1 and Table 10-2: Distribution of Recruited Premises: Strata, Participant Status for SCE2 show how these sites were distributed. These data may slightly differ from later data in this report due to misclassifications found in the Dodge data.

	PG&E												
Strata	1		2		3		4		5		Subtotal		Total
Category	P	NP	P	NP	P	NP	P	NP	P	NP	P	NP	
Government	3	4	1	4							4	8	12
Grocery	1	3		2							1	5	6
Hospital	2	3	2	1	2	2					6	6	12
Industrial	4	5	3	2							7	7	14
Miscellaneous	5	4	5	4			1				11	8	19
Office	12	4	13	10	9	12	6	2			40	28	68
Restaurant	2	4	1	3				1			3	8	11
Retail	5	5	3	6	6	3	2	1			16	15	31
School	7	4	7	6	3	7	1	5			18	22	40
Warehouse	4	6	3	8	1	1	1	2	1		10	17	27
Warehouse (R)	11										11	0	11
Subtotal	56	42	38	46	21	25	11	11	1		127	124	251
Total	98		84		46		22		1		251		

Table 10-1 : Distribution of Recruited Premises: Strata, Participant Status for PG&E

	SCE												
Strata	1		2		3		4		5		Subtotal		Total
Category	P	NP	P	NP	P	NP	P	NP	P	NP	P	NP	
Government	3	5	3	4	1			1			7	10	17
Grocery	1	1		2							1	3	4
Hospital	1	1	1	4							3	5	8
Industrial	2	4	1	3		4					3	11	14
Miscellaneous	6	5	3	4	2	5		1			11	15	26
Office	5	6	2	5	2	2	2	4	3	7	14	24	38
Restaurant	3	2	3	1							6	3	9
Retail	3	6	2	6	4	4	4	5			13	21	34
School	12	11	5	9	4	7					21	27	48
Warehouse	2	4		1		1					2	6	8
Subtotal	38	45	20	39	13	23	6	11	7	3	80	125	205
Total	83		59		36		17		10		205		

Table 10-2: Distribution of Recruited Premises: Strata, Participant Status for SCE

Several lessons were learned from the recruitment phase of the survey. First, persistence is required to correctly identify and speak to contacts. Because recruiting, survey scheduling, decision-maker, and Title-24 capture occurred on a parallel track, this persistence caused customer relations problems in a few cases; every attempt was made to minimize these problems. Second, since site pre-qualification was not always successful and the scheduling phase experienced an over 20% attrition rate, over-recruiting was crucial to meeting project targets.

It was also crucial to have good contact information for successful recruiting, scheduling, and Title 24 capture. Participant contact information is lost when using the Dodge record. Finally, sample staging extends the recruitment completion schedule.

10.2 ON-SITE SURVEYS

The on-site survey phase began July 12 and continued through October 18. A total of 407 buildings at 347 premises were surveyed during this time period. Table 10-3 provides a disposition summary for the 460 recruited premises. A more detailed disposition is provided in the scheduling section below.

	Number
Successfully Recruited Premises	460
Premises Not Surveyed	113
Total Premises Surveyed	347
Premises Disqualified Post-Survey	2
Premises Used for Analysis	345

Table 10-3: Disposition Summary of Recruited Premises

10.2.1 Auditor Training

The evaluation team trained fourteen surveyors on July 1st, 2nd and 3rd. This training included surveying two newly constructed PG&E customer sites. Of these fourteen surveyors, eleven were trained as primary surveyors and three as alternates. Due to surveyor attrition and the tight schedule, all fourteen worked on the project.

10.2.2 Scheduling

The scheduling for the on-site surveys began with one full-time scheduler. Several time-consuming problems were encountered which slowed the pace of scheduling, in particular the necessity of multiple contacts, the need to streamline auditors' location with their schedules, and the parallel recruiting and scheduling. It soon became apparent that a single scheduler would be unable to meet the completion timetable; first five auditors and finally a second full-time scheduler were added to improve the scheduling rate. Figure 10-1 shows the number of surveys scheduled over time, and indicates when additional scheduling resources were added to meet the established timetable.

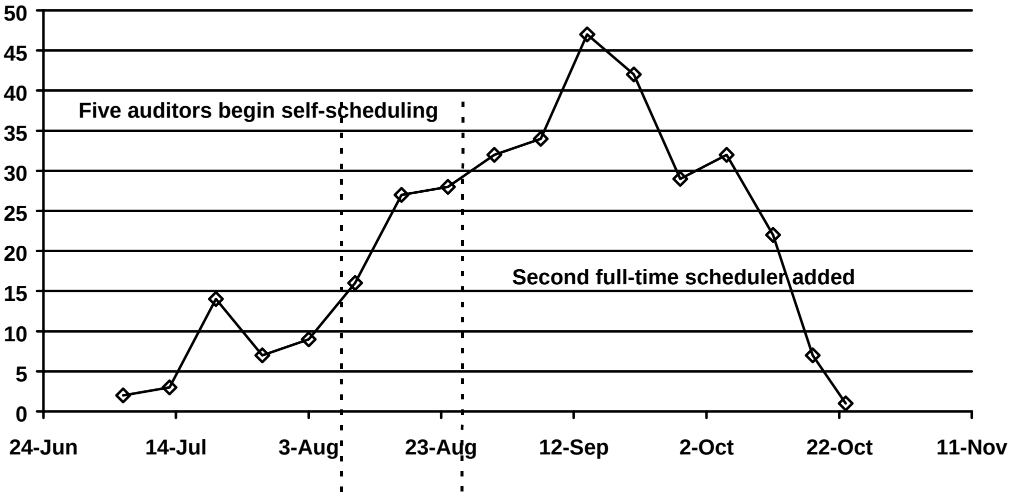

Figure 10-1 : Number of Audits Scheduled Per Week

Figure 10-2 shows the on-site survey completion timeline. In the final month of the survey phase, the two alternate auditors were added to the active auditor pool. With these additional resources, the surveys were completed according to the numerical and timetable targets.

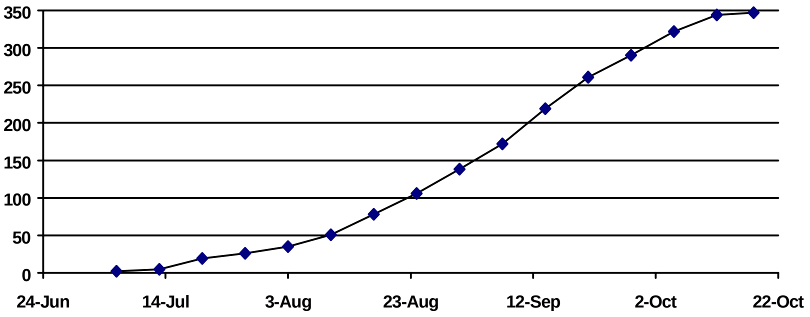

Figure 10-2: Survey Completion Timeline

10.2.3 Premise Survey Implementation and Results

A total of 347 premises were surveyed, for a total of 407 buildings. Of these, one premise was excluded due to customer refusal during the Decision-Maker survey phase and a second premise was excluded after discovering that it was a refrigerated warehouse in the non-refrigerated warehouse category. This left a total of 345 premises and 405 buildings -- eleven of which are refrigerated warehouse participants -- for modeling.

Table 10-4 summarizes the survey results, and Tables 10-5 and 10-6 show these successfully surveyed sites by utility, participation status, and strata.

	PG&E	SCE
Participant	102	68
Non-participant	81	94
Total	183	162

Table 10-4: Summary of Surveyed Premises

	PG&E												
Strata	1		2		3		4		5		Subtotal		Total
Category	P	NP	P	NP	P	NP	P	NP	P	NP	P	NP	
Government	3	4	1	1							4	5	9
Grocery		2		2							0	4	4
Hospital	2	4	1	1	2						5	5	10
Industrial	2	2	1	2							3	4	7
Miscellaneous	5	1	7	2							12	3	15
Office	8	4	7	6	9	8	3	1			27	19	46
Restaurant	1	3	1								2	3	5
Retail	3	4	2	4	7		3	1			15	9	24
School	7	4	6	3	2	6	2	4			17	17	34
Warehouse (NF)	1	3	4	7				2	1		6	12	18
Warehouse (R)	11										11	0	11
Subtotal	43	31	30	28	20	14	8	8	1		91	81	183
Total	74		58		34		16		1		183		

Table 10-5: Distribution of Completed Surveys: Strata, Participant Status for PG&E

	SCE												
Strata	1		2		3		4		5		Subtotal		Total
Category	P	NP	P	NP	P	NP	P	NP	P	NP	P	NP	
Government	3	4		4			1	1			4	9	13
Grocery			1	1							1	1	2
Hospital	1		1	3							2	3	5
Industrial	1	3	1	1		3					2	7	9
Miscellaneous	5	4	7	9							12	13	25
Office	4	4	1	2	2	1	4	3	2	5	13	15	28
Restaurant	2	2	1	1							3	3	6
Retail	1	6	1	4	3	3	4	5			9	18	27
School	10	4	6	11	4	5					20	20	40
Warehouse (NF)	2	3		1		1					2	5	7
Subtotal	29	30	19	37	9	13	9	9	2	5	68	94	162
Total	59		56		22		18		7		162		

Table 10-6: Distribution of Completed Surveys: Strata, Participant Status for SCE

Over three-quarters of the successfully recruited sites were surveyed. Figure 10-3 shows that of the successfully recruited sites, 14.9% were not surveyed because they were found to be ineligible sites. Some of these reasons include: the wrong building being recruited, incomplete alterations, non energy-related or minor modifications, the building no longer in use, the building was not a PG&E/SCE customer, etc. This figure also shows that 9.8% of successfully recruited sites later refused to participate in the survey, or were not surveyed for other reasons. Refusal reasons vary, but the most common include being too busy or superiors rescinding the decision to participate. The ‘other’ category includes being unable to reach the given contact person, the contact canceling or not keeping the survey appointment, and reaching the end of the time frame for surveys. This information is summarized in Table 10-7.

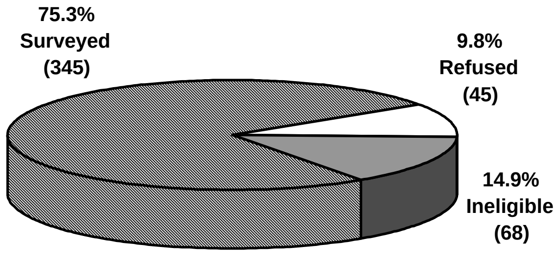

Figure 10-3: Disposition of Recruited Sites

	PG&E		**SCE**		**Total**	
	Refused	Ineligible	Refused	Ineligible	Refused	Ineligible
Participant	12	12	6	10	18	22
Non-participant	12	27	15	19	27	46
Subtotal	24	39	21	29	45	68
Total	63		50		113	

Table 10-7: Summary of Non-Surveyed Sites

The unsurveyed sites fall into one of eight ‘reason’ categories, and are broken out by building type, strata, and participation status for each utility in Table 10-8 and Table 10-9.

PG&E PARTICIPANT DISPOSITION CODES FOR ON-SITE SURVEYS									
Building type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
Government									0
Grocery									0
Hospital	1								1
Industrial									0
Miscellaneous	1							1	2
Office	2		6				1		9
Restaurant	1								1
Retail	3		1						4
School	1		2						3
Warehouse (NF)	1		3						4
Total	10	0	12	0	0	0	1	1	24

PG&E NON-PARTICIPANT DISPOSITION CODES FOR ON-SITE SURVEYS									
Building type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
Government				3					3
Grocery			1						1
Hospital				1			1		2
Industrial			2	1	1			1	5
Miscellaneous			3						3
Office	4		4						8
Restaurant	2			1	2				5
Retail			1	1	1		1		4
School	1	1	1		2				5
Warehouse (NF)	1		2						3
Total	8	1	14	7	6	0	2	1	39

1 = Refused to participate
2 = Refused due to multiple contacts
3 = Incorrect building, work incomplete, light alterations, closed, etc.
4 = Non-1994 participant
5 = Not in either service utility area
6 = No contact - wrong information
7 = No contact after at least 5 calls and supervisor intervention
8 = End of survey time frame reached

Table 10-8: Sites Not Surveyed -- Disposition Codes for PG&E Recruited Sites

SCE PARTICIPANT DISPOSITION CODES FOR ON-SITE SURVEYS									
Building type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
Government			1				1	1	3
Grocery									0
Hospital									0
Industrial									0
Miscellaneous			1						1
Office	1		2						3
Restaurant			1						1
Retail		1	3						4
School			2						2
Warehouse, Non							1	1	2
Warehouse, Ref									0
Total	1	1	10	0	0	0	2	2	16

SCE NON-PARTICIPANT DISPOSITION CODES FOR ON-SITE SURVEYS									
Building type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
Government	1							1	2
Grocery									0
Hospital			1					1	2
Industrial	2				1		1		4
Miscellaneous			1						1
Office			2		3	1	2		8
Restaurant	1								1
Retail	2	1	2	2					7
School			7			1			8
Warehouse, Non	1								1
Total	7	1	13	2	4	2	3	2	34

1 = Refused to participate
2 = Refused due to multiple contacts
3 = Incorrect building, work incomplete, light alterations, closed, etc.
4 = Non-1994 participant
5 = Not in either service utility area
6 = No contact - wrong information
7 = No contact after at least 5 calls and supervisor intervention
8 = End of survey time frame reached

Table 10-9: Sites Not Surveyed -- Disposition Codes for SCE Recruited Sites

10.3 DATA QUALITY CONTROL

The evaluation team undertook an extensive quality control (QC) effort for this project. Due to the magnitude and complexity of the data which must be collected to model Commercial/Industrial buildings, it was a very challenging task to create a clean, complete, error-free data set. The following section describes the procedures used during the data entry phase of this project. These procedures were implemented to ensure the integrity of the data collection effort, from data collection to data delivery. The following data entry/cleaning procedures will be discussed in detail in this section:

- Initial technical review of the hard copy survey instrument
- Quality control (QC) of participant measure retention information
- Double-key data entry
- Computerized quality control of survey data
- Investigation of QC errors, ascertain accurate responses
- Edit of survey databases with accurate data
- Delivery of raw survey data

10.3.1 Initial Technical Review of the Hard Copy Survey Instrument

The survey instrument used in this project consisted of 25 pages of detailed building envelope and HVAC data which had to be linked together through operating areas, zones and HVAC systems. Since every building was different, one stock computerized check of the overall consistency of the survey data was impractical. It was therefore necessary to perform a manual review of the entire survey instrument to check for any inconsistencies that a computer might not find. Inconsistencies checked for in the technical review included:

- Verified the sketch with the reported square footage, opaque surfaces, and orientations
- Overall check for missing data
- Use of photographs to verify window types, shading, overhangs, floor height, etc.
- Verified that the System/Zone Association Checklist was consistent with other survey responses
- Read surveyor's notes for any special instructions regarding data,
- Made sure all data were reasonable, (i.e., a school with 24 hour operation is not reasonable)

Any inconsistencies or errors found in the data were resolved immediately before the data was entered into the database. Errors were either resolved by a telephone call to the original surveyor or by a telephone call back to the site. In a few instances, the original surveyor had to make another trip back to the site to collect the correct data.

10.3.2 Quality Control of Participant Measure Retention Information

Participant measure information included some or all of the following items;

- Proposed lists of measures (some that were installed and rebated, some that were not installed, and some that were installed, but not rebated)
- Price quotes and specification sheets from various HVAC, lighting and other vendors with prices and specifications of suggested equipment (not necessarily the equipment that was finally installed)
- Copies of the rebate check
- Post-field inspection notes (often handwritten notes regarding what was actually installed, but not necessarily rebated, in the facility)
- Rebate program applications (different applications were used for lighting, HVAC, etc.)
- Various Title 24 compliance documentation (usually only for proposed/rebated measures)
- Acceptance letter for rebated measures (from incentive coordinator to the customer)
- Copies of invoices for the equipment installed at the facility (not always the rebated equipment)
- Printouts from the utility billing file with customer information
- Various other related information

Also included with the SCE participant information were computerized documentation of measures proposed (but not necessarily installed or rebated). The information in these data didn't identify the exact measures proposed, but listed measures categories, such as “heat pump <65,000 Btuh”, with the efficiency and quantity that was proposed.

The surveyors used the measures information to identify which rebated measures were actually in the field and checked off any rebated measure that was found in the field on the hard copy survey form. To the extent that measure information was available from the utilities and clearly defined, the Aspen surveyor recorded them on the survey instrument. The following procedure was followed as the QC check on the measures information;

1. Number the measure on the measure list/folder
2. Locate each measure in the on-site survey instrument, circle it and check the measures box on the survey form
3. Go back to the measures list and write “located, see page XX” for each measure.
4. For any measure that can not be located on the on-site survey instrument, write one of the following three dispositions on the measures list/folder.
    a.) Not located, Install done.
    b.) Not located, Install not done.
    c.) Not located, Install unknown.

Once the survey form was completed, it was checked against the participant files, where available. Discrepancies were resolved, if possible, by engineer review, phone calls to the surveyors, and in some cases, phone calls to the customer site. The main reasons for discrepancies were:

- Multiple buildings/floors at a site; all buildings or floors were not surveyed.
- It was often difficult to determine from the program files what equipment was rebated.
- Variable speed drives were often included with HVAC equipment, making it difficult to identify them
- A small number of measures were either removed, or changed from the program documentation. This was especially true of lighting and HVAC equipment.
- The site contact was not knowledgeable about the equipment

Appendix A contains the detailed site-by-site measures information including any problem resolution.

Figure 10-4 is a summary of the percentage of the number of measures found from the on-site survey forms, compared to the number of measures that were listed in the program files. Four categories are listed in Figure 10-4: lighting, ballasts, packaged HVAC, and motors. During the QC phase, for each of these measure items at each participant site, Aspen counted the number of measures shown on the verification or computer printouts, and checked them against the number found on the on-site survey form. The results listed in Figure 10-4 are the number of measures located during the on-site audit as a percentage of the number of rebated measures listed in the program. As the largest differences occurred in multi-building/multi-floor sites, Figure 10-4 also shows the same percentage with the deletion of all multi-building/multi-floor sites.

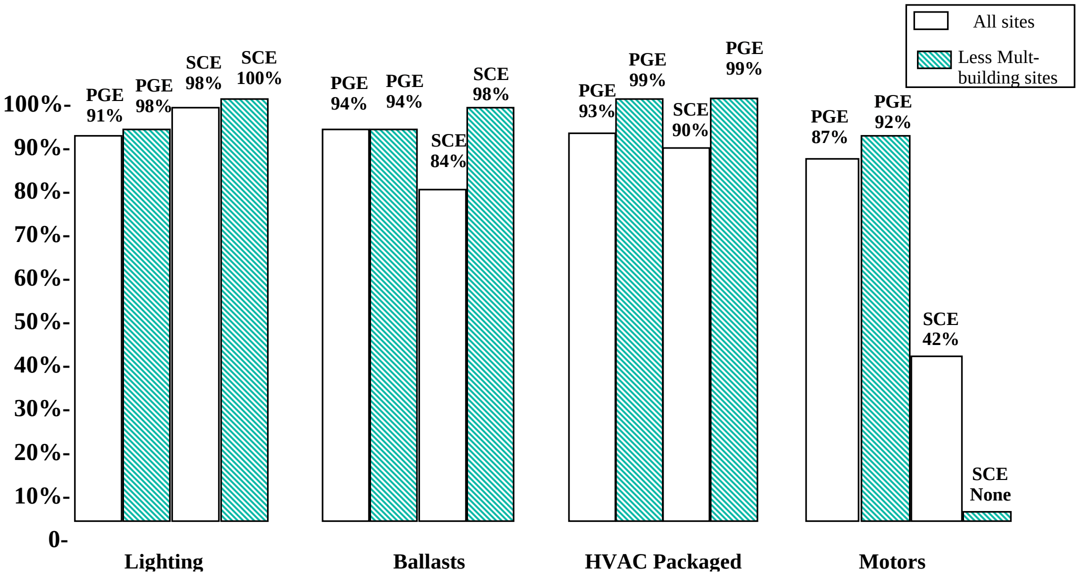

Figure 10-4: Measures QC: Percent of As-Found to Expected

The following lessons were learned during the measures QC phase:

- Program forms should better identify measures where possible
- Multiple level QC is necessary. Auditors, analysts, engineers, and project management staff were all involved in the measures QC process.

10.3.3 Double-Key Data Entry

The surveys were entered by the data entry clerk using the double-key method to ensure the accuracy of the data entry process. This process requires the data to be key entered into the computer twice (at a latter date than the first entry) by the data entry clerk. The data entry computer program compares the responses of the two sets of data and prompts the clerk during the second entry process with an error message if the two responses differ. The clerk must then carefully double-check the actual hard copy survey and either enter the correct response or seek assistance from the engineering staff if the correct response is unclear.

The data-entry program, which was programmed using Foxpro software, places the data into a total of 13 different tables based on the sections of the survey form. This was necessary due to the nature of the survey form as well as the nature of the data that was collected. Since larger sites contain multiple pieces of HVAC and other equipment, many of the equipment databases allow multiple observations (rows of data) for the same customer. Interview questions, on the other hand, only require one response per site, so several databases only contained one observation per customer. A coded survey form was developed that described the 13 databases and the variables included in them.

10.3.4 Computerized Quality Control of Survey Data

After the initial technical review and double-key data entry process, the computerized databases were checked by a rigorous quality control program. The Aspen data quality checking program consists of 119 data quality checks, including range checks, completeness checks, and internal consistency checks. The 13 databases were converted from DBF files to SAS data sets, and the quality checking program was developed in SAS statistical analysis software. The verification procedures of the data entry program are summarized by the following;

- Completeness Checks - These types of checks verify the proper use of skip patterns integral to the survey instrument. For example, if a surveyor lists any miscellaneous equipment in the equipment section, then there must also be a miscellaneous equipment schedule in the schedules section of the survey instrument.
- Range Checks - There are numerous range checks on all numerical, technical, and engineering data. Some examples of a range checks are; 0-100% where percents are required, 0-24 hours a day, or 50-99° thermostat setpoints.
- Internal Consistency Checks - These types of checks compare responses from one query with those of another query to assure consistency of the responses. For example, there are checks on A/C cooling tons per square feet to check the consistency with a pre-specified range of acceptable responses.

Appendix C of this report lists every quality control check performed on these data. Each check has an associated QC number and a reference to either the page of the questionnaire or the survey database for which the check applies.

10.3.5 Investigate all QC Errors and Ascertain Accurate Responses

The quality control program created a report of all QC errors failed, which surveys failed them, and a site by site listing of all QC checks failed by survey ID number. Each QC failure was investigated individually to determine the cause of the error so that the proper action could be taken to correct the data. A review of the hard copy survey instrument would reveal any obvious errors that could be corrected in-house without further review. These were errors such as data entry errors, where the data entry clerk entered something different from what was actually written on the survey instrument.

Other errors required a technical review of the survey instrument by engineering staff to determine the correct response. Many times, notes written in the margins or in the comment fields helped to identify the correct responses. If the correct response could not be resolved by an in-house review of the survey instrument, the original surveyor was contacted and was responsible for obtaining the correct data. The original surveyor either went back to the site to get the correct data, called the site contact to get the correct data, or referred to his notes to recall the correct data.

10.3.6 Edit Survey Databases With Accurate Data

Once the correct data responses were identified, edits were made to the raw survey data. All edits were made to the raw survey in the form of a data editing program developed in SAS software. A data editing program such as the one used here allowed the raw data to remain unedited, as well as created a means by which to document all edits made to the data.

Each edit made to the SAS data editing program included the date on which the edit was performed and one of the following three classifications to categorize the type of edit;

- Data entry error - where the data entered differs from the written survey
- Per engineer review - review by either the senior engineer or the original surveyor where the correct response was determined
- Per technical review of survey form - where Aspen technical staff reviewed the survey and were able to determine the correct response. Usually notes in the margins or in comment fields helped to identify correct data.

10.3.7 Delivery of Raw Survey Data

Final raw survey data has been delivered. This data included;

- Raw survey data (unedited) in DBF and SAS 6.04 format (13 databases)
- Edited survey data in DBF and SAS 6.04 format (13 databases)
- Coded survey form with survey variables, databases, and coded responses indicated
- Data dictionary with file structures and coded responses for each variable of each data set

Interim survey databases were delivered to AEC for modeling purposes throughout the project term. These data files were delivered in DBF format along with a data dictionary and coded survey form.

10.3.8 Additional Quality Control

Two additional measures ensured both the quality of the data and the job performed by the auditors; clarifications and instructions communicated to the auditors, and customer satisfaction surveys.

During the survey phase, PG&E and SCE made necessary clarifications and modifications to improve the quality of the data. These and all other instructions were communicated to all auditors in writing via memoranda. Select important memoranda are attached in Appendix C.

The thirteen main auditors were spot-checked throughout the survey period. The purpose of this spot-check was to make sure the auditors were going to the sites and representing the utility companies appropriately. A total of 42 sites were contacted and provided responses for this spot check. The survey consisted of three questions and the opportunity for the respondent to provide any additional comments. A summary of the survey results is presented here.

- The first question asked if the auditor was on time. Forty of the respondents said yes. they were. Of the remaining two, one said that the auditor was a few minutes early, and the other said that the auditor was a little late.
- The second question asked if the auditor was courteous. Forty-one of the respondents replied positively to this question. The one person who did not reply said that he knew only that the auditor was there, but did not deal with him.
- The final question asked if the auditor was thorough. Four of the respondents did not answer this question because they said they did nothing more than let the auditor in, so they were unsure of how complete the auditor was. The other 38 respondents all said that the auditor was thorough.
- Most respondents chose not to provide additional comments. Some people reiterated that the auditors were very courteous or very thorough, others added that the auditors were very knowledgeable. There were only two negative comments from all 42 respondents. One person said that the survey was longer than expected, and the other said that the surveyor was disorganized.

10.4 TITLE 24 COLLECTION

Title 24 specifies energy efficiency design standards for the envelope, lighting, and mechanical components of buildings. These standards apply to all Commercial buildings with a few exceptions, including hospitals, historical renovations, refrigerated warehouses, unconditioned warehouses and storage buildings, and office spaces that comprise less than 10% of the total square footage. Also exempt are government agencies and work done for the Americans with Disabilities Act. The Title 24 documents contain detailed lists of prescribed equipment or energy performance calculations and, thus, are usually completed and submitted by the architect and/or electrical and mechanical engineers.

Several hurdles must be overcome when trying to collect Title 24 documents:

- The documents were filed three to five years ago for buildings constructed in 1994, which meant that many of the pertinent files were archived or otherwise not readily accessible
- The documents are lengthy, which meant that customers incurred non-trivial copying and mailing charges
- Several phone calls were required to identify and track down the person who was responsible for completing the documentation
- The document collection effort must coincide with the on-site and decision-maker survey efforts, which meant that customers became overburdened and complained about the level of effort required to complete the research project
- Many of the participant project files contained only partial Title 24 documentation, which means that all customers in the sample, not just the non-participants, must be contacted for Title 24 documentation
- Obtaining the documents from building departments required written permission from the building owner and architect/engineer to release the documents. Also, the request from the local building departments cannot be made over the phone or in writing. Instead, a trip to each local building department office was required to make the request in person

Given these challenges, the following plan was implemented for collecting the Title 24 documents:

- Partial documentation was extracted from the program project files
- Requests for the documentation were made during the on-site recruiting and scheduling phone calls and the decision-maker survey call
- A Title 24 ‘detective’ followed up on the leads generated in the recruiting, scheduling, and survey phone calls

The collection efforts yielded the following results:

Category	PG&E	SCE
Received complete or partial documentation	66	45
Documentation was promised but never received	17	23
Refused to send or could not find documentation	78	82
Exempt from Title 24	30	12
TOTAL	191	162

Table 10-10: Title 24 Documentation Collection

This effort included contacting a few customers who ended up not having an on-site survey completed.

Based on our collection experience, engineers and architects are the best contacts for obtaining the documents. The documents are often dead-filed, however, so retrieval costs are non-trivial and thus many contacts are not willing to retrieve the documentation.

10.5 DECISION MAKER SURVEY

The purpose of the decision-maker survey was to collect data to support the net-to-gross analysis. The questionnaire contained a very detailed question battery to determine reasons for equipment choices, reasons for efficiency choices, and information on free-ridership and partial participation. The survey coincided with the on-site survey and Title 24 calling effort, commencing on July 28th and continuing through October 10th.

For the decision-maker survey, 833 contacts were supplied to CATI. These 833 contacts included multiple contacts per site (project). Of these 833 contacts, 625 (75%) were contacted and 346 (42%) answered the survey. 259 buildings were represented by the 346 respondents, and there were 87 multiple responses across these 259 buildings. The 11 refrigerated warehouses were not included in the decision-maker effort. The breakdown of decision-maker responses by utility and participation status, building type, and building size are shown in Table 10-11 through Table 10-13. The sample provided an adequate number of observations across participation status and building characteristics for the Net-to-Gross regression analysis.

Company and Participation Status	**Buildings With Fully Answered Decision Maker Survey**	
	Number	Percent
PG&E Participants	60 of 90	67
PG&E Non-Participants	58 of 106	55
SCE Participants	47 of 71	66
SCE Non-Participants	94 of 127	74
TOTAL	259 of 394	66

Table 10-11: Decision-Maker Sample: Utility and Participation Status

Building Type	**Buildings With Fully Answered Decision Maker Survey**			
	Participant Buildings		**Non-Participant Buildings**	
	Number	Percent	Number	Percent
Government	6 of 8	75	12 of 16	75
Grocery	0 of 1	0	4 of 7	57
Hospital	4 of 9	44	7 of 9	78
Industrial	4 of 7	57	9 of 11	82
Miscellaneous	15 of 20	75	12 of 23	52
Office	24 of 37	65	25 of 48	52
Restaurant	3 of 4	75	2 of 8	25
Retail	14 of 22	64	25 of 31	81
School	31 of 44	71	50 of 64	78
Warehouse, Non Ref	6 of 7	86	6 of 18	33
TOTAL	107 of 159	67	152 of 235	65

Table 10-12: Building Type

Square Feet	**Buildings With Fully Answered Decision Maker Survey**			
	Participant Buildings		**Non-Participant Buildings**	
	Number	Percent	Number	Percent
0 to 25,000	59 of 86	69	89 of 147	61
25,001 to 50,000	17 of 28	61	34 of 44	77
50,001 to 75,000	5 of 8	63	9 of 12	75
75,001 to 100,000	7 of 11	64	11 of 12	92
100,001 or more	19 of 26	73	9 of 20	45
TOTAL	107 of 159	67	152 of 235	65

Table 10-13: Square Feet

The sample contained sufficient variation to perform the econometric analysis of spillover among non-participants. Almost one half of the non-participant sites with at least one fully answered survey had decision makers who were aware of the program, had interaction with utility staff, and considered participating in the rebate program. These customers therefore classify themselves as partial participants according to their survey responses. (The impact of partial participation is determined via modeling in the Net-to-Gross analysis reported elsewhere in this report.) The number of participants, partial participants, and non-participants, in the sample based on survey responses, are shown in Figure 10-5.

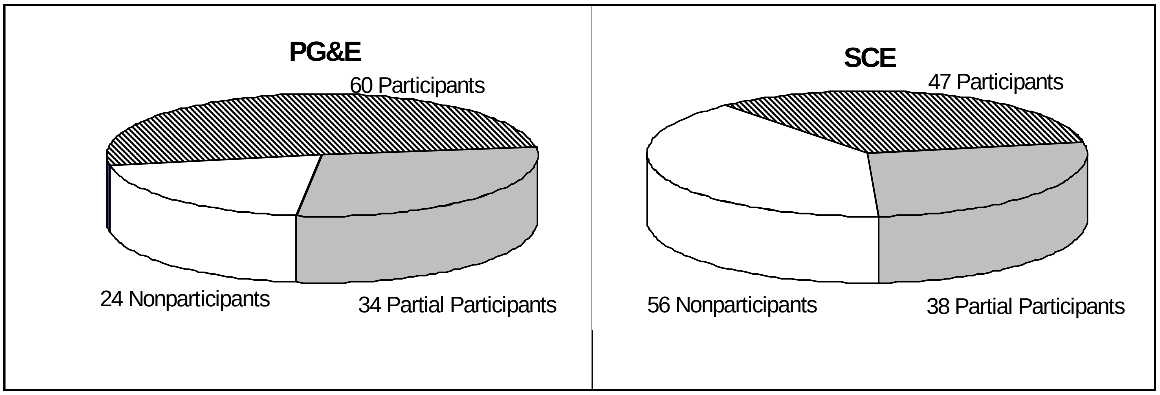

Figure 10-5: Number of Participants, Partial Participants, and Non-Participants

Two questions were asked to determine the extent of free-ridership. Figure 10-6 shows that around 70 percent of the participants classify themselves as free-riders because they said they would have specified the same efficiency even without the program. The same question was asked in a slightly different way, namely, “Did the program have any influence on your decision to specify and install the equipment you did?” Figure 10-7 shows that less than 30% of the participants are free-riders based on answers to this question. Because of the inconsistent answers to these two questions, the true extent of free-ridership is difficult to measure from the survey data.

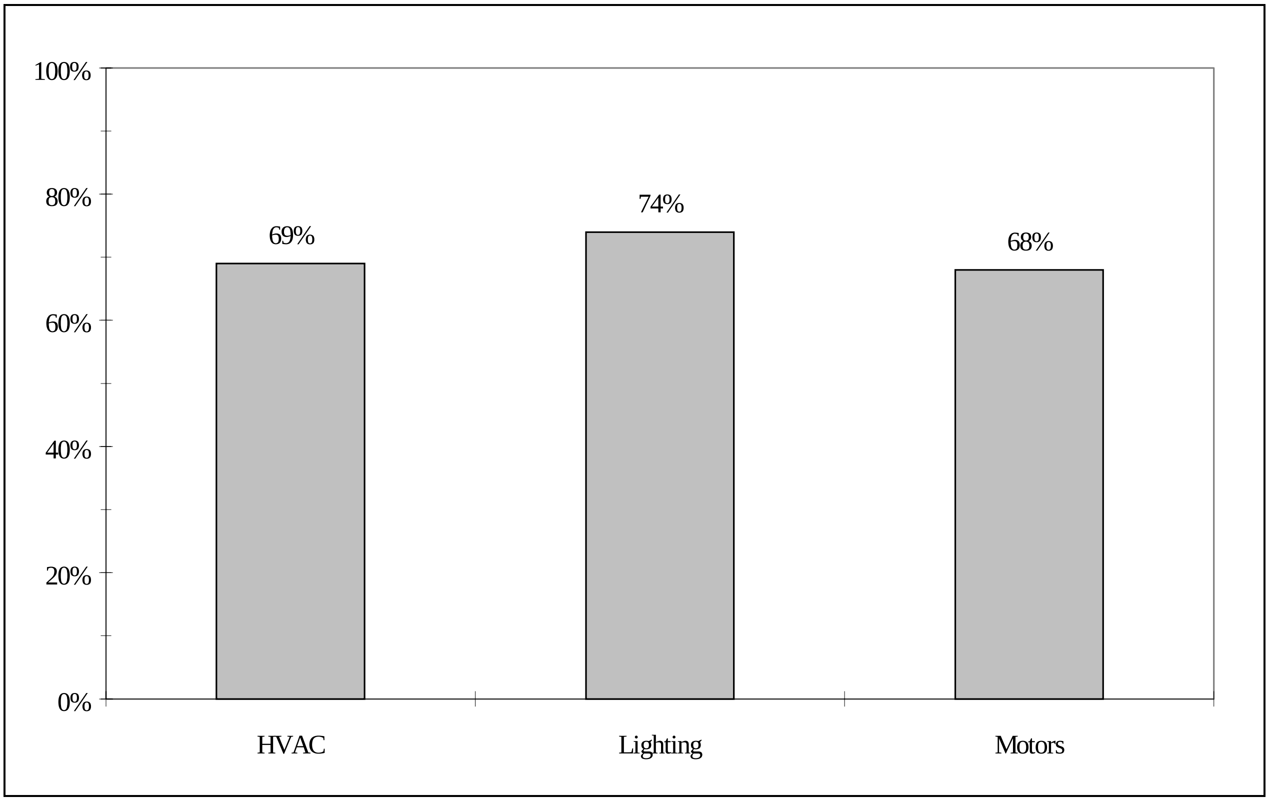

Figure 10-6: Percentage of Participants Who Would Have Specified the Same Efficiency Without the Program

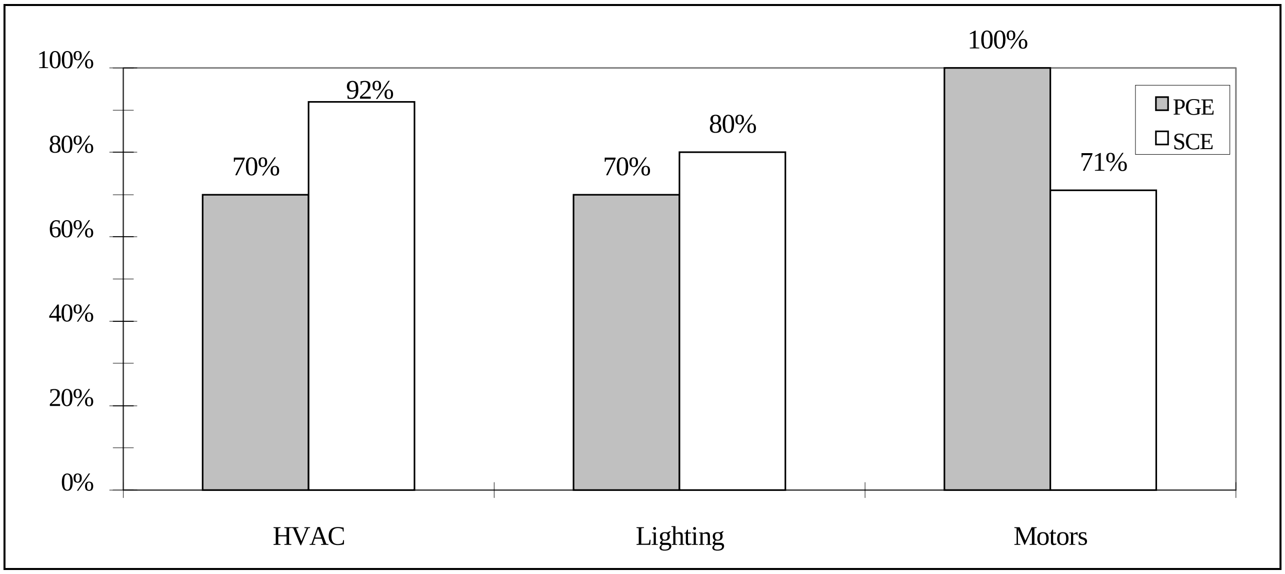

Figure 10-7: Percentage of Participants Who Say that the Program Influenced Their Decision to Specify and Install the Equipment They Did

The question "How did you first hear about the program?" was also asked. Figure 10-8 and Figure 10-9 show the ways in which most customers heard about the program. It's interesting to note that many non-participants say they heard about the program through a utility representative. This means that these non-participants either chose not to participate or were not eligible for the program.

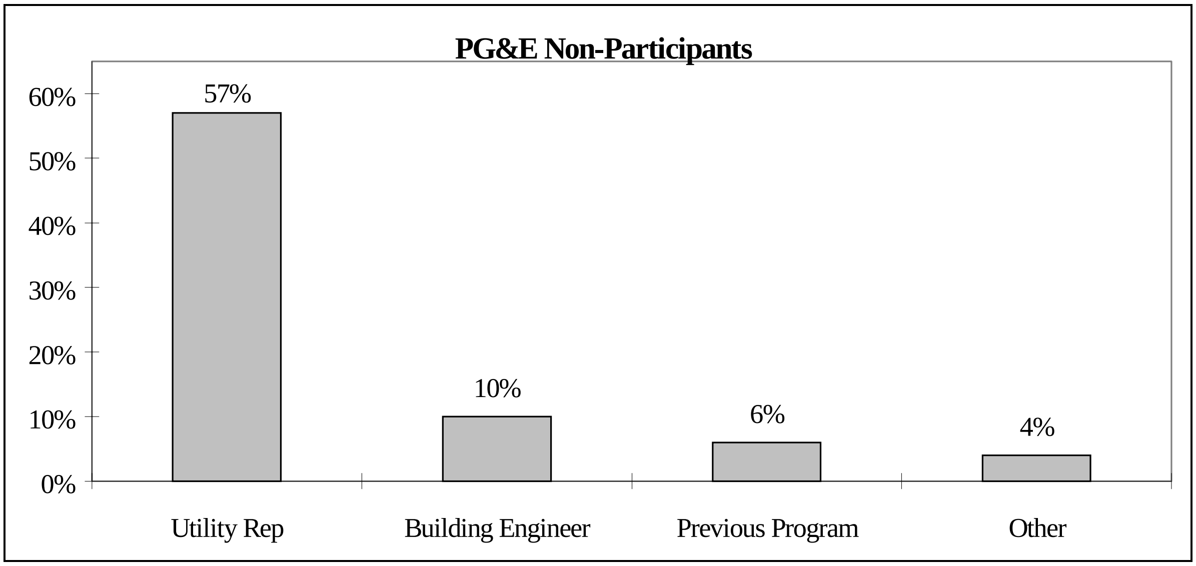

Figure 10-8: Ways Which PG&E Customers Heard About the Program

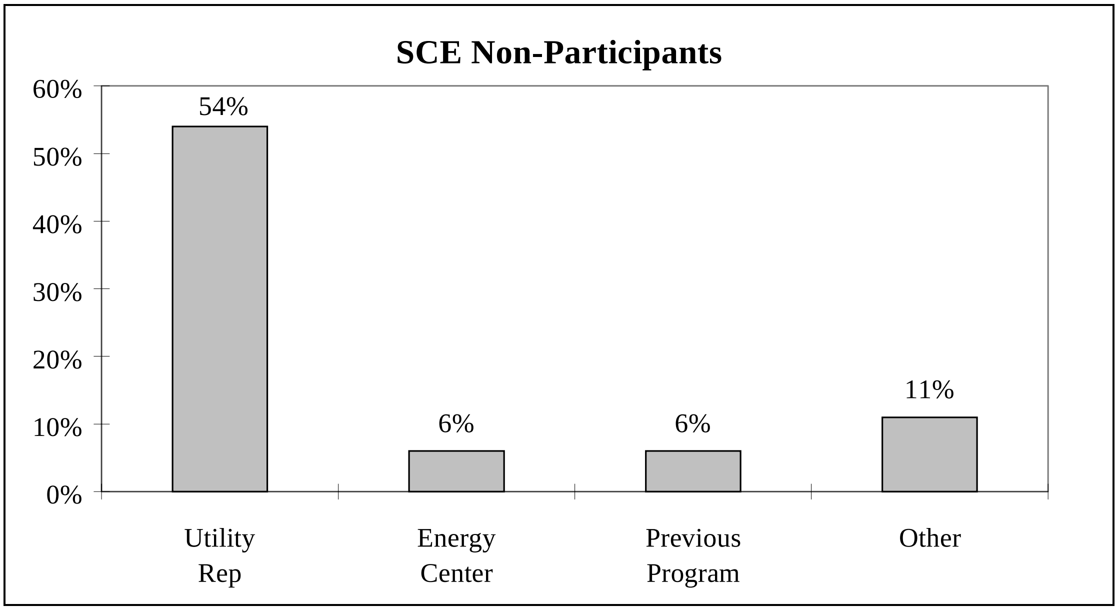

Figure 10-9: Ways Which SCE Customers Heard About the Program

Several lessons were learned during implementation of the survey:

- The length and detail of the questionnaire reduced the response rate due to customer fatigue. The combination of a long, detailed questionnaire which required twenty minutes to complete, and additional customer time commitments for scheduling the on-site survey and supplying Title 24 documents led to some customer refusals for completion of the decision-maker survey.

- Decision-makers were difficult to reach. Many decision-makers were unavailable and never completed the entire survey, even though up to eleven attempts were made to reach each decision-maker.
- For a detailed question battery, technically trained interviewers facilitate smooth completion of the survey.
- The survey flow explicitly accounted for contacts who were decision-makers for multiple buildings. However, the programmed survey flow required completion of the full survey for each building. Ideally, a set of key questions should be asked for each building in future studies to avoid customer fatigue.

11. DOE-2.1 ENGINEERING MODELS

11.1 MACHINE-BUILT MODELING

This section covers the basic approach used to generate the machine-built DOE-2 models. DOE-2.1e, Version 114 was used throughout this study. The machine-built models were created by a computer program that took building description information from the on-site surveys and Title 24 documents and created DOE-2 input files according to a set of rules. Additional data sources, such as manufacturers' catalog data and other engineering references were also used to fully specify the DOE-2 models. The overall process used to develop the machine-built models is described in this section. For a complete discussion of specific modeling assumptions and default parameters, please consult Appendix D.

11.1.1 On-Site Survey

The primary data source for the machine-built models was the on-site survey. The survey form was designed so that the surveyors in the field made key modeling decisions on model zoning and equipment/space association. The form was designed to follow the logical progression of an on-site survey process. The form starts out with a series of interview questions. Conducting the interview first helps orient the surveyor to the building and allows time for the surveyor to gain the trust of 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. An example of the on-site survey form is shown in Appendix A. The contents of the form are summarized as follows:

11.1.1.1 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 1995. The questions covered occupancy, as a percent of total surveyed floor space, and HVAC operation during the tenant finish and occupancy of the space. Responses to these questions were used in 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. The assignment was arbitrary, to cover buildings that did not operate on a normal Monday through Friday workweek. 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 that 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 that 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.

Local HVAC control. 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 were entered.

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 central HVAC systems. A series of questions were used to define the operation of the central HVAC system. 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. Questions regarding hot water requirements for food service and hotel/nursing home operations were covered in this section. The existence of water conservation devices was also covered.

Power generation. The operation of any on-site power generation equipment was described in this section. The responses to these questions were used to assist in the model calibration process.

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, minimum condensing temperature, and predominant defrost mechanism was identified.

Thermal energy storage. A few basic questions about the operation of the building thermal energy storage system were covered in this section. The full specification of the thermal energy storage model was done on a case-by-case basis.

11.1.1.2 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 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. The Title 24 assembly name from the ENV form was associated with each enclosing surface. 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. Observations on the number of glass panes for reach in cases, the use of anti-sweat heaters, and the display lighting type were recorded. Remote compressor systems were inventoried by make, model number, compressor system type, and total compressor horsepower. Each compressor 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 hp 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 hp were recorded. Each equipment entry 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, collector tilt, and storage capacity. Pools and spas were inventoried by surface area and location (indoors or outdoors). 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. This section served as the primary link between the on-site survey and billing data for non-participants. 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.

11.1.1.3 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.

11.1.2 Title 24 Data

Hardcopy documentation of the Title 24 compliance was collected during the course of the on-site and decision-maker surveys. Data from the compliance forms was entered into a Title 24 database.

11.1.3 DOE-2 Model Development

An automated process was used to develop basic DOE-2 models from data contained in the on-site surveys, Title 24 forms, and other engineering data. The basic model development process is outlined as follows:

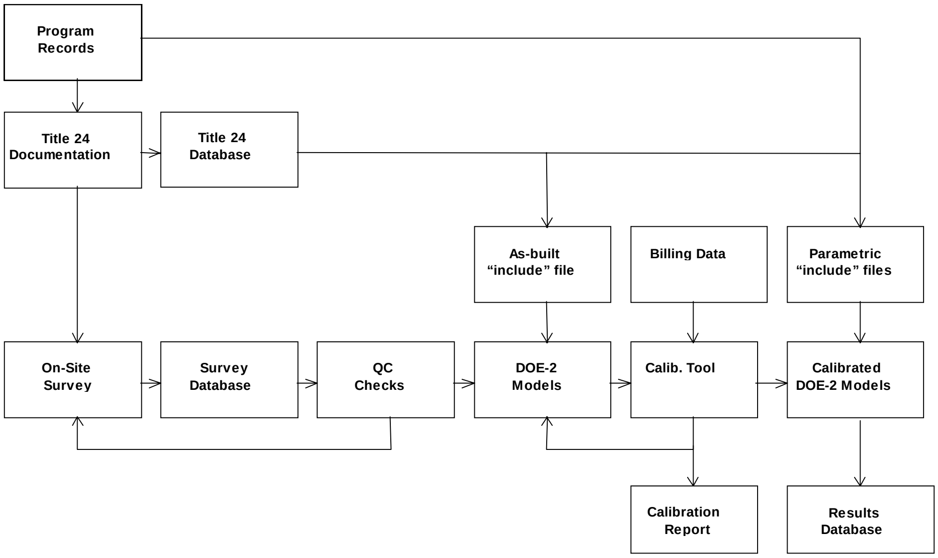

Figure 11-1: Machine-Built Model Process

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.

11.1.3.1 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. Hourly schedules were created by the software 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 Title 24 documents were used to develop the DOE-2 inputs. If the Title 24 documents were not available, default values for the glass conductance was assigned according to the glass type specified in the on-site survey. If the shading coefficient was specified in the on-site survey, it was used. Otherwise, default values for shading coefficient were used. If the glass types 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 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. Depending on the control type, the impact of these controls on lighting consumption was simulated as either a reduction in connected load, or as a modification to the lighting schedule. Daylighting controls were simulated using the "functions" utility in the loads 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. The daylight factor was entered into the functions 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.

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 surveyors entered the input rating of the equipment. 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.

11.1.3.2 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 were 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 were modified on a monthly basis in the same manner as the fan operating schedule.

Exterior lighting schedule. The exterior lighting schedule was 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 that follows the annual variation in day length 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 1994 ARI rating catalog. Additional data were obtained directly from manufacturers' catalogs issued during 1993 and 1994. 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 set forth 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, as shown below:

$$\mathrm{kW} = \frac{\mathrm{hp} \times 0.746}{\eta_{\mathrm{motor}}} \times \mathrm{RLF}$$

where:

kW = input power

hp = nameplate motor hp

η_{motor} = motor efficiency

RLF = rated load factor

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. The rated load factor was used to adjust the nameplate input rating to the actual running load. Rated load factors developed from the short-term monitoring data were used, as described in section 4. 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 prescribed in the 1995 ACM.

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 requirements 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 survey 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 based on the make and model number of the compressors surveyed, and the suction temperatures corresponding to each of the three systems defined above. 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 were 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.

11.1.3.3 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 full-load efficiency. For centrifugal chillers over 250 tons, custom performance curves were developed from manufacturers' test data specific to the chiller installed in the building.

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.

Thermal energy storage. Thermal energy storage (TES) systems simulations were specified based on the survey responses and additional program data. TES systems were generally not covered under the programs. Only one site in the study received an incentive for a TES installation.

11.1.4 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 were received in a variety of formats. The first step in the process was to select the relevant fields from the data received, and reformat the data into a consistent format.
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 1995 weather data, using the 1995 occupancy as reported by the surveyors. The annual hourly (8760) electricity consumption for 1995 was simulated, and the modeled consumption and demand was aggregated to correspond to the meter read dates from the billing data.
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.

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 were provided to the modeling calibration team, as shown in Table 11-1. These calibration parameters fall into two general categories: 1) influential yet unobservable parameters, and 2) parameters derived from secondary data sources, which include manufacturers' data and short-term monitoring. The model calibration team was trained to not make unreasonable adjustments to the calibration parameters. The model calibrators 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.
8. Ship and archive input and calibration files. Once the first 100 models were successfully calibrated, they were shipped to sent to RLW Analytics for review. Subsequent models entered the batch parametric run process.

Monthly schedule adjustment	Primary hot water loop pump minimum speed
Lighting diversity	Primary chilled water loop pump minimum speed
Plug load diversity	Tower design approach temperature
Plug load internal gains	Condenser water setpoint temperature
Heating thermostat setpoint	Tower fan energy
Cooling thermostat setpoint	Motor efficiency for tower fans
Solar gain through windows	Minimum speed for VSD controlled towers
Integrated economizer	Tower pump head
Minimum outside air ratio	DHW water use
Upper limit for air-side economizer operation	TES schedule
Heating supply air temp control	Refrigerated case heat gains from conditioned space
Cooling supply air temp reset schedule	Refrigerated case internal gains from lights, fans, etc.
Evaporative system direct effectiveness	Refrigerated case heat gains from unconditioned space
Evaporative system indirect effectiveness	Refrigeration compressor efficiency
Heat pump defrost control	Refrigeration tower minimum condensing temp

Table 11-1: Model Calibration Parameters

In over half of the cases, it was not possible to calibrate the models. The availability of complete billing data that was well matched to the modeled space was a major limitation. 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 shares. Even when complete 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 un-calibrated or partially calibrated. The results of the calibration activity are summarized in Figure 11-2. Note that the billing data were not useable for over 50 percent of the sites. Of the sites with useable billing data, over 70 percent of the models were successfully calibrated.

A special study was carried out to determine the effect of the calibration on the savings of the site. A regression analysis was used to compare the gross annual kWh savings after calibration to the annual kWh of the savings before calibration. The sample for this analysis included both participants and nonparticipants. For the 103 sites included in this analysis, the regression indicated a very strong correlation between the savings after calibration and the savings before calibration, with an R-squared of 0.93. Based on the slope of the zero-intercept regression, the savings after calibration were, on average, about 0.93 times the savings before calibration. These results indicate that the effect of calibration was small relative to the statistical precision of the final results.

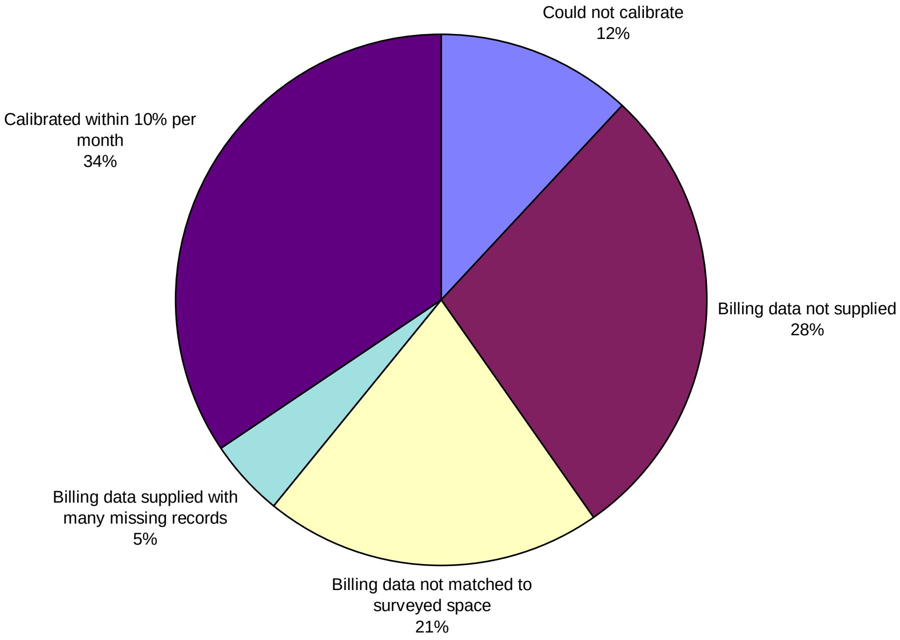

Figure 11-2: Model Calibration Activity Results

11.2 PARAMETRIC RUNS

A set of six parametric runs was defined for the study, and the models were modified and re-run as required. A description of each parametric run follows:

11.2.1 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 California Energy Commission.

11.2.2 Baseline Parametric Run

Key building performance parameters were reset to a baseline condition to calculate gross energy savings for participants and non-participants. The California State Energy Code (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 applies 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, such as grocery store refrigeration systems. In situations where Title 24 does not address building types or equipment covered under the program, baseline parameters equivalent to those used for program design were used.

An attempt was made to collect Title 24 compliance documents for all buildings included in the evaluation. However, it was not be possible to collect Title 24 compliance documents for many of the buildings in the study. Efficiency parameters were derived from the Title 24 requirements to establish the baseline building performance.

11.2.2.1 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, along with fixed overhang dimensions were used to establish baseline glazing shading coefficients. 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.

11.2.2.2 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. For each parametric run, a new system size was calculated from a parametric sizing run and the as-built sizing ratio.

11.2.2.3 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.

11.2.2.4 Other Building Attributes

Baseline specifications were developed for the gross energy savings calculations for measures not covered under Title 24, principally grocery store refrigeration measures. Baseline assumptions used during program design were obtained from the PG&E advice filings for the 1994 program year. Baseline assumptions were developed to estimate gross savings resulting from:

- Refrigerated case display lighting, evaporator fan motor efficiency, reach-in door R-value, and anti-sweat heater control improvements.
- Compressor part-load efficiency improvements resulting from the use of parallel-unequal multiplex systems.
- Oversized condenser systems and floating head-pressure controls.

11.2.3 Additional Parametric Runs

Once the as-built and baseline building models were defined, an additional set of parametric runs were done. The baseline model was returned to the as-built design in a series of steps outlined as follows:

1. Envelope. All baseline envelope parameters were returned to their as-built condition.
2. Envelope plus lighting. All baseline envelope and lighting parameters were returned to their as-built condition.
3. Envelope plus lighting plus mechanical. All baseline envelope, lighting and HVAC parameters were returned to their as-built condition.
4. Energy Commission run. The final set of parametric runs for the NRNC evaluation was an "Energy Commission" run, where the fixed assumptions used in the Comply-24 software (which was used to develop program estimates of measure savings) were substituted for the as-designed and operated parameters collected during the on-site survey. Both as-built and baseline runs were made using these assumptions. The purpose of these parametrics was to assess the differences between savings estimates made prior to construction, which use a set of standard assumptions, to the savings estimated post-occupancy, which use actual operating assumptions and parameters.

11.3 HANDBUILT MODELING

11.3.1 Purpose of the Handbuilt Modeling

The purpose of building 103 handbuilt models was to validate and fine tune the machine-built models. The modeling team involved in the handbuilt work was able to include information not used in the machine-built models, namely auditor notes, detailed inspection of program files and in some cases, additional site contacts, to improve upon the machine-built model. Information from the handbuilt models then became part of a feedback loop that improved the machine-built models.

11.3.2 Distribution of Handbuilt Models

The sample of handbuilt models was representative of the machine-built sample with respect to both counts of participant/non-participant sites and building type. Figure 11-3 shows the distribution of handbuilt models.

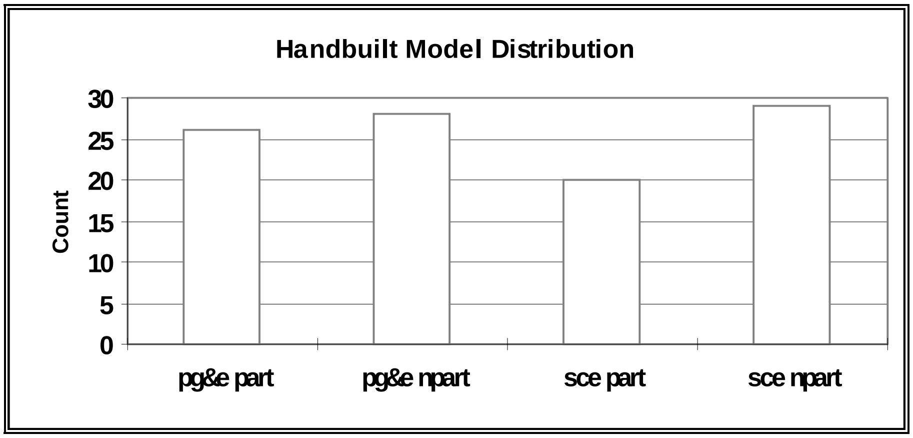

Figure 11-3: Distribution of Handbuilt Models by Utility and Participation

The rationale for the distribution of handbuilt models following the program's population by building type was slightly different than had been the case for the machine-built models. The primary concern regarding the choice of handbuilt sites was that all technology types and program measures are represented in the handbuilt sample. Building type was used as a proxy for equipment and technology type, for example grocery stores were included in the handbuilt sample to ensure that refrigerated cases were checked, large office buildings ensured that central plant attributes were included in handbuilt models and small offices and school sites tended to contain packaged HVAC equipment. All technology types and measures were included in the distribution of handbuilt models. Table 11-2 provides details on the distribution of the handbuilt models by utility, building type and participant/ non-participant designation.

Building Type	Part./ Non Part.	PGE HB	SCE HB	PGE MB	SCE MB
Government	npart	1	2	5	8
Government	part	1	2	4	7
Grocery	npart	2	1	5	2
Grocery	part	2	1	2	1
Hospital	npart	3	1	5	4
Hospital	part	2	1	7	3
Industrial	npart	1	5	3	8
Industrial	part	0	2	3	4
Miscellaneous	npart	0	2	3	15
Miscellaneous	part	3	0	9	11
Office	npart	10	4	24	20
Office	part	7	5	34	12
Restaurant	npart	1	1	3	2
Restaurant	part	1	1	3	3
Retail	npart	2	4	9	21
Retail	part	2	5	13	11
School	npart	5	5	27	28
School	part	6	3	20	29
Warehouse, Non Ref	npart	3	3	12	5
Warehouse, Non Ref	part	2	1	6	2
	Total	**54**	**49**	**197**	**196**

Table 11-2: Distribution of Handbuilt Models by Building Type

11.3.3 What are Handbuilt Models?

How did the handbuilt models differ from the machine-built models? The modifications made to the machine-built models to create the handbuilt models fell into two categories:

1. Modifications that corrected errors in the machine-built models. These errors were the result of data entry mistakes, auditor mis-identification of building parameters, mistakes on the audit form, etc. An example of a modification of this type was an entry for the cooling air supply temperature of 68 degrees F. This value was taken from the audit form correctly, but the auditor either misunderstood the question or made a recording error. In this case the value was changed in the handbuilt model to 55 degrees F to reflect standard practice.
2. Modifications made to the models based on improved information. These modifications were part of the calibration process. This process consisted of modifying pre-defined calibration parameters *in situations where the modified value was more accurate than the value used in the machine-built model.* This type of modification was possible because of the additional data resources available for use in creating the handbuilt models.

Figure 11-4 shows the distribution of modifications made to the machine-built models. Lighting and "plug load" power densities and scheduling were the most common modifications to the machine-built models during the handbuilt calibration process. The nine most commonly made model modifications shown in Figure 11-4 represent 65% of the modifications made in producing the handbuilt models. Appendix F contains a listing of the modifications and site identifiers for all of the handbuilt models.

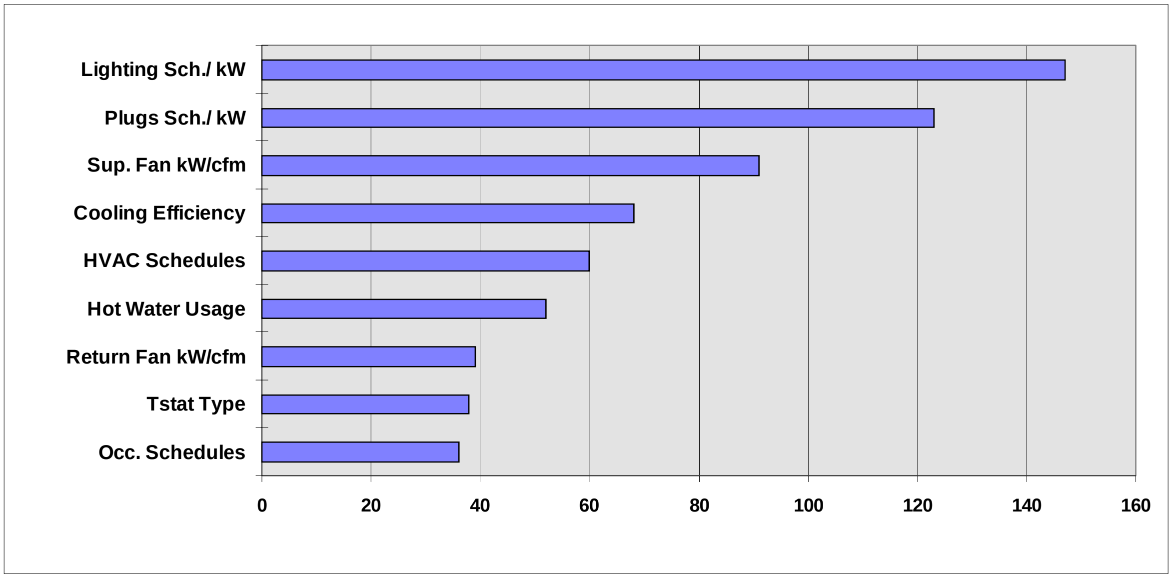

Figure 11-4: Distribution of Modifications to Handbuilt Models

11.3.4 Handbuilt Model Calibration Process

The as-built machine generated DOE-2 model was the starting point for each of the handbuilt models. Additional site information not used in the machine-built model was collected for use in creating the handbuilt models. That information included some or all of the following: utility program files, Title24 documents, manufacturer's efficiency test data and the surveyor's on-site notes. Surveyors often included comments in the margins of the on-site form which could not be incorporated into the regimented data entry process used in the production of the machine-built models, but which was used for the handbuilt modeling. In a few cases the surveyor or maintenance personnel at a particular site were contacted to verify information.

Steps in the Process

1. The on-site audit form values were checked for reasonableness.
2. After reviewing all available information, the DOE-2 input files were scrutinized to ensure the machine-built model accurately reflected the site information found in the audit form and the utility project file. Inconsistencies were investigated and resolved.
3. The machine-built model's hourly kW output was run into the Visualize-IT™ Calibration Tool data visualization software. This step allowed the modelers to quickly assess the modeled scheduling and demand intensities for the major end-uses. If available, billing data was used to calibrate the models. In many cases the Figure 6-1 illustrates what an initial run might look like.

Table 11-3 lists the initial range checks that were made for each handbuilt model. Values outside the listed ranges were accepted if verified in the audit form, but only after the modeler was convinced that the audited value was correct.

Model Value	Acceptable/Typical Value	Audit Value	Accepted?
Square Footage	+/- 10% of Actual		
EUI	See ASHRAE p32.6, Table 4 +/- 25%?		
Area/ton	100 - 1000 sf/ton (300 - 600 typ.)		
Zoning	Check		
Lighting W/sf	0.8 - 2.8 W/sf		
Equipment W/sf	0.1 - 1.5 W/sf		
Supply Air Temp.	50 - 60 F (55 deg. F typ.)		

Table 11-3: Modeling Range Checks for Handbuilt Models

The Visualize-IT™ data visualization software was used to view the 8760 hourly output from the model and also to compare modeled and billed demand and consumption data. Billing data was not useable in many cases because of large differences between metered and modeled square footage. For example, a single meter might be used for a multi-tenant building in which the modeled space was a small percentage of the space on the billing meter.

An EnergyPrint™ graphical image was used to display an entire year's demand profile. The EnergyPrint uese the vertical scale for hour of the day, the horizontal scale for day of the year and color/tint for demand. For example, a particular site was marked for further investigation during the calibration process because the EnergyPrint showed an unusually steep demand peak between approximately three and five p.m., and almost no use during the remainder of the day. In addition the site's usage was reduced considerably during the summer. A short inspection of both the project file and the audit form confirmed that the model reflected information gathered during the audit and the audit information was plausible. This site was a synagogue at which Hebrew school is taught during the afternoon. According to the audit form, occupancy goes down slightly during summer months and up slightly during Chanukah. Both of these scheduling attributes were shown in the EnergyPrint. The handbuilt modeler made small modifications to the cooling system efficiency and capacity based on manufacturer's data, however the machine-built model was fundamentally accurate. In this case, the occupancy pattern for the site was the driving force behind the demand, consumption and savings numbers.

The monthly kWh consumption (right plot) and peak demand (left plot)are shown in Figure 11-5. The dotted lines on the kWh plot represent ±10% of the billed energy use. The kWh plot shows that the simulation results are within ±10% of the billed energy use for ten of the twelve months.

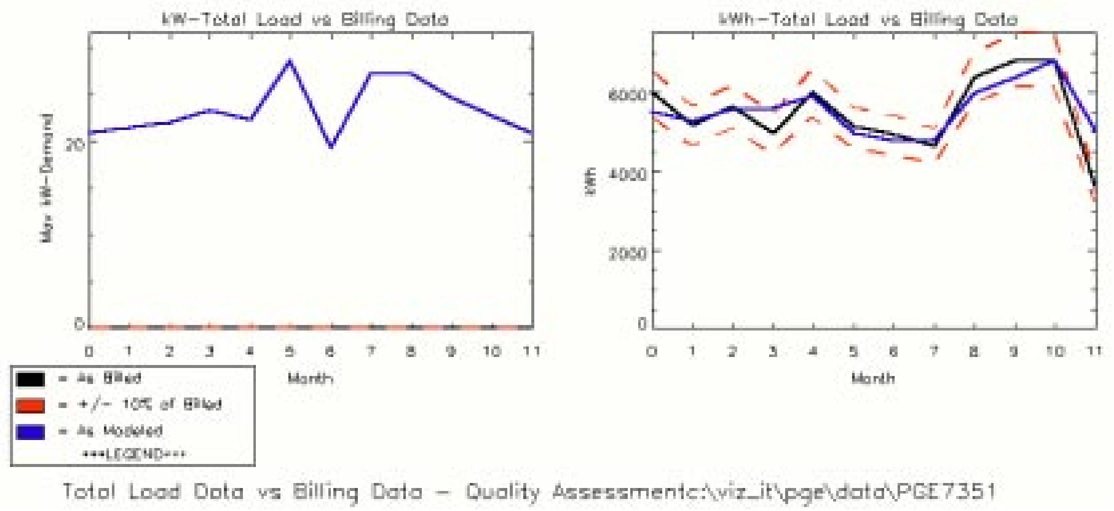

Figure 11-5: Monthly Billing and Modeled Comparison for a Handbuilt Site

11.3.5 Handbuilt Modeling - Findings

Two types of findings came from the handbuilt modeling process. The first set of findings were relatively informal and consisted of daily feedback to the machine-built model staff of any programming errors, odd results or potential problems with audit data that were seen during the handbuilt modeling. A few of these items were systematic, but in general the feedback consisted of isolated audit discrepancies, mistaken engineering assumptions or data entry mistakes. Two examples of systematic errors that were found using this feedback mechanism concerned the calculation of domestic hot water consumption and the placement of return fans in small packaged cooling equipment. Early in the handbuilt modeling process, it was discovered that domestic hot water usage was too high in the models. A formula in the models had been improperly programmed and was corrected. It was also discovered that some auditors were improperly listing return fans on small packaged cooling equipment. After discussions among staff modeling engineers and research into cooling equipment manufacturer’s design specifications, it was confirmed that small packaged equipment were not available with return fans as an option. As a result of this finding, return fans were removed from all packaged equipment under 20 tons capacity. Appendix F summarizes the details of the feedback loop results.

The second result that came out of analyzing the frequency and magnitude of changes made to the models during the handbuilt modeling process. The goal was to determine if any model changes made during the handbuilt process that were wide spread enough to justify making global changes in all the machine-built models. For example, if a large number of the handbuilt models had their lighting power density levels reduced by 5%, it would be necessary to investigate whether or not there was a consistent bias in the machine-built models with respect to lighting power levels. If a consistent bias was found, the machine-built lighting level may have to be reduced across the board. To analyze whether consistent bias was present, the frequency and magnitude of modifications made to the handbuilt model sites was analyzed.

The primary test for determining whether a handbuilt modification could be considered for global feedback to the machine-built modeling process was that the modification had to have a high frequency as defined by Figure 11-4, and the modification had to be large enough in percentage terms to have a significant effect on the results. In addition, engineering judgment was employed to determine if a modification was reasonable.

Figure 11-6 shows an example of the analysis done on the handbuilt modeling process. In this case, a plot of handbuilt cooling efficiency vs. machine-built cooling efficiency shows all the cases in which the efficiency of one of the handbuilt model's cooling systems was changed. The plot shows that a significant number of changes were made to cooling system efficiency during the handbuilt modeling process, however the line passing through this scatter has a slope of 0.977. In other words, there were many changes made to cooling efficiency during the handbuilt modeling process, but the end result was that the changes were self canceling and/or very small. As a result, no global changes to the cooling efficiency portion of the machine-built modeling process were made.

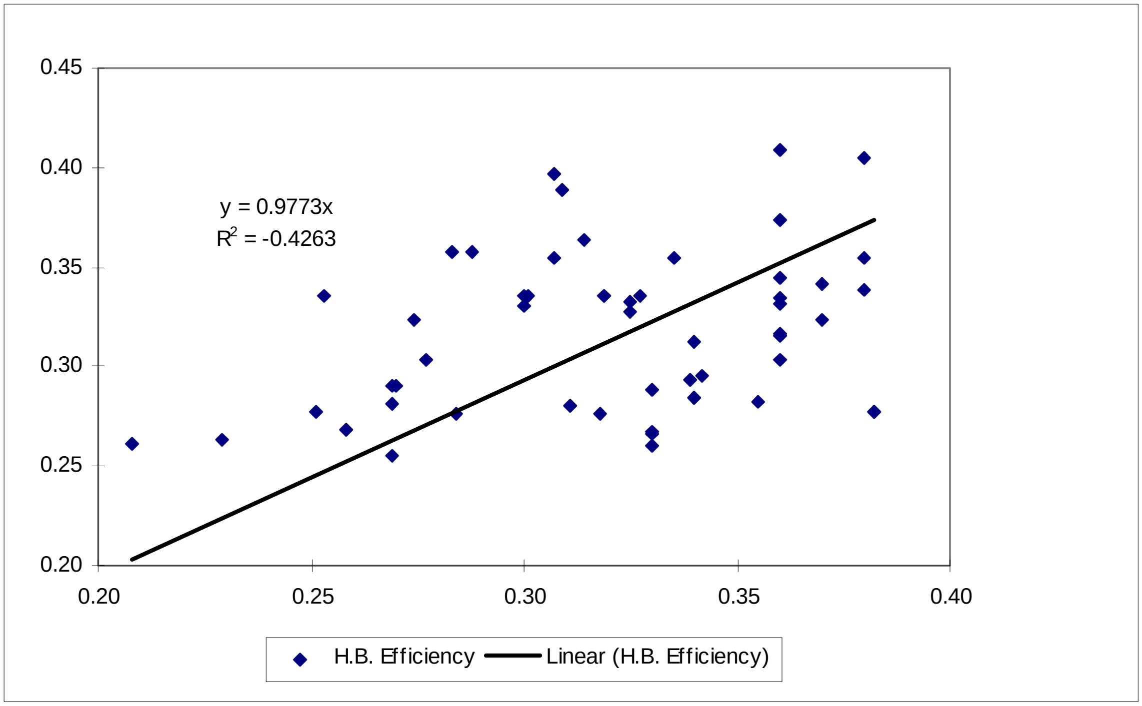

Figure 11-6: Scatter Plot of Cooling Efficiency - Handbuilt vs. Machine-built

Analyses similar to this cooling efficiency example were carried out for several modeling parameters including supply fan power assumptions, lighting schedules, exhaust fan power and flow assumptions, daily and monthly scheduling of miscellaneous electrical and lighting loads, and cooling setpoints. As a result of these analyses, three global changes were made to the machine-built models. The three changes were in addition to the informal feedback discussed above:

1. The lighting "MONTHLY ADJUSTMENT" parameter used in the model to change lighting levels by month was given a floor value of 25%. This reflects the finding that in spite of the audit reported "off" values for the adjustment during supposedly unoccupied periods, many sites had electrical intensities that remained relatively high. Schools were particularly prone to this, namely they reported no occupancy during the summer months, but the electrical intensity of the site often remained at 30 - 50% of the value found during the school year.

2. Return fans were removed from all package units equal to or smaller than 20 tons capacity. It was thought that the auditors probably made this mistake since manufacturers do not typically

offer a return fan as an option on smaller package units, but a significant number of audits showed return fans on units as small as two tons.

3. Set the "lighting on" diversity cap at 90% and the "lighting off" diversity floor at 10%. This is in agreement with the analysis of the handbuilt models, the short term monitored data, and the LCAP study from the Pacific Northwest. A significant number of sites had minimum lighting levels set at 0% of installed power and maximum lighting levels set at 100% of installed capacity. In practice, buildings rarely if ever have all their lighting turned on or off.

Global modification of other items was discussed, but it was determined that supply and exhaust fan power, domestic hot water loads and exhaust fan power and flow rates had been addressed by earlier informal feedback to the machine-built modeling team.

11.3.6 The Baseline Models

Baseline Models used in Program Savings Calculations. Savings estimates are the difference between the building as it is operated and an assumed baseline building. Other portions of this report cover the details of the baseline building assumptions, however it is necessary to point out that a final quality check was made to ensure that the baseline models were correctly defined. Although not expressly part of the handbuilt modeling process, this check was undertaken to ensure accurate savings estimates and so is rightly grouped with the portion of the report dedicated to model improvement.

Savings estimates for all sites, handbuilt and machine-built, were calculated. Two statistical tests of reasonableness were made on the estimates:

1. The estimate was expressed as a percentage of baseline consumption. If this number was greater than 50%, the site was flagged.
2. A regression plot of evaluated savings estimate vs. program savings estimate was made. Sites that fell more than two standard deviations outside of the best-fit line were flagged.

Sixteen of the approximately 200 participant sites were flagged for one of the two reasons stated above. All flagged outlier sites were investigated. The outliers were either confirmed as accurate, corrected if possible and necessary, or removed from the analysis.

The inspection and validation of savings outliers was an important step necessary to identify potential problems in the baseline models. This step ensured that the savings estimates utilized a valid baseline model.

Baselines for Additional Parametric Runs. Once the as-built and baseline building models were defined, an additional set of parametric runs were done. The baseline model was returned to the as-built design in a series of steps outlined as follows:

1. Envelope. All baseline envelope parameters were returned to their as-built condition.
2. Envelope plus lighting. All baseline envelope and lighting parameters were returned to their as-built condition.
3. Envelope plus lighting plus mechanical. All baseline envelope, lighting and HVAC parameters were returned to their as-built condition.
4. Energy Commission run. The final set of parametric runs for the NRNC evaluation was an “Energy Commission” run, where the fixed assumptions used in the Comply-24 software (which was used to develop program estimates of measure savings) were substituted for the as-designed and operated parameters collected during the on-site survey. Both as-built and baseline runs were made using these assumptions. The purpose of these parametrics was to assess the differences between savings

estimates made prior to construction, which use a set of standard assumptions, to the savings estimated post-occupancy, which use actual operating assumptions and parameters.

12. NET IMPACT ANALYSIS

12.1 INTRODUCTION

The purpose of the net impact analysis is to predict the energy efficiency design of buildings in the absence of the program. One cannot assume that program participants would have designed buildings strictly according to the minimum Title 24 standards in the absence of the program. Even with no program incentives, buildings may have been designed above the standards due to market incentives and decision-maker preferences. For example, if energy prices are relatively high, energy efficient equipment may still pass payback or return on investment criteria even without rebates and thus be installed in buildings. If this is the case, then the gross impact for participant buildings overstates the impact that the program has on energy usage. This free rider effect requires a negative net adjustment to the gross impact.

Just the opposite is true for non-participant buildings. The gross impact assumes that the program had no impact on the design of non-participant buildings. However, just because a building did not officially participate in the program does not mean that the program did not affect the energy design of the building. The utility's program staff may have interacted with the owner or design staff during the planning stages of the building but, for various reasons, the building did not qualify for a program rebate, or the decision-makers elected not to apply for a rebate. If these program interactions affected the energy design of the building, then the gross impact understates the impact that the program has on energy usage. This partial participant spillover effect requires a positive net adjustment to the gross program impact.

Dividing the sample into three groups helps to clarify the net impact analysis and the definitions for free riders, partial participants, and spillover effects. Figure 12-1 shows the three groups and the adjustments that need to be made to the gross energy savings estimates. The height of the bars represents the savings for each group, which is defined as the difference between the as-built energy design and the Baseline. Figure 12-1 is a hypothetical illustration of the net-to-gross concept. See chapter 4 for the actual net findings of this report.

Participant free riders	Buildings that participated in the program but would most likely have been designed above the Title 24 standards even if the program had not existed. The free rider estimate will require a reduction of the gross program impact estimate.
Partial participant spillover	Non-participant buildings that are designed above the Title 24 standards due, at least in part, to interaction with utility staff and program information. For instance, this group may have had interaction with utility staff during the design stage but for various reasons did not receive a rebate from the program. The partial participant spillover estimate will increase the gross impact estimate.
Non-Participant	Buildings in which the decision-makers were not aware of the program. This group is used to control for naturally occurring efficiency choices due to market incentives.

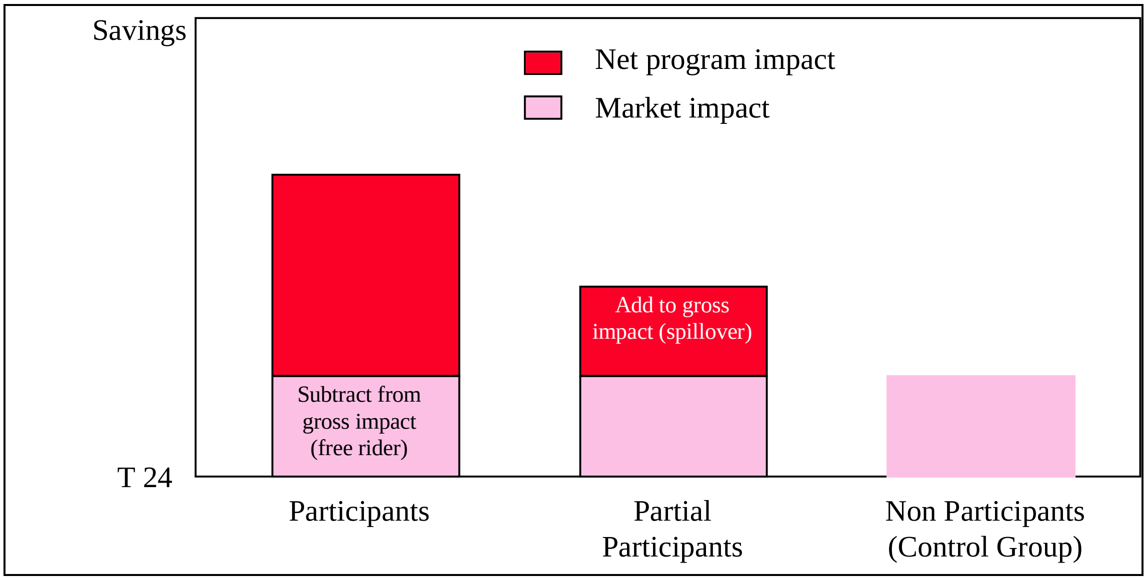

Figure 12-1: Adjustments to Gross Program Impact

12.2 METHODS

Although we have no way of knowing how each building would have been built absent the program, we can predict the energy design of the building using its unique site and decision-maker characteristics within a regression framework. Regression methodology isolates the average effects that program factors and other explanatory characteristics have on the energy efficiency design of buildings, allowing us to predict the design of the building in the absence of the program.

The model of efficiency choice in nonresidential building design is based on economic and decision-maker characteristics. Businesses make investment choices based on economic criteria, such as payback period, return on investment, or net present value. Equipment prices, weather (for some end-uses), building use, ownership type, number of tenants, and other variables determine whether energy efficient equipment meet these economic criteria. Decision-maker characteristics, including preferences for high efficiency design, are also important in determining the efficiency design of newly constructed buildings. *The hypothesis is that any factor that increases the value of the investment will have a positive impact on the energy efficiency design of the building.*

In prior nonresidential new construction impact evaluation studies, the energy design of a building was specified as a function of available economic and decision-maker characteristics.[7] Many of these same explanatory characteristics were also used in a customer decision study of nonresidential new construction equipment purchases.[8] The relationship between efficiency choice and explanatory characteristics for building *i* is written as:

$$efch_i = a + B_P X_P + B_{SS} X_{SS} + B_{PP} X_{PP} + B_S X_S + B_D X_D + B_W X_W$$

where $efch$ = efficiency choice;
$B_P X_P$ = parameter and variable vectors of program participation;

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[7] Pacific Gas and Electric Company, *Nonresidential New Construction Impact Evaluation Study*, October 22, 1993; Southern California Edison Company, *Design for Excellence Nonresidential New Construction Incentive Program Impact Evaluation*, November 12, 1993.

[8] Southern California Edison Company, *Customer Decision Study: Analysis of Nonresidential New Construction Equipment Purchase Decisions*.

$B_{SS}X_{SS}$ = parameter and variable vectors of the double inverse Mill's self-selection factor;
$B_{PP}X_{PP}$ = parameter and variable vectors of partial participant indicators;
B_SX_S = parameter and variable vectors of site characteristics;
B_DX_D = parameter and variable vectors of decision-maker characteristics;
B_WX_W = parameter and variable vectors of weather characteristics.

Efficiency choice is defined as the savings margin, which is the percentage difference between the simulated Baseline energy usage and the simulated As-Built energy usage. Using engineering estimates of efficiency choice at the building level instead of the end-use level provides a comprehensive measure that captures the interactive end-use effects of the building's efficiency design.

The self-selection factors, being unobservable, are estimated using predicted values from a participation decision equation. A double inverse Mill's ratio approach was followed in this study to correct for self-selection bias.[9] The hypothesis is that participants are more predisposed to high efficiency choices and thus are more likely than non-participants to design at levels more efficient than the Title 24 standards. If this *naturally-occurring* self-selection factor is not accounted for in the efficiency choice equation, estimating parameters using non-participant data would tend to understate the efficiency design of the building in the absence of the program and overstate the program's net impact. The second self-selection term to enter the equation is the inverse Mill's ratio for participants only. This *net savings* self-selection term accounts for correlation between the participation variable and the level of net savings for participants.

Unlike statistically adjusted engineering billing analysis equations, the list of explanatory variables in this model does not include any engineering variables. The purpose of this model is to predict energy efficiency choices as a function of exogenous factors that influence the design decision, including program rebates and information. Engineering variables, such as efficiency ratings (e.g., SEER), are endogenous choices rather than exogenous variables. In other words, engineering design variables are the choices that are explained by the model, and are not the exogenous variables that explain the choice. Therefore, engineering variables that may appear on the right hand side in statistically adjusted engineering billing analysis equations appear on the left-hand side for the purpose of explaining energy efficiency choices.[10]

The participant decision equation is written as a function of site and decision-maker characteristics for building i:

$$part_i = a + B_SX_S + B_DX_D$$

Here $part_i$ indicates whether a building participated in the program (received a rebate). A probit formulation was specified and the maximum likelihood technique was used to estimate the coefficients. These techniques provide consistent and efficient estimators for probit models.

One technical issue regarding estimation of the efficiency choice equations is truncation of the dependent variable. In theory, efficiency choice as defined should be truncated at zero since any building that

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[9] Xenergy Inc., *Net Savings Estimation: An Analysis of Regression and Discrete Choice Approaches*, prepared for CADMAC Subcommittee on Base Efficiency, March 1996. The Double Mills procedure assumes that the energy choice of participants is approximately normally distributed. A Kolmogorov-Smirnov test was carried out to test this assumption. See footnote 5.

[10] For example, a prior evaluation of the SCE Design for Excellence program used COP as a measure for efficiency choice. (*Design for Excellence Nonresidential New Construction Incentive Program Impact Evaluation*, November 12, 1993, p. 8-17.)

complies with the Title 24 efficiency standards should have as-built energy consumption equal to or greater than the Title 24 standard. In other words, strict compliance with Title 24 standards would truncate the dependent variable in the model at zero. In practice, however, the efficiency choice distribution across buildings in the sample is distributed normally and not truncated at zero.[11] Of the 259 buildings in the modeling sample, 22 percent had dependent variables that were negative. Estimation techniques to correct for truncation, therefore, are not applicable for this analysis.

12.3 DATA

RLW Analytics used the following data in the net impact estimation:

- Decision-maker survey for program, site, and decision-maker characteristics
- On-site survey for site-specific characteristics of each building
- Program project files for participation and program characteristics
- Database of simulation results for efficiency choice dependent variables
- Climate zone information from the California Energy Commission

Data collection methods and summaries of the data for these sources are described elsewhere in this report(chapter 10). The decision-maker survey provided data for 259 buildings for the net-to-gross analysis. Four outliers were dropped from this sample, which left a total of 255 buildings for estimation of the participation and efficiency choice equations.[12]

Table 12-1 lists the variables used in the analysis. All of the independent variables that come from decision-maker survey data are based on discrete answer choices, so they are re-coded as dummy variables. Building types, which were significant explanatory variables in prior studies, and climate zones are also properly defined as dummy variables. Two continuous variables were included in the analysis, square footage and a weekly occupancy load variable. These were collected during the on-site survey.

Variable (Source)	**Definition**
Dependent Variables	
Participation (binary) (program files)	Indicates if a building received a program rebate. (1=Received rebate).
Efficiency choice (simulation results database)	Savings ratio, where the numerator is the percentage difference between the simulated Title 24 and as-built kW and kWh, and the denominator is the simulated Title 24 kW and kWh.
Explanatory Variables	
Building types (binary) (on-site survey)	Indicate building types of grocery, hospital, industrial, miscellaneous, office, restaurant, retail, school, and warehouse.
Climate zones (binary) (CEC)	A set of binary variables that indicate climate zone. Climate zone 14 was broken into eastern and western sub-zones for the analysis.
Square footage (on-site survey)	Size of building measured in 1,000 square foot units.

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[11] The Kolmogorov-Smirnov normality test value is 0.0343.

[12] Residual plots were used to identify potential outliers or influential observations. The underlying engineering models were carefully reviewed and corrected if specific errors were identified. All changes were fully documented. In the case of these four sites, it was not possible to correct the models so the sites were dropped from the analysis.

Variable **(Source)**	**Definition**
Operating hours (on-site survey)	Number of scheduled operating hours for the building during a typical week.
Construction type (on-site survey)	A set of binary variables that indicate construction types of new construction, addition, and major renovation.
Ownership (DM survey, Q45)	A set of binary variables that indicate ownership types of private business, government, investors, developers, and franchiser.
Building circumstances (DM survey, Q46)	A set of binary variables that indicate the circumstances under which a building was built: owner built for its business, owner built for a tenant, spec built, chain built.
Tenants (DM survey, Q47)	A set if binary variables to indicate either single occupant or multi-occupant building.
Separate elec. meter (DM survey, Q48)	A binary variable that indicates if occupants have separate electric meters.
Owner input (DM survey, Q50)	A binary variable that indicates if the owner had significant input in the design of the building.
Pre-existing plans for chain (DM survey, Q51)	A binary variable that indicates if a chain used pre-existing plans.
First cost vs. operating cost (DM survey, Q52)	A binary variable that indicates if first cost is an overriding consideration.
Investment criteria (DM survey, Q53)	A set of binary variables indicating investment criteria of simple payback, ROI, and net present value.
Significance of energy costs (DM survey, Q54)	A set of binary variables that indicate the level of importance of energy costs for the business(es) that occupy the building.
Importance of energy efficiency in fuel choice (DM survey, Q60)	A binary variable that indicates energy efficiency is very important in the choice of fuel.
Utility (DM and on-site surveys)	A set of binary variables that indicate PG&E and SCE utilities.
Lighting/HVAC rebate (program files)	A set of binary variables for each utility that indicate if a building received a rebate for lighting and HVAC, lighting only, or HVAC only.
Refrigeration rebate (program files)	A binary variable that indicates if a grocery, retail, or restaurant building received only a refrigeration rebate.
Partial Participant (DM survey, Q25, Q27, Q28)	A binary variable for each utility that indicates if a non-participant knew of the program, had involvement with utility staff, and considered participating but chose not to.
Self selection (participation equation)	Double inverse Mill's ratio computed from participation equation results. An inverse Mill's ratio variable is included for all buildings, and an additional inverse Mill's ratio is included for participant buildings only.

Table 12-1: Variable Definitions

12.4 RESULTS

12.4.1 Participation Decision

Maximum likelihood estimation methods were used to estimate the participation decision equations. Model runs were completed on variations of the initial decision equation. The final estimated participation decision equation has a log-likelihood value of -146.72 and correctly predicts the participation decision for 68% of the buildings. This 68% concordance falls within the range of prior studies, which reported concordances as low as 62% and as high as 80%.[13]

The preliminary models included:

- Climate zone variables
- Building type variables
- Building square footage
- Building weekly occupancy load
- Type of ownership for the building
- The circumstances under which the building was built
- The number of tenants in the building
- Whether occupants are separately metered
- The degree of input the owner had in the design process
- The importance of first cost versus operating cost and the investment criteria that were used
- The significance of energy costs for the businesses that will occupy the building
- The importance of energy efficiency in the choice of fuel.

All of the variables were tried in the models. Based on the coefficient values and t-tests for these runs, variables were dropped or combinations of discrete answer choices were combined into one dummy variable. For example, rather than having investor-owned and developer-owned dummy variables enter the model separately, these answer choices were combined into one variable. The final model specification includes only those variables that have an impact on the participation decision.

Table 12-2 shows the coefficient and t-ratio for each variable. From this table, it can be seen that the probability of participation varies by climate zone. Overall, restaurants and miscellaneous buildings, simple payback criteria, and the importance of energy efficiency in fuel choice positively influenced program participation. Further, buildings owned by the developer/investor have a lower probability of participation, presumably because the developer is typically more concerned with lowest first cost than with long-term savings.[14] The probability of participating in the program was found to be higher for buildings for which energy efficiency was very important.[15]

The inverse Mill's ratio for participants and non-participants was calculated from the results of this equation to correct for self-selection bias in the net savings equations.

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[13] Pacific Gas and Electric Company, *Nonresidential New Construction Impact Evaluation Study*, October 22, 1993; Southern California Edison Company, *Design for Excellence Nonresidential New Construction Incentive Program Impact Evaluation*, November 12, 1993.

[14] This variable was not statistically significant at the 10% level but was retained in the model because the absolute value of the t-ratio was greater than one.

[15] The significance of energy costs to the building's occupants did not have a statistically significant effect on participation. There are several possible reasons: (a) The building designers may not have known how the building's occupants would feel about energy costs, (b) The energy efficiency variable may already represent the effect of this variable, or (c) the survey respondents may have had difficulty recalling how important these issues were at the time of program participation. This is a limitation of a retrospective survey.

Variable	**Coefficient (t-ratio)**
Constant	-0.343 (-1.628)
Square Feet (000)	0.005*** (2.531)
Restaurant Building	1.483** (2.153)
Miscellaneous Building	0.761*** (2.513)
Climate Zones 5 and 6	-1.315*** (-4.075)
Climate Zones 8 through 10	-0.977*** (-4.150)
Climate Zones 12 and 13	-0.475** (-2.091)
Climate Zone 14-East	-0.886** (-1.970)
Simple Payback Criteria	0.477*** (2.599)
Owned by Developer/Investor	-0.330 (-1.455)
Energy Efficiency Very Important	0.340* (1.724)
Log Likelihood = -146.7232, n=255 *** = significant, α=0.01; ** = significant, α=0.05; * = significant, α=0.10	

Table 12-2: Participation Decision Model

12.4.2 Efficiency Choice Equations

Efficiency choice equations were estimated for annual building energy consumption (kWh) and coincident peak demand (kW for the summer on-peak costing period). Least squares estimation methods were used to estimate the efficiency choice equations. White's consistent estimators of the coefficient covariance matrix were used to correct for heteroskedasticity.[16] To maximize statistical efficiency, all PG&E/SCE respondents were analyzed as a single sample. However, interaction variables were used to identify and represent effects that were significantly different between the two utilities. The final kWh and kW equations have R-squared values of 0.25 and 0.20 respectively, which is typical for cross-sectional analyses in diverse samples.

Model runs were completed on variations of these initial specifications, with the final models being specified using F-tests and t-tests to determine if combinations and individual variables added explanatory significance to the model.[17] For example, the program rebate variables were interacted with

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[16] White, H., "A Heteroskedasticity Consistent Covariance Matrix and a Direct Test for Heteroskedasticity," *Econometrica*, **46**, 1978, 817-38. Heteroscedasticity was also minimized by specifying the dependent variable to be the efficiency choice measured as a percentage of base use, rather than the savings in kw or kwh. Our approach is closely related to using the later specification but then using WLS reflecting base use.

[17] The use of F-tests and t-tests in combination provides information on the degree of colinearity in the sample. Colinearity exists when explanatory variables are correlated with other explanatory variables or with linear combinations of other explanatory variables. One indicator of colinearity is when adding a set of variables passes an

building types, square footage, climate zones, and other variables. F-tests were conducted to determine if including these interactive variables improved the explanatory power of the model. All of the F-values were less than one, so the interactive effects were not included in the final equations.[18]

The final equations include the program participant variables, double Mill's ratio variables, and the climate, building and decision-maker variables that were statistically significant. Table 12-3 shows the coefficients and t-ratios of the final equations. The program participant coefficients are positive and statistically significant for each utility, with values in the range of nine to seventeen.[19] The interpretation of these coefficients is that the program rebate increases the energy efficiency design of the building between nine and seventeen percent above the Baseline, holding all other factors constant. These findings are consistent with past studies, which found, that the lighting rebate accounted for a 15 percent savings in energy consumption.[20] One result, which is not intuitive, is that kWh and kW savings from buildings that received both lighting and HVAC rebates were not consistently larger than buildings that received only a lighting or HVAC rebate. One explanation may be that, due to the higher costs of efficient equipment and cash flow limits, slightly lower efficiency lights and HVAC equipment are specified in buildings which get both rebates than in buildings which get a rebate for only lighting or HVAC.

The self-selection variables (Mill's ratio variables) were retained in the model simply to reduce any concern the results might be biased by self selection. However, these variables were not statistically significant and had very small t-ratios. This indicates that these variables were not important factors in the model.

The sensitivity of the spillover coefficients to different partial participant definitions was tested. Combinations of four survey questions were used for the different definitions. These questions were:

1. Have you heard about the program?
2. Did you have interaction with the utility staff during the design?
3. If you had interaction, how involved was the utility staff (on a scale of 1 to 7)?
4. Did you consider participating in the program?.

The partial participant coefficients and t-values were insensitive to how a partial participant is defined. The final definition used in the equations is that a partial participant building is one in which a decision-maker had knowledge of the program, had interaction with utility staff, and had considered participating in the program but chose not to. The partial participant coefficients in the kWh and kW efficiency choice models were not statistically significant at $\alpha=0.10$, and so these variables were dropped from the final analysis. Other determinants of efficiency choices include building type, decision-maker characteristics, and climate zones. It should be noted that the climate zone variables capture not only weather effects, but also all effects that are unique to a zone's specific geographic area. For instance, differences in local building practices may also be captured by the climate zone variables.

The decision-maker characteristics all have the hypothesized sign, except for efficiency significance. This variable has a positive effect on participation, but a negative effect on energy efficiency choices.

F-test but none of the variables that were added pass the individual t-tests. In cases where colinearity was suspected, to the extent possible variables were redefined and the specification was re-tested.

[18] One (1) is the .05 critical value of an F-test with infinite number of degrees of freedom in the numerator and the denominator.

[19] The refrigeration rebate variable was not specified because all of the refrigeration rebates were part of the PG&E program.

[20] Pacific Gas and Electric Company, *Nonresidential New Construction Impact Evaluation Study*, October 22, 1993

What the data suggest is that decision-makers who view energy efficiency as an important factor in fuel choice are more likely to participate in the program, but the energy design of their buildings, holding all other factors constant, is less above the Title 24 standards than their counterparts who do not view energy efficiency as a significant factor in fuel choice. The participation result is intuitive, while the efficiency choice result is counter-intuitive. The results may have been influenced by the wording of the question or where the question was placed in the survey. Future research on decision-maker preferences regarding energy efficiency should probe more deeply into this issue with a battery of survey questions rather than just one. A battery of questions that are answered consistently will provide more assurance that the respondent understands the questions and is not just responding with answers that they think the interviewer wants to hear.

The efficiency choice equations were used to predict the efficiency design of the building in the absence of the program. Predictions were made for each building in the net-to-gross sample. The predicted efficiency choice equation for building *i* is written as:

$$\text{Pred. Effic.Choice}_i = \text{As-built Effic. Choice}_i - (B_P X_{P,\,i}) - (B_{SSP}\text{SelfSelP}_i) - (B_{PP}\text{PartParticipant}_i)$$

where as-built efficiency choice is the percentage difference between the baseline and as-built annual kWh or summer on-peak kW (dependent variables from the equation), $(B_P X_{P,\,i})$ are the program coefficient and variable vectors, $(B_{SSP}\text{SelfSelP}_i)$ is the net savings inverse Mill’s coefficient and variable, and $(B_{PP}\text{PartParticipant}_i)$ are the partial participant coefficient and variable vectors. If a coefficient was not statistically significant (different from zero), the coefficient was set to zero in the prediction equation. Since the net savings inverse Mill’s ratio coefficient was not statistically significant in either of the models, the $(B_{SSP}\text{SelfSelP}_i)$ term effectively dropped out of the prediction equation. The partial participant coefficients were also set to zero since neither the PG&E or SCE coefficients were positive and statistically significant. Thus, the $(B_{PP}\,\text{PartParticipant}_i)$ term also dropped out of the predicted net savings equation.

The building level predicted efficiency choices were then used within the sampling design framework[21] to estimate the net impacts for the PG&E and SCE programs, which are presented in chapter 4. This sampling methodology is discussed in the chapter 7.

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[21] The sampling-based analysis gave confidence intervals for net savings using a similar methodology used to estimate the gross savings. Therefore, it was not necessary to calculate standard errors from the efficiency-choice regression analysis. This also made the final inference less dependent on the specification of the efficiency-choice model.

	Coefficient (t-ratio)	
Variable	**Annual kWh**	**Summer On-Peak kW**
Constant	9.602*** (3.003)	6.927* (1.848)
Received Lighting Rebate Only -- PGE	17.241*** (3.444)	15.220*** (2.908)
Received HVAC Rebate Only -- PGE	11.796*** (2.715)	16.252*** (3.129)
Received Lighting and HVAC Rebate -- PGE	17.303*** (3.646)	16.658*** (3.300)
Received Lighting Rebate Only -- SCE	16.661*** (2.533)	11.901* (1.641)
Received HVAC Rebate Only -- SCE	15.872* (1.819)	14.802* (1.721)
Received Lighting and HVAC Rebate -- SCE	9.122** (2.148)	9.850* (1.909)
Received Refrigeration Rebate	9.230*** (2.545)	9.528** (2.351)
Naturally-Occurring Self Selection Variable	3.224 (0.788)	1.706 (0.381)
Net Savings Self Selection Variable	0.997 (0.172)	-2.141 (-0.327)
Office, Hospital, Miscellaneous Building	3.959 (1.590)	5.576** (2.024)
School Building	10.936*** (4.235)	14.854*** (4.973)
Restaurant Building	-22.683*** (-5.456)	-11.978*** (-2.665)
Climate Zones 1 and 2	13.572* (1.656)	18.870*** (2.968)
Significant Input by Owner	3.683* (1.851)	N/A
First Cost Criteria	-6.653** (-2.041)	N/A
Energy Efficiency Very Important	-9.112*** (-4.097)	-6.230** (-2.284)
*** = significant, α=0.01; ** = significant, α=0.05; * = significant, α=0.10		

Table 12-3: Efficiency Choice Equations

13. REFRIGERATED WAREHOUSES

The refrigerated warehouse program covers a wide variety of measures, including improved insulation levels on walls, roofs and piping, oversized condensers, improved efficiency compressors and condensers, and other refrigeration plant improvements. A total of 16 facilities participated in the program. According to the Statewide DSM Evaluation Protocols, the refrigerated warehouse program was evaluated using the methodology outlined in Table C-9. In accordance with Table C-9, standard engineering algorithms were used to evaluate the gross impacts of the program. Due to the fairly small number of participating facilities, a census of participants was attempted. In the recruiting phase of the project, five facilities refused to participate, leaving a total of eleven sites for the study.

A comparison group analysis was not required by the protocols. The protocols did encourage additional data collection for the purpose of creating proxies for measure adoption in the absence of the program. However, due to the high rate of program market penetration, the Refrigerated Warehouse program personnel felt that it would be difficult to establish design practices in the absence of the program from a survey of design professionals and non-participating owners. Thus, the baseline facility characteristics were established from the program Advice Filings[22], and a default 0.75 net to gross value was adopted, in accordance with the protocols.

The evaluation consisted of the following steps:

1. Obtain program documentation. Program records for each participating facility were obtained for each program participant.
2. Conduct on-site survey. An on-site survey of each program participant was conducted to verify program records and obtain information about facility design and operation that was required to create the engineering model.
3. Calculate gross impacts. An engineering model was created for each refrigerated warehouse program participant. Gross impacts of the program were calculated using program baseline assumptions as reported in the program Advice Filings.
4. Calculate net impacts. A default 0.75 net to gross value was adopted, based on the CEC evaluation protocols.

13.1 ENGINEERING APPROACH

A combination of engineering algorithms and simulations were used to calculate the energy performance of each participant site. The TRNSYS transient simulation program was the primary engineering analysis tool. TRNSYS is a general purpose, hour-by-hour building energy simulation program, similar to the DOE-2 program. The TRNSYS program provides a library of standard component models suitable for simulating building heat transfer and basic refrigeration equipment performance. Standard component models were used to simulate envelope loads, heat and moisture loads due to ventilation, and internal heat gains from lighting, product loading, and vehicle operations. Custom component models were developed and incorporated into the program to simulate the performance of specialized refrigeration equipment such as industrial refrigeration evaporators, defrost systems, heat and moisture infiltration through doorways, evaporative condensers, and industrial refrigeration compressor systems. The following sections describe the engineering approaches used in the TRNSYS model.

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[22] PG&E Advice Filing 1812-G-A/1450-E-A January 1994

13.1.1 Walls

The TRNSYS transfer function zone load model was used to simulate the refrigeration loads. This module uses the ASHRAE transfer function method to calculate transient heat conduction through the exterior surfaces of the facility. Wall and roof sections were defined, and transfer function coefficients were calculated for each section. The transfer functions were used by the program to calculate the heat flow through the wall and roof sections on an hour-by-hour basis as a function of the temperature of the refrigerated space, the outdoor temperature, and the incident solar radiation. The time-delayed response of the heat flow through sections with significant thermal mass, such as concrete walls and roof elements were modeled using this approach, providing a realistic simulation of the timing of the heat gains to the refrigerated space, and thus, the time of day impacts on peak refrigeration loads.

13.1.2 Infiltration

Infiltration was modeled using algorithms for infiltration by air exchange taken from the ASHRAE handbook. This approach accounted for heat gains resulting from room-to-room air density differences, and allowed infiltration through open doorways to be modeled as a function of the door type, frequency of doorway use, the doorway operation cycle length, the amount of time that the doorway remained open between operating cycles, and the temperature and moisture difference between the air masses in the spaces connected by the doorway.

13.1.3 Product and process loading

Product and process loads were calculated from the volume of product processed or cooled, the initial temperature, and final product temperatures, and the specific heat or latent heat of fusion of the product treated. Product thermal properties were taken from the ASHRAE Handbook. A series of schedules were defined for each product cooling process. Since the cool-down time of the various foods stored in the facilities occurred over a number of hours, refrigeration load schedules were developed to calculate the loads imposed on the refrigeration system from the product received each hour, as well as the heat absorption rate of partially-cooled product received during previous hours. In this manner, the transient cooling processes occurring in the facility and thus the timing of the refrigeration loads were accurately simulated. Schedules for both sensible and latent heat gains to the space were developed. Latent heat gains included moisture additions from wet product, as well as respiration from ripening fruit in long-term storage.

In addition to product loads, internal heat gains from lighting, warehouse personnel, process equipment, forklifts and other vehicles, and evaporator fans were calculated as a load on the space. Sensible and latent heat from the defrost process that re-enters the space was added to the other sources of internal loads.

13.1.4 Evaporators

Once the loading on the system from the shell, infiltration, and internal processes was calculated, these loads were then imposed on the evaporators. Defrost loads were calculated from the internal moisture gains to the space, and the humidity ratio of saturated air at the evaporator surface temperature. For purposes of this analysis, the coil surface temperature was assumed equal to the evaporator suction temperature. The hourly loads imposed on the evaporators were summed, and an evaporator part-load ratio was calculated, as shown in equation 13-1:

$$\mathrm{PLR}_{\mathrm{evap}} = \frac{\text{hourly evaporator load}}{\text{evaporator capacity}} \tag{13-1}$$

Depending on the fan control strategy, fan energy was adjusted based on the hourly part load ratio. For single-speed fans that ran continuously regardless of load, no adjustment was made. For single-speed fans that cycle on and off with load, and variable speed fans that modulate with load, the hourly fan energy as a function of part-load ratio was calculated according to Figure 13-1:

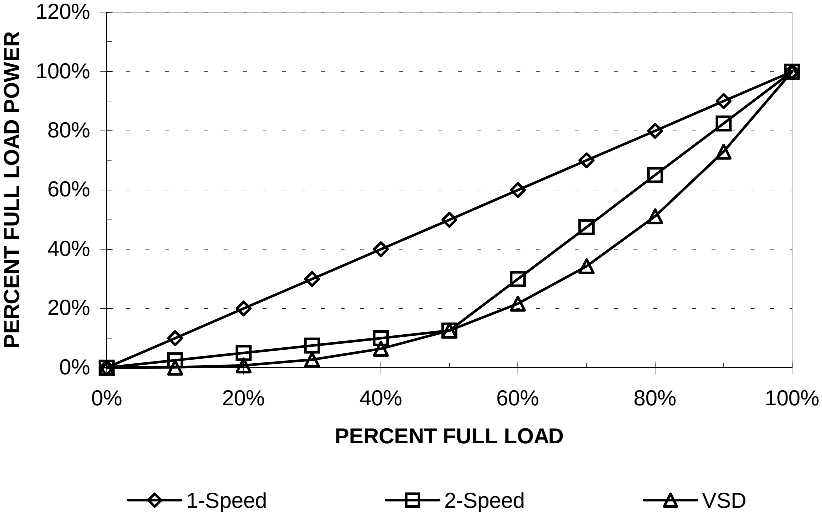


Figure 13-1: Evaporator Fan Part-Load Performance

Evaporator fan heat gains were fed back to the loads module in an iterative process, until hourly load convergence was reached. The solution of the hourly load equations, and convergence of the various load components was facilitated by the TRNSYS program.

13.1.5 Defrost

Defrost energy requirements were modeled using an energy balance approach, which accounted for energy exchange in the form of heat and moisture gains to the conditioned space occurring during the defrost process and energy removed with the defrost condensate. Both defrost efficiency and the proportion of heat and moisture re-entering the space were observed to be functions of initial and final evaporator surface temperatures.

Two defrost techniques were observed to be used in the refrigerated warehouses participating in this study: water wash, and hot gas. Water wash defrost was assumed to have a neutral impact on energy use, primarily because no compressor energy is required. Also, reclaimed heat was generally available for warming the defrost make-up water. Hot gas defrost energy was computed as the energy contained in the accumulated ice divided by the defrost efficiency and compressor COP. This energy was included as part of the compressor energy consumption in systems employing hot gas defrost. In accordance with program requirements, all defrost operation was scheduled off during the noon to six p.m. peak period.

13.1.6 Pipe and vessel heat gains

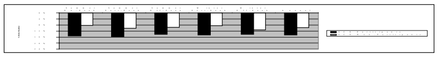
The loads imposed on the compressor plant from piping and vessel heat gains were calculated from the overall conductance of the insulated piping system and refrigerant vessels, and the temperature difference between the low-temperature system and hourly ambient conditions:

$$Q_{pipe,vessel} = \left(U_{pipe}A_{pipe} + U_{vessel}A_{vessel}\right) \times \left(T_{suction} - T_{ambient}\right) \qquad (13\text{-}2)$$

These heat gains were added to the evaporator heat gains. Pipe friction losses were converted to an equivalent temperature drop, based on the change in suction temperature per unit of suction pressure near the suction temperature setpoint.

13.1.7 Compressors

Compressor energy was calculated from the hourly loads imposed on the system, the suction temperature, and the condensing temperature. Suction temperature was calculated from the space temperature, the evaporator approach temperature, and the suction line pressure drop:



(13-3)

Manufacturers’ catalog data and/or compressor performance software were used to create a bi-quadratic regression model, expressing compressor full-load capacity and brake horsepower (bhp) as a function of suction and condensing temperature, as shown below:

$$TR = a_1 \times T_{suction} + b_1 \times T_{suction}^2 + c_1 \times T_{condensing} + d_1 \times T_{condensing}^2 + e_1 \times T_{suction} \times T_{condensing} + f_1 \qquad (13\text{-}4)$$

$$bhp = a_2 \times T_{suction} + b_2 \times T_{suction}^2 + c_2 \times T_{condensing} + d_2 \times T_{condensing}^2 + e_2 \times T_{suction} \times T_{condensing} + f_2 \qquad (13\text{-}5)$$

where:

TR = refrigeration capacity (tons)

bhp = compressor shaft power (hp)

$T_{suction}$ = suction temperature

$T_{condensing}$ = condensing temperature

$a_i..f_i$ = regression coefficients

The regression models developed from manufacturers’ data are shown in Tables 13-1 and 13-2.

		Regression Coefficients						Regression Limits			
Make	**Model**	**F**	**A**	**B**	**C**	**D**	**E**	**Tsuc low**	**T suc hi**	**T disch low**	**T disch hi**
CARRIER	5H-60	57.88903095	1.254492846	0.007234945	-0.414396989	0.000833349	-0.005140659	-40	40	80	120
FES	11-S	44.4330763	1.038051948	0.010338474	-0.13586039	0.000258117	-0.003829545	10	40	75	105
FES	12-S	53.64242387	1.410653409	0.013992379	0.020628908	-0.000935531	-0.004023629	10	40	75	105
FES	13-L	83.93954951	1.927605519	0.02255276	-0.161396104	-0.000393669	-0.006954545	10	40	75	105
FES	16-L	145.2214849	3.713035475	0.033248226	-0.151349952	-0.001183078	-0.010784468	0	40	75	105
FRICK	RDB-100	317.6750487	7.588796569	0.055547678	-0.755613445	-0.000445378	-0.014962255	-80	0	0	40
FRICK	RDB-177	293.2185187	6.101502562	0.034772281	-0.471848014	-0.001469032	-0.004658805	-80	0	0	40
FRICK	RWB-II-100	179.9095323	4.296970588	0.0314387	-0.503462185	0.000256303	-0.009345098	-40	40	75	115
FRICK	RWB-II-100E	159.9601238	3.511205882	0.026335088	-0.063764706	-0.000235294	-0.001054902	-40	40	75	115
FRICK	RWB-II-134	239.8117371	5.727595588	0.041924871	-0.669714286	0.000331933	-0.012443627	-40	40	75	115
FRICK	RWB-II-177	317.6750487	7.588796569	0.055547678	-0.755613445	-0.000445378	-0.014962255	-40	40	75	115
FRICK	RWB-II-222	400.2679047	9.55442402	0.069947575	-0.956554622	-0.000533613	-0.018823039	-40	40	75	115
FRICK	RWB-II-60E	95.10299357	2.109793931	0.015792208	-0.026619359	-0.000325107	-0.000618626	-40	40	75	115
FRICK	RXB-30	54.25561477	1.310318627	0.00961032	-0.159714286	0.00012605	-0.003077451	-40	40	75	115
FRICK	RXB-50	87.58717382	2.129284314	0.01565387	-0.246487395	0.000134454	-0.004994118	-40	40	75	115
HOWDEN	XRV-163.193	131.9534816	3.395307722	0.025096017	-0.221784759	-0.000915753	-0.008160028	-40	40	65	115
HOWDEN	XRV-204.165	239.6080801	6.019676526	0.044522002	-0.442849695	-0.001202891	-0.013751204	-40	40	65	115
HOWDEN	XRV-204.193	261.7843912	6.458121207	0.046064234	-0.537091491	-0.001057992	-0.014890429	-40	30	65	115
MYCOM	160VLV	128.4662786	3.265322222	0.023756133	-0.188563492	-0.001597222	-0.007173333	-40	40	65	115
MYCOM	200M	200.0324611	4.52337316	0.03120202	0.129426623	-0.002691071	-0.001918961	-50	40	65	115
MYCOM	200VL2.6	273.6964054	6.724809524	0.047162698	-0.623119048	-0.002212302	-0.01652381	-40	40	65	115
MYCOM	200VM2.6	225.6145536	5.580876984	0.03935119	-0.491595238	-0.002053571	-0.013545238	-40	40	65	115
MYCOM	200VSD	171.4952414	4.22823254	0.030450397	-0.350166667	-0.001228175	-0.009631905	-40	40	65	115
MYCOM	250VSD	329.2003237	7.991862338	0.062236291	-0.703392063	-5.15873E-05	-0.012482857	-50	30	-20	30
MYCOM	8WB-10	102.1024094	2.541890124	0.017274612	-0.477845257	-0.000209316	-0.008322363	-40	40	65	115
MYCOM	8WB-25	105.3267774	2.606879768	0.017714688	-0.504281208	-0.000134242	-0.008541819	-40	40	65	115
MYCOM	N8WB	167.0182834	3.853949085	0.023937446	-1.067081847	0.001231942	-0.014840362	-40	40	65	115

Table 13-1: Brake Horsepower Regression Coefficients

		Regression Coefficients						**Regression Limits**			
Make	**Model**	**F**	**A**	**B**	**C**	**D**	**E**	**Tsuc low**	**T suc hi**	**T disch low**	**T disch hi**
CARRIER	5H-60	18.13591813	-0.37377502	-0.00394158	0.339271475	-0.001059114	0.009111277	-40	40	80	120
FES	11-S	30.61404221	0.015438312	3.16558E-05	-0.283587662	0.006201299	0.000352273	10	40	75	105
FES	12-S	18.21925918	0.001903409	-0.00028738	0.094041607	0.006197406	0.000881133	10	40	75	105
FES	13-L	42.89308036	0.034553571	0.000232143	-0.33875	0.011526786	0.000482143	10	40	75	105
FES	16-L	77.74222196	0.053300575	0.000924257	-0.631874401	0.020693672	0.000622723	0	40	75	105
FRICK	RDB-100	39.07498911	-0.32865847	-0.0038999	1.335836218	0.001035713	0.010870589	-80	0	0	40
FRICK	RDB-177	65.61160909	-0.58313662	-0.00651872	2.366754037	0.002353917	0.020208403	-80	0	0	40
FRICK	RWB-II-100	30.48397833	-1.28748284	-0.00744634	1.144235294	0.008058824	0.025436765	-40	40	75	115
FRICK	RWB-II-100E	37.24600398	-1.57090686	-0.01020826	0.954201681	0.010798319	0.02759902	-40	40	75	115
FRICK	RWB-II-134	40.81064573	-1.71655147	-0.00992601	1.521109244	0.010773109	0.033913235	-40	40	75	115
FRICK	RWB-II-177	32.10583702	-2.97486765	-0.01861992	2.52907563	0.010953782	0.052491176	-40	40	75	115
FRICK	RWB-II-222	40.62941066	-3.74555392	-0.02347265	3.181042017	0.013810924	0.066093137	-40	40	75	115
FRICK	RWB-II-60E	23.80571151	-1.11682612	-0.00766435	0.585446261	0.006761653	0.018517065	-40	40	75	115
FRICK	RXB-30	13.02537041	-0.43177696	-0.00306151	0.340336134	0.002693277	0.008532843	-40	40	75	115
FRICK	RXB-50	21.19532729	-0.70373284	-0.00496161	0.553092437	0.004378151	0.013890686	-40	40	75	115
HOWDEN	XRV-163.193	53.1636412	-0.5388626	-0.00409989	0.39489244	0.009101411	0.013303069	-40	40	65	115
HOWDEN	XRV-204.165	95.49666828	-0.92426046	-0.00715423	0.621853886	0.016304608	0.023062899	-40	40	65	115
HOWDEN	XRV-204.193	104.4248136	-0.54717589	-0.00348563	0.658325273	0.017971754	0.020188578	-40	30	65	115
MYCOM	160VLV	-15.7121922	-1.28328968	-0.00343308	1.90552381	-0.000230159	0.021754762	-40	40	65	115
MYCOM	200M	-15.2042023	-2.2151618	-0.01040593	2.693929654	0.0032875	0.038735931	-50	40	65	115
MYCOM	200VL2.6	-39.0712437	-2.61238095	-0.00892208	3.918055556	-0.001315476	0.044085714	-40	40	65	115
MYCOM	200VM2.6	-32.7089111	-2.22100079	-0.00729131	3.288111111	-0.001218254	0.037128095	-40	40	65	115
MYCOM	200VSD	-19.1619012	-1.66983095	-0.0073934	2.461968254	-0.00097619	0.030415714	-40	40	65	115
MYCOM	250VSD	105.5632133	0.280505916	0.000130772	1.399131746	0.000769841	0.000771905	-50	30	-20	30
MYCOM	8WB-10	1.081574971	-1.11154143	-0.00917848	1.418005173	-0.004554237	0.020771029	-40	40	65	115
MYCOM	8WB-25	0.961011334	-1.13920307	-0.00941557	1.457678218	-0.004688966	0.021293562	-40	40	65	115
MYCOM	N8WB	1.238461174	-1.57178055	-0.01300295	2.014503972	-0.006480835	0.029387995	-40	40	65	115

Table 13-2: Refrigeration Capacity Coefficients

A typical plot of compressor performance is shown in Figures 13-2 and 13-3.

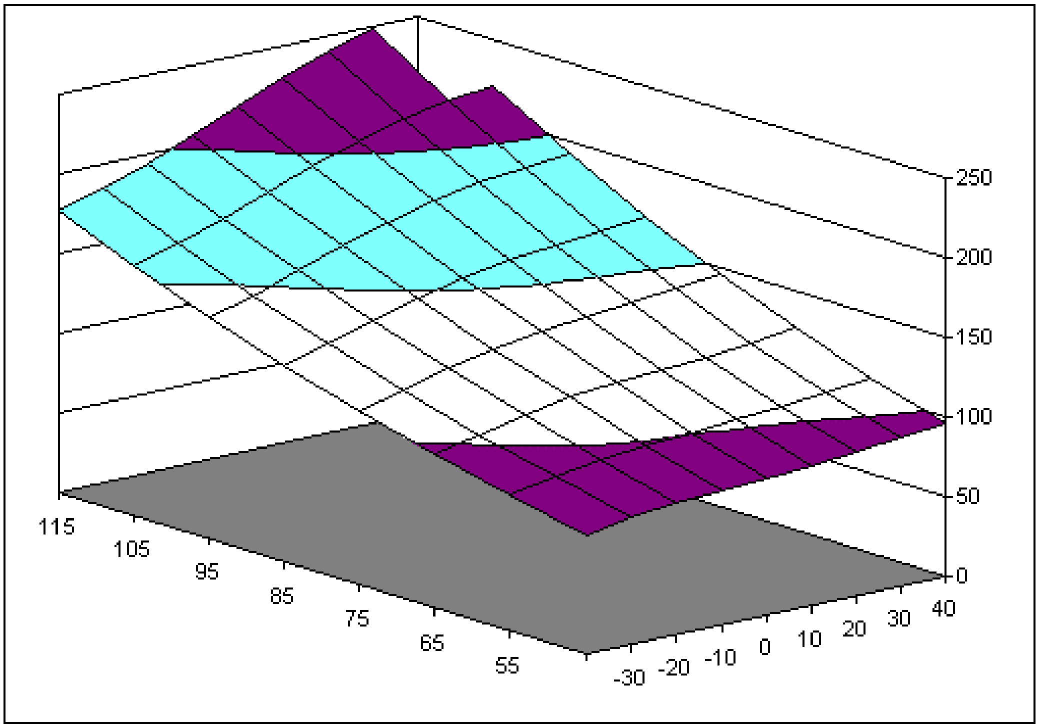


Figure 13-2: Compressor Brake Horsepower as a Function of Suction and Discharge Temperature

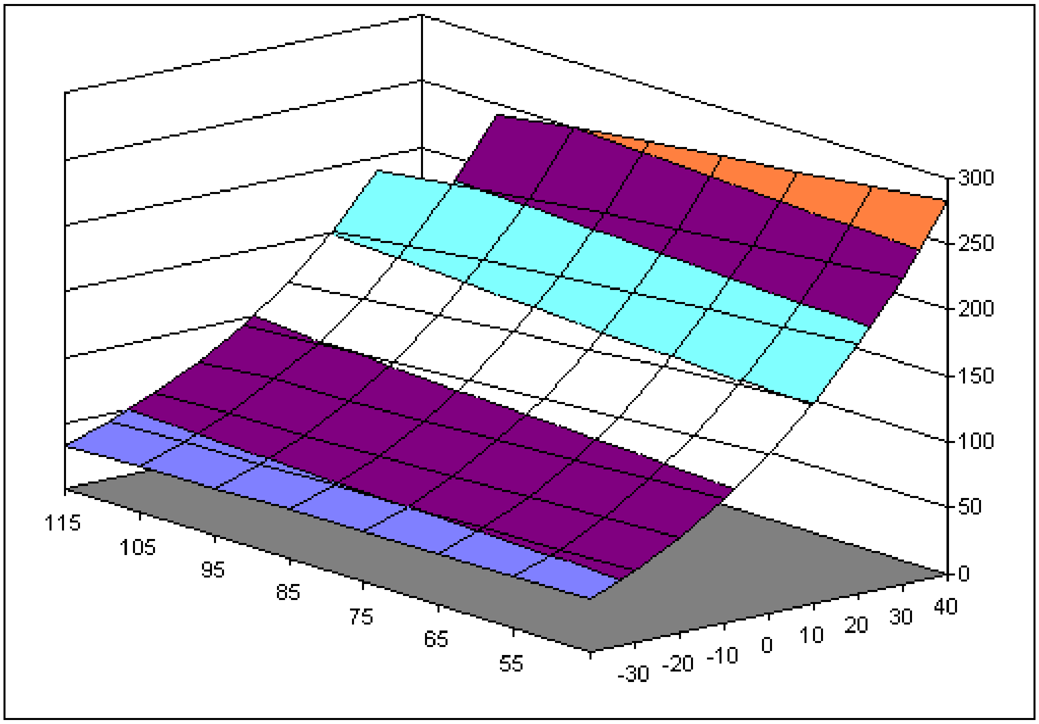


Figure 13-3: Compressor Capacity as a Function of Suction and Discharge Temperature

The regression models were used to calculate the full-load refrigeration capacity and brake horsepower. The full load capacity is the total refrigeration effect that the compressor can supply at a given set of suction and condensing conditions. However, the compressors run at full load only a few hours each year. As the loads imposed on the compressors decrease from the maximum possible output, the compressors employ various unloading techniques to reduce the refrigerant flow rate to match the system load. Individual compressors in a multi-compressor system may be sequenced to meet the required load. Within each compressor, control devices are used to modulate compressor output. The impact of these load control strategies was calculated using a part load response curve. At each hour, the compressor part load ratio was calculated as follows:

$$\mathrm{PLR}_{\mathrm{comp}} = \frac{\text{hourly compressor load}}{\text{compressor capacity}} \qquad (13\text{-}6)$$

Manufacturers' catalog data were used to develop compressor part-load response curves for the compressor models covered under the study. The catalog data were fit to a polynomial equation, and the compressor brake horsepower was adjusted as shown in Figure 13-4. Individual compressors in a multi-compressor plant were sequenced on a seasonal basis, depending on the refrigeration requirements of the process.

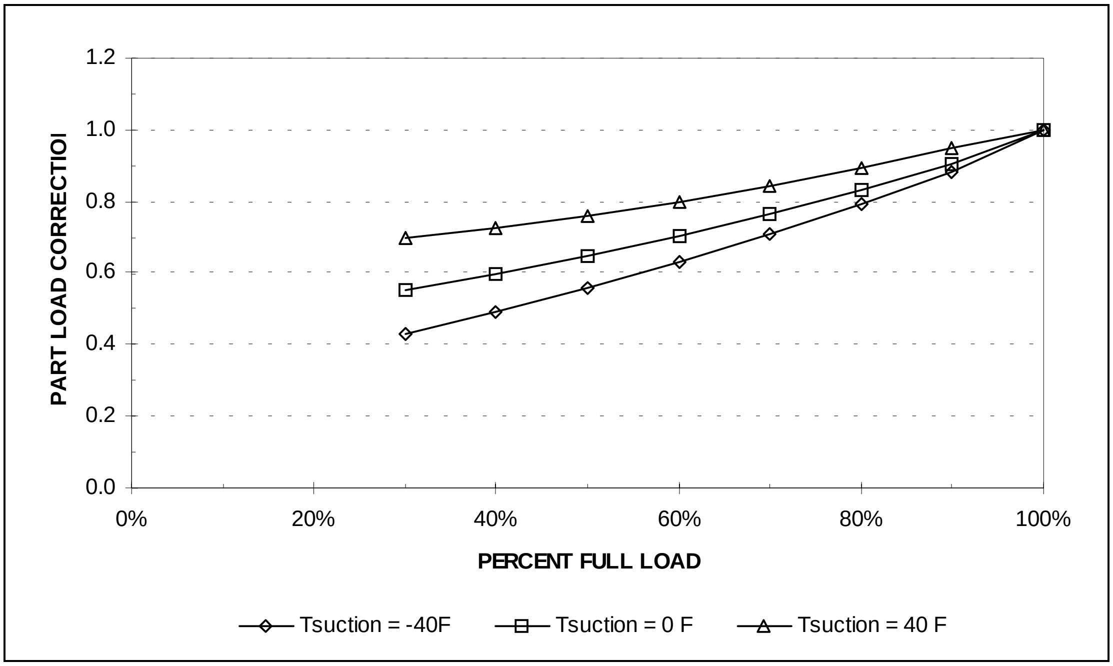


Figure 13-4: Compressor Part-Load Performance

13.1.8 Condensers

Condenser performance, in terms of heat rejection rate and fan energy, is a function of condensing temperature, ambient wet-bulb temperature, and part-load ratio. The condenser performance was modeled based on the heat rejection rate of the condenser at standard conditions, and an adjustment factor based on condensing temperature and wet bulb temperature. As with the compressor models, manufacturers' catalog data were used to develop a bi-quadratic regression model of the condenser heat rejection adjustment factor as a function of condensing temperature and wet-bulb temperature:

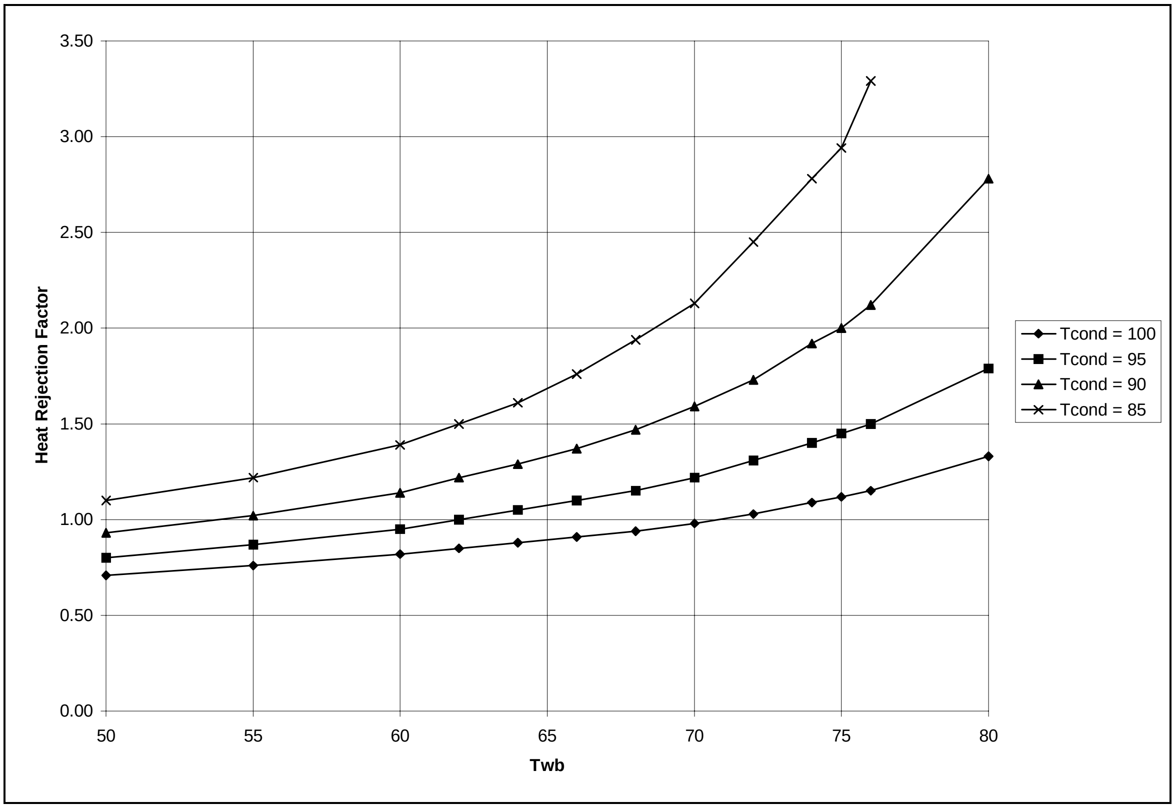


Figure 13-5: Condenser Heat Rejection Factors

The hourly condensing temperature is function of the heat rejection capacity of the condenser, the load imposed on the condenser by the compressor plant, and the condenser temperature control strategy employed. In these facilities, two types of condenser temperature control strategies were employed:

1. Pressure control. The condenser fans are run at maximum capacity, thus maximizing the heat rejection rate of the condenser and minimizing the condensing temperature. As the condensing temperature approaches the minimum condensing temperature setpoint, condenser fan flowrate is controlled to maintain the condensing temperature at the minimum condenser temperature setpoint.
2. Wet-bulb control. Condenser fan flow rate is controlled to maintain a fixed difference between the condensing temperature and the wet-bulb temperature. If the condensing temperature is at or above the fixed differential, the fans run at maximum capacity. As the condensing temperature approaches the condensing temperature setpoint, the fan flow rate is reduced to maintain the fixed differential. As with pressure control, the condenser fan flow rate is also controlled to maintain the condensing temperature at the minimum condenser temperature setpoint.

The strategy used to simulate these two control actions is described as follows:

Pressure control. The heat rejection capacity of the condenser at a given wet-bulb and condensing temperature was compared to a calculation of the total heat rejected by the compressor plant. The condensing temperature was re-calculated in an iterative process until the heat rejection rate equaled the total heat rejected. If the calculated condensing temperature was less than the condenser low limit temperature, the condenser temperature was fixed at the low-limit temperature, and the condenser fan capacity was reduced. The condenser part-load ratio was calculated as follows:

$$\mathrm{PLR}_{\mathrm{cond}} = \frac{\text{hourly heat rejection by compressor plant}}{\text{condenser heat rejection capacity at current conditions}} \qquad (13\text{-}7)$$

The fan energy was calculated according to the following part-load curve:

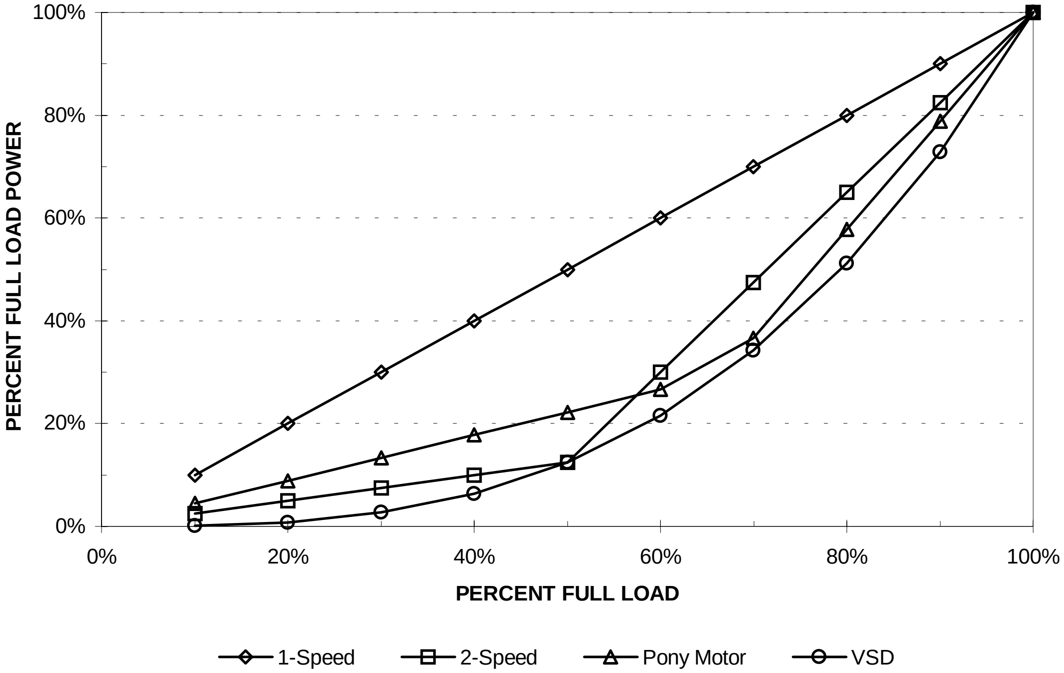


Figure 13-6: Condenser Fan Part-Load Performance

Note, in this model, the condenser capacity was assumed to vary linearly with condenser fan flow rate, down to a part-load ratio of 10%. Below 10%, heat rejection was assumed to occur via natural convection.

Wet-bulb control. A condensing temperature setpoint was calculated based on the hourly wet-bulb temperature. For this project, a fixed differential of 10°F was used. If the heat rejection rate of the condenser at the control point was less than the total heat rejected by the compressor plant, the condensing temperature was allowed to float above the setpoint until the heat rejection rates were equal. If at the condensing temperature setpoint, the heat rejection capacity of the condenser was greater than the total heat rejected, the condensing temperature was fixed at the setpoint and the condenser fan flow rate was modulated. Fan energy as a function of condenser part load ratio was calculated in the same manner described above.

As may be evident from the preceding discussion, there are many interdependencies between the facility load, compressor capacity and bhp, condensing temperature and condenser fan energy. Each of the component simulation modules were simulated in an iterative manner during each time step until convergence between the calculated loads and temperatures was achieved. The convergence calculations were facilitated by the TRNSYS program.

13.2 MODEL VALIDATION

In order to check the response of the TRNSYS simulation model to bin method calculations used in the program design, a series of studies were done. Below are some comparative results from the TRNSYS hourly simulation model and the bin method calculation used in the program Advice Filing for calculating savings from oversized condensers. The TRNSYS model was modified to accept the loads, compressor performance map, and exact condenser size and power used in the bin method calculation. The compressor part-load correction factors were removed from the simulation. The weather used in the simulation was annual average in Climate Zone 12 (middle Central Valley/Merced). The weather used in the initial bin calculation was from Air Force weather data for Castle AFB near Merced. The TRNSYS simulation assumed the improved condenser has two-speed fans, and wet-bulb reset of condensing temperature. The results of the comparison are shown in Table 13-3 below:

Method	**Compressor and Condenser kWh savings / evaporator ton**	**Compressor kW savings**
Simulation	1259	33
Bin	1228	39
Difference	31 (8%)	-6 (-15%)

Table 13-3: Model Performance Comparison

As is evident from the above comparison, the simulation model predicts energy savings within 8% of the bin calculation, and predicts demand savings within 15% of the bin calculation. The discrepancy in the results is due to a number of factors:

- Differences in the weather data.
- The regressed compressor curve did not exactly match the compressor curve use in the bin method. The simulated heat rejection factors were double-checked against the table values and found to be within two percent.

Condensing temperature over the year for the baseline and improved warehouses are shown in Figure 13-7

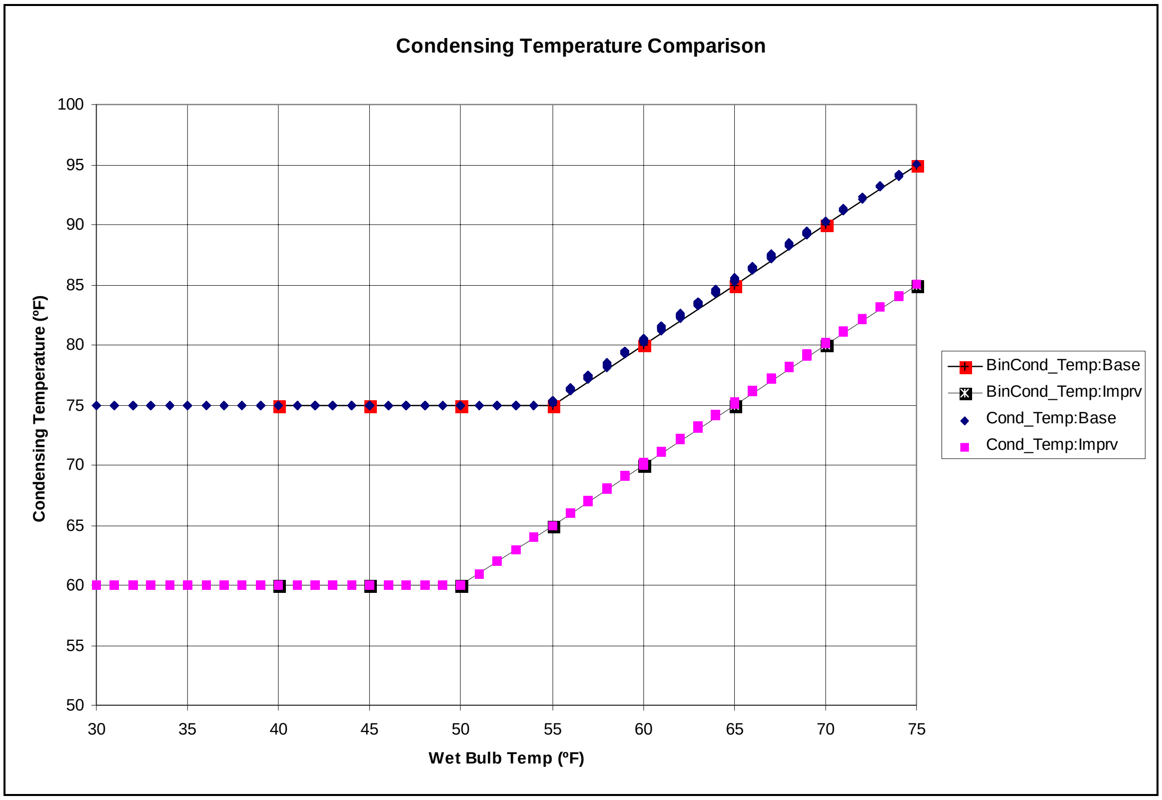


Figure 13-7: Condensing Temperature Comparison

As is evident from the Figure 13-7, the condensing temperatures track virtually identically. Fan operation was tracked over course of the annual simulation, and compared to the bin method results. The hourly results are plotted against the bin results in Figure 13-8.

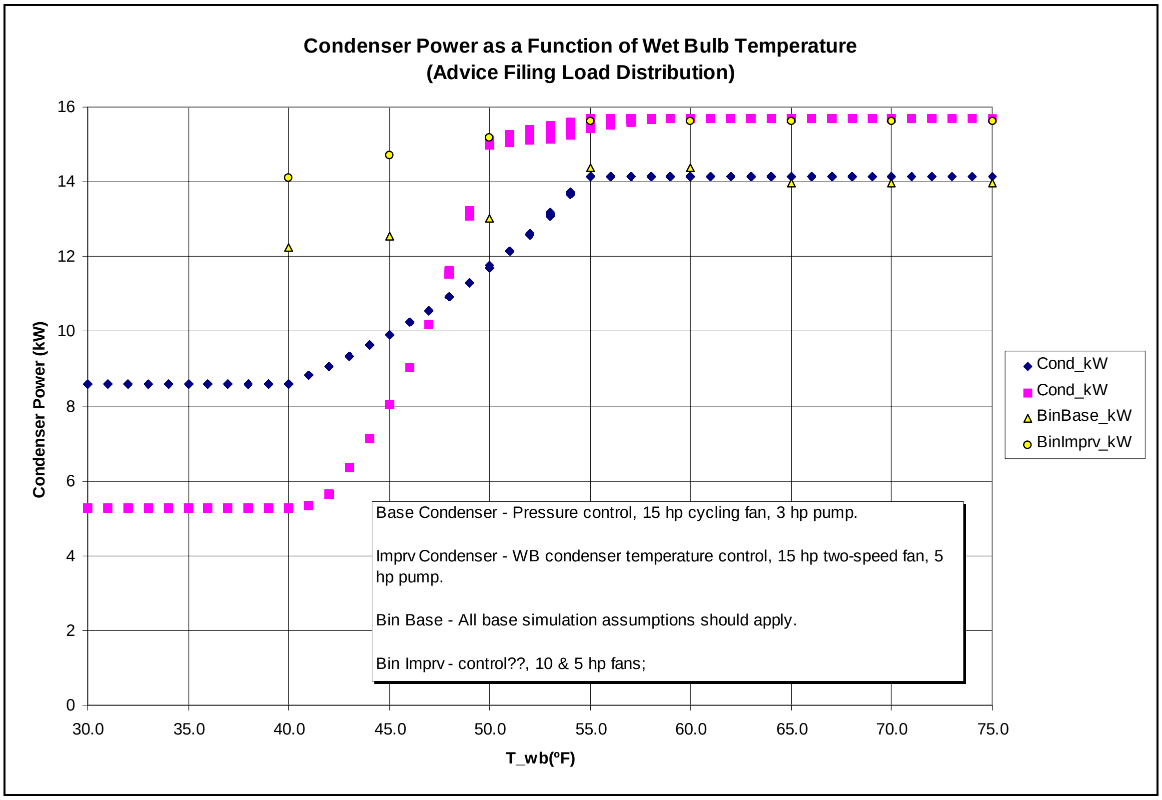


Figure 13-8: Condenser Power as a Function of Wet Bulb Temperature

As is evident from Figure 13-8, the simulated fan power response differs from the bin model. It was not entirely clear exactly which fan volume control strategy was used in the bin calculations. The simulation uses a fairly rigorous approach to modeling fan power at lower loads and lower wet-bulb temperatures, and the simulated tower fan response appears to be reasonable. Since the differences in the models occur at low wet-bulb temperatures and low loads, the overall impact of the differences on annual energy consumption are negligible.

The modeled compressor attempted to mimic the model in the bin calculation. The fit is not exact because of the regression model used in the simulation does not model a piece-wise linear function particularly well, as shown in Figure 13-9.

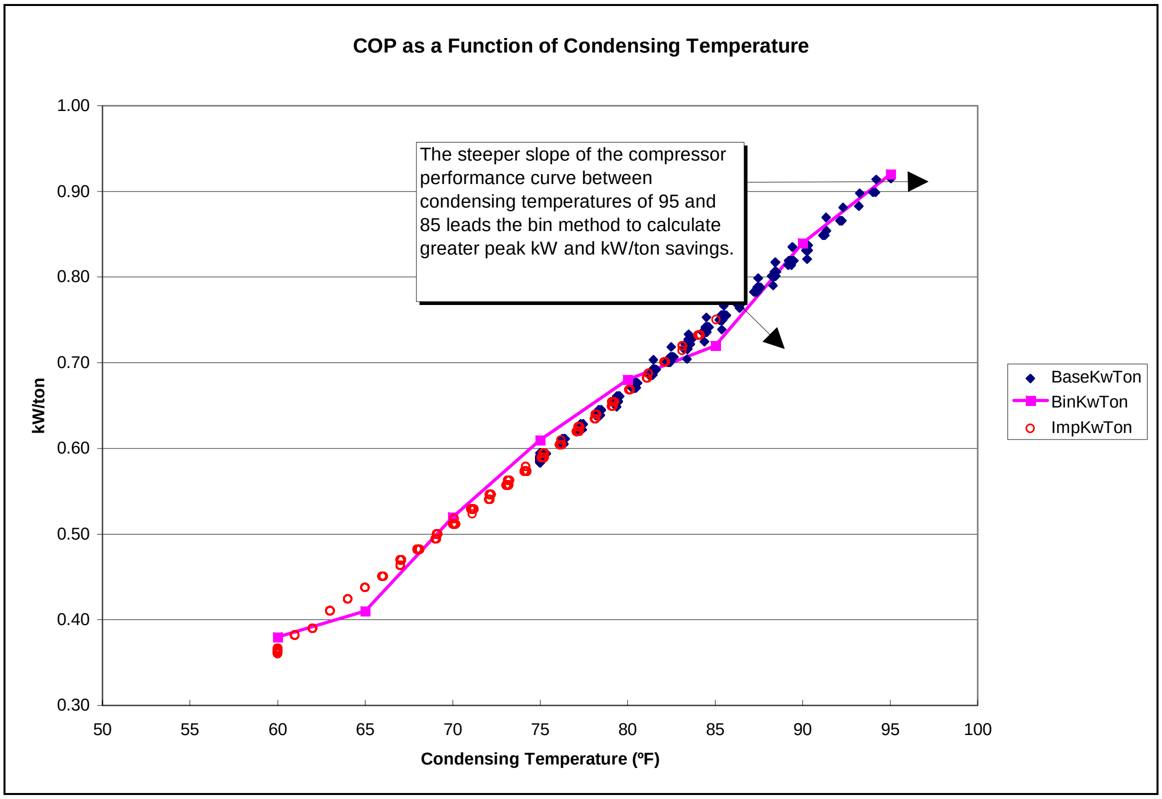


Figure 13-9: COP as a Function of Condensing Temperature

The regression model does not quite capture the inflections in the COP used in the bin method, but follows its trend accurately across the range of condensing temperatures. The dip in the kW/ton value used by the bin method at 85ºF causes the bin method to predict greater compressor power savings when the condensing temperature is reduced from 95ºF to 85ºF.

13.3 GROSS SAVINGS CALCULATIONS

The as-built performance of the facility was calculated from the facility characteristics verified during the on-site survey. Since there are no energy standards for refrigerated warehouses, the PG&E program baseline equipment specifications as reported in the Advice Filings served as the baseline or reference point for the gross impact calculations. Gross savings for each participant were calculated from the difference in the energy consumption between the facility modeled with the baseline specifications and the facility modeled with the as-built efficiency specifications.

13.3.1 As-built models

Models of each facility were constructed from a combination of program documents and on-site surveys. Hard-copy program documents were obtained from PG&E for each participant. The required documentation included application forms, facility plans, building load calculations, equipment specification sheets, system operations manuals and proof of purchase documents. The documentation requirements for this program were quite stringent, thus the documents provided much of the information necessary to construct the engineering models, including geometric information and general facility specification contained on the buildings plans. Specification sheets provided much of the equipment performance information. Proof of purchase documents were compared to design specifications to identify equipment substitutions that may have affected energy savings.

All refrigerated warehouse program participants were contacted during the customer contact and recruitment phase of the project. An on-site survey was conducted for each program participant that agreed to participate in the evaluation. The on-site survey was used to obtain the following information:

1. ***Verify facility design information***. Facility physical dimensions, equipment nameplate data, and other design parameters provided in the program file were field-verified. Additional facility description data required to develop the engineering model were collected.
2. ***Verify the installation of rebated measures***. All rebated measures were identified, and the physical count and nameplate data were compared to program records.
3. ***Determine facility operation***. The facility operations data necessary to construct the engineering model was also be collected. Interview questions identified facility operations parameters such as:
    - Current operating hours
    - Current operating months
    - Future production and/or construction plans
    - Product types received, receiving schedule, and product receiving temperature
    - Product shipping schedule
    - Process water flow schedules, temperature, and source (when heat recovery is used)
    - Number and size of forklifts or other vehicles used, operating schedules
    - Vehicle recharging schedules

During the facility walk-through portion of the on-site survey, additional equipment and facility operating parameters were observed such as:

- Space temperatures for coolers, freezers, loading vestibules, etc.
- Defrost schedules
- Suction pressures
- Minimum head pressure setpoints

These data were combined with the program information to construct a description of the design and operation of each participating refrigerated warehouse facility.

Once the on-site surveys were conducted, an as-built TRNSYS model of each facility was constructed. A brief summary of the characteristics of each facility is shown in Table 13-4. See Appendix G for a more complete description of each facility.

13.3.2 Baseline

PG&E program baseline equipment specifications served as the baseline or reference point for the gross impact calculations. Gross savings for each participant were calculated from the difference in the energy consumption between the facility modeled with the baseline efficiency specifications and the facility modeled with the as-built efficiency specifications. The baseline specifications used to develop the models are summarized in Table 13-5.

Site ID	**Description**	**Shell insulation**	**Pipe, vessel insulation**	**Quick-close doors**	**Increased pipe size**	**Oversized evaporative condensers**	**Efficient evaporators**	**Liquid subcooling**	**2nd low temp evaporator**	**Improved profile compressor**	**Efficient battery charger**	**EMS**
PGE7151	Vegetable processing and packing	✔	✔		✔	✔	✔					
PGE7210	Frozen food storage and distribution	✔	✔	✔	✔	✔	✔			✔	✔	
PGE7338	Short-term and seasonal fruit storage	✔	✔		✔	✔	✔	✔				
PGE7339	Vegetable processing			✔	✔	✔	✔	✔		✔		
PGE7343	Short- and long-term storage			✔	✔	✔					✔	
PGE7353	Carrot processing						✔					
PGE7393	Short-term vegetable storage	✔	✔		✔	✔	✔			✔		✔
PGE7396	Pet food processing and storage	✔	✔	✔	✔	✔	✔					
PGE7409	Vegetable and fruit processing (no storage)				✔	✔			✔	✔		
PGE7467	Carrot processing and packing					✔						
PGE7469	Frozen food distribution	✔			✔	✔	✔					

Table 13-4: Facility Description

Attribute	**Application**	**Baseline Characteristics**	**Program Minimum**	**Incentive Levels**	**Comments**	**Reference**
Lighting	All refrigerated space	Not addressed	0.6 W/SF	none	Since no incentives paid, installed lighting will be held energy-neutral.	
Roof Insulation	Cooler	R-30	R-30	R-40 - R-50	Baseline = program minimum	NRNC- A - A7
	Freezer	R-45	R-45	R-50 - R-100	Baseline = program minimum	NRNC- A - A7
Wall Insulation	Cooler	R-25	R-25	R-35 - R-45	Baseline = program minimum	NRNC- A - A7
	Freezer	R-35	R-35	R-40 - R-60	Baseline = program minimum	NRNC- A - A7
Vessel insulation	Cooler	R-10	R-11	R-16		NRNC- A - 40
	Freezer	R-17	R-14	R-24	Baseline higher than program minimum	NRNC- A - 41
Pipe insulation	Cooler - pipe dia .5 - 1.5 in.	R-6	R-3.5	R-5	Baseline higher than incentive levels	NRNC- A - 40
	pipe dia 2 - 5 in.	R-9	R-5.5	R-8	Baseline higher than incentive levels	
	pipe dia 6 - 12 in.	R-10	R-5.5	R-11	Baseline higher than program minimum	
	Freezer - pipe dia .5 - 1.5 in.	R-9	R-5	R-8	Baseline higher than incentive levels	NRNC- A - 40
	pipe dia 2 - 5 in.	R-14	R-8	R-11	Baseline higher than incentive levels	
	pipe dia 6 - 12 in.	R-15	R-8	R-16	Baseline higher than program minimum	
Doors	Forklift doors - open to ambient	Slow-closing automatic door, 14 second cycle time.	None	Quick-close door		NRNC- A - 42
	Forklift doors - open to adjacent space	Open door with strip curtain	None	Quick-close door		Pers comm, Stan Tory
	Material pass-through doors	Open door with strip curtain	None	Quick-close door	50% reduction in door use and infiltration	Pers comm, Stan Tory
Evaporators	Fan control	One-speed	None	Two speed, VSD		NRNC- A - 44
	Fan power	0.39 hp/ton	None	0.3 hp/ton		NRNC- A - 44
	Motor efficiency	Standard efficiency	None	High efficiency		NRNC- A - 44
	Approach temperature	20 °F	None	8 °F		NRNC- A - 44

Attribute	Application	Baseline Characteristics (from Advice Filings)	Program Minimum	Incentive Levels	Comments	Reference
Low temperature piping design	Systems with loads at different temperatures	Lowest value for all evaporators	None	Separate low temp suction line	Second system < -25°F SST, > 10°F below initial system	
Pipe sizing	Suction line pressure drop	0.5 psi/100 ft, max of 2.0 total	None	Upsize one pipe diameter		NRNC-A-F12
	Discharge line pressure drop	1.5 psi/100 ft, max of 3 total	None	Upsize one pipe diameter		NRNC-A-F12
Liquid sub-cooling	High pressure liquid	No sub-cooling	None	5 °F difference between refrigerant and cooling water		
Evaporative condensers	Approach temperature	20 °F	10 °F	Same as program minimum		NRNC - A56
	Minimum condensing temperature	75 °F	60 °F	Same as program minimum		NRNC - A56
	Condensing temperature control	Pressure control	Wet-bulb control for systems > 300 T	Same as program minimum	Program minimum and incentive level is press control for systems < 300 T	
	Motor efficiency	Standard	Energy-efficient	Same as program minimum		NRNC - A55
	Fan control	One-speed	Two speed	Same as program minimum		NRNC - A55
	Fan and pump power	0.09 hp/ton	0.11 hp/ton	Same as program minimum	Lower condensing temp makes up for higher fan hp	Pers comm., Stan Tory
Compressors	Efficiency	Stock compressor bhp/ton from manufacturer.	None	10% improvement over stock compressor efficiency		Pers comm, Stan Tory
	Motor efficiency	Standard efficiency	None	Premium efficiency		NRNC - A-54
	Oil cooling	Liquid-injection	Thermo-syphon oil cooling > 300 T	Thermo-syphon oil cooling all sizes T	Must use thermosyphon oil cooling to get compressor incentive	NRNC - A-54
Battery chargers		Ferro-resonant battery charger with manual timer	None	Select from list of qualifying models		

Table 13-5 (contd.): Refrigerated Warehouse Baseline and Incentive Efficiency Levels

Attribute	Application	Baseline Characteristics (from Advice Filings)	Program Minimum	Incentive Levels	Comments	Reference
Energy Management System	Control of refrigeration plant	Standard controls	None	Evap fan control, reset suction based on load, reduced defrost time, reduced condensing temp by monitoring condensibles, compressor sequencing to maintain > 50% loading		NRNC-A-64

Table 13-5 (contd.): Refrigerated Warehouse Baseline and Incentive Efficiency Levels

13.4 MODEL CALIBRATION

Once the simulation models were developed, the results of models of several sites were compared to billing data collected during the 1995 calendar year. Sites for calibration were selected based on the completeness of the billing data, and the match between the modeled space and the space served by the meter(s), as described in Table 13-6

SITE ID	% surveyed / metered space	Comments
PGE7151	18	Bad match, could not calibrate
PGE7210	100	Adjusted loading up to full connected load, still way under billing data, assume bad match
PGE7338	100	Reasonable calibration
PGE7339	not reported	Successfully calibrated
PGE7343	100	Metered data values unrealistically small - possible missing accounts
PGE7353	40	Bad match, could not calibrate
PGE7393	100	Successfully calibrated
PGE7396	45	Bad match, could not calibrate
PGE7409	not reported	Multiple billing records received, could not match any to model
PGE7467	not reported	Model connected load only a small fraction of metered demand, assume bad match between billing data and model
PGE7469	10	Bad match, could not calibrate

Table 13-6: Summary of Site Calibration Activities

Monthly energy consumption comparisons between the models and the billing data for the three sites that were successfully calibrated are shown in Figures 13-10 to 13-12. Note that two of the three sites were calibrated within 10 percent of monthly energy consumption. The third site, while varying on a monthly basis, was calibrated reasonably well on a seasonal and annual basis.

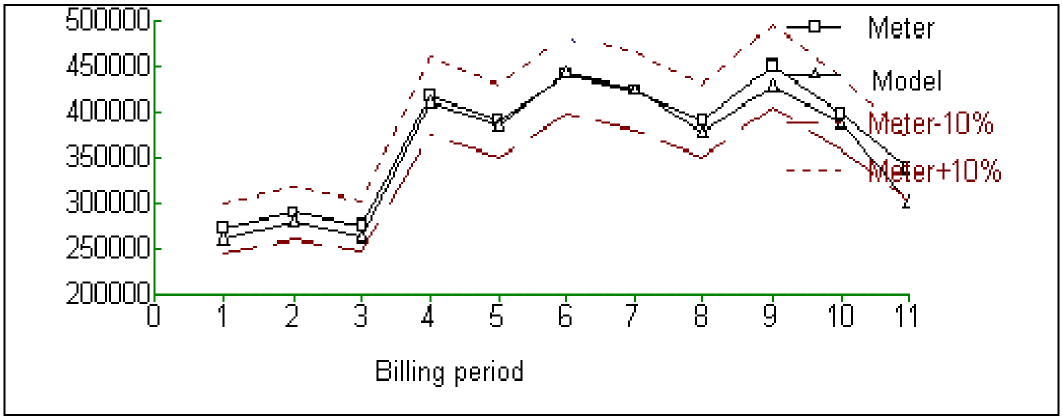


Figure 13-10: Calibration Results for PGE7393

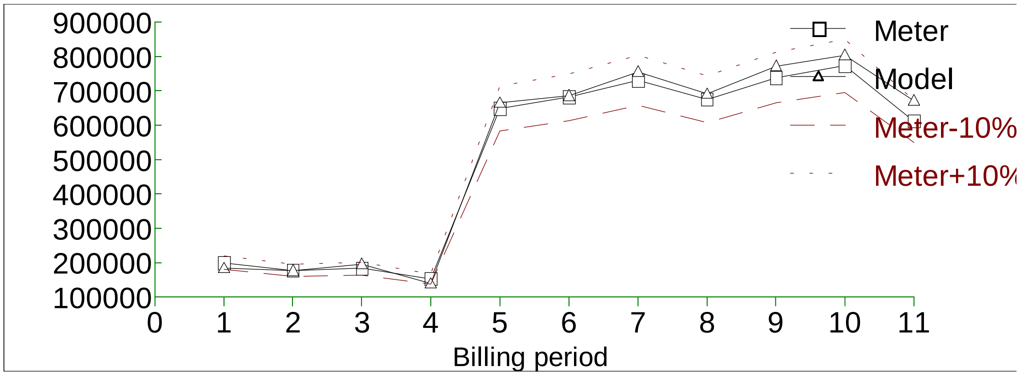


Figure 13-11: Calibration Results for PGE7339

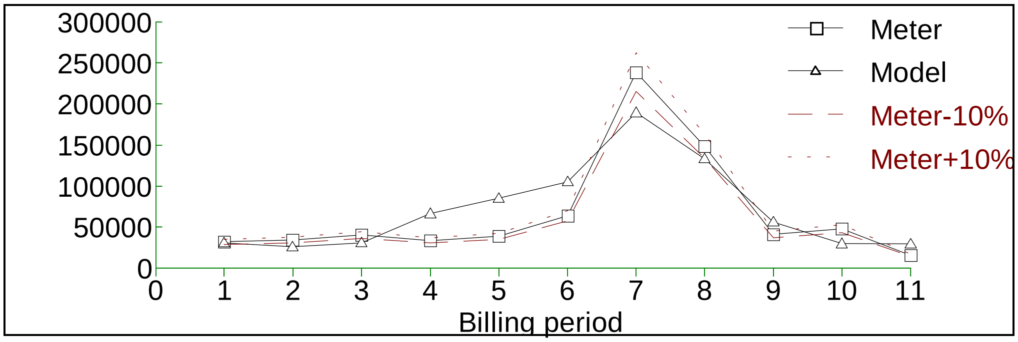


Figure 13-12: Calibration Results for PGE7338

13.5 RESULTS

13.5.1 Gross Savings

Annual gross energy and demand savings estimates for each site are shown in Tables 13-7 and 13-8. The savings estimates are broken out by end-use, as described below:

1. Miscellaneous Process. Energy consumption from process loads located in the refrigerated space. An example of these loads includes machinery, forklifts and other vehicles.
2. Lighting. Energy consumption from interior lighting located in the refrigerated space.
3. Condenser. Energy consumption from condenser fans and pumps.
4. Compressor. Energy consumption from space cooling and process cooling compressors.
5. Evaporator. Energy consumption from evaporator fans.

Along with the estimated savings, expected saving from the post-field verification spreadsheets are also displayed. The realization rate on gross savings is simply the estimated savings divided by the program expected savings.

Site ID	Misc. Process	Lighting	Condenser	Compressor	Evaporator	Total	Program Estimates	Realization Rate
PGE7151	0	0	6,910	2,501,144	374,298	2,882,752	3,049,196	0.945
PGE7210	17,259	0	43,270	1,956,380	207,220	2,208,288	1,214,681	1.818
PGE7338	0	0	-23,420	248,341	128,767	353,835	952,490	0.371
PGE7339	0	0	-174,774	372,279	-69,476	128,974	2,649,940	0.049
PGE7343	3,827	0	30,046	315,459	42,873	388,750	1,051,024	0.370
PGE7353	0	0	9,055	406,540	291,674	707,285	253,298	2.792
PGE7393	0	0	-387,241	1,461,619	41,860	1,118,219	2,854,146	0.392
PGE7396	0	0	-2,567	756,019	2,925	757,319	510,594	1.483
PGE7409	0	0	-124,222	891,994	0	768,490	1,443,035	0.533
PGE7467	0	0	-20,816	583,862	277,170	840,140	580,402	1.448
PGE7469	0	0	-12,560	174,807	41,133	203,316	115,341	1.763
Total						10,357,367	14,674,147	0.706

Table 13-7: Annual kWh Savings by Site

Site ID	Misc. Process	Lighting	Condenser	Compressor	Evaporator	Total	Program Estimates	Realization Rate
PGE7210	0	0	-8	442	112	530	426	1.244
PGE7338	0	0	6	435	53	500	238	2.101
PGE7339	0	0	-2	146	66	210	123	1.707
PGE7151	0	0	-49	-3	-40	-50	335	-0.149
PGE7343	0	0	8	214	27	248	185	1.341
PGE7353	0	0	1	61	10	76	19	4.000
PGE7393	0	0	-111	403	12	310	526	0.589
PGE7396	0	0	-1	190	1	191	93	2.054
PGE7409	0	0	-37	285	0	243	215	1.130
PGE7467	0	0	-8	68	26	80	90	0.889
PGE7469	0	0	-2	21	6	26	14	1.850
Total						2,364	2,264	1.044

Table 13-8: Summer Peak kW Savings by Site

Overall, the program achieved approximately 71 percent of the expected kWh savings and 104 percent of the expected demand savings. The site-by-site kWh realization rates vary from a minimum of 0.05 to a maximum of 2.8. Similarly, the realization rates for summer peak demand savings vary from a minimum of -0.15 to maximum of 4. Explanations for the wide variability in site-by-site results are as follows:

- The gross savings are calculated for both incented and non-incented measures. Several energy efficiency strategies were incorporated into the program minimum specifications which paid no incentives and were not included in the program savings estimates. Also, several participants adopted energy efficiency strategies, such as variable speed drives on evaporator fans and pumps, but did not receive incentives from the program. The extent to which the buildings were constructed above or below the baseline affected the gross savings, regardless of the incentives provided.
- One of the key assumptions in the development of the savings estimates was the equipment loading. The total compressor plant capacity (ton) and the peak load (ton) imposed on the compressors are shown in Table 13-9. The compressors were generally loaded between about 80 to 100 percent of their capacity, except for site PGE7339, where the loading was reduced during calibration. Note, the compressor capacity generally exceeded the evaporator capacity due to normal compressor over-sizing inherent in the design process. The program generally paid incentives based on the evaporator, rather than the compressor size. See the site summaries in Appendix G for more information on product and /or process loading.
- Another key assumption in the development of the savings estimates was the annual facility utilization, expressed as the annual full-load hours. The annual full-load hours are defined as the total annual refrigeration load (ton-hours) divided by the compressor plant capacity (tons) at design conditions. The original bin method model used during program design assumed an annual loading of approximately 6825 full-load hours in the Central Valley, and 7568 full-load hours in coastal locations. These values are consistent with 24 hour per day, year-round operations. Several of the sites surveyed indicated seasonal fluctuations in product processed and/or received, as well as daily production schedules of fewer than 24 hours per day. Based on the equipment loading from the calibrated engineering models, the following plant full-load hours were calculated as shown in Table 13-9:

Site ID	Compressor Size (T)	Peak Load (% of compressor size)	Annual FLH
PGE7151	1587	89%	3237
PGE7210	720	81%	3095
PGE7338	472	83%	883
PGE7339	1360	66%	2401
PGE7343	676	86%	762
PGE7353	282	97%	6599
PGE7393	736	84%	2291
PGE7396	206	83%	3060
PGE7409	529	96%	3020
PGE7467	553	78%	4679
PGE7469	34	100%	7037

Table 13-9: System Loading

The low realization rates for sites PGE7338 and PGE7343 are attributable to the seasonal nature of the operations, resulting in low utilization of the equipment. Employing a monthly correction factor to these sites to account for the seasonal operations would improve the realization rates for those facilities.

- Site PGE7339 showed the most disappointing results. The site was the third largest, in terms of expected energy savings, was reasonably well-loaded, yet the realization rate was close to zero. This site was included in the program, even though it did not meet the program minimum specifications for wall and roof insulation. The building is basically un-insulated, thus the baseline building peak refrigeration load is about 40% smaller than the as-built building peak load. Since the baseline load is smaller, the refrigeration plant size is also smaller. In order to load the systems in both buildings equivalently, the capacities of the evaporators, compressors, condenser pumps and condenser fans in the baseline model were reduced. The baseline building annual energy consumption was smaller due to the smaller equipment, thus the energy savings for evaporators and condensers were negative. Energy savings for the compressor plant were also reduced, since the as-built plant needed to meet a much greater annual load.

The impact of the lack of insulation was calculated by the design engineer to be about 160 tons, thus a penalty of 160 tons was included in the program incentive calculations. The simulation predicted a difference of about 380 tons - more than twice the cooling load penalty calculated by the design engineer. The design engineer did not include the effect of solar heat gains on the building surfaces when calculating the insulation impacts, thus partially explaining the difference in the cooling load penalty calculations.

The impact of this particular site has a major influence on the overall results. If this site was eliminated from the analysis, the overall program realization rate for energy would be closer to 85%.

- Negative savings for condenser fans and pumps were generally expected, since the oversized condensers covered under the program generally require more fan and pump horsepower to achieve lower approach temperatures. The program specifies a maximum value of 0.11 bhp per evaporator ton, while the baseline was set at 0.09 bhp per evaporator ton to account for the increased fan power requirements. The oversized condensers improve the efficiency of the compressor plant, resulting in a positive combined compressor and condenser energy savings. However, the as-built condenser fan and pump horsepower at a few sites was excessive. For example, as-built condenser fan and pump horsepower of 0.186 bhp/ton for site PGE7393 was more than twice the baseline value. Similarly, the as-built condenser fan and pump horsepower of 0.175 bhp/ton for site PGE7409 was almost twice the baseline value. The excessive fan and pump horsepower at these sites contributed to reduced energy savings.
- Positive condenser savings were noted when the fan and pump hp were at or near baseline levels. Since the incented condensers generally used wetbulb control, the reduced operating hours of the fans at part-load conditions coupled with small differences in fan and pump hp resulted in positive condenser savings at a few sites.

In general, the realization rates for facilities that were well-designed and reasonably well-loaded exceeded 1.0, indicating that the program savings calculations were conservative. The realization rates can be improved in the future by incorporating a seasonal adjustment factor to the energy savings calculations for facilities with variable loading, and by adhering more strictly to the program minimum specifications at all facilities.

13.5.2 Net Savings

Net savings were evaluated by adopting a default 0.75 net to gross, as allowed by the CPUC protocols. As discussed previously, five program participants refused to participate in the evaluation. The program estimates of savings for each of these customers are shown in Table 13-10.

PG&E Job Number	kWh	kW
60027	309,604	37
60040	284,780	55
60043	442,042	55
60053	577,823	61
80073	74,421	10
Total	1,688,670	218

Table 13-10: Program Estimates of Gross Savings for Customers Refusing to Participate in the Evaluation

Since the full census of participants was not studied, the gross realization rate for the sites studied was applied to the savings estimates for program participants who refused to participate in the evaluation. The adjusted savings for each of the refusing customers was then allocated across each end-use and costing period. The net program savings, including all participants, allocated by end-use and costing period are shown in Table 13-11:

End-Use	Costing Period	Net kWh Savings	Net kW Savings
Whole Building	Summer On Peak	1,123,899	1,810
	Summer Partial Peak	1,162,094	1,713
	Summer Off Peak	2,519,953	1,886
	Winter Partial Peak	1,671,639	1,418
	Winter Off Peak	2,184,591	1,402
Misc. Equip and Process	Summer On Peak	0	0
	Summer Partial Peak	19,803	44
	Summer Off Peak	0	0
	Winter Partial Peak	8,231	24
	Winter Off Peak	0	0
Condenser	Summer On Peak	-237,081	-166
	Summer Partial Peak	-211,006	-166
	Summer Off Peak	-224,957	-165
	Winter Partial Peak	-107,467	-186
	Winter Off Peak	-35,751	-216
Lighting	Summer On Peak	0	0
	Summer Partial Peak	0	0
	Summer Off Peak	0	0

	Winter Partial Peak	0	0
	Winter Off Peak	0	0
Compressors	Summer On Peak	1,871,968	1,860
	Summer Partial Peak	1,855,198	1,795
	Summer Off Peak	2,969,270	1,929
	Winter Partial Peak	2,211,161	1,529
	Winter Off Peak	2,546,341	1,551
Evaporators	Summer On Peak	265,702	225
	Summer Partial Peak	290,931	188
	Summer Off Peak	407,084	189
	Winter Partial Peak	287,838	219
	Winter Off Peak	341,501	210

Table 13-11: Net Program Savings by End-Use and Costing Period