1997 Commercial Energy Efficiency Incentive Program Evaluation

Study No. 567

Submitted to:

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Executive Summary

ES.1 Overview

This report presents an impact evaluation of Southern California Edison's (SCE) 1997 Commercial Energy Efficiency Incentive Program. The program provided monetary incentives to commercial utility customers for installing certain energy efficient equipment as part of a retrofit program. Regional Economic Research, Inc. conducted the analysis under contract to SCE. Ms. Shahana Samiullah was SCE's Project Manager. ASW Engineering Management Consultants, Inc. conducted on-site and decision maker surveys.

ES.2 Program Description

SCE's 1997 Commercial Energy Efficiency Incentive Program (97 CEEI) provided monetary incentives to commercial utility customers for installing certain energy-efficient equipment as part of a retrofit program. Incentives were divided into 1) customized system incentives, which were based on cost and expected savings of the retrofit, and 2) mail-in rebates. Measures eligible for customized financial incentives include the following:

- Efficient plant improvements, which are retrofits consisting of customized process-specific enhancing measures,
- Retrofits of air compressors and air compressor systems,
- Industrial relighting, which covers lighting retrofits for process related areas,
- Improvements in chilled water systems, including chillers, chilled water pumps, condenser pumps, cooling towers, and air handling distribution systems,
- Energy Management Systems (EMS), which are hardware and software systems that control energy usage within a building or process, and include lighting controls, space conditioning controls, commercial refrigeration controls, process controls, and water services controls,
- Supermarket Energy Optimization (SEO), which applies to most aspects of food stores including lighting, space conditioning, and commercial refrigeration,
- Variable speed drives (VSD) designed to provide energy savings for hydraulic pumping systems in agricultural and water service uses, and
- Indoor and outdoor lighting system replacements and modifications, daylight system controls and delampling.

Mail-in rebate coupons were available for the following lighting and HVAC upgrades:

- LED exit signs, and
- Packaged air conditioning units and heat pump units exceeding certain efficiency ratings.

Predominantly installed measures in the 97 CEEI include ASDs for motors and space conditioning equipment, energy management systems for space conditioning and lighting, indoor lighting system modifications, and LED exit signs.

ES.3 Study Objectives

The project focused on both gross and net energy and demand impacts. An extensive integrated database was developed comprised of data from several sources including billing and weather records, program records, on-site surveys, and engineering analyses. A statistically adjusted engineering model was estimated with data on both participants and nonparticipants, and a net-to-gross analysis was used to derive net program savings.

Key objectives for this study included the following:

- To estimate the gross and net energy and demand impacts of the program at the whole-building and end-use levels,
- To produce estimates as described in Table 6 of the Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand-Side Management Programs (Protocols), as adopted by the California Public Utilities Commission (D-93-05-063) and revised January 1997, and
- To produce documentation as described in Table 7 of the Protocols.

ES.4 Overview of Approach

The overall methodology was designed to comply with both the principles of good evaluation and the stipulations of the CPUC Protocols. The methodology consisted of the elements described below.

- ***On-Site Survey.*** An on-site survey was conducted to collect information on participants and nonparticipants. This information included detailed information on DSM measures installed over the study period, as well as changes in equipment stocks, building characteristics, operating schedules, and occupancy rates. The completed on-site surveys included 291 participants and 200 nonparticipants. The collection of end-use metered data at key sites was included to supplement the survey data.

- ***Decision-Maker Survey.*** A decision-maker survey was conducted to support the analysis of the net influence of the program on DSM behavior. The survey was completed for a sample of 234 participants and 185 nonparticipants. Not all sites responded to the decision-maker survey due to 1) their unwillingness to take the time, or 2) the unavailability of an appropriate decision maker.
- ***Engineering Analysis.*** An engineering analysis was used to develop initial engineering estimates. These impacts from energy efficiency measure installations by customer sites can be interpreted as the effects of DSM measures on participants' and nonparticipants' energy use, without regard to the attribution of these impacts to participation in the program. DOE-2 analyses were performed for HVAC and process measures. Simple engineering algorithms were used to estimate direct effects of lighting and, in some cases, miscellaneous measures. Estimates of lighting and HVAC usage and impacts were refined with end-use metering data.
- ***Statistically Adjusted Engineering Analysis.*** The statistically adjusted engineering (SAE) analysis is a means of statistically reconciling engineering estimates obtained from the engineering analysis with observed changes in energy consumption. It is applied as a reconciliation step in the estimation of *gross load impacts*, and leads to estimates of *ex post adjusted gross savings*. The SAE model is designed to control for non-program historical effects like changes in weather, structural alterations, and modifications of operating hours, and it is specified in a way that recognizes variations in timing of adoptions of measures within and across sites. SAE analysis is a form of load impact regression analysis and clearly satisfies the CPUC Protocols.
- ***Efficiency Choice Analysis.*** A set of efficiency models was developed to discern the influence of the program on adoptions of energy measures. *Net load impacts* are those that are attributable to the program. They are typically derived through correcting the *gross load impacts* to account for free ridership and free drivership. This analysis resulted in a set of net-to-gross ratios for use in converting *gross load impacts* to the *net load impacts* attributable to the program.

The analysis utilized data: 97 CEEI participant records, SCE billing file records, weather data, and information collected during on-site surveys, decision-maker surveys and end-use metering. These data elements were used to develop engineering estimates of savings by end use for each surveyed site. The engineering savings estimates were developed from DOE-2 simulations and standard engineering algorithms. These engineering estimates, along with billing and weather data, were then used in the statistically adjusted engineering (SAE) analysis. This analysis yielded statistical adjustment rates as well as ex post adjusted gross savings by end use. The net-to-gross analysis was completed using the efficiency modeling approach, which involves statistically modeling efficiency choices in terms of program participation and other determinants. The results of the net-to-gross analysis are net-to-gross factors and estimates of net realized savings by end use.

ES.5 Preview of Results

Adjusted gross savings estimates for sites with HVAC, process, and indoor lighting measures were developed in this study. In conformance with Table C-9 of the CPUC Protocols for miscellaneous measures, estimates for sites with exit signs and/or outdoor lighting but with no indoor lighting, and for sites with refrigeration measures only are reported using SCE's reported *ex ante* estimates and net-to-gross ratios.[1]

Figure ES-1 presents a summary of the estimated program energy and demand savings. Included in the table are statistically adjusted gross savings and net savings by end use for energy and demand impacts.

- ***Energy.*** Annual statistically adjusted gross savings were estimated to be nearly 91 GWh. This is roughly 77% of SCE's gross verified *ex ante* savings estimate. Net program savings were estimated to be 84.5 GWh, which is 88% of SCE's net verified energy savings.
- ***Demand.*** Adjusted gross peak demand savings are 10.9 MW, approximately 90% of SCE's gross verified demand savings. Net program demand savings are estimated to be 10.3 MW, roughly 7% higher than SCE's net verified demand savings.

Reasons for the lower energy and higher demand savings estimates will be discussed in Sections 4 and 5 of this report.

[1] Feeder tables in SCE's AEAP filing.

Figure ES-1: Summary of Estimated Program Savings by End Use (kWh)

Program Measure	SCE Ex Ante Gross Verified Savings (kWh)	SCE Net Verified Savings (kWh)	RER Statistically Adjusted Gross Savings (kWh)	RER Statistically Adjusted Net Savings (kWh)
Lighting				
Indoor Ltg.	*40,675,037*		*32,370,017*	*31,075,216*
LED Ltg. Only	*824,610*		*824,610*	*634,950*
Outdoor Ltg. Only	*501,023*		*501,023*	*385,788*
Total Lighting	***42,000,670***	***32,338,709***	***33,695,650***	***32,095,954***
HVAC	46,843,033	40,285,008	28,925,614	25,743,796
Miscellaneous				
Process	21,412,329	17,129,863	20,707,979	20,707,979
Refrigeration	6,704,788	5,363,830	6,704,788	5,363,830
Pumping	760,068	608,054	760,068	608,054
All	**117,720,887**	**95,725,465**	**90,794,098**	**84,519,613**

Figure ES-2: Summary of Estimated Program Savings by End Use (kW)

Program Measure	SCE Ex Ante Gross Verified Savings (kW)	SCE Net Verified Savings (kW)	RER Statistically Adjusted Gross Savings (kW)	RER Statistically Adjusted Net Savings (kW)
Lighting				
Indoor Ltg.	*7,662*	*5,900*	*7,266*	*6,976*
LED Ltg. Only	*100*	*77*	*100*	*77*
Outdoor Ltg. Only	*0*	*0*	*0*	*0*
Total Lighting	***7,762***	***5,977***	***7,366***	***7,053***
HVAC	4,074	3,504	2,035	1,811
Miscellaneous				
Process	174	139	1,430	1,430
Refrigeration	20	16	20	16
Pumping	17	13	17	13
All	**12,047**	**9,649**	**10,868**	**10,323**

1

Introduction

1.1 Introduction

This report presents an impact evaluation of Southern California Edison's (SCE) 1997 Commercial Energy Efficiency Incentive Program. Regional Economic Research, Inc. (RER) conducted the analysis under contract to SCE. Ms. Shahana Samiullah was SCE's Project Manager. ASW Engineering Management Consultants, Inc. (ASW) conducted the on-site and decision-maker surveys.

The remainder of this section defines the study objectives, describes the program, discusses general evaluation issues, provides an overview of the data and methodology used in the study, presents a summary of the results, and previews the remainder of the study.

1.2 Study Objectives

This project focused on the analysis of the gross and net energy and demand impacts of the 1997 Commercial Energy Efficient Incentive Program (97 CEEI). An extensive integrated database was developed using data from several sources, including billing and weather records, program records, on-site surveys, and engineering analyses. A statistically adjusted engineering model was estimated with data on both participants and nonparticipants, and a net-to-gross analysis was used to derive net program savings.

At the start of the project, a number of key objectives were established. These included the following:

- To estimate the gross and net energy and demand impacts of the program at the whole-building and end-use levels,
- To produce estimates as described in Table 6 of the *Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand-Side Management Programs* (CPUC Protocols), as adopted by the California Public Utilities Commission (D-93-05-063) and revised January 1997, and
- To produce documentation as described in Table 7 of the CPUC Protocols.

The approach used in the study was well suited to the achievement of these objectives.

1.3 Program Description

SCE's 1997 CEEI Program provided monetary incentives to commercial customers for installing certain energy-efficient equipment as part of a retrofit program. Incentives were divided into 1) customized system incentives, based on the cost and expected savings of the retrofit, and 2) mail-in rebates. Measures eligible for customized financial incentives include the following:

- Efficient plant improvements, which are retrofits consisting of customized process-specific enhancing measures,
- Retrofits of air compressors and air compressor systems,
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- Improvements in chilled water systems, including chillers, chilled water pumps, condenser pumps, cooling towers, and air handling distribution systems,
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- Supermarket Energy Optimization (SEO), which applies to most aspects of food stores including lighting, space conditioning, and commercial refrigeration,
- Variable speed drives (VSD) designed to provide energy savings for hydraulic pumping systems in agricultural and water service uses, and
- Indoor and outdoor lighting system replacements and modifications, daylight system controls and delampling.

Mail-in rebate coupons were available for the following lighting and HVAC upgrades:

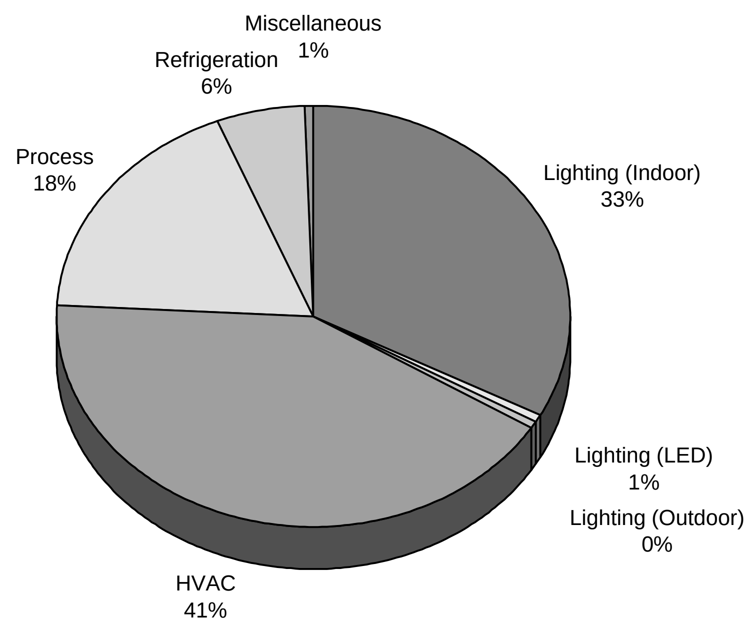
- LED exit signs, and
- Packaged air conditioning units and heat pump units exceeding certain efficiency ratings.

Although some of the categories were designed for specific sectors (e.g., industrial relighting), participants in other sectors (like commercial customers) were permitted on occasion to apply for these category-specific incentives.

There were roughly 514 coupons written under SCE's 1997 Energy Efficiency Incentive Program for commercial, industrial and agricultural customers. These coupons were written not only for individual sites but also for companies with chain outlets and multiple accounts at the same sites. As part of this study, these coupons were identified as covering 1,044 different sites.[1] Of these, 318 coupons representing 875 sites were identified as participants in the 97 CEEI.

The CPUC Protocols[2] require evaluation of indoor lighting and HVAC end uses. Evaluation is required for additional end uses as necessary to account for at least 85% of the program savings. Hence, for the 97 CEEI, this included indoor lighting, HVAC and process measures.[3] The measures installed in the 97 CEEI were predominantly VSDs for motors and space conditioning equipment, EMS for space conditioning and lighting, and indoor lighting system modifications. SCE's total estimate of verified net program savings for commercial customers in the 97 CEEI is 95,725 MWh and 9.65 MW. Figure 1-1 presents the proportional distribution of SCE's verified net program savings by end use.

Figure 1-1: Verified Ex Ante Net Savings by End Use in 97 CEEI



1 A site is defined as a premise or premises served by a single account or group of accounts where the service name is the same, and the premise or premises are on the same side of the street and/or share the same transformer.

2 See *Protocols and Procedures for the Verification of Costs, Benefits and Shareholder Earnings from Demand-Side Management Programs*, as adopted by California Public Utilities Commission Decision 93-05-063, January 1997, Table C-4 and C-9.

3 While process is a miscellaneous measure in the feeder sheets to Table E-2 and Table E-3, it is included in the study as it is part of the measures making up 85 percent of program savings.

1.4 General Evaluation Issues

Defining Energy Efficiency

A portion of the evaluation of any demand-side management (DSM) program focuses on the different choices of energy efficiency made by participants and nonparticipants. Defining energy efficiency for participants and nonparticipants requires reference points. In this study, energy efficiency was measured relative to compliance with building and appliance efficiency requirements. This does not mean that standards comprise the overall baseline for the evaluation; they merely comprise convenient intermediate baselines for the gross savings analysis.

Defining Ex Ante Gross, Ex Post Gross, and Ex Post Net Program Impacts

The CPUC Protocols refer to gross and net impacts and comment on *ex ante* and *ex post* estimates of savings. Some confusion can be avoided if clear definitions are adopted of three concepts: *ex ante* gross impacts, *ex post* adjusted gross impacts, and net impacts. In the remainder of this report, these terms are used in the following ways:

- ***Ex ante gross savings*** are those submitted by SCE in its first-year earnings claim. These *ex ante* savings estimates are restricted to measures adopted through the program and are expected on the basis of prior assumptions on the behavior of direct program participants.
- ***Ex post adjusted gross savings*** are those estimated after the fact and are based on actual observations on the behavior of direct program participants. They are *ex post* in the sense that they have somehow been "verified" after the fact. They are "adjusted" in the sense that they have been reconciled against actual changes in energy consumption. As will be explained, these estimates of adjusted gross savings are developed using a method that involves both engineering and statistical analyses. For measures covered by the program, these statistically adjusted savings estimates might differ from the *ex ante* gross estimates because of the assumptions underlying the *ex ante* estimates. Like *ex ante* estimates, gross *ex post* program impacts can be derived explicitly for measures adopted through the program. However, we also estimate statistically adjusted savings stemming from other program-eligible DSM activities conducted by both participants and nonparticipants, since these estimates will be needed for the net-to-gross analysis.
- ***Ex Post Net impacts*** are those savings actually attributable to the program. They can differ from adjusted gross savings because of free ridership and free drivership. In this context, *free ridership* would indicate that some of the measures adopted through the program would have been adopted in the absence of the program. Free drivership can take two forms. *Participant free drivership* would be conveyed through the adoption of measures by participants (in participating or nonparticipating buildings) outside the program. *Nonparticipant free drivership* could also operate through the program's influence on measure adoptions for nonparticipating buildings. As shown in the remainder of this report, net impacts

were defined as statistically adjusted gross savings corrected for the effects of free ridership. These estimates also capture the part of free-drivership consisting of non-rebated activities in participating buildings.

1.5 Data

The integrated database used in the evaluation of the 97 CEEI has five major elements.

- ***Survey Data.*** On-site survey data were collected for 291 participant and 200 nonparticipant commercial sites. Decision-maker survey data were collected for 234 participants and 185 nonparticipants. End-use metered data were also collected for some lighting and HVAC measures.
- ***Participant File Data.*** These data include 97 CEEI program records for all participating commercial sites.
- ***Billing Data.*** Consumption histories were collected from the SCE billing frame for the surveyed participant and nonparticipant sites.
- ***Weather Data.*** This includes actual weather data from the SCE weather stations and typical meteorological year (TMY) data from CEC weather zones.
- ***Engineering Estimates.*** DOE-2 simulations and other standard engineering algorithms were used to develop engineering estimates of savings from data collected during the on-site surveys and from data in the participant files.

These data were used to develop an integrated database containing information for 491 sites.

1.6 Overview of Approach

The overall methodology was designed to comply with both the principles of good evaluation and the stipulations of the CPUC Protocols. The methodology consisted of the elements described below.

- ***On-Site Survey.*** An on-site survey was conducted to collect information on participants and nonparticipants. This information included detailed information on DSM measures installed over the study period, as well as changes in equipment stocks, building characteristics, operating schedules, and occupancy rates. The completed on-site surveys included 291 participants and 200 nonparticipants. The collection of end-use metered data at key sites was included to supplement the survey data.
- ***Decision-Maker Survey.*** A decision-maker survey was conducted to support the analysis of the net influence of the program on DSM behavior. The survey was completed for a sample of 234 participants and 185 nonparticipants. Not all sites responded to the decision-maker survey due to 1) their unwillingness to take the time, or 2) the unavailability of an appropriate decision maker.

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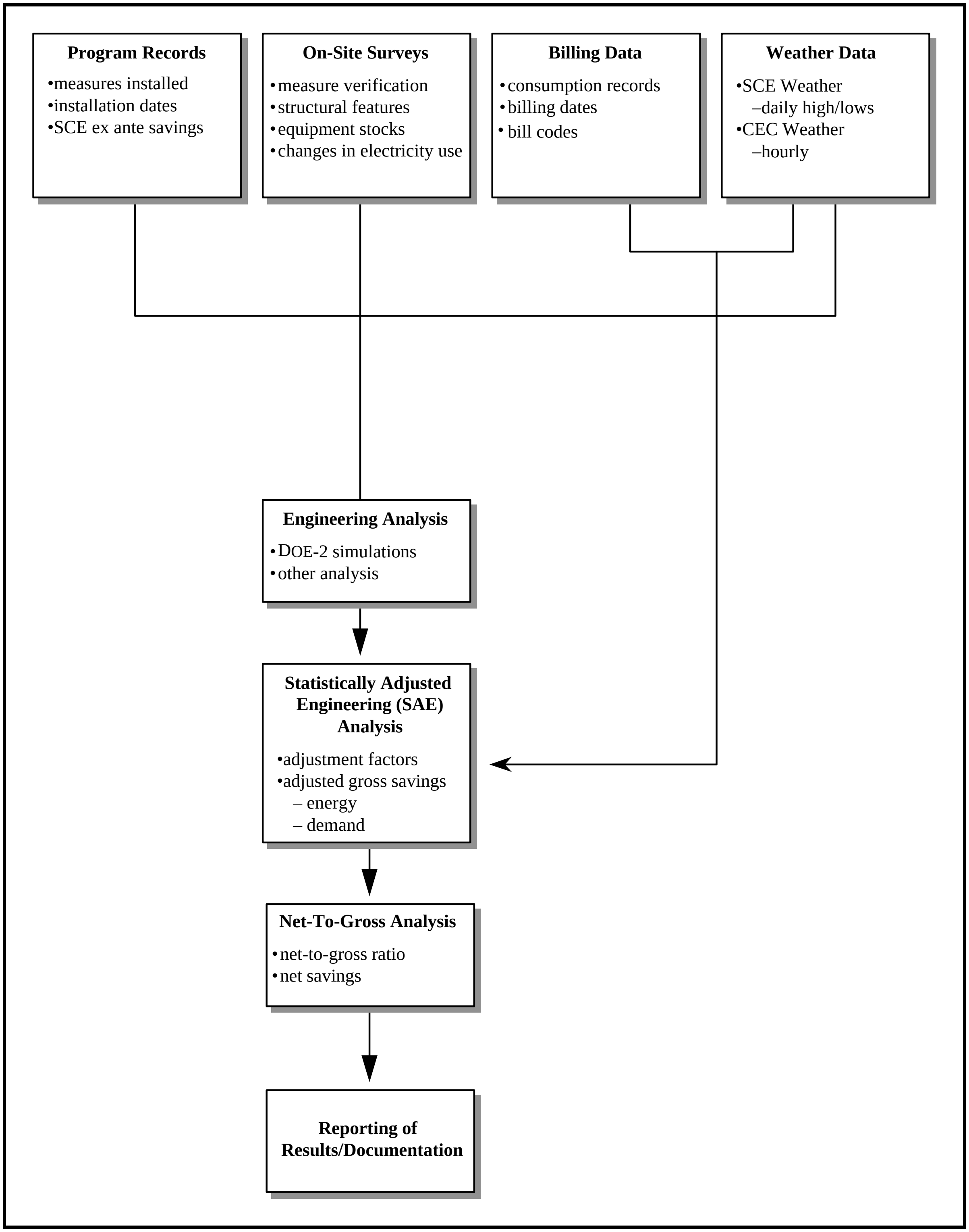
- ***Statistically Adjusted Engineering Analysis.*** The statistically adjusted engineering (SAE) analysis is a means of statistically reconciling engineering estimates obtained from the engineering analysis with observed changes in energy consumption. It is applied as a reconciliation step in the estimation of *gross load impacts*, and leads to estimates of *ex post adjusted gross savings*. The SAE model is designed to control for non-program historical effects like changes in weather, structural alterations, and modifications of operating hours, and it is specified in a way that recognizes variations in timing of adoptions of measures within and across sites. SAE analysis is a form of load impact regression analysis and clearly satisfies the CPUC Protocols.
- ***Efficiency Choice Analysis.*** A set of efficiency models was developed to discern the influence of the program on adoptions of energy measures. *Net load impacts* are those that are attributable to the program. They are typically derived through correcting the *gross load impacts* to account for free ridership and free drivership. This analysis resulted in a set of net-to-gross ratios for use in converting *gross load impacts* to the *net load impacts* attributable to the program.

Figure 1-2 presents an overview of the impact evaluation approach. As shown, the analysis utilized four types of primary data: 1997 CEEI participant records, data collected during the on-site surveys, SCE billing file records, and weather data. These data elements were used to develop engineering estimates of savings by end use for each surveyed site. The engineering savings estimates were developed from DOE-2 simulations and standard engineering algorithms. These engineering estimates, along with billing and weather data, were then used in the SAE analysis, yielding statistical adjustment coefficients as well as adjusted gross savings by end use.

The net-to-gross analysis used the efficiency modeling approach, which involves statistically modeling efficiency choices in terms of program participation and other determinants. A set of net-to-gross ratios was developed reflecting both free-ridership and participant free-drivership effects. This approach accounts for the nature of the retrofit program.[4] The results of the net-to-gross analysis are net-to-gross factors and estimates of net impacts by end use.

[4] Approximately 95% of program savings are due to retrofit measures.

Figure 1-2: Overview of Impact Evaluation Approach



1.7 Preview of Results

Adjusted gross savings estimates for sites with HVAC, process, and indoor lighting measures were developed in this study. In conformance with Table C-9 of the CPUC Protocols for miscellaneous measures, estimates for sites with exit signs and/or outdoor lighting but with no indoor lighting, and for sites with refrigeration measures only are reported using SCE's reported *ex ante* estimates and net-to-gross ratios.[5]

Table 1-1 presents a summary of the estimated program energy and demand savings. Included in the table are statistically adjusted gross savings and net savings by end use for energy and demand impacts.

- ***Energy.*** Annual statistically adjusted gross savings were estimated to be nearly 91 GWh. This is roughly 77% of SCE's gross verified *ex ante* savings estimate. Net program savings were estimated to be 84.5 GWh, which is 88% of SCE's net verified energy savings.
- ***Demand.*** Adjusted gross peak demand savings are 10.9 MW, approximately 90% of SCE's gross verified demand savings. Net program demand savings are estimated to be 10.3 MW, roughly 7% higher than SCE's net verified demand savings.

Reasons for the lower energy and higher demand savings estimates will be discussed in Sections 4 and 5 of this report.

5 Feeder tables in SCE's AEP filing.

Table 1-1: Summary of Estimated Program Savings by End Use (kWh)

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Table 1-2: Summary of Estimated Program Savings by End Use (kW)

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Total Lighting	***7,762***	***5,977***	***7,366***	***7,053***
HVAC	4,074	3,504	2,035	1,811
Miscellaneous				
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Refrigeration	20	16	20	16
Pumping	17	13	17	13
All	**12,047**	**9,649**	**10,868**	**10,323**

1.8 Organization of the Report

The remainder of this report is organized as follows:

- Section 2 describes the sample design, data collection and data integration process used in the study analysis.
- Section 3 provides a discussion of the engineering estimates developed for use in the analysis.
- Section 4 provides a general description of the SAE approach, the specific model, and presents the gross statistically adjusted savings.
- Section 5 describes the net-to-gross analysis and presents the net statistically adjusted energy and demand savings.
- Appendix A contains a copy of the on-site survey instrument.
- Appendix B contains copies of the decision-maker surveys for participants and nonparticipants.
- Appendix C contains site information sheets and the program participation coupon.
- Appendix D compares RER and SCE engineering estimates of savings.
- Appendix E summarizes weather data.
- Appendix F contains a description of the on-site metered HVAC data.
- Appendix G provides an overview of the SITEPRO system.
- Appendix H presents the regulatory tables.

2

Data

2.1 Overview

This section describes the sample design, survey design and implementation, and construction of the integrated database used in the evaluation of SCE's 1997 Commercial Energy Efficiency Incentive Program (97 CEEI). The sample design consists of the development of a participant and nonparticipant sample for the on-site audit, decision-maker survey and end-use metering data collection, and is discussed in Section 2.2. Section 2.3 presents the design and implementation of the on-site and decision maker surveys. The survey disposition and the development of expansion weights are also presented in this section. Integration of the database for the statistically adjusted engineering analysis is presented in Section 2.4.

2.2 Sample Design

This section discusses the development of a participant frame and sample, a nonparticipant frame and sample, and an end-use metering sample. The sample design used a *modified census* approach for participants who installed HVAC, indoor lighting and process measures and a completed sample of 200 nonparticipants matched to participants by building type and annual consumption level. The participant and nonparticipant sampling plans are described below.

Participant Frame and Sample

The first steps of the participant sampling plan were to define the unit of sampling and the sample frame.

Sampling Unit. The sampling unit (site) was defined to be a premise or premises served by a single account or group of accounts where the service name is the same, and the premise or premises are on the same side of the street, and/or share the same transformer. This definition is consistent with SCE's streetwalk algorithm.[1]

[1] *Rebuild of Custloc, Modification of Streetwalk to Include Customer Names*, J. Peterson, SCE internal memo, February 1997. Sites for this study were aggregated based on streetwalk identifier *GRP2IDX*.

Sample Frame. The 1997 Energy Efficiency Incentive program participant database of 514 coupons was screened to include only commercial customers.[2] The coupons are identified by CIR[3] number and there are three types of participant coupons: regular, multiple, and chain.

- ***Regular.*** These coupons cover sites that have only a single service account. Sites for regular accounts were identified by mapping service accounts to the streetwalk identifier on the SCE billing frame.
- ***Multiple.*** These coupons cover situations where there are multiple sites with one or more service accounts all in the same general location. Good examples of multiple accounts are a mall or an office complex. Sites for multiple coupons were developed by identifying all service accounts associated with each coupon and mapping these to the streetwalk identifier on the SCE billing frame. This process required a review of the hard copy coupon data by RER and SCE program staff.
- ***Chain.*** Coupons written for chains are characterized by a single coupon covering many site accounts—all of which are at different locations. Good examples of a chain coupon are chain grocery stores and chain drug stores. These coupons were handled in the same manner as multiple accounts. Again, a case-by-case review by RER and SCE program staff was made to ensure all sites and accounts associated with each chain coupon were identified.

Given the sampling unit as defined above, each of the 318 commercial coupons was evaluated to identify sites and to verify service account numbers, locations, and savings. In the process, common sites were identified and aggregated. In particular, cases where more than one regular coupon was written for the same site, or where a regular coupon was written for a chain or multiple sites, were aggregated. In some cases, SCE was asked to provide additional data and/or accounts to complete the database.

The following screens were then applied to these sites to develop the sample frame of participant coupons.

- ***HVAC, Indoor Lighting, and Process Measures.*** The database was screened to include only sites that installed an HVAC, indoor lighting, or process measure. This approach is consistent with the requirements of the CPUC protocols.[4]

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[2] The screening was accomplished by 1) including all observations where the variable *IND_CLSS* was coded "C," 2) eliminating coupon number 4, which was found to be an industrial site incorrectly labeled as commercial, and 3) adding coupon number 782, which is in fact a commercial site but was incorrectly coded in the database. This resulted in a database of 318 coupons.

[3] CIR is the Customer Incentive Reference number.

[4] The protocols require evaluation of installations representing 85% of program savings. See *Protocols and Procedures for the Verification of Costs, Benefits and Shareholder Earnings from Demand-Side*

- ***LED Exit Signs.*** Sites that installed only LED exit sign measures were screened from the database.

This resulted in a sample frame of 289 coupons representing 731 participating sites that had HVAC, indoor lighting, or process measures installed under the program. Table 2-1 summarizes the screening process.

Table 2-1: Summary of Participant Screening Process

Screen	Coupons	Sites
Include commercial sites only	318	875
Include sites with HVAC, indoor lighting, or process installations only	303	823
Omit sites that have only LED exit sign installations	289	731

For purposes of developing a comparable nonparticipant sample, the participant sample frame was stratified by building type.[5] A summary, by building type (ten types), of the final participant frame is presented in Table 2-2.

Management Programs, as adopted by California Public Utilities Commission Decision 93-05-063, January 1997, Table C-4 and Table C-9.

5 Building types based on facility SIC codes were provided by SCE for each meter. For site with multiple meters, the building type associated with the meter having the highest annual consumption was assigned to the site.

Table 2-2: Participant Sample Frame by Building Type

Building Type	Population	Percent
Offices	110	15.0
Restaurants	22	3.0
Retail	169	23.1
Food Stores	116	15.9
Warehouses	12	1.6
K-12 Schools	168	23.0
Colleges/Universities	16	2.2
Hospitals/Clinics	31	4.2
Hotels/Motels	28	3.8
Miscellaneous	59	8.1
Total	**731**	**100.0**

To develop the participant sample, a census was attempted of all sites except chain or multiple groups with more than three sites; in these cases, the groups were sampled. A completed sample size of 300 was desired. Using a response rate of 90%,[6] a sample consisting of 334 sites was selected.

To derive this sample, the following procedure was utilized:

- All sites represented by regular coupons were selected.
- Of the sites with chain or multiple coupons, those chain or multiple groups that contained three or fewer sites were selected.

As a result of this procedure, 242 sites with selected. Another 92 sites were needed to complete the sample of 334. The remaining 487[7] sites to select from consisted of 294 chain sites and 193 multiple sites. Two of the chain store groups were divided into store types. In one case, this was based upon a store-type indicator, and in the other case, it was based upon types of installed measures.

6 Derived from survey responses from the 1996 Commercial Energy Management Hardware Rebate Program Impact Evaluation.

7 CIR 577, a large government agency with two sites, was dropped from the sample at the customer's request to SCE's representative.

The remaining sample of 92 sites were selected proportionally across groups of chain or multiple sites on the basis of savings per site using the following criteria:

- A minimum of three sites were chosen from each chain or multiple group, with two exceptions:
  - First, for groups with ten or fewer sites, two sites were chosen from the group, and
  - Second, for groups with fewer than three sites, all of the sites were included.
- For the three groups with the largest savings, fewer sites were selected. This determination was made based on the homogeneous nature of the sites in these groups, consistencies of installation of measures across sites, and previous experience using a similar process in other studies. Further, for two groups with a mixture of measures across sites, we increased the number of sites selected.

This method would have been sufficient to derive the needed sites; however, sites from groups that represent school districts could not be chosen in this manner due to the problem of not being able to allocate savings across the individual schools in each district. The difficulty entailed 1) not knowing which installations to verify at any one school, and 2) not having a way to expand the sampled results to the population. For these reasons, it was decided to regroup schools and non-schools separately. For non-school groups, the above procedure was employed. These results are summarized in Table 2-3. For school groups, three school districts were chosen to represent all schools, as shown in Table 2-4.

Table 2-3: Non-Schools in Multiple and Chain Sample Selection

No. of Sites	Total Savings	Savings per Site	No. Sites Selected
28	10,212,987	364,750	9
27	7,863,336	291,235	7
8	2,448,820	306,103	4
38	2,266,054	59,633	3
5	1,868,729	373,746	5
42	1,826,244	43,482	3
47	1,178,096	26,180	3
33	1,033,230	31,310	3
23	709,527	30,849	3
14	833,139	59,510	4
8	350,744	43,843	2
11	316,800	28,800	3
17	253,777	14,928	3
9	128,321	14,258	2
5	95,067	19,013	2
1	14,071	14,071	1
316	**31,398,942**	**1,721,711**	**57**

Table 2-4: School Districts in Multiple and Chain Sample Selection

No. of Sites	Total Savings	Savings per Site	No. Sites Selected
34	1,269,004	37,324	0
22	816,150	37,098	0
12	535,453	44,621	12
15	500,457	33,364	15
31	320,847	10,350	0
8	188,157	23,520	0
17	144,949	8,526	0
12	120,083	10,007	0
6	108,333	18,056	0
8	85,712	12,245	8
6	34,074	5,679	0
171	**4,123,219**	**240,790**	**35**

The final participant sample is presented by building type in Table 2-5. The completed sample was expected to be 90% of this size, for a total of 300 sites.

Table 2-5: Final Participant Sample by Building Type

Building Type	No. Sites	Percent
Offices	90	26.9
Restaurants	7	2.1
Retail	30	9.0
Food Stores	31	9.3
Warehouses	12	3.6
K-12 Schools	50	15.0
Colleges/Universities	14	4.2
Hospitals/Clinics	31	9.3
Hotels/Motels	26	7.8
Miscellaneous	43	12.9
Total	**334**	**100.0**

For purposes of sampling a comparable nonparticipant group, the participant sample was also stratified by annual pre-program consumption (high and low).[8] The high-low break points were derived using the following approach:[9]

- ***Offices (1,000 MWh).*** Large offices are considered to be 50,000 square feet or more with an annual intensity of 20 kWh per square foot.
- ***Restaurants (150 MWh).*** Large restaurants are assumed to be greater than 2,500 square feet with an average annual intensity of 60 kWh per square foot.
- ***Retail (500 MWh).*** Large retail sites are considered to be more than 30,000 square feet with an annual intensity of roughly 17 kWh per square foot.
- ***Food Stores (1,000 MWh).*** Large food stores are assumed to be larger than 20,000 square feet with an annual intensity of 50 kWh per square foot.

8 Pre-program participation consumption data were used to develop estimates of annual consumption. For the majority of sites, 1996 consumption data were used. For sites with incomplete 1996 data, 1997 data was used.

9 Annual intensities were consistent with annual averages developed in the Commercial Data Development Handbook, EPRI, 1993.

- ***Warehouse (500 MWh).*** Large warehouses are assumed to be larger than 20,000 square feet with an annual intensity of 25 kWh per square foot.
- ***K-12 Schools (500 MWh).*** Large K-12 schools are assumed to be greater than 50,000 square feet with an annual intensity of 10 kWh per square foot.
- ***Colleges and Universities (500 MWh).*** Large colleges and universities were assumed to be greater than 50,000 square feet with an annual intensity of 10 kW per square foot.
- ***Hospitals and Clinics (2,500 MWh).*** Inspection of the participant data revealed a clear break point in the participant data between what appear to be small clinics and hospitals. This break point implies that large hospitals and clinics are greater than 125,000 square feet with an annual intensity of 20 kWh per square foot.
- ***Hotels and Motels (500 MWh).*** Large motels are assumed to be greater than 33,333 square feet with an annual intensity of 15 kWh per square foot.
- ***Miscellaneous (1,000 MWh).*** Large miscellaneous sites are assumed to be greater than 66,000 square feet with an annual intensity of 15 kWh per square foot.

Table 2-6 presents a summary of the participant sample by annual consumption level and building type.

Table 2-6: Participant Sample

Building Type	KWh Strata	Sample	Percent
Office	High (> 1,000 MWh)	52	15.57
	Low (<= 1,000 MWh)	38	11.38
Restaurant	High (> 150 MWh)	6	1.80
	Low (<= 150 MWh)	1	0.30
Retail	High (> 600 MWh)	17	5.09
	Low (<= 600 MWh)	13	3.89
Food Stores	High (> 1,000 MWh)	16	4.79
	Low (<= 1,000 MWh)	15	4.49
Warehouse	High (> 500 MWh)	8	2.40
	Low (<= 500 MWh)	4	1.20
K-12 Schools	High (> 500 MWh)	14	4.19
	Low (<= 500 MWh)	36	10.78
College/University	High (> 500 MWh)	10	2.99
	Low (<= 500 MWh)	4	1.20
Hospital/Clinics	High (> 2,500 MWh)	12	3.59
	Low (<= 2,500 MWh)	19	5.69
Hotel/Motel	High (> 500 MWh)	9	2.69
	Low (<= 500 MWh)	17	5.09
Miscellaneous	High (> 1,000 MWh)	18	5.39
	Low (<= 1,000 MWh)	25	7.49
Total	**High**	**162**	**48.50**
	Low	**172**	**51.50**
	ALL	**334**	**100.00**

Nonparticipant Frame and Sample

The nonparticipant sample design required a completed sample size of 200 sites. A database was supplied by SCE containing sites developed by SCE staff from the streetwalk identifiers on the SCE billing frame.[10] All accounts associated with each site were grouped using a single identifier. The frame used for the nonparticipants is a *screened* list of commercial sites. In particular, the following two screens were applied. Any sites associated with a screened account were omitted from the nonparticipant frame.

Screen 1. Accounts[11] on the SCE commercial billing frame were screened by the following criteria:

- Duplicate account numbers,
- Not open in May 1998,[12]
- Missing a streetwalk identifier, and
- Insufficient billing data.[13]

Screen 2. Accounts that survived Screen 1 were then screened on the site level by the following criteria:

- Missing at least one commercial account,[14]
- Participation in 1997 CEEI,[15]
- Site contains an account payable by SCE,
- Participation in 1997 audit,
- Participation in 1997 major/large customer surveys,
- Participation in 1997 mass market survey,
- Participation in 1996 DSM Bidding program, and
- Sites marked “do not contact.”

The process resulted in a database of nonparticipant 285,981 sites. Table 2-7 presents a summary of the nonparticipant frame by building type.

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[10] The database consisted of 487,962 sites.

[11] For the first screen, the database was analyzed at the *PREMNO9* account level.

[12] An open account was designated by the variable *STAT9805* equal to one.

[13] Sufficient billing data was assumed if some positive quantity of 1996 or 1997 consumption existed, or, if not, a positive quantity of billing days existed in the year ending April 1998 and the last bill date recorded was March or April of 1998.

[14] In addition, all noncommercial *PREMNO9* accounts were omitted from the remaining sites.

[15] The participants were identified from the participant database provided by SCE (CIRSADDR). This was used for screening instead of the *REB97* variable (which was provided on the initial database and was used last year) because it was found that the *REB97* variable did not identify all participants.

Table 2-7: Summary of Nonparticipant Frame

Building Type	All Sites	Screen 1	Screen 2	Percent
Office	96,943	90,349	86,517	30.3
Restaurant	20,493	20,373	20,011	7.0
Retail	41,268	40,604	39,747	13.9
Food Stores	10,802	10,940	10,224	3.6
Warehouse	18,544	18,919	18,660	6.5
K-12 Schools	5,357	5,344	4,374	1.5
College/University	1,736	1,813	1,678	0.6
Hospital/Clinics	2,801	2,750	2,564	0.9
Hotel/Motel	2,848	2,729	2,568	0.9
Miscellaneous	287,170	249,889	99,638	34.8
Total	**487,962**	**443,710**	**285,981**	**100.0**

The nonparticipant sample was drawn from the frame in the same proportion by building type and annual consumption as participants.[16] Table 2-8 summarizes the nonparticipant sample frame and sample targets. Assuming a response rate of 33%, a database of three times the target number of sites in each category of building type and consumption level was given to ASW.

16 The distribution of all participant sites by building type is presented in Table 2-5.

Table 2-8: Summary of Nonparticipant Frame and Completed Sample Targets

Building Type	kWh Strata	All Sites	Target	Percent
Office	High (> 1,000 MWh)	544	16	8.21
	Low (<= 1,000 MWh)	85,973	14	6.84
Restaurant	High (> 150 MWh)	1,314	5	2.60
	Low (<= 150 MWh)	18,697	1	0.41
Retail	High (> 500 MWh)	1,132	26	13.13
	Low (<= 500 MWh)	38,615	20	9.99
Food Stores	High (> 1,000 MWh)	126	21	10.53
	Low (<= 1,000 MWh)	10,098	11	5.34
Warehouse	High (> 500 MWh)	167	2	1.09
	Low (<= 500 MWh)	18,493	1	0.55
K-12 Schools	High (> 500 MWh)	281	7	3.69
	Low (<= 500 MWh)	4,093	39	19.29
College/University	High (> 500 MWh)	44	3	1.37
	Low (<= 500 MWh)	1,634	2	0.82
Hospital/Clinics	High (> 2,500 MWh)	35	3	1.64
	Low (<= 2,500 MWh)	2,529	5	2.60
Hotel/Motel	High (> 500 MWh)	199	2	1.23
	Low (<= 500 MWh)	2,369	5	2.60
Miscellaneous	High (> 1,000 MWh)	455	6	2.74
	Low (<= 1,000 MWh)	99,183	11	5.34
Total	**High**	**4,297**	**91**	**46.24**
	Low	**281,684**	**109**	**53.76**
	ALL	**285,981**	**200**	**100.00**

Replace on Burnout or Net Acquisition

A final issue in the development of the nonparticipant sample design is the adequacy of the nonparticipant sample in representing *replace-on-burnout* (ROB) and net acquisition activities. DSM actions can be broken into five types: new construction, major renovations, retrofit decisions, replace-on-burnout, and net equipment acquisitions. We assume that new construction and major remodels will be channeled through SCE's new construction program, and will ignore them in this study. *Retrofit decisions* involve pre-failure replacement of energy-using equipment or installation of devices that influence the way in which host equipment uses energy. These decisions are made continuously, and require only the presence of the energy-using equipment. The sample design developed above should ensure the adequate representation of nonparticipants facing the important retrofit measures covered by the program. In order to support the analysis of net program impacts on decisions involving *replace-on-burnout or net acquisition of energy-using equipment* (e.g., chillers or packaged air conditioning units), however, it is necessary to have a sample of nonparticipants who faced these decisions over the relevant time period. A simple random sample would be unlikely to yield an adequate number of nonparticipants facing some such decisions. Thus, some means of targeting this sample was necessary. The methods used to identify these customers included the following:

- ***Customer Representatives.*** Some equipment replacements tend to be fairly major events, and would probably be noted by SCE's customer representatives (although those recognized by representatives are also highly likely to be pulled into the program). The SCE management staff contacted customer representatives to uncover prospects.
- ***Trade Allies.*** A limited number of equipment vendors were tapped as a source of information on recent purchases of energy-using equipment covered by the program.

Using these methods, we were able to develop a list of eight sites[17] that completed a chiller retrofit during the 1997 program year.

End-Use Metering Sample

The end-use metering sample design was structured around expected savings. In particular, the expected savings by measure for the 731 participant sites were calculated. A sample of 10 HVAC and 15 lighting sites was then distributed across measures by percent of total savings. Table 2-9 and Table 2-10 summarize the break out of the metering sample by

[17] A large air conditioning and heating manufacturer in Southern California identified these sites. The SCE customer representatives did supply information relating to sites that had completed retrofit type decision (mainly lighting retrofits). However, the SCE representatives were unable to provide data on replace-on-burnout sites.

measure type and end use for lighting and HVAC, respectively. Within each measure type, sites were recruited by total savings, with larger sites being recruited first. This was done until strata targets were reached.

Table 2-9: End-Use Metering Sample Design – HVAC Measures

Measure	Savings	% Savings	Sample
Adj. Speed Drive, (HVAC)	17,105,674	36.35	4
Air Distribution System	301,791	0.64	0
Chilled Water Controls	621,283	1.32	0
Chillers	6,086,977	12.94	1
Component	124,956	0.26	0
Cooling Tower	247,003	0.52	0
Economy Cycle	2,932,217	6.23	1
EMS (Space Conditioning)	17,305,847	36.77	4
Misc. (Space Conditioning)	1,928,913	4.10	0
Motors (HVAC)-Three Phase	409,574	0.87	0
Total	**47,064,235**	**100.00**	**10**

Table 2-10: End-Use Metering Sample Design – Lighting Measures

Measure	Savings	% Savings	Sample
Component-Delamping	2,017,720	5.19	1
Daylighting Systems	6,259	0.02	0
Energy Management Sys. (Lighting)	9,153,977	23.55	3
Indoor Ltg. Sys. Modif. & Replace	25,942,233	66.73	10
Timeclock/Occupancy Sensors	1,756,835	4.52	1
Total	**38,877,024**	**100.00**	**15**

2.3 Survey Design and Implementation

This section describes the following:

- The design and implementation of the on-site survey,
- The design and implementation of the decision-maker survey,
- The end-use monitoring,
- Survey dispositions, and
- Weighting.

On-Site Survey

Survey Design

An on-site survey questionnaire was designed to satisfy three objectives:

- To assess the implementation of eligible and non-eligible measures,[18]
- To collect current information on the facility to support the analysis of energy usage and realized DSM impacts, and
- To ascertain site changes that could affect energy usage over the period covered by the billing analysis.

The on-site instrument is comprehensive in addressing facility characteristics, modes and schedules of operation, and electrical and mechanical systems. The level of information derived from on-site characteristics depends to some extent on the uses of the data. In this study, the survey instrument focused primarily on site features that were particularly relevant to the performance of the DSM measures. For lighting measures, emphasis was placed on inventories, controls, and hours of operation. For HVAC measures, the focus was on equipment features, operating schedules, and general building characteristics.

The survey was designed to also collect information on changes at the site so that billing analyses could be designed to control for these changes in the course of assessing adjusted gross impacts. These changes include changes in equipment stocks, structural alterations, changes in occupancy rates and schedules, and DSM activities outside the program.

Specifically, the survey instrument asks questions on the following business characteristics:

- Industry type,
- Year established,
- Building specifications,

[18] Eligible measures include all measures covered by the 97 CEEI that were installed by at least one 1997 participant.

- Major changes and renovations at the site after 1995,
- Operating schedules,
- Usage characteristics, and
- Verification of equipment used before and after retrofitting.

Survey Pre-testing

The on-site survey was pre-tested on a sample of nine participating sites by ASW Engineering Management Consultants, Inc. (ASW). These nine sites were mutually agreed upon by the project manager, RER and ASW. RER supplied ASW with a list of 37 participants that represented the full range of conservation project types. ASW completed on-site visits for four sites with HVAC conservation measures and five with indoor lighting measures. The pre-test on-site surveys were performed by ASW engineers who documented questions and observations on the survey instrument. Further, the engineers noted any additional information that should be included in the survey.

RER and ASW project staff reviewed the pre-test results from the perspective of their ultimate use in assessing energy loads and impacts. A number of relatively minor changes were subsequently made to the on-site survey instrument. A copy of the final on-site survey instrument is provided in Appendix A. [19]

Survey Implementation

ASW personnel conducted and implemented the on-site surveys. Their efforts included the following:

- Preparing the data collection instrument,
- Selecting and training field staff,
- Scheduling on-site visits,
- Reviewing program documentation,
- Collecting characteristic data on site,
- Conducting end-use monitoring, and
- Coding and verifying the data collected.

The on-site data collection effort was completed by ASW. ASW's field staff for the on-site data collection effort consisted of experienced staff engineers and highly qualified energy surveyors who have collected data for on-site data collection projects for SCE and other utilities. Each member of the field staff has considerable experience in collecting data on end-uses in a variety of commercial and industrial facilities. Training sessions were held at

[19] A draft on-site survey instrument was designed by ASW and RER. Copies were sent to SCE staff for comments and edits that were then incorporated into the final version.

ASW's offices to instruct field staff in requirements specific to the 97 CEEI on-site survey effort.

Scheduling of visits were handled by an ASW staff member who has considerable experience in this area. That individual made contact with the customer, explained the purpose of the visit, screened prospective sites for targeted activities (replacements and acquisitions), and arranged the date and time of the data collection visit.

After the survey visits were scheduled, ASW prepared a timetable and other particulars for the on-site visits. These included the names and locations of the businesses visited, the contact persons at the businesses and their telephone numbers, and the dates and times planned for the visits. This information was used to administer and manage the data collection effort. Weekly copies of scheduling status reports were sent to the SCE project manager as part of project management and reporting.

Prior to any site visit, ASW's field staff reviewed the documentation for the site.[20] The program coupons were reviewed by the analysis engineers and compared to the SCE database to assess the measures for which data needed to be collected and to verify the information in the SCE program database. Information verified included building square footage, addition and remodel areas if applicable, building type, and program measures. Special attention was given to distinguishing rebated[21] measures *versus* recommended measures. A complete list and description of the rebated and recommended measures were provided to the surveyor. During the on-site survey, the surveyor verified the installation of the rebated measures and assessed whether the recommended measures were in good working order.

During the on-site data collection visit, the field staff accomplished two major things. First, they verified that the measures that were rebated were indeed installed, that they were installed correctly, and that they still function properly. Second, they collected the data needed to analyze the energy savings that have been realized from the installed measures.

To verify that measures have been installed and that the installation has been done correctly, ASW's field staff examined the following:

- For lighting measures, ASW checked and verifyed the installation of light bulbs, ballasts, reflectors, and controls. ASW also estimated lighting levels.

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[20] A site-specific summary sheet containing all relevant data will be developed by RER. RER provided these sheets, SCE program records, and 1997 Commercial Energy Efficiency Incentive Coupons to ASW. Examples of these sheets and the program coupons are presented in Appendix C.

[21] Rebated measures include all measures installed by participants for which a financial incentive or rebate was received under 97 CEEI.

- For HVAC measures of packaged systems, ASW obtained nameplate information for the installed equipment. Using this information, ASW later obtained the manufacturer's data on efficiencies, which was then checked against the efficiency claimed on the application. For measures that apply to built-up systems, ASW checked fan and pump motors to verify their efficiency and capability for variable speed drive.
- For motors, information pertaining to efficiency was obtained from nameplates.
- For control measures, ASW checked for proper installation and enumerated the type and number of control points installed.

In some cases, the survey team worked with site management and with the installation contractor to establish that installed measures were indeed working properly.

As the second aspect of the on-site visit, data were collected on a wide variety of other factors that affect energy use by end-uses. Data on these factors were needed in order to analyze and to verify the energy savings of rebated measures.

- For lighting, important factors include the numbers and types of fixtures, lamps, and ballasts, and the usage patterns for lighting in different parts of a site. Outside lighting was surveyed as part of this effort.
- For space cooling, energy use varies according to the type of cooling equipment and distribution systems and depends more on a building's type, size, age, and structural characteristics and on weather conditions.

Data were also needed that pertain to the present pattern of and recent changes in energy use at a site. To support this component of the survey, RER provided ASW with energy-use histories for each site. Data for 12 previous months (if available) were used in order to establish any seasonal aspects in the pattern of energy use, as well as to identify major changes in usage that could be linked to structural, operational or other factors.

Data was collected from several sources during the on-site visit.

- ***Interview with Facility (Site) Staff.*** Data was collected first through interviews with the staff of the site. The interview with site staff provided information on occupancy schedules, lighting schedules, ventilation schedules, equipment schedules, operational practices, maintenance practices, and a number of other "human factors" that are associated with energy use at the site. These data also cover general decision-making criteria.
- ***Review Site-Specific Documentation.*** Surveyors also reviewed documents or records at the site, including basic building plans and dimensions from structural and architectural drawings (if available) and wall, window, roof, and floor material characteristics from architectural drawings. These data also include

information on HVAC systems and equipment, on lighting, and on hot water systems from mechanical, electrical, and plumbing plans.

- ***Visual Inspection.*** Visual inspections were made of control settings, lighting levels, inventory of end-use appliances and equipment, ventilation rates, building population, occupancy level, and other parameters.

Photographs of a site and of its electrical and mechanical systems were also taken during the on-site visit. Our experience has been that photographs taken during a visit are a highly useful means of verifying the data that are collected.

ASW used a number of quality control procedures throughout the on-site data collection effort to ensure that the data collected were of high quality. As the survey progressed, each completed data collection form was thoroughly reviewed by our field staff supervisor. Care was taken to make sure a form was completely filled out and that the data collected were of acceptable quality. Other checking procedures were used once the data has been entered into the database management system.

Completed data collection forms were coded and verified in ASW's offices. In-house data entry staff were provided guidelines on items to check for possible inconsistencies in response and were given procedures for following up on missing responses and apparently inconsistent answers. After a completed data collection form had been coded, the data was entered into a computerized database.

Completed Sample Structure

Table 2-11 and Table 2-12 present an overview of the completed sample as compared to the target for participants and nonparticipants, respectively. Each table includes the number of completed surveys for each building type and strata, in addition to the strata target.

Table 2-11: Completed Participant Sample for On-site Survey

Building Type	kWh Strata	All Sites	Targeted		Completed	
			No.	Percent	No.	Percent
Office	High (> 1,000 MWh)	544	52	15.57	49	16.84
	Low (<= 1,000 MWh)	85,973	38	11.38	33	11.34
Restaurant	High (> 150 MWh)	1,314	6	1.80	6	2.06
	Low (<= 150 MWh)	18,697	1	0.30	1	0.34
Retail	High (> 600 MWh)	1,132	17	5.09	7	2.41
	Low (<= 600 MWh)	38,615	13	3.89	6	2.06
Food Stores	High (> 1,000 MWh)	126	16	4.79	16	5.50
	Low (<= 1,000 MWh)	10,098	15	4.49	15	5.15
Warehouse	High (> 500 MWh)	167	8	2.40	7	2.41
	Low (<= 500 MWh)	18,493	4	1.20	3	1.03
K-12 Schools	High (> 500 MWh)	281	14	4.19	13	4.47
	Low (<= 500 MWh)	4,093	36	10.78	35	12.03
College/ University	High (> 500 MWh)	44	10	2.99	5	1.72
	Low (<= 500 MWh)	1,634	4	1.20	3	1.03
Hospitals/ Clinics	High (> 2,500 MWh)	35	12	3.59	8	2.75
	Low (<= 2,500 MWh)	2,529	19	5.69	18	6.19
Hotel/Motel	High (> 500 MWh)	199	9	2.69	8	2.75
	Low (<= 500 MWh)	2,369	17	5.09	18	6.19
Misc.	High (> 1,000 MWh)	455	18	5.39	15	5.15
	Low (<= 1,000 MWh)	99,183	25	7.49	25	8.59
Total	**High**	**4,297**	**162**	**48.50**	**134**	**46.05**
	Low	**281,684**	**172**	**51.50**	**157**	**53.95**
	ALL	**285,981**	**334**	**100.00**	**291**	**100.00**

Table 2-12: Completed Nonparticipant Sample for On-site Survey

Building Type	kWh Strata	All Sites	Targeted		Completed	
			No.	Percent	No.	Percent
Office	High (> 1,000 MWh)	544	16	8.21	17	8.50
	Low (<= 1,000 MWh)	85,973	14	6.84	14	7.00
Restaurant	High (> 150 MWh)	1,314	5	2.60	5	2.50
	Low (<= 150 MWh)	18,697	1	0.41	1	0.50
Retail	High (> 600 MWh)	1,132	26	13.13	26	13.00
	Low (<= 600 MWh)	38,615	20	9.99	20	10.00
Food Stores	High (> 1,000 MWh)	126	21	10.53	21	10.50
	Low (<= 1,000 MWh)	10,098	11	5.34	11	5.50
Warehouse	High (> 500 MWh)	167	2	1.09	2	1.00
	Low (<= 500 MWh)	18,493	1	0.55	1	0.50
K-12 Schools	High (> 500 MWh)	281	7	3.69	7	3.50
	Low (<= 500 MWh)	4,093	39	19.29	39	19.50
College/ University	High (> 500 MWh)	44	3	1.37	3	1.50
	Low (<= 500 MWh)	1,634	2	0.82	2	1.00
Hospitals/ Clinics	High (> 2,500 MWh)	35	3	1.64	3	1.50
	Low (<= 2,500 MWh)	2,529	5	2.60	5	2.50
Hotels/ Motels	High (> 500 MWh)	199	2	1.23	2	1.00
	Low (<= 500 MWh)	2,369	5	2.60	5	2.50
Misc.	High (> 1,000 MWh)	455	6	2.74	6	3.00
	Low (<= 1,000 MWh)	99,183	11	5.34	10	5.00
Total	**High**	**4,297**	**91**	**46.24**	**92**	**46.00**
	Low	**281,684**	**109**	**53.76**	**108**	**54.00**
	ALL	**285,981**	**200**	**100.00**	**200**	**100.00**

Decision-Maker Survey

Survey Design

A decision-maker survey was designed to collect information on energy efficiency decisions to be used in the net-to-gross analysis. The questions included in this survey were designed to ascertain the attitudes and perceptions relating to energy use and choice of energy using equipment by the key decision makers. The survey included a series of pre-screening questions to ensure that a qualified decision maker was interviewed.

Survey Pre-Testing

Concurrent with the pre-testing of the on-site survey, ASW staff also pre-tested the decision-maker survey. A copy of the final participant and nonparticipant surveys are provided in Appendix B.

Survey Implementation

The decision-maker survey was administered by ASW during the scheduling portion of the on-site survey. [22] If the appropriate decision maker was not available or unidentified, the survey was administered at the time of the audit. In a limited number of cases, the appropriate decision maker was identified at the time of the on-site and the decision-maker survey was administered in a follow up telephone interview.

Completed Sample Structure

The completed sample consists of 234 participants and 185 nonparticipants. Fewer decision-maker surveys were completed than on-site surveys. One reason for the lower response rate is the unwillingness on the part of some sites to spend the time to answer the survey. Another reason is the unavailability of an appropriate decision maker. Table 2-13 and Table 2-14 present an overview of the completed sample of participants and nonparticipants, respectively. Each table includes the number of completed surveys for each building type and strata.

[22] Special questions and protocols were used to qualify the customer before conducting the decision-maker survey. These protocols were put in place to assure that a qualified representative from each site would answer the decision-maker survey.

Table 2-13: Completed Participant Sample for Decision-Maker Survey

Building Type	kWh Strata	Completed	
		No.	Percent
Office	High (> 1,000 MWh)	36	15.38
	Low (<= 1,000 MWh)	27	11.54
Restaurant	High (> 150 MWh)	3	1.28
	Low (<= 150 MWh)	1	0.43
Retail	High (> 600 MWh)	14	5.98
	Low (<= 600 MWh)	13	5.56
Food Stores	High (> 1,000 MWh)	6	2.56
	Low (<= 1,000 MWh)	10	4.27
Warehouse	High (> 500 MWh)	6	2.56
	Low (<= 500 MWh)	2	0.85
K-12 Schools	High (> 500 MWh)	12	5.13
	Low (<= 500 MWh)	27	11.54
College/ University	High (> 500 MWh)	4	1.71
	Low (<= 500 MWh)	3	1.28
Hospitals/ Clinics	High (> 2,500 MWh)	7	2.99
	Low (<= 2,500 MWh)	8	3.42
Hotel/Motel	High (> 500 MWh)	5	2.14
	Low (<= 500 MWh)	14	5.98
Misc.	High (> 1,000 MWh)	14	5.98
	Low (<= 1,000 MWh)	22	9.40
Total	**High**	**107**	**45.73**
	Low	**127**	**54.27**
	ALL	**234**	**100.00**

Table 2-14: Completed Nonparticipant Sample for Decision-Maker Survey

		Completed	
Building Type	**kWh Strata**	**No.**	**Percent**
Office	High (> 1,000 MWh)	16	8.65
	Low (<= 1,000 MWh)	14	7.57
Restaurant	High (> 150 MWh)	5	2.70
	Low (<= 150 MWh)	1	0.54
Retail	High (> 600 MWh)	23	12.43
	Low (<= 600 MWh)	20	10.81
Food	High (> 1,000 MWh)	12	6.49
Stores	Low (<= 1,000 MWh)	11	5.95
Warehouse	High (> 500 MWh)	2	1.08
	Low (<= 500 MWh)	1	0.54
K-12	High (> 500 MWh)	7	3.78
Schools	Low (<= 500 MWh)	38	20.54
College/	High (> 500 MWh)	3	1.62
University	Low (<= 500 MWh)	2	1.08
Hospitals/	High (> 2,500 MWh)	3	1.62
Clinics	Low (<= 2,500 MWh)	5	2.70
Hotels/	High (> 500 MWh)	2	1.08
Motels	Low (<= 500 MWh)	5	2.70
Misc.	High (> 1,000 MWh)	5	2.70
	Low (<= 1,000 MWh)	10	5.41
Total	**High**	**78**	**42.16**
	Low	**107**	**57.84**
	ALL	**185**	**100.00**

End-Use Monitoring Implementation

To supplement the on-site data collection, end-use metering of 22 measures (9 HVAC and 13 lighting measures) was conducted at 20 sites. The monitoring data was used to obtain information on operating hours and other important factors for lighting and HVAC measures.

Procedures for Monitoring Lighting. For lighting measures, ASW monitored the post-retrofit hours of operation as the basis for calculating lighting efficiency savings. For this monitoring of lighting operating hours, ASW used Time-of-Use (TOU) data loggers. The TOU loggers provided a time profile of on-off usage and therefore allowed the calculation of kWh usage according to peak/off-peak periods. (In practice, the loggers sense when a fixture is on by detecting the light emitted from a fixture when it is operating.)

For each facility with lighting efficiency measures that was selected for monitoring, we developed a sampling plan for monitoring a sample of "last points of control" for retrofitted fixtures in different types of usage areas to determine average operating hours of such fixtures. The degree of homogeneity among fixtures within a defined usage area should be high, thus requiring that only a few fixtures be monitored to determine hours of operation. However, there should be some degree of variation in operating hours among usage areas.

Procedures for Monitoring HVAC. ASW's approach for HVAC monitoring involved (1) making one-time measurements of voltage, current, and power factor of the motor, and (2) conducting continuous measurements of amps over a period of time in order to obtain the data needed to develop motor load profiles and calculate demand and energy savings.

One-time measurements required the use of portable or hand held measurement equipment. Measurements of voltage, current, and power factor were made on the motor in question. The power was calculated from the one-time measurements.

Survey Dispositions

Participants

Of the originally targeted 300 sites, 15 were represented by a large drug store chain. This chain participant opted to provide essential site information for 133 of its sites rather than allowing a detailed on-site data collection for a sample of 15 sites. This change modified the target sample to 285, and on-site surveys were completed for 291 sites.

Nonparticipants

Table 2-15 presents a summary of the disposition of each sampled nonparticipant site. The survey protocol required that a maximum of four contact attempts be made to each sample site. As shown, 268 sites were contacted and a total of 390 calls were made in order to obtain a survey group of 200[23] nonparticipants. These results yield a response rate of 75%.

[23] An additional nine sites are shown as completed; these were deemed unusable and subsequently not used in the analysis.

Table 2-15: Disposition of Nonparticipant On-Site Survey Contacts

Disposition	First Call	Second Call	Third Call	Fourth Call	Total
Completed Survey	165	21	15	8	209
Scheduled Callback	2	3	1	8	14
Left Message	35	25	15	1	76
Busy	1	1	1	3	6
Answering Machine	4	1	1	0	6
No Answer	7	1	5	0	13
Call Back Later	14	10	1	0	25
Over Quota	1	1	0	0	2
Wrong Number	6	0	0	0	6
Initial Refusal	18	0	0	0	18
Mid-Terminate	2	0	0	0	2
Business/Fax	1	0	0	0	1
Disconnected Number	12	0	0	0	12
Total	268	63	39	20	390

Weighting

Participant Weights

A set of case weights was used to expand *ex post* adjusted gross savings from the sample to the population in absolute terms and per square foot. These weights were calculated for each building type and consumption strata and are discussed below and presented in Table 2-16.[24]

SCE *ex ante* gross savings were used to derive participant case weights (*partCaswt*) by building type (*b*) and pre-participation annual consumption levels (*c*). The participant case weight needs to account for the attempted census of regular accounts and the sampling of school and non-school multiple and chain accounts. Specifically,

$$(1) \quad partCaswt_{b,c} = \frac{exantesav(partpopulation)_{b,c}}{exantesav(partsample)_{b,c}}$$

[24] Note that similar weights were derived with SCE *ex ante* gross demand savings to expand estimated kW savings.

where *exantesav(partpopulation)* are the *ex ante* gross savings of the participant population, and *exantesav(partsample)*, the *ex ante* gross savings from the completed sample of participants, is defined below.

$$(2)\quad exantesav(partsample)_{b,c} = exantesav(regular)_{b,c} + exantesav(schlmultchn)_{b,c}\frac{exantesav(popschl)}{exantesav(sampschl)} + \sum_m exantesav(nschlmultchn\_mtyp_m)_{b,c}\frac{exantesav(popmtyp_m)_{b,c}}{exantesav(sampmtyp_m)_{b,c}}$$

where *exantesav(regular)* are the *ex ante* gross savings from the regular and multiple and chain accounts with fewer than three sites. *Exantesav(schlmultchn)* are the *ex ante* gross savings from the completed sample of school multiple and chain accounts with more than three sites. These savings are weighted by the ratio of *ex ante* gross savings for the population school multiple and chain accounts (*exantesav(popschl)*) to *ex ante* gross savings from the completed sample of all school multiple and chain accounts (*exantesav(sampschl)*).[25] $Exantesav(nschlmultchn\_mtyp_m)$ are the *ex ante* gross savings from non-school multiple and chain accounts with measure type *m*.[26] These savings are weighted by the ratio of *ex ante* gross savings for the population of measure type *m* ($exantesav(popmtyp_m)$) to the *ex ante* gross savings for the completed sample of measure type *m* ($exantesav(sampmtyp_m)$).

The $partCasewt_{b,c}$ was then used to develop case weights for each of the sampled groups as described below.

$$(3)\quad Caswtreg_{b,c} = partCaswt_{b,c}$$

$$(4)\quad Caswtschl_{b,c} = partCaswt_{b,c}\frac{exantesav(popschl)}{exantesav(sampschl)}$$

$$(5)\quad (Caswtnonschl\_mtyp_m)_{b,c} = partCaswt_{b,c}\frac{exantesav(popmtyp_m)_{b,c}}{exantesav(sampmtyp_m)_{b,c}}$$

[25] The school multiple and chain accounts are presented in Table 2-4.
[26] The non-schools in chain and multiple sites are presented in Table 2-3.

where *Caswtreg* is the weight used for regular accounts, *Caswtschl* is the weight used for school accounts, and *Caswtnonschl_mtyp* is the weight used for non-school multiple and chain accounts of measure type *m*.

Table 2-16: Participant Case Weights

Building Type	kWh Strata	Sample Group	Case Weight
Office	High	Regular Accounts	1.14
		Non-school Multiple and Chain Accounts with Lighting	1.23
		Non-school Multiple and Chain Accounts with Lighting & HVAC	1.14
		Schools	4.14
	Low	Regular Accounts	1.07
		Non-school Multiple and Chain Accounts with Lighting & HVAC	1.07
		Schools	3.88
Restaurant	High	Regular Accounts	1.00
		Non-school Multiple and Chain Accounts with Lighting	6.73
	Low	Regular Accounts	52.71
Retail	High	Regular Accounts	1.10
		Non-school Multiple and Chain Accounts with Lighting	2.70
	Low	Regular Accounts	1.00
		Non-school Multiple and Chain Accounts with Lighting	6.32
Food Store	High	Regular Accounts	1.01
		Non-school Multiple and Chain Accounts with Lighting	21.04
		Non-school Multiple and Chain Accounts with HVAC & Refrig.	1.01
		Non-school Multiple and Chain Accounts with Lighting, HVAC & Refrig	3.18
	Low	Regular Accounts	1.00
		Non-school Multiple and Chain Accounts with Lighting	4.17
		Non-school Multiple and Chain Accounts with Lighting, HVAC & Refrig	2.52
Warehouse	High	Regular Accounts	1.04
	Low	Regular Accounts	1.00
K-12 School	High	Regular Accounts	1.11
		Schools	4.01
	Low	Regular Accounts	1.16
		Schools	4.22
College or University	High	Regular Accounts	1.16
	Low	Regular Accounts	1.13
Hospital or Clinic	High	Regular Accounts	1.08
	Low	Regular Accounts	1.10
Hotel or Motel	High	Regular Accounts	1.00
		Non-school Multiple and Chain Accounts with Lighting	1.00
	Low	Regular Accounts	1.08
		Non-school Multiple and Chain Accounts with Lighting	1.08
Misc.	High	Regular Accounts	1.24
	Low	Regular Accounts	1.07
		Non-school Multiple and Chain Accounts with Lighting	5.78

Nonparticipant Weights

A set of weights were developed to expand the nonparticipant sample to the population for use in the net-to-gross analysis discussed in Section 5.[27] The case weights for nonparticipants (*nonpartCaswt*) will be mean per unit by stratum (building type (*b*) and pre-participation annual consumption (*c*)). These relative case weights based on the nonparticipant frame will be further expanded to the population of nonparticipants using a mean per unit case weight.

$$(3) \quad nonpartCaswt_{b,c} = \frac{N_{b,c}}{nrandom_{b,c}} \times \frac{N_{nonpartpop}}{n_{frame}}$$

where $N_{b,c}$ is the frame count and $nrandom_{b,c}$ is the sample count from the random sample. $N_{nonpartpop}$ and n_{frame} are the population of nonparticipants and the total number of nonparticipant sites in the frame, respectively. Table 2-17 presents the nonparticipant case weights.

[27] The estimation of the participation model will necessitate the use of these case weights based on nonparticipant site counts for the implementation of weighted non-linear least squares.

Table 2-17: Nonparticipant Case Weights

Building Type	kWh Strata	Case Weight
Office	High	35
	Low	6,722
Restaurant	High	288
	Low	20,465
Retail	High	50
	Low	2,113
Food Store	High	7
	Low	1,005
Warehouse	High	91
	Low	20,242
K-12 School	High	44
	Low	115
College or University	High	16
	Low	894
Hospital or Clinic	High	13
	Low	554
Hotel or Motel	High	109
	Low	519
Misc.	High	83
	Low	10,856

2.4 Database Integration

Overview

The components required to construct the database are as follows:

- Program records,
- Survey data,
- Billing records,
- Weather data, and
- Engineering estimates.

The collection of survey data is described earlier in this section. A description of program records, billing records and weather data is presented below. Engineering estimates are presented in Section 3.

Program Records

Program data were provided by SCE at a measure level in hard-copy and computer-readable format. It was collapsed to the site level and used along with billing data to provide information sheets to ASW to facilitate the on-site surveys. Typical information provided included the following:

- Identification of the business,
- Building characteristics,
- Description of the installed measures,
- A listing of meters on the premises, and
- Estimated annual consumption.

Information from this database was used to produce summary sheets for each site. These summaries were given to ASW to facilitate the on-site surveys.[28]

In addition, SCE's reportable savings are part of the database. These have been summarized to the site level, and can also be further collapsed to end use. Table 2-18 and Table 2-19 show a breakdown of the savings by end use.

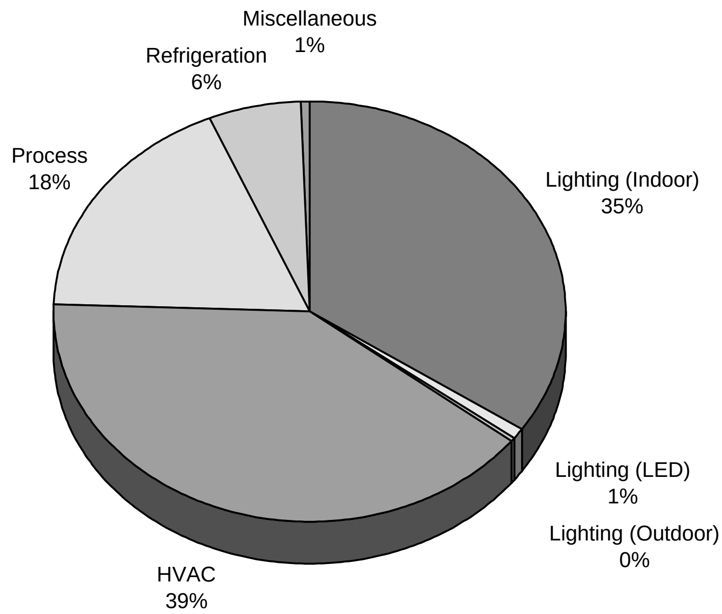
The measures installed in the 97 CEEI were predominantly VSDs for motors and space conditioning equipment, energy management systems for space conditioning, refrigeration and lighting, and indoor lighting modifications. SCE's ex ante gross estimates of savings for the 97 CEEI program were 118,276,788 kWh and 11,398 kW.

[28] A sample is in Appendix C.

Table 2-18: SCE Gross Ex-Ante Savings by Measure

Program Measure	Percentage of End Use	Ex-Ante Savings (kWh)	Ex-Ante Savings (kW)
Space Conditioning			
EMS	37	17,305,847	39
VSD	36	17,105,674	9
Chiller 600 – 2,000 ton	7	3,162,554	1,115
Economy cycle	6	2,932,217	24
Chiller 200 – 600 ton	5	2,350,338	936
Miscellaneous	4	1,928,913	285
Chilled water controls	1	621,283	23
Chiller 75 – 200 ton	1	563,087	371
Motors – 3 phase	1	409,574	889
Air Distribution System	1	301,791	11
Cooling Tower	1	247,003	54
A/C Units	0	124,956	92
Chiller < 75 tons	0	10,998	7
Lighting (Indoor)			
System Modification	51	20,619,485	5,427
EMS	23	9,153,977	0
System Replacement	13	5,322,748	1,282
Delamping	5	2,017,720	470
Occupancy Sensors	4	1,756,835	1
LED Exit Signs	4	1,432,899	164
Daylighting Systems	0	6,259	0
Lighting (Outdoor)			
System Replacement	84	1,585,209	0
System Modification	16	295,669	0
CFBS	0	8,204	0
Process			
VSD	53	11,370,220	0
Air Compressor System	16	3,364,998	2
Miscellaneous	13	2,765,094	0
Motors – 3 Phase	11	2,259,779	141
Pump System Controls	7	1,443,871	0
Air Compressor	1	196,527	22
EMS	1	112,953	0
Refrigeration			
EMS	83	5,595,864	0
Miscellaneous	10	673,080	19
Anti-Sweat Heater Control	4	258,405	0
VSD	3	209,100	0
Water Services			
VSD	100	763,657	16
Total		118,276,788	11,398

Figure 2-1: SCE Gross Ex-Ante Savings



Billing Records

SCE provided consumption data for participants and nonparticipants. This included billing cycle data for usage, meter numbers, read dates, and number of billing days by premise ID for the December 1995 through September 1998 period. This time period satisfies CPUC Protocols Table 5 Item D regarding required billing data.

The consumption data in the final database were derived directly from customer billing files. These billing records, while reasonably accurate, contained some anomalies that could have been troublesome in the analysis. The billing records of the sample were inspected closely for the following problems:

- Erroneous billing days and/or read dates,
- Abnormal monthly consumption, and
- Missing or zero electricity usage (the latter may indicate an inactive account).

Anomalies were found, including high reads, inconsistencies due to new accounts, and transfers of accounts to new tenants. Considerable time was spent with SCE to line up the consumption figures properly with the sites. This entailed checking individual meters on approximately 80 sites and adding or deleting meters from sites where appropriate.

Typical building intensities were compared to building intensities calculated from the data. Anomalies were investigated along with inconsistencies in square footage. This was done in some cases by examining audit records that included floor plans. In other cases, additional information was collected from the site. As a result, changes were made in the square footage of approximately 60 sites. Table 2-19 presents building intensities in the sample by building type and participant status for those sites where energy usage could be lined up with square footage.

Table 2-19: Summary of Average Building Intensities

Building Type	No. in Sample	Mean
Participants		
Offices	82	16
Restaurants	7	91
Retail Stores	13	15
Food Stores	31	52
Warehouses	10	11
K-12 Schools	48	9
Colleges & Universities	8	15
Hospitals & Clinics	26	21
Hotels & Motels	26	13
Miscellaneous	40	23
Subtotal Participants	291	
Nonparticipants		
Offices	31	30
Restaurants	6	51
Retail Stores	46	24
Food Stores	32	57
Warehouses	3	9
K-12 Schools	46	7
Colleges & Universities	5	17
Hospitals & Clinics	8	11
Hotels & Motels	7	13
Miscellaneous	16	21
Subtotal Nonparticipants	200	
Total	**491**	

Consumption data were merged with weather data by weather station number and bill date. The merged data were then calendarized using read dates and number of billing days in order to maintain consistency with the monthly engineering estimates of usage and savings.

Weather Data

Actual daily high and low temperatures by weather zone were obtained from SCE's weather files. The data covered the period January 1995 through September 1998 for each of 24 weather zones. Monthly high and low temperatures by weather zone were used to construct heating degree days (HDD) and cooling degree days (CDD).[29]

Typical meteorological year (TMY) weather data by California Energy Commission (CEC) weather zones were used as normal weather. A standard TMY of weather data is constructed by reviewing individual months of weather data from each weather station over a 23-year period. A typical month for each of the 12 calendar months from the long-term period of record is chosen and combined to form the TMY. Selection basis for a typical month consists of 13 daily indices calculated from the hourly values of dry-bulb and wet-bulb temperature, wind velocity, and solar radiation. Month/year combinations with statistics "close" to the long-term statistics are candidates for typical months. Final selection of a typical month includes consideration of persistence of weather patterns.

Figure 2-2 presents actual annual CDDs and HDDs averaged over all SCE weather stations represented in the evaluation sample during 1995, 1996, 1997 and 1998 compared with the average normal TMY HDD and CDD.

Weather data were merged with other database components by SCE weather station account numbers and read dates. Additional details on the weather data are described in Appendix E.

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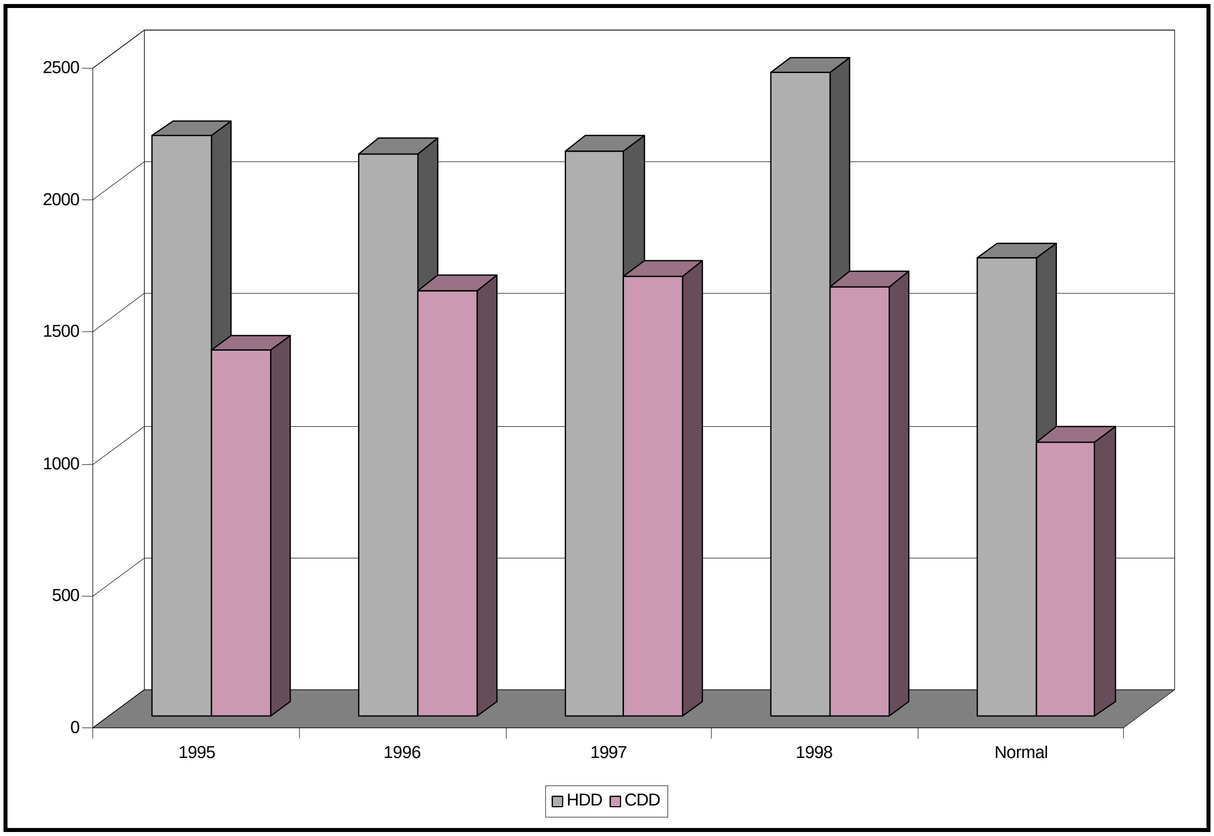
[29] Heating and cooling degree days are computed as follows:

HDD base 65 = max{0, (65 - daily average temperature)}

CDD base 65 = max{0, (daily average temperature - 65)}

daily average temperature = (daily maximum temperature + daily minimum temperature) / 2.

Figure 2-2: Annual HDD and CDD for 1995 - 1998



Data Transformations

RER staff worked with SCE to correct anomalies in the data by examining inconsistencies in billing data, square footage, and building intensities. Observations with strong influences on the SAE model estimations were identified and considered. These efforts resulted in the following modifications to the database used for the SAE analysis.

- Approximately 30 sites were omitted due to 1) the inability to line up billing meters with the surveyed and rebate-affected space, including sites with shared meters and sites where a small area was surveyed within a larger complex, or 2) meter change-outs and long periods of zero consumption or inconsistent patterns of consumption.
- Approximately 1,200 observations from the remaining sites were omitted due to anomalous consumption data. Specifically, these were unexplained patterns of increases or decreases in consumption that were inconsistent with other site characteristics.

- Two nonparticipant sites which were found to be parking lots were omitted.
- The aggregation of sites reduced the total number of sites by seven.[30]

It is important to note that although these sites were omitted from the SAE analysis, they were not deleted from the database. In determining net savings, they were included in the analysis since they contained valid engineering estimates of savings.

To ensure consistency across customer accounts with different read dates, the following data transformations were performed:

- Historical consumption and weather data were normalized to a 30.4-day billing period with the use of billing days and read dates.
- Weather data were converted to billing cycle degree-day measures with the use of billing days and meter read dates. In order to make these values consistent with the usage levels contained in billing records, degree days were also normalized to a 30.4-day billing period.

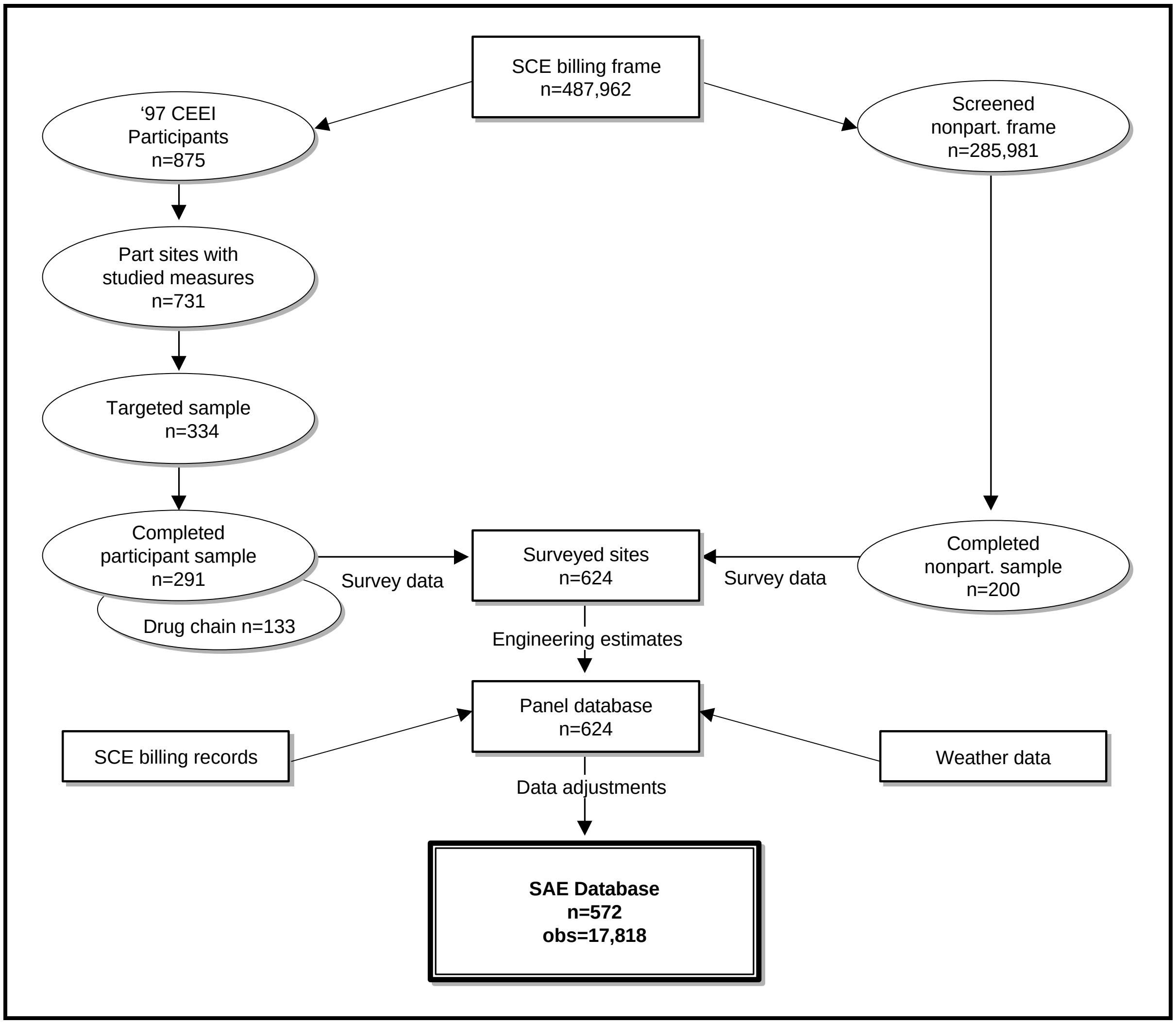
Final Database Structure

The data sections were merged by site identification number and time period into one integrated panel database. This final database contains unique (constant over time) site characteristics that have been "fanned out" with monthly consumption and weather data, thereby creating monthly observations for each site. The final integrated database used for the SAE analysis consists of 17,818 observations representing 572 commercial sites.[31] Figure 2-3 illustrates the development process.

[30] These are cases where, although two distinct GRPID2X numbers existed, the on-site audit determined them to be in fact one business location.

[31] A large drug store chain opted to provide information on 133 sites rather than allow on-site data collection for a sample of 15 sites. This increased the number of sites in the analysis database.

Figure 2-3: Database Integration



3

Engineering Estimates of Measure Savings

3.1 Overview

This section discusses the methods used to develop engineering estimates of savings by measure and site for all eligible and non-eligible DSM measures. In particular, the data collected were used to develop engineering estimates of the energy and demand savings of the various energy conservation measures installed by customers participating in the SCE Commercial Energy Efficiency Incentive Program ('97 CEEI). RER engineering estimates were developed from on-site survey data, SCE coupon materials, the latest monthly consumption and demand data provided by SCE, and on-site metered data. The major types of measures to be analyzed include the following:

- HVAC measures,
- Lighting measures,
- Process measures, and
- Refrigeration measures.

Four analysis scenarios were required to develop the three levels of monthly energy use and demand savings needed for the SAE analysis. The four analysis scenarios performed were:

- ***Post-Retrofit Usage.*** This scenario is the level of energy consumption (*POSTKWH*) and demand (*POSTKW*) corresponding to the current state (efficiency, size, hourly schedule, etc.) of the installed measures.
- ***Pre-Retrofit Usage.*** This scenario is the level of energy consumption (*PREKWH*) and demand (*PREKW*) corresponding to the state of the measure prior to the replacement and/or change reflected in the Post-Retrofit scenario.
- ***Rebated Baseline (Minimum Standard) Usage.*** This scenario is the level of energy consumption (*BASEKWH*) and demand (*BASEKW*) for rebated measures only, for which the state of the measure was set equal to national and/or state standards, if applicable (i.e. cooling efficiencies, motor efficiencies, etc.). The baseline state of other measures not affected by such standards was set to Pre-Retrofit conditions.
- ***Total (Rebated+Non-Rebated) Baseline (Minimum Standard) Usage.*** This scenario is the level of energy consumption (*TBASEKWH*) and demand

(*TBASEKW*) for all eligible measures, for which the state of the measure was set equal to national and/or state standards, if applicable (i.e. cooling efficiencies, motor efficiencies, etc.). The baseline state of other measures not affected by such standards was set to Pre-Retrofit conditions.

These levels of usage were used to develop the following savings estimates:

- ***Customer Savings.*** Customer energy ($KWHCUST_j$) and demand ($KWCUST_j$) savings for each measure (*j*) are the difference between pre- and post-energy consumption and demand, respectively. These are the savings that are expected in the customer's bill from each measure. Note that in the case of net new purchases this may be an increase in usage (pre-retrofit usage equals zero). Specifically,

  (5) $KWHCUST_j = PREKWH_j - POSTKWH_j$

  (6) $KWCUST_j = PREKW_j - POSTKW_j$

- ***Reportable Savings.***[1] Reportable energy ($KWHREP_j$) and demand ($KWREP_j$) savings is the difference between baseline and post-retrofit energy use and demand, respectively. These estimates are used to convert the estimates of statistically adjusted savings to the savings relative to code. Specifically,

  (7) $KWHREP_j = BASEKWHj - POSTKWH_j$

  (8) $KWREP_j = BASEKWj - POSTKW_j$

- ***Credited Savings.*** SCE uses the reportable savings as the basis for reporting program savings. However, in some instances the '97 CEEI is credited with only a portion of the reportable energy and demand savings. For example, in cases where lighting fixtures have been delamped and retrofit with high-efficiency lamps and ballasts, only the delamping is credited to the '97 CEEI, while the savings from the installation of high-efficiency lamps and ballasts are credited to another SCE program. Credited savings for each measure are reported and used to develop program savings.

A brief description of the development of these engineering estimates for each major type of measure is presented below.

[1] SCE uses the reportable savings as the basis for reporting program savings.

3.2 Lighting Savings Estimates

Analyzing the savings from lighting measures required data for retrofitted fixtures on (1) wattages before and after retrofit and (2) hours of operation. To determine these baseline and post-retrofit demand values for lighting efficiency measures, MARS data on standard wattages of lighting fixtures and ballasts were used.[2] These data provided information on wattages for common lamp and ballast combinations.

Energy Savings. Post-retrofit, pre-retrofit, rebated baseline, and total baseline[3] usage levels were calculated for each lighting measure. Per-fixture baseline demand, retrofit demand, and appropriate post-retrofit operating hours were used to calculate these annual energy consumption levels. These values were used to calculate customer, reportable, and credited savings, as defined above.

Peak Period Demand Savings. Peak period demand savings were derived similarly to energy savings. In particular, pre-retrofit, post-retrofit, and baseline peak demand levels were estimated. Baseline and post-installation average demands were calculated by dividing the total kWh usage during the peak period by the number of hours in the peak period. These pre-retrofit, post-retrofit, and baseline demand levels were then used to calculate customer, reportable, and credited peak demand savings.

On-Site Metered Lighting Data. The main objective for metering lighting was to obtain information about the post-retrofit operating hours and, indirectly, the percent of lights on for those lighting systems affected by the '97 CEEI. At each site where monitoring was implemented, up to 10 Time-of-Use (TOU) data loggers were installed by ASW to record on/off operation of individual lighting fixtures. Data loggers were placed, per a site-specific plan, to give a representive sample of overall site operation. The total fixture wattage for each metered fixture was also recorded. This data was used to examine on/off times for each fixture, and it also allowed rough calculations of kWh usage for peak/off-peak periods. Monitoring was conducted for a minimum of two continuous weeks.

Using the on-site metered lighting data, an adjustment factor for operating hours was derived. This entailed lining up areas of operation and building types and deriving a weighted average of lighting hours of operation for each type of area. Square footage was used to weight across building types. An adjustment factor was calculated as a ratio of metered hours to audited hours.

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2 SCE provided ASW with the version of MARS used by SCE staff to calculate savings from the '97 CEEI program.

3 A working assumption that sites need not meet system-wide density requirements, but must meet national equipment standards was used for lighting baseline estimates of usage and demand.

Table 3-1: Adjustment Factors for Lighting Hours Based on Metered Data

Area of Operation	Adjustment Factor
Classroom	1.00
Conditioned Storage	1.00
Cooking	1.22
Dining Room	0.90
Grocery	0.97
Hallway	0.98
Industrial Process	1.00
Lab	1.00
Library	1.00
Medical Exam Room	0.83
Office	0.86
Office common areas	1.19
Operating room	1.00
Other, Conditioned	1.00
Other, Unconditioned	1.00
Patient Room	1.00
Public Assembly	1.00
Repair, conditioned	1.00
Restroom	1.00
Retail	0.72

Secondary Lighting Impacts. In cases where there is electric space conditioning, secondary impacts from the installation of lighting measures were calculated. A secondary impact factor was derived using MARS data based on building type and size, location and operating hours. The results were then adjusted for monthly weather fluctuations using actual weather. These factors were applied to the energy ($KWHCUST_{lighting}$ *and* $KWHREP_{lighting}$) and demand ($KWCUST_{lighting}$ and $KWREP_{lighting}$) savings for sites based on whether or not they have electric space conditioning to derive a secondary impact.

3.3 HVAC, Process, and Refrigeration Measure Savings Estimates

HVAC, Process, and Refrigeration measure estimates of savings were developed with SITEPRO.[4] SITEPRO simulations were performed for every site where a change in any of these end uses was found during the on-site survey. Note that this included both rebated and non-rebated measures. Non-HVAC engineering estimates were provided directly by SITEPRO and HVAC estimates were generated by DOE-2. A more detailed description is presented in Appendix D.

4 A description of SITEPRO is provided in Appendix G.

HVAC Measures. Incentives have been provided for Variable Speed Drives (VSDs) for fan and pump applications, Energy Management Systems (EMS), chiller replacement, high-efficiency motors, high-efficiency package/rooftop units, and Custom HVAC measures. One or more of these measures could be present at any customer location. For example, a quite common combination was VSDs with an EMS. The information collected through the on-site survey and the program information database was used to develop "before" and "after" conditions for the rebated measures. The information on these conditions was then used to conduct a DOE-2 analysis of kWh and kW savings for each site receiving an HVAC related measure. Performance parameters for the rebated and non-rebated measures that were used in the Pre-Retrofit and Post-Retrofit runs were obtained from the on-site survey and from SCE coupon materials. Title 20 standards were reviewed to establish the performance parameters used for the baseline runs.[5] The building simulations were validated against billed monthly and annual energy use, and also against the on-site metered data, if available.

On-Site Metered HVAC Data. HVAC measures at eight sites were metered on-site. These measures included VSD controlled air handlers, chillers, and pumps, and space temperatures for EMS controlled systems. Up to three VSDs and three EMS zones per site were monitored. System Amps were monitored for VSD controlled equipment and temperatures were monitored for the EMS sites. Measurements were taken for a minimum of four continuous weeks. The on-site metered data were examined and used as a final check of the engineering assumptions and savings estimates.

Weather Data for HVAC Simulations. Typical Meteorological Year (TMY) weather data obtained from the California Energy Commission were used for the DOE-2 simulations. Although weather data is available for all 16 CEC climate zones, only eight climate zones relevant to the study were utilized for the simulations.[6]

Process Measures. The '97 CEEI program provided incentives to supermarkets for refrigeration and for process measures for some commercial customers including high-efficiency motors, VSDs, and custom motor measures. In most cases, estimates of pre-retrofit, post-retrofit, and baseline energy usage and demand were modeled in DOE-2. In instances where DOE-2 is unable to be used to derive impacts, engineering estimates of savings were developed using simplified engineering algorithms and data from product literature and previous studies of savings for these measures. Performance parameters for the rebated and non-rebated measures that were used in the Pre-Retrofit, Post-Retrofit, and

5 *Energy Efficiency Standards for Residential and Nonresidential Buildings*, California Energy Commission, July 1995 (Tables B-13 and B-14).

6 See Appendix E for more weather information.

baseline runs were obtained from the on-site survey, from SCE coupon materials, and from applicable motor standards.

Refrigeration Measures. Incentives were provided primarily for EMS control of anti-sweat heaters and floating head pressure, but also for VSD controlled condensers. Relevant performance parameters for the rebated and non-rebated measures that were used in the Pre-Retrofit, Post-Retrofit, and baseline runs were obtained from the on-site survey and from SCE coupon materials.

3.4 Summary of Engineering Estimates

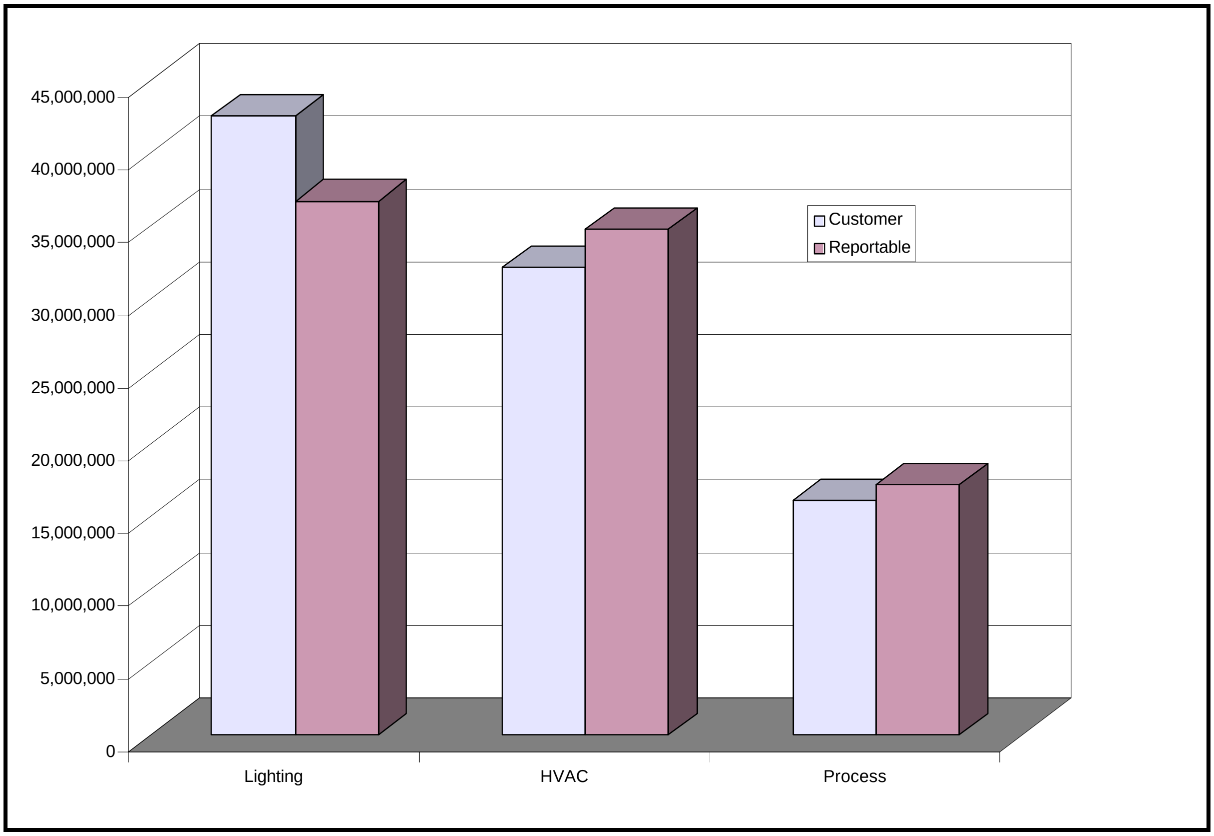
A summary of engineering estimates by end use and building type is presented in Table 3-2 and in Figure 3-1. Both customer and reportable savings estimates are presented and have been weighted to represent the population of participants.[7]

Table 3-2: Summary of Engineering Estimates of Energy Savings

	Lighting		HVAC		Process	
Building Type	**Customer (kWh)**	**Reportable (kWh)**	**Customer (kWh)**	**Reportable (kWh)**	**Customer (kWh)**	**Reportable (kWh)**
Offices	12,849,376	10,151,017	6,800,265	5,454,611	0	0
Restaurants	434,955	328,310	181,127	68,476	0	0
Retail Stores	2,834,134	3,645,630	52,717	4,710,882	0	0
Food Stores	6,996,876	6,718,078	4,010,125	4,010,125	0	0
Warehouses	1,749,532	1,565,633	0	0	(651,546)	465,559
K-12 Schools	9,007,550	7,111,545	744,071	242,617	0	0
Colleges	961,900	585,962	5,974,086	6,256,757	0	0
Hospitals	2,821,702	2,445,276	7,470,497	6,049,011	0	0
Hotels	1,367,881	1,224,691	704,402	724,147	0	0
Misc.	3,588,638	3,007,968	6,235,581	7,333,511	16,791,089	16,791,089
Total	**42,612,544**	**36,784,110**	**32,172,871**	**34,850,137**	**16,139,543**	**17,256,648**

7 Weights used are described in Section 2.3.

Figure 3-1: Savings Estimates by End Use



4

Statistically Adjusted Engineering Analysis

4.1 Introduction

This section presents the results of the analysis of *ex post adjusted gross savings*. The analysis consists of the application of the SAE approach, a means of calibrating engineering estimates of savings to changes in consumption, and controlling for other changes at the sites in question. Subsections 4.2 and 4.3 discuss the background of the analysis and provide a general description of the logic and application of the SAE approach. Subsection 4.4 discusses model specification and the estimation of the SAE model. The *ex post adjusted gross savings* developed from this analysis are presented in Subsection 4.5.

4.2 Background

Section 3 described how the engineering analyses were calibrated against billing and end-use metering data. Nonetheless, even calibrated engineering estimates ignore the possibility of *rebound*, or *snap-back, effects*. Moreover, they ignore the possibility that engineering biases might differ across levels of efficiency, in which case calibration to pre- or post-installation consumption and/or metering results will not fully calibrate estimates of *savings* derived from the engineering model. While calibrated engineering estimates can play an important role in the assessment of *ex post* gross program impacts, this approach will be supplemented with another statistical adjustment process termed the SAE approach.

The principal advantages of the SAE approach relative to other techniques are

- It can be used to estimate savings for individual energy efficiency measures or groups of measures,
- To the extent that it takes advantage of detailed engineering information, it increases the efficiency of the overall estimation process,
- It is relatively efficient in preserving degrees of freedom,
- It is amenable to the analysis of a heterogeneous set of program participants receiving a broad range of DSM measures, and
- It generates end-use-specific statistical adjustment rates that can be generalized and applied to engineering estimates developed for other comparable sites.

4.3 The General SAE Approach

General Logic and Model Specification

The SAE modeling process is illustrated in Figure 4-1. In this application, the model relates changes in energy consumption to conservation activities and a series of other factors. Prior engineering estimates of conservation impacts are included directly in the model. Other variables are included to control for installations of other (non-program) energy efficiency measures and changes in weather conditions, site square footage, occupancy, hours of operation, and other appliance stocks. For the purposes of this analysis, the SAE model is represented as:

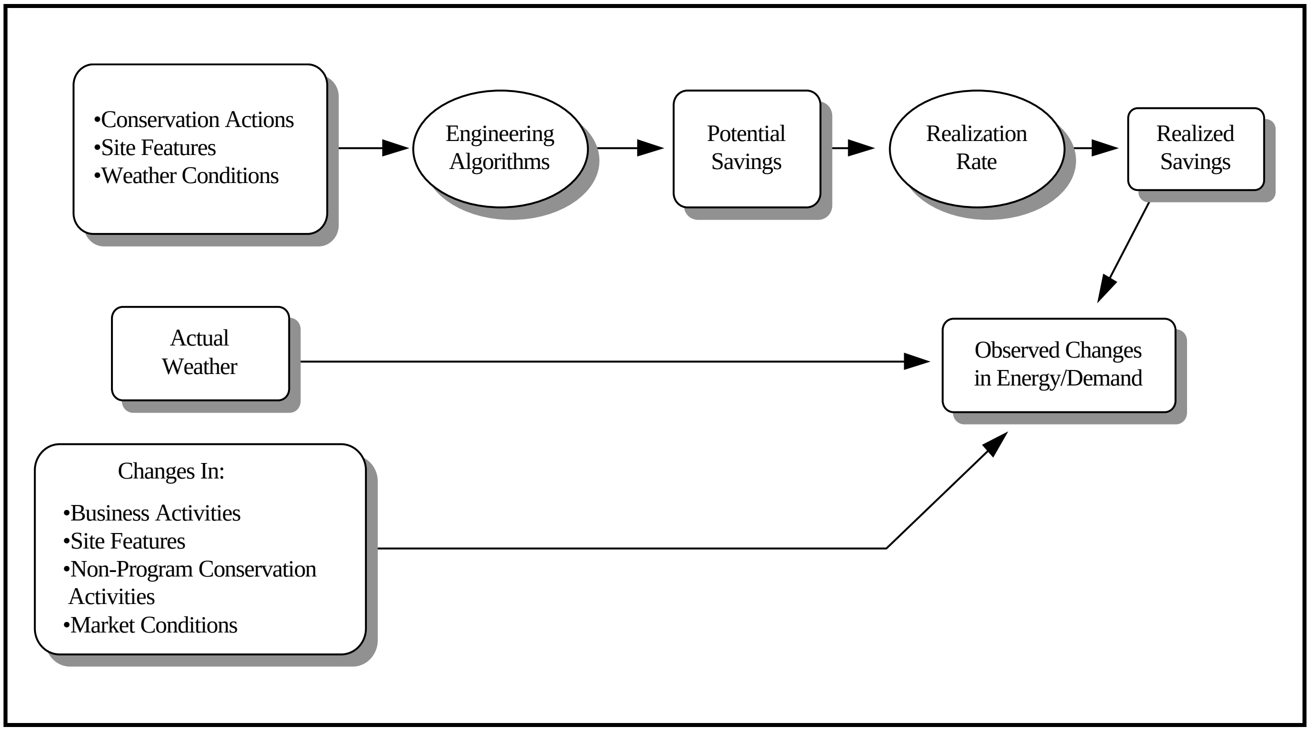
$$(1) \quad \Delta KWH_{it} = \sum_{k=1}^{K} f_k \begin{pmatrix} SAV_{ikt}, \Delta SC_{it}, \Delta OC_{it}, \Delta WC_{it}, \Delta MC_{it}, \Delta S_{ikt}, \\ SC_{it}, OC_{it}, WC_{it}, MC_t, S_{ikt}, \varepsilon_{it} \end{pmatrix}$$

where

$DKWH_{it}$ = the change in energy consumption for site *i* over a 12-month period,
SAV_{ikt} = a set of engineering estimates of expected savings in month *t* for end use *k* and site *i*,
SC_{it} = a set of site characteristics like square footage or number of floors,
OC_{it} = a set of variables representing operating characteristics like thermostat settings,
WC_{it} = is an indicator of weather conditions, MC_t is a vector of market conditions,
S_{ikt} = is a binary indicator of the presence of the *k*th electric end use, and
e_{it} = a random error.

Note that in this general model, both the levels of and changes in the explanatory variables are included. The levels would constitute interaction terms, playing the role of conditioning the effects of changes. For instance, the site square footage and HVAC system indicators would be interacted with the change in weather conditions.

Figure 4-1: The SAE Modeling Process



4.4 SCE 1997 CEEI Statistically Adjusted Engineering Model

Model Specification

The specific SAE model used for this evaluation is designed to cover all eligible space conditioning, indoor lighting, process, and refrigeration program measures. These eligible measures included both rebated and non-rebated measures. In addition to the eligible measures, the model specification covers non-eligible lighting and space conditioning measures. In particular, the model specification includes separate terms for eligible and non-eligible measures. This approach was used due to differences in the methodology used to derive the *ex ante* engineering estimates of savings for each type of measure.

The 1997 CEEI SAE model is specified as:

$$(2)\quad \frac{\Delta KWH_{it}}{SQFT_i} = b_0 + b_1\frac{\Delta ESAVLIT_{it}}{SQFT_i} + b_2\frac{\Delta ESAVHVAC_{it}}{SQFT_i} + b_3\frac{\Delta ESAVPROC_{it}}{SQFT_i}$$

$$+ b_4\frac{\Delta ESAVREF_{it}}{SQFT_i} + b_5\frac{\Delta NELIGLIT_{it}}{SQFT_i} + b_6\frac{\Delta SQFTHDD_{it}}{SQFT_i}K12$$

$$+ b_7\left[\frac{(HDD_{it} - NHDD_{it})}{NANHDDi}\right]\Delta ESAVHVHT_{it} + b_8\left[\frac{(CDD_{it} - NCDD_{it})}{NANCDDi}\right]\Delta ESAVHVCL_{it}$$

$$+ b_9\left[\frac{(HDD_{it} - NHDD_{it})}{NANHDDi}\right]\Delta ESAVHVVT_{it} + b_{10}\left[\frac{(CDD_{it} - NCDD_{it})}{NANCDDi}\right]\Delta ESAVHVVT_{it}$$

$$+ (b_{11}OFF + b_{12}RST + b_{13}RET + b_{14}FOD + b_{15}WHS + b_{16}K12 + b_{17}COL + b_{18}HOT$$

$$+ b_{19}MIS)ESH_i PHEAT_i \Delta HDD_{it} WIN_t$$

$$+ (b_{20}OFF + b_{21}RST + b_{22}RET + b_{23}FOD + b_{24}WHS + b_{25}K12 + b_{26}COL + b_{27}HOS$$

$$+ b_{28}HOT + b_{29}MIS)PCOOL_i \Delta CDD_{it}$$

$$+ (b_{30}RST + b_{31}FOD + b_{32}HOS + b_{33}MIS)\frac{\Delta OPHOURS_{it}}{SQFT_i}$$

$$+ (b_{34}OFF + b_{35}WHS + b_{36}K12 + b_{37}MIS)\frac{\Delta SQFT_{it}}{SQFT_i}$$

$$+ b_{38}RST_i + b_{39}RET_i + b_{40}FOD_i + b_{41}WHS_i + b_{42}K12_i + b_{43}COL_i$$

$$+ b_{44}HOS_i + b_{45}HOT_i + b_{46}MIS_i + b_{47}D300_{it} + b_{48}D468_{it}$$

$$+ b_{49}D468_{it}\Delta CDD_{it} + b_{50}D791_{it} + b_{51}REM96_{it} + b_{52}REMODEL_{it} + e_{it}$$

where:

$DKWH_{it}$	=	Twelve-month change in monthly consumption (KWH_{it}–KWH_{it-12})
$SQFT_i$	=	Total site square feet
$\Delta ESAVLIT_{it}$	=	Twelve-month change in engineering estimate of kWh savings from installation of lighting energy efficiency measures (kWh)
$\Delta ESAVHVAC_{it}$	=	Twelve-month change in engineering estimate of kWh savings from installation of HVAC energy efficiency measures (kWh)
$\Delta ESAVPROC_{it}$	=	Twelve-month change in engineering estimate of kWh savings from installation of process energy efficiency measures (kWh)
$\Delta ESAVREF_{it}$	=	Twelve-month change in engineering estimate of kWh savings from the installation of refrigeration energy efficiency measures
$\Delta NELIGLIT_{it}$	=	Twelve-month change in non-eligible lighting changes (kWh)
$\Delta SQFTHDD_{it}K12$	=	Twelve-month change in square footage for schools interacted with weather
$\Delta ESAVHVHT_{it}$	=	Twelve-month change in engineering estimate of the heating portion of kWh savings from installation of HVAC energy efficiency measures (kWh)
$\Delta ESAVHVCL_{it}$	=	Twelve-month change in engineering estimate of the cooling portion of kWh savings from installation of HVAC energy efficiency measures (kWh)
$\Delta ESAVHVVT_{it}$	=	Twelve-month change in engineering estimate of the ventilation portion of kWh savings from installation of HVAC energy efficiency measures (kWh)
HDD_{it}	=	Monthly heating degree days (base 65)
ΔHDD_{it}	=	Twelve-month change in HDD_{it} ($HDD_{it} – HDD_{it-12}$)
CDD_{it}	=	Monthly cooling degree days (base 65)
ΔCDD_{it}	=	Twelve-month change in CDD_{it} ($CDD_{it} – CDD_{it-12}$)
$NHDD_{it}$	=	Monthly heating degree days based on CEC monthly TMY weather data (base 65)
$NANHDD_{it}$	=	Annual heating degree days based on CEC monthly TMY weather data (base 65)
$NCDD_{it}$	=	Monthly cooling degree days based on CEC monthly TMY weather data (base 65)
$NANCDD_{it}$	=	Annual cooling degree days based on CEC monthly TMY weather data (base 65)
$\Delta SQFT_{it}$	=	Twelve-month change in $SQFT_{it}$ ($SQFT_{it}$- $SQFT_{it-12}$)
$\Delta OPHOURS_{it}$	=	Twelve-month change in operating hours
ESH_iPHEAT_i	=	Percentage of electric heating
$PCOOL_i$	=	Percentage of electric cooling

WIN_t	=	Binary variable equal to 1 if the month is in the heating season (October through April); 0 otherwise.
OFF_i	=	Binary variable equal to 1 if the site is an office; 0 otherwise
RST_i	=	Binary variable equal to 1 if the site is a restaurant; 0 otherwise
FOD_i	=	Binary variable equal to 1 if the site is a food store; 0 otherwise
RET_i	=	Binary variable equal to 1 if the site is a retail store; 0 otherwise
WHS_i	=	Binary variable equal to 1 if the site is a warehouse; 0 otherwise
$K\text{-}12_i$	=	Binary variable equal to 1 if the site is a K-12 school; 0 otherwise
COL_i	=	Binary variable equal to 1 if the site is a college or university; 0 otherwise
HOS_i	=	Binary variable equal to 1 if the site is a hospital or medical clinic; 0 otherwise
HOT_i	=	Binary variable equal to 1 if the site is a hotel or motel; 0 otherwise
MIS_i	=	Binary variable equal to 1 if the site is a miscellaneous building; 0 otherwise
$D300_{it}$	=	A dummy for a specified period for site 300[1]
$D468_{it}$	=	A dummy for a specified period for site 468
$D791_{it}$	=	A dummy for a specified period for site 791
REM96_{it}	=	A dummy for a specified period for a large drug chain remodeled in 1996
REMODEL_{it}	=	A dummy for a specified period for a large drug chain remodeled in 1997 or after

Conceptual Issues Relating to the Specification and Application of the Model

In the design and use of the SAE model, a number of conceptual issues had to be resolved. These issues are discussed below.

- ***Bases for Replace-on-Burnout Savings.*** As noted in Section 3, two types of engineering estimates of savings were developed for replace-on-burnout (ROB) measures. The first used the site's previous equipment as a baseline, while the second used code as a reference. The first type of savings estimate was included in the SAE model to reflect the fact that observed changes in usage reflect these savings. However, subsequent analysis was used to convert the resultant estimates of savings to the savings relative to code.
- ***Deferred Load.*** The net acquisitions of energy-efficient equipment defer loads. In these cases, the action was represented in the SAE model with an engineering estimate of usage, given the actual efficiency of the equipment. Then, savings

1 These dummy variables were used to control for other changes made at these sites. The variable for site 468 is also included as an interaction variable with weather.

were derived by contrasting this usage with the level that would have been experienced had the equipment just met Title 20 standards.

- ***Definition of Pre- and Post-Installation Periods.*** The SAE method makes use of information on expected savings from specific DSM measures, rather than relying on simple binary pre- and post-program indicators. As a result, the pre- and post-installation periods are defined specifically with respect to individual measures. If a site installed three measures at different times, each measure essentially had its own pre- and post-installation period. For this reason, it was important to collect reasonably reliable information on the timing of DSM actions.
- ***Treatment of Different Equipment Types.*** Both rated and non-rated equipment types, as well as equipment affecting more than one end use might be found at any given site. Engineering estimates of savings were included in the model by end use, and separate adjustment rates were estimated by end use. Rated equipment were treated differently than non-rated equipment, in the sense that its savings will have to be referenced to code. One of the advantages of the SAE approach is that the engineering estimates of savings can be disaggregated by measure. This allows the conversion of savings of rated measures to the appropriate code references after the statistical adjustment rate for the applicable end use has been estimated. This point is discussed further below.

Estimating the Model

The SAE model was estimated with data covering both participants and nonparticipants. The total sample size consisted of 572 sites and 17,818 monthly observations. The 572 sites included 439 of the 491 sites for which on-site surveys had been completed, as well as 133 drug store sites for which the chain provided information outside the on-site survey effort. The 52 sites that were subjected to the on-site but excluded from the estimation database were excluded because of the inability to match consumption to the audited site, the consolidation of premises that proved to be the same sites, the exclusion of two outdoor lighting accounts, and the presence of anomalous consumption data. Roughly 1,200 individual monthly observations for the included sites were excluded because of anomalies in individual observations.

In estimating the model, particular care was given to the potential for errors due to the timing of the installation of measures. Errors in timing can make estimation of impacts difficult. The installation dates were taken from the participation files and in many cases crossed checked with hard copy coupon data. In some cases, installation dates were overridden based on inspection of the coupon data. Given this approach, the installation dates should be reasonable accurate but may still contain some small errors. To allow for this, a two-month deadband was used to omit the month of adoption and the preceding month from the model estimation process.

Statistical issues relating to estimation are considered below.

- ***Autocorrelation.*** Autocorrelation, which is a common problem in this kind of analysis, was found to be significant. It was mitigated by a generalized least squares routine that has become reasonably standard in the industry for the analysis of panel data.[2] This approach entails retrieving residuals from a first stage regression, normalizing these residuals by site-specific means, estimating a regression relating the current value of the normalized residuals to their lagged values, using the associated autocorrelation coefficient to transform the data, and the use of the transformed data in a second estimation step.
- ***Heteroskedasticity.*** Given the variation in the scales of sites, heteroskedasticity also proved to be a problem. While normalizing consumption by an indicator of scale (site square footage) partly mitigates this problem, it was necessary to implement a generalized least squares method for resolving remaining problems of heteroskedasticity. In this process, we used the residuals estimated from an initial regression to estimate site-specific error variances, then used these estimated variances to transform the data in a way that ensured homoskedastic errors.
- ***Outliers.*** Outliers were reviewed extensively. In some cases, observations were set equal to missing for individual sites for some or all time periods. These cases were comprised of instances where changes in occupancy had taken place, where consumption data simply seemed anomalous, or where large unexplained changes in consumption had occurred over time.[3]
- ***Customer Heterogeneity.*** Customers differ in many respects. Some differences can be quantified fairly easily and some cannot. In the SAE model, we included a variety of variables reflecting conditions and changes in conditions at the sites in question. These variables partly control for heterogeneity. Moreover, the use of a 12-month change version of the model also "nets out" many of the differences factors affecting the level of consumption across sites. (For instance, differences in non-HVAC equipment stocks tend to fall out when 12-month changes are taken.) In a sense, the 12-month change model can be considered to be derived from a level-form fixed effects model.
- ***Self-Selection Bias.*** In some contexts, self-selection bias can be extremely troublesome. If our billing analysis model included a participation variable on the right side, we would clearly need to mitigate self-selection bias through the use of one of the standard approaches to be discussed later. However, self-selection is not a serious issue in an SAE model like the one estimated in this evaluation. The SAE model controls for actions taken by both participants and nonparticipants, and simply relates these actions to changes in consumption. There is no reason, for

2 Hsiao, Cheng. Analysis of Panel Data. Econometric Society Monograph, Cambridge University Press, 1966.

3 For example, one site exhibited sporadic increases of consumption of up to 125% with no apparent pattern or explanation.

instance, to believe that any inherent excluded differences between participants and nonparticipants will affect the rate at which an engineering estimate of savings from delamping is realized in the form of reductions in usage. That is, there is no reason to believe that the estimate of the adjustment coefficient will be biased by self selection.

SAE Model Estimation Results

The estimated SAE model is presented in Table 4-1. While we will spare the reader a full recitation of the estimated coefficients and standard errors, the following results should be highlighted:

- The estimated adjustment coefficient on lighting savings is 0.88, suggesting that 88% of the savings estimated with our simple lighting engineering algorithms are actually realized in the form of reductions in usage.
- The adjustment coefficient in HVAC savings is just under 83%, indicating that HVAC savings simulated with DOE-2 are not fully realized in the form of reductions in usage.
- For process savings, the adjustment coefficient exceeds 1.0. According to this result, actual savings are roughly 20% higher than the engineering estimates developed by RER in the course of the analysis. This presumably indicates that the simulation assumptions were somewhat conservative.
- The adjustment factor for refrigeration was set equal to 1.0 to reflect the fact that *ex ante* estimates of savings were to be used for this end use (due to the low overall level of refrigeration savings from the 1997 program). By constraining the coefficient on refrigeration savings to equal 1.0, we are simply forcing consistency with the overall treatment of refrigeration savings.[4] Note that it was necessary to include refrigeration savings in the model even though it was not a studied measure, as some sites with studied measures also had refrigeration installations.
- While the terms containing changes in cooling degree-days are positive (as expected) and generally highly significant, the coefficients on heating degree-days are mixed. The generally insignificant impact of heating degree-days is not particularly surprising, given the low saturation of electric heating in the sample.
- The impacts of changes in operating hours and square footage are significant for some building categories but not for others.

4 Note that the freely estimated coefficient was a little less than 1.0. Using this lower coefficient estimate would have created an upward bias in the overall estimate of program savings.

Table 4-1: Model Estimation – Generalized Least Squares

Explanatory Variables	Coefficient	*(t-stat)*
Intercept	0.010949	(6.989)
DESAVLIT / SQFT	-0.883025	(-26.725)
DESAVHVAC / SQFT	-0.825689	(-15.406)
DESAVPROC / SQFT	-1.196456	(-11.299)
DESAVREF / SQFT	1.000	-
DNELIGBLIT / SQFT	-.261936	(-5.669)
(DSQFTHDD / SQFT)K12	0.001247	(1.822)
((HDD-NHDD)/NANHDD)ΔESAVHVHT	10.566436	(0.651)
((CDD-NCDD)/NANCDD)ΔESAVHVCL	-0.576071	(-1.761)
((HDD-NHDD)/NANHDD)ΔESAVHVVT	-11.362643	(-2.179)
((CDD-NCDD)/NANCDD)ΔESAVHVVT	-3.730938	(-1.254)
DHDD(ESH)(PHEAT)(WIN)(OFF)	-0.000365	(-2.004)
DHDD(ESH)(PHEAT)(WIN)(RST)	-0.001254	(-0.490)
DHDD(ESH)(PHEAT)(WIN)(RET)	-0.000209	(-1.725)
DHDD(ESH)(PHEAT)(WIN)(FOD)	0.000079666	(0.272)
DHDD(ESH)(PHEAT)(WIN)(WHS)	-0.000126	(–0.103)
DHDD(ESH)(PHEAT)(WIN)(K12)	0.000093353	(1.023)
DHDD(ESH)(PHEAT)(WIN)(COL)	-0.000409	(-1.530)
DHDD(ESH)(PHEAT)(WIN)(HOT)	0.000491	(4.003)
DHDD(ESH)(PHEAT)(WIN)(MIS)	-0.000545	(-0.649)
DCDD(PCOOL)(OFF)	0.000626	(13.794)
DCDD(PCOOL)(RST)	0.003027	(4.855)
DCDD(PCOOL)(RET)	0.000861	(19.783)
DCDD(PCOOL)(FOD)	0.001134	(8.542)
DCDD(PCOOL)(WHS)	0.000621	(2.082)
DCDD(PCOOL)(K12)	0.000574	(18.716)
DCDD(PCOOL)(COL)	0.000900	(8.731)
DCDD(PCOOL)(HOS)	0.001062	(15.159)
DCDD(PCOOL)(HOT)	0.000636	(10.723)
DCDD(PCOOL)(MIS)	0.001019	(11.364)

Table 4-1: Model Estimation – Generalized Least Squares (cont.)

Explanatory Variables	**Coefficient**	***(t-stat)***
ΔOPHOURS/SQFT(RST)	0.025556	(2.384)
ΔOPHOURS/SQFT(FOD)	-0.000658	(-0.604)
ΔOPHOURS/SQFT(HOS)	0.001278	(0.255)
ΔOPHOURS/SQFT(MIS)	0.072765	(10.779)
DSQFT / SQFT(OFF)	0.454111	(1.119)
DSQFT / SQFT(WHS)	-0.362745	(-0.495)
DSQFT / SQFT(K12)	0.360005	(3.159)
DSQFT / SQFT(MIS)	10.126826	(4.421)
RST	-0.058495	(-1.352)
RET	-0.023610	(-4.311)
FOD	-0.011019	(-0.891)
WHS	-0.008366	(-1.215)
K12	-0.006614	(-1.614)
COL	-0.011781	(-0.910)
HOS	-0.009681	(-1.461)
HOT	0.001713	(0.298)
MIS	0.006498	(0.888)
D300	0.164553	(1.946)
D468	0.453361	(1.643)
D468DCDD	-0.000052145	(-0.038)
D791	0.128233	(1.548)
REM96	-0.700632	(-21.453)
REMODEL	-0.482576	(-15.393)
Adjusted R-Squared	0.3042	

4.5 Inference of *Ex Post* Adjusted Gross Savings

General Approach to Estimating Ex Post Adjusted Gross Savings

Once the SAE model was estimated, the *adjusted gross savings* associated with the installation of a set of energy efficiency measures relating to end use *k* for site *i* were derived as:

$$(3) \quad Impact_{ikt} = \left[\partial \Delta KWH_{it} \,/\, \partial SAV_{ikt} \right] SAV_{ikt}$$

where $\P KWH_{it}/\P SAV_{ikt}$ can be considered a statistical adjustment rate for the measure(s) in question. This statistical adjustment rate can be specified to vary across conditions and sites. As explained later, this characteristic allows the weather-normalization of impacts, as well as the assessment of factors contributing to statistical adjustment rates significantly different from one. As also explained below, the results of the SAE analysis can also be converted to reflect the appropriate baseline for gross savings – the prevailing code.

Weather-Normalizing Impacts

The general SAE formulation recognizes that realized program savings can vary across sites. To some extent, this is picked up by the fact that the *ex ante* engineering estimate of savings (SAV_{ikt}) varies across sites. However, it is also recognized by allowing the adjustment term to vary across sites and over time. One implication of this specification is the ability to weather-normalize impacts. That is, the model was designed so that the impact of a DSM measure depends upon prevailing weather conditions, and the impact was simulated under the assumption of normal weather.[5] In this study, this procedure entailed two steps: first, the savings estimate SAV_{ikt} was defined with respect to normal weather; second, the statistical adjustment rate function was specified to include a term representing the deviation of actual weather from normal weather. This approach supports the estimation process, in that it accounts for the dependence of actual savings on actual weather. It also accommodates weather normalization of the estimated impact through the solution of the impact expression under the assumption of normal weather (i.e., zero deviation of actual from normal weather).

Adjusting Estimates for Efficiency Standards

For some DSM measures, the impact derived from the SAE model will not directly represent *adjusted gross savings* relative to the appropriate baseline. Given the reliance on billing data, which reflect conditions at the site, the engineering savings estimated included in the SAE model (SAV_{ikt}) indicates savings relative to pre-installation conditions, and the model yields a corresponding savings estimate. However, savings relative to code can be inferred by

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5 Sebold, Frederick D., Boqing Wang, and Thomas A. Mayer. "Evaluating the Impacts of Northwest Commercial New Construction Programs." National Energy Program Evaluation Conference. Chicago, IL. August 1995.

multiplying the initial engineering estimate of savings relative to code by the statistical adjustment rate on the savings variable included in the model. Moreover, deferred savings from net acquisitions can be simulated by multiplying the statistical adjustment rate on estimated usage by the corresponding engineering estimate of savings from efficiency above code.

Developing Time-of-Use Energy and Demand Impacts

The results of the SAE analysis were derived on a billing-cycle basis. In order to satisfy the requirements of the CPUC Protocols these impacts were then translated into peak kW impacts. For HVAC measures, this was facilitated by the availability of calibrated DOE-2 estimates of hourly impacts. For lighting, operating patterns were developed on the basis of lighting schedules and TOU metering. These patterns were used to transform estimated energy impacts from the billing analysis into demand impacts. The derivation of demand savings by end use is explained further below.

Expanding Sample Estimates of Gross Savings

Once the billing analysis was completed, it was necessary to expand the estimated *adjusted gross savings* of sampled participants to the program population. One option in this regard would have been to use a mean-per-unit approach. However, this would presume the homogeneity of sites within strata. Instead, case weights based on energy consumption were used to expand savings estimates for participating sites, essentially resulting in ratio estimators.[6]

Estimates of Adjusted Gross Energy Savings

Table 4-2 presents the *ex post adjusted gross savings* by end use for the 1997 CEEI Program. Included in the table are calibrated engineering estimates of measure statistical adjustment rates and *adjusted gross savings*. In addition, SCE's verified gross *ex ante* savings are presented for comparison. As shown, RER's *ex post adjusted gross energy* savings is roughly 78% of the SCE's *ex ante* gross estimate. The results of the SAE analysis by major end use are discussed below.

6 The weighting scheme used in the analysis relating to the use of SCE ex ante savings is discussed earlier in Section 2.3.

Table 4-2: 1997 CEEI Gross Energy Savings by End Use

Program Measure	**RER Engineering Estimate of Gross Savings (kWh)**	**Statistical Adjustment Rate**	**RER Adjusted Gross Savings (kWh)**	**SCE *Ex Ante* Verified Gross Savings (kWh)**
Lighting				
Indoor Ltg.	*36,784,110*	*0.88*	*32,370,017*	*40,675,037*
LED Ltg. Only	*824,610*	*1.00*	*824,610*	*824,610*
Outdoor Ltg. Only	*501,023*	*1.00*	*501,023*	*501,023*
Total Lighting	***38,109,743***		***33,695,650***	***42,000,670***
HVAC	34,850,137	0.83	28,925,614	46,843,033
Miscellaneous				
Process	17,256,649	1.20	20,707,979	21,412,329
Refrigeration	6,704,788	1.00	6,704,788	6,704,788
Pumping	760,068	1.00	760,068	760,068
All	**97,681,385**		**90,794,098**	**117,720,887**

Gross Lighting Energy Savings. The *ex post* adjusted gross lighting savings were estimated in three components.

- ***Indoor Lighting.*** Indoor lighting covers all sites with at least some indoor lighting measures installed. These sites were covered explicitly by the SAE analysis and site-specific engineering savings estimates were derived for all surveyed sites. Engineering estimates of savings for these sampled sites were expanded to total program gross indoor lighting savings using the appropriate case weights. *Adjusted gross savings* were then estimated as the product of the statistical adjustment rate and the engineering estimate of savings. As shown in Table 4-2, the statistical adjustment rate on indoor lighting was estimated to be 0.88. Indoor lighting accounts for roughly 96% of adjusted gross lighting savings and approximately 37% of total adjusted gross savings.
- ***Outdoor Lighting Only.*** Sites with outdoor lighting only were not surveyed as part of this study. For these cases, we adopted SCE's *ex ante* gross savings estimates as per the CPUC Protocols. Further, the statistical adjustment rate used to calculate *ex post* gross savings was assumed to be equal to 1.0. Outdoor lighting accounts for approximately 1% of adjusted gross lighting savings.

- ***LED Exit Sign Only.*** Sites with LED exit signs only were also not surveyed as part of the study. Per the CPUC Protocols, for these sites, we adopted SCE's *ex ante* gross savings estimates and applied a statistical adjustment rate of 1.0. LED exit sign only lighting accounts for just over 2% of adjusted gross lighting savings.

By design, the LED exit sign only and outdoor lighting only sites have the same *ex post* adjusted gross savings as SCE's *ex ante* gross savings. However, *ex post* gross savings for indoor lighting is roughly 80% of SCE's *ex ante* estimate. This difference is mainly attributable to the estimated statistical adjustment rate of 88%, although our calibrated engineering estimate of gross savings for indoor lighting is roughly 8% lower than SCE's *ex ante* gross savings.

One reason contributing to the difference between our engineering estimates of gross indoor lighting savings and SCE's *ex ante* estimates is a difference in operating hours. In particular, operating hours as reflected in SCE coupon data were found to be significantly exaggerated for hotels and motels sample wide. After a considerable study of coupon and audit and billing data for these sites, operating hours were adjusted to bring them more into line with actual usage.

It should be noted that the statistical adjustment rate on lighting is considerably higher than estimated last year for the 1996 program. As noted in last year's evaluation, the low statistical adjustment rate for the 1996 program seemed to be attributable to the fact that numerous sites had very high lighting energy use densities relative to typical buildings of similar type in the pre-retrofit case. This problem seems to have been largely resolved in the 1997 program.

Gross HVAC Energy Savings. The *ex post* adjusted gross HVAC savings account for almost 32% of all *ex post* program savings. However, RER's estimate of adjusted gross HVAC savings is only 62% of SCE's *ex ante* savings estimate. Part of this difference is attributable to the fact that the statistical adjustment rate for HVAC is only 0.83. Relatively low adjustment factors for HVAC are not unusual, partly because actual behavior relating to HVAC systems often differs from the stylized assumptions used in engineering analyses. However, it should also be noted that RER's engineering estimates of HVAC savings amount to only 75% of SCE's *ex ante* savings. The difference between SCE's *ex ante* and RER's engineering estimates of gross HVAC savings can be primarily attributed to the difference in methods employed by RER and SCE for estimating these savings. The most significant methodological differences include the following:

- ***Different Approach for Simulating HVAC VSD Applications.*** RER used a building simulation program (SITEPRO/DOE-2) to assess the savings whereas SCE analyses typically used the MARS Motors module. The main difference in these two approaches is that the building simulation analyzes the VSD-controlled equipment as part of a total HVAC system as described in the on-site survey data, whereas the MARS approach evaluates savings in isolation from the HVAC system using a "typical" operating profile which may or (typically) may not reflect actual operation for a specific site.

- ***More Detailed Approach to Modeling Energy Management Systems.*** Differences between SCE and RER savings for EMS measures are the result of the more detailed simulation capabilities of DOE-2 versus the SCE MARS HVAC evaluation. SITEPRO /DOE-2 is an hourly simulation program and utilizes on-site survey data including actual business hours, end use schedules, hourly weather data, and different weekday, weekend, and holiday operation. The MARS HVAC program is a more simpler bin-based method and had only one schedule defined. In addition, DOE-2 also had the ability to simulate some EMS controls that MARS could not do effectively. For instance, optimum fan start can only be simulated in MARS as a reduction in operating hours, whereas DOE-2 applies this as a real control based on the applicable environmental conditions.
- ***Differences in SCE Assumptions Versus On-Site Survey Data.*** Some sites, especially the larger more complex sites with multiple measures, often showed discrepancies between the SCE assumptions and data gathered from the on-site survey. Most of the differences can be attributed to the difficulty of trying to adequately document the measures and savings for such sites. Because these differences were almost always unique to that site, it is not possible to generalize about them. However, what made these discrepancies most significant is that the affected sites were typically responsible for a considerable percent of overall program savings.
- ***Incorporation of On-Site Monitored Data for Some Sites.*** For those few sites where on-site monitoring was performed, results of the metered data were incorporated into the simulation wherever possible.

Each of these factors is explained more fully in Appendix D. The discussion includes specific examples of sites where the engineering estimates differed substantially.

Ex Post Adjusted Gross Process Savings. RER's ex post adjusted gross savings estimates show that process accounts for 22% of all program savings. While RER's engineering estimate of gross savings is only 80% of SCE's *ex ante* savings, the statistical adjustment rate of 1.20 makes ex post adjusted gross savings 96% of SCE's *ex ante* savings. The high statistical adjustment rate is apparently the result of relatively conservative assumptions used by RER in its engineering simulations. Given the significance of the estimated adjustment rate of 1.20 and a 90% confidence interval of 1.02 to 1.37, this result is apparently not due to chance.

Ex Post Adjusted Gross Refrigeration Savings. As per the CPUC's Protocols, SCE's estimates of refrigeration savings were used as final estimates. Sites with refrigeration measures only were omitted from the analysis altogether, but sites with refrigeration measures and measures covering other studied end uses were included in the analysis. As explained earlier, however, the statistical adjustment factor for refrigeration for these latter sites was constrained to be equal to 1.0 for the sake of consistency. As shown in Table 4-1, adjusted refrigeration savings account for 7% of all program savings.

Ex Post Adjusted Gross Pumping Energy Savings. SCE's *ex ante* savings estimates for pumping were less than 1% of SCE's total program *ex ante* savings. Per CPUC Protocol Table C-9, sites with only miscellaneous measures were excluded from the sample and were not included in the SAE analysis.[7] As a result, gross savings and ex post adjusted gross savings were set equal to SCE's *ex ante* savings.

Ex Post Adjusted Gross Demand Savings

Table 4-3 presents the ex post adjusted gross demand savings for the 1997 CEEI program. The gross demand savings were estimated as the product of the statistical adjustment rates discussed above and engineering estimates of demand impacts developed by the project team or (when project estimates were unavailable) extracted from SCE's program records. The development of these engineering estimates of demand impacts is considered below.

Adjusted Gross Lighting Demand Savings. Adjusted gross demand savings were estimated for indoor lighting sites only. The following assumptions were used in the process of estimating these demand impacts:

- For high-efficiency lamps and ballasts and delamping measures, demand impacts were estimated using the energy savings and the ratio of lighting demand to lighting energy usage derived from the lighting metering results.
- For EMS systems, demand savings were assumed to be equal to zero.
- For occupancy sensors, demand savings were assumed to be equal to zero.

As explained above, SCE's gross verified demand savings were used for sites with outdoor lighting only and LED exit signs only. As shown in Table 4-3, the estimated adjusted gross demand impact for the program's lighting measures amounts to 7.3 MW. This estimate is roughly 95% of SCE's gross verified demand savings for lighting.

Adjusted Gross HVAC Demand Savings. RER's adjusted gross demand savings for HVAC measures is 2.0 MW. This is roughly half as large as SCE's *ex-ante* estimate. The lower estimate is attributable to generally lower estimates of HVAC savings at all hours, coupled with lower peak fractions yielded by the DOE-2 simulations.

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7 While process is a miscellaneous measure, it is included in the study as it is part of the measures making up 85% of program savings.

Table 4-3: Ex Post Adjusted Gross Demand Savings by End Use

Program Measure	RER Gross Savings (kW)	Statistical Adjustment Rate	RER Adjusted Gross Savings (kW)	SCE Gross Verified Savings (kW)
Lighting				
Indoor Ltg.	*8,257*	*0.88*	*7,266*	*7,662*
LED Ltg. Only	*100*	*1.00*	*100*	*100*
Outdoor Ltg. Only	*0*	*1.00*	*0*	*0*
Total Lighting	***8,357***		***7,366***	***7,762***
HVAC	2,452	0.83	2,035	4,074
Miscellaneous				
Process	1,192	1.20	1,430	174
Refrigeration	20	1.00	20	20
Pumping	17	1.00	17	17
All	**12,037**		**10,868**	**12,047**

Adjusted Gross Process Demand Savings. RER's estimated adjusted gross demand savings for process measures are considerably higher than those claimed by SCE. This is the result of relatively conservative assumptions used by SCE in estimating process savings.

Adjusted Gross Refrigeration and Pumping Demand Savings. In keeping with the treatment of energy savings for these end uses, we used SCE's estimates of peak demand savings for refrigeration and pumping measures.

Confidence Intervals

The CPUC Protocols require the specification of confidence intervals for both gross and net savings estimates. This is not a straightforward exercise when an SAE model is specified with separate adjustment factors on individual end uses, insofar as the standard error of total realized savings depends on the variances and covariances of all of the estimated statistical adjustment rates. Confidence intervals were developed for gross realized savings using the following approach:

- First, the SAE model was re-estimated using a composite of all of the savings variables, each multiplied times its own coefficient from Table 4-1. That is, the composite (SAV_{it}) was defined as:

$$SAV_{it} = \sum_k \hat{d}_k SAV_{kit}$$

where $\hat{d}_k$ is the estimated coefficient from Table 4-1 and SAV_{kit} is the savings term for end use k. Of course, the expected coefficient of this composite variable is 1.0, since this form of the model is equivalent to the one presented earlier.

- Second, the standard error of the composite variable, which is a relative standard error in the sense that the coefficient is normalized to 1.0, was used to develop a confidence interval for adjusted gross energy savings.
- Third, the same relative standard error was used to construct confidence intervals for demand savings.

The following confidence intervals for energy savings resulted from this analysis:

- 90% confidence interval: 90,794,098 ± 4,824,208 kWh
- 95% confidence interval: 90,794,098 ± 5,747,993 kWh

The corresponding confidence intervals for demand savings are as follows:

- 90% confidence interval: 10,868 ± 577 kW
- 95% confidence interval: 10,868 ± 688 kW

5

Net-to-Gross Analysis

5.1 Introduction

The net-to-gross analysis focuses on estimating the net impact of the 1997 CEEI Program on energy and demand savings. This net impact is defined to account for both free ridership and, to the extent possible, participant free drivership. Free ridership is reflected as a consequence of the inclusion of nonparticipant adoptions in the analysis. Participant free drivership is encompassed by the analysis insofar as the net-to-gross calculations are based on estimated total rebated and non-rebated savings at the participating site. If a participant installs measures without rebates at a participating site, this will be captured by the net-to-gross ratio. However, if a participant installs non-rebated measures at other nonparticipating sites under his/her control, this will not be captured by the analysis.

5.2 Overview of the Net-to-Gross Analysis Approach

RER's approach to the estimation of net impacts entailed the use of efficiency decision modeling. As part of this effort, a set of statistical models was developed to characterize efficiency choices in terms of program participation and other decision-maker characteristics.[1] Efficiency modeling can be considered a type of decision analysis.[2] To provide a full assessment of the impacts of the programs on energy efficiency decisions, the analysis focuses on comprehensive end-use indicators of energy efficiency, rather than on the adoptions of discrete measures. As explained earlier, engineering estimates of savings were developed for each end use and site. These estimates, coupled with the results of the SAE analysis, were used to define a set of efficiency indices as:

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1 Two general approaches fall under this category. One option is to develop a set of discrete choice models, one for each covered DSM measure. This modeling approach is normally favored by RER when a program offers a reasonable small set of distinct DSM measures and could be applied to major decisions such as chiller replacements. However, the SCE program under consideration here offers a wide range of specific measures, many of which are substitutes for each other. Developing a wide range of interrelated adoption models would be a cumbersome process. Instead, *RER developed a set of efficiency choice models to explain the choice of levels of end-use efficiency.*

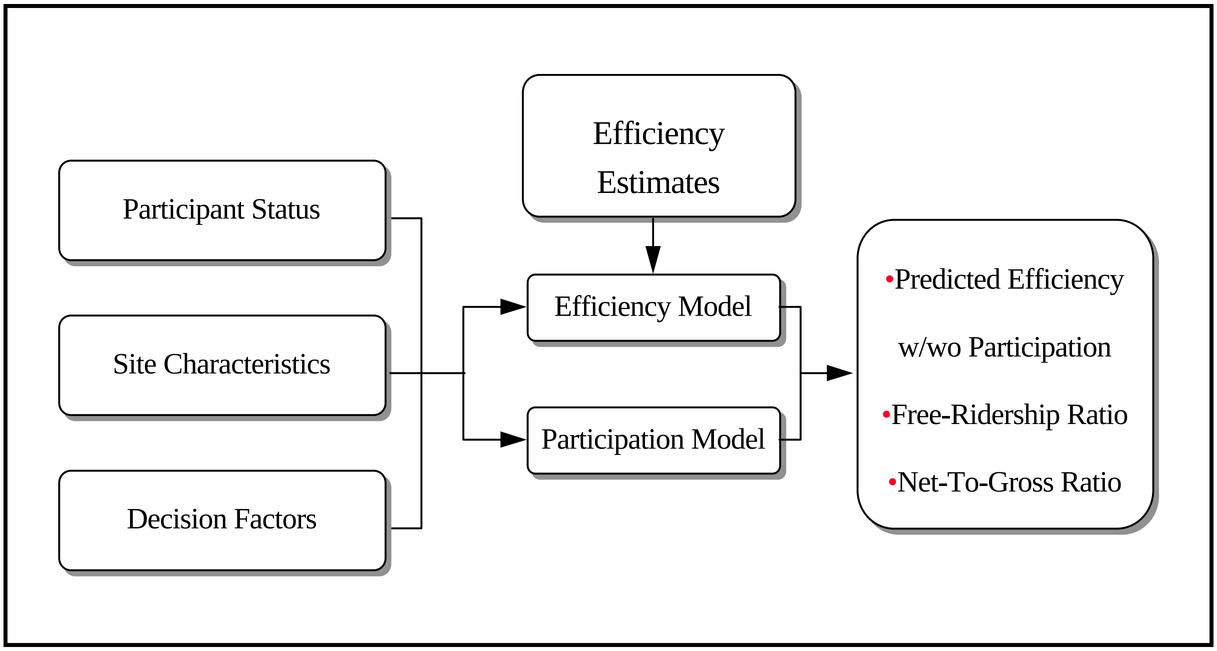
2 Sebold, Frederick D., Boqing Wang, and Thomas A. Mayer. "Evaluating the Impacts of Northwest Commercial New Construction Programs." *National Energy Program Evaluation Conference.* Chicago, IL. August 1995.

$$(1) \quad EFF_{ik} = \frac{adj_{ik} SAVC_{ik}}{SQFT_i}$$

where $SAVC_{ik}$ is the weather-normalized engineering estimate of savings for end use k relative to the appropriate baseline (code, if applicable), and adj_{ik} is the statistical adjustment rate on savings from end use k for site i.

A set of efficiency models was developed to estimate the net impact of the program on customers' choices of end-use efficiency levels. The general logic of an efficiency model is illustrated in Figure 5-1. As shown, several factors affect the choice of efficiency. Program participation, of course, is expected to encourage adoptions of high-efficiency equipment. Other factors also influence these decisions. Site characteristics affect the viability or attractiveness of DSM options. However, adoptions can also be affected by many of the factors (both observable and non-observable) influencing program participation. Therefore, estimation of the impact of participation on efficiency might be plagued with self-selection bias. Some means of mitigating this bias is necessary.

Figure 5-1: Efficiency Choice Model



The general form of the efficiency model used for the net-to-gross analysis is:

$$(2) \quad EFF_{ik} = g_k\left(PART_i, SITE_i, DECISION_i, MR_i, m_i\right)$$

where $PART_i$ is a binary indicator of site participation, $DECISION_i$ is a set of decision variables, $SITE_i$ is a set of site characteristics, and MR_i is an inverse Mills Ratio developed from an estimated participation equation of the general form:

$$(3) \quad PART_i = h(SITE_i, DECISION_i, w_i)$$

The participation equation and a set of efficiency equations can be estimated using data on efficiency choices, site features, decision-maker characteristics, a binary participation variable, and the factors affecting participation. For this analysis, information on site features was obtained through the on-site survey. Decision-maker characteristics (attitudes, perceptions, and decision criteria) also affect the likelihood of installation of energy efficiency measures, and were included in the model to control for differences across sites. Information on decision-maker features was collected from the decision-maker survey conducted in the course of recruiting on-site participants or during the on-site visit.

5.3 The Participation Model

General Formulation

In recognition of the binary nature of the participation decision, the participation equation for site *s* was specified in logistic form as:

$$(4) \quad PART_i = \frac{e^{f(X_i)}}{1 + e^{f(X_i)}}$$

where $f(X_i)$ can be considered an attractiveness function for participation. The initial specification of the attractiveness function is presented below:

$$(5) \quad f(X_i) = f(OWN_i, EFFIMP_i, PAYBACK_i, SQFT_i, NUMREN_i,$$

$$BCAT_i, ISCE_i, POTEN_i, EREB_i, PREVPART_i,$$

$$ENERCOST_i, CHAIN_i, ANNKWH_i, AVGCDD_i, e_i)$$

where:

OWN_i	=	A binary variable indicating that the facility is owned as opposed to leased
$EFFIMP_i$	=	A binary variable indicating that the respondent considers energy efficiency important or very important in deciding to purchase lighting, HVAC, refrigeration or process equipment or controls
$PAYBACK_{ik}$	=	The maximum allowed payback for energy efficiency decisions for end use *k*
$SQFT_i$	=	Site square footage
$NUMREN_i$	=	Number of renovations the respondent has been involved with in the last three years
$BCAT_i$	=	Vector of building category dummies
$ISCE_i$	=	A binary variable indicating that the respondent considers information from SCE influential or very influential in deciding to purchase lighting, HVAC, refrigeration or process equipment or controls
$POTEN_i$	=	A binary variable indicating that the respondent considers the potential to save energy at the site high or very high prior to 1997
$EREB_i$	=	A binary variable indicating that the respondent considers equipment rebates influential or very influential in deciding to purchase lighting, HVAC, refrigeration or process equipment or controls
$PREVPART_i$	=	A binary variable indicating that the respondent has participated in a previous Edison energy efficiency program
$ENERCOST_i$	=	Percentage of overall operating expenses represented by energy costs for this facility
$CHAIN_i$	=	A binary variable indicating if the site is part of a chain
$ANNKWH_i$	=	1996 annual consumption in kWh
$AVGCDD_i$	=	Average monthly CDD (base 65)
e_i	=	Random error term

The rationales for these variables are fairly straightforward.

- Owner occupancy (OWN_i) is generally considered conducive to participation in DSM programs because the savings from energy efficiency accrue to the decision makers in such cases.
- The relative importance of efficiency in equipment purchases ($EFFIMP_i$) is expected to be positively associated with the value of the information provided by DSM programs.
- The required payback period for energy efficiency investments ($PAYBACK_i$) influences the value of incentives as well as the disposition toward energy efficiency, although this influence may not be monotonic.

- Site square footage may have multiple impacts on participation. Larger sites (as indicated by the value of $SQFT_i$) may have more incentive to participate because of their lower hassle costs relative to the prospective benefits of participation, as well as because of their arguably higher likelihood of being aware of the availability of programs. It may also be true that utilities tend to more actively recruit larger sites.
- The number of renovations in which the site decision maker has participated ($NUMREN_i$) may influence participation by enhancing awareness of program options.
- Building categories (as represented by the vector of binary variables, $BCAT_i$) can also be expected to affect the likelihood of participation because of the different practices, attitudes and perceptions of the decision makers at these sites. For instance, we generally find that schools and colleges are extremely likely to participate in such programs.
- The expressed importance of information from SCE in making equipment decisions ($ISCE_i$) reflects the value the decision maker places on the kinds of information disseminated by the utility through DSM programs.
- The importance of equipment rebates in making efficiency decisions ($EREB_i$) has a direct influence on the participation decision.

Model Estimation

The model was estimated using a sample of sites for which decision-maker surveys had been conducted. This included 234 participants and 185 nonparticipants. It should be noted all observations must be weighted appropriately prior to the estimation of the participation equation, insofar as the sample is stratified on the basis of the participation variable as well as other factors. Mean per unit case weights were used for this purpose. The participation equation was initially estimated using two nonlinear estimation procedures included in SAS specifically for this purpose: PROC CATMOD and PROC LOGISTIC. Unfortunately, it was discovered after a fairly long investigation that the standard errors yielded by these procedures are incorrect when case weights are used to weight the sample observations. (It is unclear whether the estimated coefficients are also biased. The SAS Institute is reportedly developing new estimation algorithms.) As an alternative to these non-linear precedures, a log-odds specification was used. This specification is given by the reformulation of equation (4) as:

$$(5) \quad \ln\left[\frac{PART_i + v}{1 - PART_i + v}\right] = f(X_i)$$

where *v* is a small value added to the numerator and the denominator of the expression to account for the fact that $PART_i$ is a binary (0,1) variable. This increment makes the expression an approximation, but is necessary to avoid division by zero and taking the log of zero. The log-odds formulation provides the advantage that it can be estimated using linear least squares. Since the SAS algorithm for weighting linear least squares is not subject to the errors inherent in the non-linear algorithms, this allows the correct application of the case weights.

When we first applied the case weights and estimated the participation model, we discovered that the Mills Ratio generated by the model was extremely highly correlated with the participation variable. This appeared to result from the fact that the case weights differed dramatically between participants (who were fairly heavily sampled) and nonparticipants (who were sampled far less intensively), and was probably compounded by the fact that the log-odds formulation gives rise to extreme values of the dependent variable for nonparticipants. As a result, less extreme weights (the square roots of the case weights) were used in the estimation process. It is fairly well known that the use of weights other than case weights will yield a biased estimate of the intercept term in $f(X_i)$. However, we were able to apply a procedure attributable to Ben-Akiva to correct this bias.[3]

Model Results

The estimated form of the efficiency model is presented below in Table 5-1. Two versions of the model are depicted. The first contains all of the variables included in the initial specification, while the second includes only those variables with t-values in excess of 1.0. The estimates developed with version 2 suggest the following findings:

- Decision-makers with longer critical paybacks (higher values of $PAYBACK_i$) were more likely to participate in the 1997 CEEI program.
- Larger sites (in terms of both square footage as well as annual electricity consumption) were more likely to participate in the program.
- The more renovations in which the decision-makers had participated, the more likely he/she was to participate in the 1997 program.
- The liklihood of participation was positively related to the (self-reported) potential for energy savings.
- The liklihood of participation was also positively related to the (self-reported) fraction of on-site costs comprised of energy costs.
- Office buildings and warehouses were significantly more likely to be treated under the program.

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[3] Ben-Akiva, M., and S. Lerman, *Discrete Choice Analysis: Theory and Application to Predict Travel Demand*, Cambridge, MA: MIT PRess.

Overall, the participation model discriminates fairly well between participants and nonparticipants. One indicator of the explanatory power is that the model predicts and average probability of participation of 0.002 for nonparticipants and 0.347 for participants.

Table 5-1: Participation Model Estimation

Dependent Variables	Version 1	Version 2
	LNPART	***LNPART***
Intercept	-7.807488 (-10.867)	-7.426254 (-12.616)
OWN	-0.198203 (-0.851)	
EFFIMP	-0.116294 (-0.501)	
PAYBACK	0.021232 (2.797)	0.017936 (2.873)
LNSQFT	0.217913 (2.909)	0.196272 (2.943)
NUMREN	0.122907 (6.308)	0.126985 (6.958)
OFF	0.811712 (2.385)	0.742425 (2.826)
RST	0.929503 (1.578)	0.738087 (1.434)
RET	0.012083 (0.035)	
FOD	-0.182316 (-0.433)	
WHS	1.142889 (1.640)	1.010034 (1.741)
K12	-0.043229 (-0.103)	
COL	0.681028 (0.785)	
HOS	0.715231 (1.110)	0.677840 (1.127)
HOT	0.829384 (1.250)	0.739280 (1.222)
ISCE	0.180458 (0.693)	0.269934 (1.219)
POTEN	0.528101 (1.960)	0.503360 (1.936)
EREB	0.169660 (0.667)	
PREVPART	-0.001004 (-0.003)	
ENERCOST	0.065375 (2.766)	0.062781 (2.829)
CHAIN	0.601950 (1.209)	0.573492 (1.193)
ANNKWH	0.000000155 (3.372)	0.000000163 (3.673)
AVGCDD	0.001607 (0.669)	
Adjusted R^2	0.3152	0.3245

Development of Mills Ratios

The estimated model was used to develop Mills Ratios for all of the sites.

5.4 The Efficiency Choice Models

Specification of the Efficiency Choice Models

An efficiency choice equation was specified and estimated for lighting and HVAC end uses. The efficiency level for site *i* and end use *k* was specified as:

$$(6)\quad EFF_{ik} = g(OWN_i, BOTHFT_i, PAYBACK_{ik}, ENERCOST_i, POTEN_i, EFFIMP_i, SQFT_i, AVGCDD_i, AVGHDD_i, PART_i, MR_i, MRPART_i, d_i)$$

where:

EFF_{ik}	=	An efficiency index for end use *k*, composed of savings per square foot
$BOTHFT_i$	=	A binary variable indicating that financial and technical decisions relating to equipment purchases are vested in the same person
$PAYBACK_{ik}$	=	The maximum allowed payback for energy efficiency decisions for end use *k*
$AVGHDD_i$	=	Average monthly HDD (base 65)
MR_i	=	Mills Ratio
$MRPART_i$	=	$MR_i \times PART_i$
d_i	=	Error term

Again, the rationale for the inclusion of these variables in the efficiency models is fairly direct.

- Owner occupancy (OWN_i) encourages efficiency because the savings accrue to the decision-maker.
- The situation where equipment specifications and other technical aspects of equipment decisions are made by the person who is also involved in financial decisions (as represented by the binary indicator $BOTHFT_i$) should encourage efficiency because financial decisions are more likely to emphasize efficiency in such cases.
- The required payback ($PAYBACK_{ik}$) influences efficiency choices in the sense that the longer the required payback, the more likely the decision maker is to choose efficiency. Note that the end-use specific required payback will be used here.

- The importance of energy costs as a percent of operating expenses ($ENERCOST_i$) is hypothesized to have a positive influence on efficiency choices, as is the pre-1997 perceived potential for savings at the site ($POTEN_i$).
- The decision maker's relative rating of the importance of energy efficiency in making equipment decisions ($EFFIMP_i$) should be positively associated with the choice of efficiency, and the importance of first cost should have a corresponding negative association.

The participation variable ($PART_i$) is included in the efficiency models to test for the influence of the program on efficiency decisions. A self-selection correction variable (an inverse Mills Ratio, MR_i) was also included in the efficiency equation. This term is a function of the predicted probability of participation, which is derived from the estimated reduced-form equation for the participation decision. The Mills Ratio was included twice: once as a stand-alone term and once in interaction with the participation variable. This Double Mills ratio approach is attributable to Goldberg and Train.[4] This treatment embodies the characterization of self-selection bias as a case of missing variable bias.

Estimation of the Efficiency Choice Models

The efficiency models were estimated with observations on those sites for which decision-maker surveys were available. This sample included 234 participants and 185 nonparticipants. However, one site was excluded from the estimation sample because it's case weight was relatively high, causing it to dominate the sample and yield unreasonably high net-to-gross ratios for lighting.

Two versions of the lighting efficiency model are depicted in Table 5-2. Version 1 includes all of the variables discussed above in the formulation of the model. Version 2 excludes variables with t values lower than 1.0, on the grounds that these variables contribute nothing to the overall explanatory power of the model. We will focus here on the second version, which was used for final calculations. The participation variable ($PART_i$) is significant, but neither the Mills Ratio (MR_i) nor the interaction term ($MRPART_i$) are significant. As shown, the other results are mixed. For instance, interestingly, owner occupancy (OWN_i) is negatively associated with lighting efficiency. This result seems to be attributable to relatively heavy retrofit activity among participating sites with long-term leases. The sign on the lighting payback term (PAY_L_i) is also counterintuitive. It suggests that sites with longer paybacks opt for lower lighting efficiency levels than those with short required paybacks. However, we should note that this result takes participation status as given, and the likelihood of participation is strongly positively related to the length of the payback. Table

[4] Goldberg and Train (1995). "Net Savings Estimation: An Analysis of Regression and Discrete Choices Approaches." Report submitted by Xenergy, Inc. to the CADMAC Subcommittee on Base Efficiency, August 1995.

5-2 suggests that the self-reported importance of energy efficiency (*EFFIMP*$_i$) is positively related to efficiency choices, while the size of the site is negatively associated with efficiency.

Table 5-2: Lighting Efficiency Model Estimation

Dependent Variables	Version 1 *EFF_L*	Version 2 *EFF_L*
Intercept	0.334828 (1.884)	0.283817 (2.104)
OWN	-0.296337 (-2.635)	-0.292566 (-2.613)
BOTHFT	-0.013729 (-0.121)	
PAY_L	-0.008072 (-3.272)	-0.007807 (-3.206)
ENERCOST	-0.005004 (-0.564)	
POTEN	0.066161 (0.570)	
EFFIMP	0.283293 (2.233)	0.289841 (2.368)
PART	0.491452 (2.124)	0.487353 (2.504)
MR	-0.041864 (-0.229)	-0.029386 (-0.164)
MRPART	-0.233743 (-1.241)	-0.248478 (-1.331)
SQFT	-0.000001096 (-3.724)	-0.000001084 (-3.713)
Adjusted R^2	0.3041	0.3081

Table 5-3 presents the efficiency model results for HVAC. As shown, both the free-standing participation variable and the interaction term with the Mills Ratio are highly significant. Aside from the participation terms, the only significant variable in this equation is cooling degree-days, which appear to have a positive effect on efficiency. This makes sense, given that cooling requirements affect the level of savings associated with a specific cooling measure.

Table 5-3: HVAC Efficiency Model Estimation

Dependent Variables	Version 1	Version 2
	EFF_H	***EFF_H***
Intercept	-0.414487 (-1.501)	-0.383587 (-2.080)
OWN	-0.029182 (-0.246)	
BOTHFT	-0.045264 (-0.379)	
PAY_H	-0.001934 (-0.848)	-0.002251 (-1.041)
ENERCOST	0.001692 (0.180)	
POTEN	-0.064936 (-0.529)	
EFFIMP	0.171778 (1.285)	0.148915 (1.174)
PART	1.932250 (7.926)	1.932933 (10.105)
MR	0.014355 (0.075)	0.008367 (0.045)
MRPART	0.496049 (2.520)	0.503117 (2.585)
SQFT	0.000000132 (0.426)	
AVGCDD	0.003263 (2.927)	0.003072 (2.856)
AVGHDD	0.000207 (0.151)	
Adjusted R^2	0.2205	0.2305

Development of Net-to-Gross Ratios

Gross savings are typically converted to net savings through the application of net-to-gross ratios. There are several ways of estimating net-to-gross ratios, including the use of self-reported estimates of program influence, the implementation of the difference-of-differences approach, and the application of statistical modeling approaches. RER's approach to the estimation of net-to-gross ratios differed across end uses, as explained below.

HVAC and Lighting. After the efficiency model was estimated, it was used to estimate the impact of program participation on HVAC and lighting efficiency levels for specific sites. Based on these estimates, a set of net-to-gross ratios were computed. For participant *i*, the net-to-gross ratio for end-use *k* is defined as:

$$\text{(7)} \quad Net\text{-}to\text{-}Gross\ Ratio_{ik} = \left(\partial EFF_{ik} \;/\; \partial PART_i\right) / \; EFF_{ik}$$

where the net impacts in the numerator is derived as the effect of the participation variable on the site's adjusted end-use efficiency. Note that the derivative of efficiency with respect to the participation variable is a function of the Mills Ratio, and was evaluated at the mean value of the Mills Ratio for participants.

Lighting and HVAC net-to-gross ratios were developed for all participants and aggregated to the program level through the development of weighted averages of these ratios across participating sites. These expansion weights, which were discussed in Section 2, were based on stratum *ex ante* energy savings. As a result of the fact that the efficiency models were estimated using total savings from rebated and non-rebated measures, the net-to gross ratios derived from them were then applied to gross participant savings from both rebated and non-rebated measures in order to develop the appropriate estimate of net savings.[5] The net-to-gross ratios for lighting and HVAC were estimated to be 0.96 and 0.89, respectively. These values are very close to those that would have resulted from a simple difference-of-differences approach (0.9996 and 0.9997, respectively).

Process Savings. It was not possible to use a modeling approach to develop a net-to-gross ratio for process savings, due to the fact that no nonparticipants adopted process measures during 1997. However, a simple difference-of-differences approach yielded a net-to-gross ratio of 1.0 for this end use.

Refrigeration. Given the small percentage of savings associated with refrigeration measures, CPUC Protocols did not require the development of an *ex post* net-to-gross ratio for this end use. The refrigeration net-to-gross ratio filed by SCE as part of its first earnings claim (0.80) was used in the estimation of net savings.

Summary of Net-to-Gross Results

Table 5-4 presents the results of the net-to-gross analysis. As shown, the three net-to-gross ratios range from 0.96 for lighting to 1.00 for process. This is typical for retrofit decisions, where inertia discourages conservation activities. It should be kept in mind that these

[5] In this kind of statistical comparison of participants and nonparticipants, DSM activity both within and outside the program must be included in the efficiency index. Otherwise, we would be "penalizing" participants who engage in DSM beyond that rebated by the program.

estimates (like others based on difference-of-differences and modeling approaches) apply to the program year in question and do not necessarily reflect the possibility that retrofits would have been made in some future year had the program been unavailable. Even when equipment replacement decisions are made, customers are unlikely to exceed standards given the new prevalence of high minimum efficiency standards for lighting, motors, and other energy equipment.

Table 5-4: Net-to-Gross Ratios by End Use

Program Measure	Net-to-Gross Ratio
Indoor Lighting	0.96
HVAC	0.89
Process	1.00
Refrigeration	0.80

5.5 Summary of Net Program Savings

Energy

Table 5-5 provides a summary of program savings by end use. The table presents statistically adjusted gross savings, net-to-gross ratios and estimated net savings per measure. SCE estimates are also presented for purposes of comparison. Comments are provided below, organized by end use:

- ***Lighting.*** As shown, RER's estimates of gross lighting savings are roughly 80% of SCE's gross verified energy savings. This difference stems primarily from the low statistical adjustment rate on lighting. As noted in Section 4, RER's low statistical adjustment rate was probably attributable to one of two problems: errors in SCE's characterization of pre-retrofit lighting densities, or changes in operating hours associated with major reductions in lighting densities. On the other hand, RER's estimate of net savings is 99% of SCE's estimate.
- ***HVAC.*** RER's estimate of gross HVAC savings is 62% of SCE's estimate. This result traces to the fact that RER's engineering estimates of HVAC savings were considerably lower than SCE's estimates, especially for EMS measures. RER's estimate of net HVAC savings is 64% of SCE's estimate.
- ***Refrigeration and Pumping.*** No analysis was conducted for these end uses. As a result, SCE's estimates of net and gross savings were adopted for measures falling under these end uses.

- ***All End Uses.*** The estimates of gross realized savings developed in this study are approximately 78% of gross verified estimates developed by SCE. The net savings estimate is 89% of SCE's net savings estimate.

Table 5-5: Net Energy Savings

	SCE Estimates			RER Estimates		
End Use	**Ex-Ante Gross Verified Savings (kWh)**	**Net-to Gross Ratio**	**Net Verified Savings (kWh)**	**Statistically Adjusted Gross Savings (kWh)**	**Net-to Gross Ratio**	**Statistically Adjusted Net Savings (kWh)**
Lighting						
Indoor Ltg.	*40,675,037*			*32,370,017*	*0.96*	*31,075,216*
LED Ltg. Only	*824,610*			*824,610*	*0.77*	*634,950*
Outdoor Ltg. Only	*501,023*			*501,023*	*0.77*	*385,788*
Total Lighting	***42,000,670***	***0.77***	***32,338,709***	***33,695,650***		***32,095,954***
HVAC	46,843,033	0.86	40,285,008	28,925,614	0.89	25,743,796
Miscellaneous						
Process	21,412,329	0.80	17,129,863	20,707,979	1.00	20,707,979
Refrigeration	6,704,788	0.80	5,363,830	6,704,788	0.80	5,363,830
Pumping	760,068	0.80	608,054	760,068	0.80	608,054
All	**117,720,887**		**95,725,465**	**90,794,098**		**84,519,613**

Demand

Demand savings were derived in a similar fashion. This approach assumes that demand savings are subject to the same statistical adjustment rates and the same net-to-gross ratios by end use. The results are included in Table 5-6.

As indicated in Table 5-6, RER's overall estimate of statistically adjusted gross peak demand savings is roughly 90% of SCE's gross verified peak demand savings. As a consequence of the high net-to-gross ratios derived in the study, RER's net demand savings estimate is higher than SCE's verified net program savings estimate.

Table 5-6: Net Demand Savings (kW)

	SCE Estimates			RER Estimates		
End Use	**Ex-Ante Gross Verified Savings (kW)**	**Net-to Gross Ratio**	**Net Verified Savings (kW)**	**Statistically Adjusted Gross Savings (kWh)**	**Net-to Gross Ratio**	**Statistically Adjusted Net Savings (kWh)**
Lighting						
Indoor Ltg.	7,662		5,900	7,266	0.96	6,976
LED Ltg. Only	100		77	100	0.77	77
Outdoor Ltg. Only	0		0	0	0.77	0
Total Lighting	7,762	0.77	5,977	7,366		7,053
HVAC	4,074	0.86	3,504	2,035	0.89	1,811
Miscellaneous						
Process	174	0.80	139	1,430	1.00	1,430
Refrigeration	20	0.80	16	20	0.80	16
Pumping	17	0.80	13	17	0.80	13
All	**12,047**		**9,649**	**10,868**		**10,323**

Confidence Intervals

Confidence intervals were developed for net realized savings using the approach followed in Section 4 for gross realized savings. That is, the efficiency models were reestimated combining the *PART* terms (constraining the coefficients on the *PART* terms to take on the values they were estimated to have in versions 2 of the models), and a relative standard error for the composite terms was estimated. This relative standard error was then used to develop confidence intervals. Note that these confidence intervals reflect only the error stemming from estimation the net-to-gross ratios, not the errors associated with the estimation of ex post adjusted gross savings. Developing a standard error that reflects both sources of error is analytically intractable. Also note that the confidence intervals take into account standard errors of only lighting and HVAC, insofar as SCE's ex ante refrigeration estimates were used and the net-to-gross ratio for process savings was set equal to 1.0 to reflect the absence of nonparticipant process savings.

For net energy savings, the resulting confidence intervals are:

- 90% confidence interval: 84,519,613 ± 21,488,177 kWh
- 95% confidence interval: 84,519,613 ± 25,688,248 kWh

The corresponding confidence intervals for net demand savings are as follows:

- 90% confidence interval: 10,323 ± 4,191 kW
- 95% confidence interval: 10,323 ± 5,006 kW

Appendix A

On-Site Survey Questionnaire

Appendix A is available in hard copy only.

Appendix B

Decision-Maker Surveys

Appendix B is available in hard copy only.

Appendix C

Site Information Sheets and Program Participation Coupon

Site Information Sheet

Summarizes program participation coupon information including contact name and program measures. Also includes meter numbers and most recent 12 months of consumption data. A site information sheet was generated for each site and attached to each participation coupon sent to ASW.

Program Participation Coupon

A packet created by SCE for each site containing all program information.

NOTE: **In accordance with confidentiality rulings, all specific site information has been omitted from this copy.**

Appendix C is available in hard copy only.

Appendix D

Comparison of RER and SCE Engineering Estimates of Savings

D.1 Overview

SCE and RER engineering savings estimates for HVAC, Process, and Refrigeration end uses are different. As shown in Table D-1, RER's Total Rebated Reportable savings is only about 77% of SCE's Total Ex Ante savings for the sites surveyed. The difference in engineering savings estimates is primarily due to differences in methodology. Savings results are presented in the two formats shown in Table D-1 and Table D-2 to highlight and examine these methodological differences.

Table D-1 contains results summarized on a "measure category" basis. Measure categories are used to group together sites with similar measures in order to examine the savings impacts for specific combinations of measures. Table D-2 contains results for the 10 sites with the largest kWh differences. This table is used to identify on a site-basis those sites with the largest impact on savings.

Savings Differences by Measure Category. This method of examining the savings differences is similar to that used for last year's study (1996 SCE Energy Management Hardware Rebate Program), except that additional categories were added to account for the significant Process and Refrigeration savings in this year's study. The nine measure categories as presented in Table D-1 are defined as follows:

- **VSD + EMS + Other** means the measures were VSDs, an EMS for the HVAC systems, and HVAC measures other than VSD or EMS.
- **PROCESS** means the only measures were Process (motor) measures.
- **VSD** means the only measures were VSDs for HVAC applications.
- **VSD + Other** means the measures were VSDs for the HVAC systems, and HVAC measures other than VSD or EMS measures.
- **VSD + EMS + REFG** means the measures were VSDs and an EMS controlling the HVAC and refrigeration systems.

- **VSD + EMS** means the only measures were VSDs and an EMS for the HVAC systems.
- **EMS** means the only measure was an EMS for HVAC system control.
- **Other** means the measures were HVAC measures other than VSD or EMS. Examples include high efficiency HVAC motors, high efficiency chillers, etc.
- **EMS + Other** means the measures were an EMS for the HVAC systems, and HVAC measures other than VSD or EMS.
- **EMS + REFG** means the measures were an EMS controlling the HVAC and refrigeration systems.

Table D-1: Differences in Engineering Estimates of Savings by Measure

Measure Category	RER Reportable Savings (kWh)	SCE Ex Ante Savings (kWh)	Measure % of Total SCE Savings	RER Savings as % of SCE Savings
VSD+EMS+Other	12,802,535	17,087,255	32.4	74.9
PROCESS	14,032,149	16,394,449	31.0	85.6
VSD	1,616,201	3,886,851	7.4	41.6
VSD+Other	3,348,498	3,833,153	7.3	87.4
VSD+EMS+REFG	3,537,661	3,211,229	6.1	110.2
VSD+EMS	1,080,308	2,736,911	5.2	39.5
EMS	2,106,205	2,516,298	4.8	83.7
Other	1,044,187	1,253,447	2.4	83.3
EMS+Other	482,832	1,062,957	2.0	45.4
EMS+REFG	382,971	823,428	1.6	46.5
Totals	**40,433,547**	**52,805,978**	**100**	**76.6**

Observations made from Table D-1 are summarized below. Note that these statistics are only applicable for the sites that were surveyed and do not reflect the overall SCE CEEI program.

- Total RER Rebated Reportable savings is 77% of Total SCE Ex Ante savings for the sites surveyed.
- The *VSD+EMS+Other* measure category has the largest share of savings, accounting for 32.4% of Total SCE Ex Ante savings.

- The *PROCESS* measure category has the second largest share of savings, accounting for 31% of Total SCE Ex Ante savings.
- All other measure categories account for the remaining 33.8 % of Total SCE Ex Ante savings, with no individual category being more than 10% and typically about 5%.
- *VSD* and *VSD+EMS* measure categories have the largest deviation from SCE savings; RER Reportable savings are only 39% and 41.6% of SCE Ex Ante savings, respectively.
- The *VSD+EMS+REFG* measure category shows savings 10% greater than SCE's savings.
- Savings for the remaining, significant HVAC measure categories are all about the same range, typically about 85%.

Sites with the Largest Savings Impacts. Another way of evaluating the savings differences is to look at those sites with the largest savings impacts. Table D-2 presents SCE Ex Ante savings versus RER Reportable savings for the 10 sites with the largest savings differences.

Table D-2: Engineering Estimates for the 10 Sites with the largest kWh Differences

RER_SITE	kWh Difference	SCE Ex Ante Savings (kWh)	% of Total SCE Ex Ante Savings	RER Reportable Savings (kWh)
28M1	3,152,704	8,034,666	15.2	4,881,962
66M2	2,994,583	10,029,552	19.0	7,034,969
414	1,648,113	2,023,605	3.8	375,492
87	1,001,421	3,074,776	5.8	2,073,355
611	626,984	707,662	1.3	80,678
120	596,164	692,000	1.3	95,836
15	587,753	1,034,487	2.0	446,734
69	389,247	706,913	1.3	317,666
610	372,473	1,075,331	2.0	702,858
492	265,165	1,495,045	2.8	1,229,880
Totals	**11,634,607**	**28,874,037**	**54.5**	**17,239,430**

The savings differences that can be observed in these tables are primarily due to methodological differences that include:

- The use by RER of on-site survey data and simulation of that data via SITEPRO/DOE-2 versus use of the MARS system and other non-simulation type savings estimates by SCE.
- Validation of the SITEPRO/DOE-2 simulations against actual monthly bills.
- Differences in the assumptions used by SCE to evaluate savings versus data from the on-site survey.
- Other more site-specific differences that can not be generalized; every site is unique in construction and operation.

These methodology differences and their resultant effects on savings estimates are discussed in detail in the following sections.

D.2 Characterization of Methodology Differences

As previously mentioned, the savings differences that can be observed in these tables are primarily due to methodological differences, which are summarized below and discussed in detail in the sections that follow.

- ***Savings Differences for HVAC VSD Applications.*** RER used a building simulation program to assess the savings whereas SCE analyses typically used the MARS Motors module.
- ***Savings Differences for HVAC Energy Management Systems (EMS).*** RER used a building simulation program while SCE used the simplified MARS HVAC module.
- ***Savings Differences due to Discrepancies in SCE Assumptions.*** Some of the assumptions and calculations contained in the SCE coupons and on which the savings estimates were based, were found to be incomplete or incorrect when compared to the on-site data. These discrepancies often resulted in large savings differences.
- ***Savings Differences for Process Sites.*** Savings differences for the process sites were mixed, with some sites showing more savings and others showing less savings. Since process savings are relatively large and there are only five process sites, the analysis for each site is described in detail.

- ***Savings Differences for Refrigeration Sites.*** Refrigeration savings differences were primarily due to standardization of the method used to estimate savings for anti-sweat heater (ASH) control, and for SCE not taking credit for cooling energy savings for implementation of VSD HVAC fans. Simulation of refrigeration energy use from on-site survey data and adjustment of the simulation to actual bills on a monthly basis account for additional savings differences.
- ***Special Sites.*** Two sites are responsible for a large percentage of the program savings. The analysis for each of these sites is discussed in detail in the Special Sites section.

D.3 Savings Differences for HVAC VSD Applications

A significant difference in HVAC savings estimates is due to the difference in methods used to estimate savings for this measure. As shown in Table D-1, for sites where the only measure is a VSD, RER savings are about 40% of the SCE estimate. Table D-1 also illustrates the fact that almost all HVAC savings include an HVAC VSD type measure; VSD-related measure categories account for 54% of overall program savings and 84% of all HVAC savings.

Rebated HVAC VSD applications included air handling units, chillers, cooling tower fans, chilled water pumps, condenser water pumps, and hot water pumps. Since the specifics of the HVAC system design determine the loads and operation of each of these components, the best way to estimate savings for these measures is to simulate the components as part of a complete HVAC system. This is the method employed by RER via the use of on-site survey data (operating hours, schedules, weekday/weekend operation and temperature settings, etc.) in a building simulation program (DOE-2 via SITEPRO).

SCE typically used the Motors module of the MARS system to evaluate savings for HVAC VSDs. Primary inputs were motor hp, the total number of motors, the monthly operating hours, and the pre and post motor control types. Savings were then estimated by combining the calculated motor kW and monthly operating hours with a representative operating profile and performance curves corresponding to the pre and post motor control type. Example operating profiles and performance curves are given in Table D-3.

Table D-3: Typical Inputs for MARS Motors VSD Savings Calculations

% Speed	Operating Hours	Non-ASD % of Power	ASD % of Power
20	0.0	100	5
30	0.0	100	8
40	0.0	100	14
50	33.1	100	21
60	45.2	100	32
70	14.1	100	44
80	1.8	100	57
90	0.4	100	73
100	0.4	100	105

Examples of savings differences for several of the surveyed sites with either VSD cooling tower fans, air handlers, and chillers as noted are provided in Table D-4.

Table D-4: Savings Differences for HVAC VSD Applications

RER_SITE	Measure	SCE (kWh)	RER (kWh)	% of SCE
45	VSD Cooling Tower Fans	122,825	38,007	30.9
65	VSD Cooling Tower Fans	154,945	15,098	9.7
68	VSD Air Handling Units	159,754	15,656	9.8
86	VSD Air Handling Units	323,335	73,312	22.7
60	VSD Chiller	315,968	50,907	16.1
120	VSD CT Fans & Pumps	692,000	95,836	13.8

D.4 Savings Differences for HVAC Energy Management Systems

An HVAC Energy Management System (EMS) can control and monitor a variety of functions. Rebated HVAC EMS applications included economizer control, temperature setback/setup, system scheduling/shut down, optimum fan start/stop control, chilled water reset, condenser water reset, and miscellaneous others, although the bulk of savings can probably be attributed to the setback/setup and shutdown functions.

Differences between SCE and RER savings are partially due to a more detailed simulation of EMS measures in DOE-2 than could be accomplished with the SCE MARS evaluation. The best example is the more detailed simulation of internal loads and HVAC scheduling utilized by SITEPRO/DOE-2, which includes incorporation of actual business hours, end-use schedules that vary on an hourly basis, hourly weather data, and reduced operation on weekends and holidays. Another example is the more correct simulation in DOE-2 of other EMS type controls. For instance, optimum fan start can only be simulated in MARS as a reduction in operating hours, whereas DOE-2 applies this as a real control based on the applicable environmental conditions.

The MARS HVAC module apparently simulates operation via a single value, "Operating hours/month." SCE utilized this value to model EMS measures as a change in operating hours and/or changes in set point temperatures. This difference in methodologies alone can probably account for the typical 15% difference in savings shown for the EMS type categories in Table D-5. Additional savings differences are due to evaluation of EMS savings without considering interaction of the EMS with other measures. Since EMS systems were typically combined with other energy saving measures, this is a significant difference. Savings differences for several of the EMS-only sites are shown in Table D-5.

Table D-5: Savings Differences for HVAC EMS Sites

RER_SITE	SCE (kWh)	RER (kWh)	% of SCE
47	127,774	63,439	49.6
576	118,861	33,716	28.4
855	112,953	92,533	81.9

D.5 Savings Differences due to Discrepancies in SCE Assumptions

Discrepancies in the SCE savings analysis are another significant contributor to the savings differences. Most of the problems can be attributed to the difficulty of trying to adequately document the measures and savings for a large, complex site. What made these discrepancies even more significant is that most of these sites were responsible for a considerable percent of overall program savings. Four such sites are discussed below. Savings results for these sites are summarized in Table D-6.

- ***28M1.*** RER savings were only 60% of SCE's estimate. A check of the SCE energy savings versus actual bills showed SCE savings to be an unrealistic estimate at 32% of the current billed energy use. Coupon measures were poorly organized and reference materials were non-existent for some measures; there were no supporting calculations for EMS and VSD savings, the biggest savings contributors. In addition, many of the savings calculations were over-simplified spreadsheet calculations; again, no building simulation was performed. EMS lighting savings were also incorrectly included in the EMS (HVAC) measure.

- ***414.*** RER savings were only 19% of SCE's estimate. Confusing coupon documents appear to have contributed to an incorrect evaluation of savings on the part of SCE. The coupon appears to show VSDs on two 250 hp fan motors. The MARS Motors runs were done for these two motors. However, an invoice in the coupon itself and verification by the on-site survey shows that a single VSD was installed on a 250 ton chiller not two air handling fans. Further error was added by using Outlet Damper fan control (the least efficient control type) in the MARS run, whereas the on-site survey showed van-axial fan control (one of the most efficient control types). This too would artificially inflate the savings numbers. Finally, due to the highly interactive nature of these measures, the separate evaluation of savings for each measure would also probably overstate savings even if they had been done correctly.
- ***120.*** RER savings were only 14% of SCE's estimate. The measures at this site were VSDs on the HVAC system. Although the primary discrepancy is most likely due to an overestimate of VSD savings as previously discussed, it was impossible to verify this since no reference documents for the savings calculations were included in the coupon. However, RER reproduced the MARS runs for the affected motors as reported by the on-site survey, and this compared well to the savings reported by SCE, so it was assumed that these runs had just been misplaced or maybe not copied.
- ***611.*** RER savings were only 11% of SCE's estimate. The measure at this site was the installation of a single high efficiency packaged HVAC VAV unit to replace a number of smaller constant-volume packaged HVAC systems. The majority of the SCE savings came from implementation of an economizer, which were derived via a MARS HVAC run. However, there was a gross error in the floor area used (20,000 ft^2 instead of roughly 8,500 ft^2) and the internal gains used (4,500 Watts per ft^2!). In addition, per the on-site survey and confirmation of the site contact, the previous constant-volume package systems did have economizers. Furthermore, the billing analysis actually indicated increased energy use.

Table D-6: Savings Differences for Sites with Assumption Discrepancies

RER_SITE	SCE (kWh)	% of Total SCE Ex Ante Savings	RER (kWh)	RER as % of SCE
28M1	8,034,666	15.2	4,881,962	60.8
414	2,023,065	3.8	375,492	18.6
120	692,000	1.3	95,836	13.8
611	707,662	1.3	80,678	11.4

D.6 Savings Differences for Process Sites

The analysis for the five process sites is described below and savings differences are presented in Table D-7. Savings for three of the sites are actually higher than SCE's estimates.

- ***66M2.*** RER's savings are 70% of SCE's estimate. This is one of two pumping stations covered by the SCE coupon CIR 66. Both stations pump hydrocarbons to Las Vegas through large pipelines that run across the desert and over the mountains. The measures were high efficiency on both and VSD control of one of two 3,500 hp motors. The difference here is primarily due to a verification of savings versus actual bills. A detailed calculation in the SCE coupon showed savings for the VSD controlled system that was about 64% higher than the energy use and demand from actual electric bills and the on-site survey data supported. RER savings accounted for this difference and the savings shown are the result of that revision.
- ***162.*** RER's savings are 125% of SCE's estimate. This is also a pumping station. The measure was destaging (1 of 5 stages) of two multi-stage, 1,250 hp pumps. As destaging is supposed to be a linear effect, this was simulated by RER as a simple 20% adjustment to the load factor from 65% (which showed good correlation to actual bills) for the post-retrofit run to 80% for the pre-retrofit run. RER savings was higher than SCE savings, but this higher level of savings seemed to be reflected in the billing data.
- ***784.*** RER's savings are 124% of SCE's estimate. For this site, VSDs were applied to injection molding machines. The primary difference in savings for this site is due to increased operation versus that assumed by SCE. The SCE savings estimate assumed 5 days a week operation, whereas the on-site survey showed 6 days a week operation.
- ***15.*** RER's savings are only 43% of SCE's estimate. Although the measure for this site was classified as a high efficiency motor change, it was actually much more than that. A 4,500 hp motor replaced a 3,000 hp motor for a car shredder application. Savings were based on the fact that the larger motor can shred more cars (expressed as tons/hour) then the smaller motor, and hence it would take less time and less energy to process a given tonnage of cars using the larger motor than the smaller motor. However, SCE savings were also based on a dramatic increase in hours of operation. Per the on-site survey, this increase was never realized. Instead, the new motor operates the same number of hours as the old system operated, and as a result, RER savings were much lower than SCE savings.
- ***66M1.*** RER's savings are 115% of SCE's estimate. This is the second of two pumping stations covered by the SCE coupon CIR 66. The measure was high efficiency for two 2000 hp motors. The difference here was due to a difference in the approach used for the calculations. SCE savings calculations are based on a predicted, average flow rate, whereas RER calculations are performed using the

motor hp, typical weekly operating hours, a typical load factor, and validated against actual bills. RER savings are probably more accurate because they better represent actual operation of the facility as opposed to the theoretical average flow rate based calculation.

- ***491.*** RER's savings are 57% of SCE's estimate. The measure for this site was the application of VSD controls to bottling equipment. The on-site survey stated that these systems operated at 100% load factor and 95% usage factor (5% down time), and even the SCE coupon stated that 50% of the time was at 90% load and 50% was at 100% load. Since VSDs actually use more energy at 100% load, this application could actually end up using more energy. This was a very marginal application. However, SCE was given the benefit of the doubt and a load factor of 95% and weekly operating hours of 168 * 0.95 were used for the RER simulation. These assumptions are the source of the savings difference.

Table D-7: Savings Differences for Process Sites

RER_SITE	Measure	SCE (kWh)	RER (kWh)	% of SCE
66M2	High Eff. & VSD Motors	10,029,552	7,034,969	70.1
162	Destaged Pumps	2,765,094	3,451,032	124.8
784	VSD Motors	2,094,300	2,599,939	124.1
15	High Efficiency Motors	1,034,487	446,734	43.2
66M1	High Efficiency Motors	399,456	458,432	114.8
491	VSD Motors	71,560	41,043	57.3

D.7 Savings Differences for Refrigeration Sites

Twenty-four stores from three major supermarket chains were surveyed for this project. Savings for these stores are about 8 % of total SCE program savings. Refrigeration measures include VSD condensers and EMS control of anti-sweat heaters, floating head pressure (FHP) control, mechanical subcooling, and VSD condensers. In addition, some chains also installed VSDs on their constant-volume single-speed HVAC fan systems.

Refrigeration savings are primarily a result of the difference in methodologies used to estimate savings for anti-sweat heater control. RER standardized the estimate by using a cycling factor of 0.45 for all stores, whereas SCE used a different factor for each of the supermarket chains. The factor used by RER was a value that was supported by estimates from a refrigeration consultant and that had also been confirmed by SCE from actual EMS operation for one of the supermarket chains.

Additional differences resulted from the simulation of energy use, and verification against actual monthly bills, which was made possible by SITEPRO. Refrigeration energy use is simulated in SITEPRO as a function of the number and length/size of refrigerated cases and walk-ins, compressor type, and condenser type. SCE estimates typically come from estimates by SCE or the contractor who installed the measures as a simple % of hours the system was expected to be off or on, connected load, and number of hours of operation.

Finally, for one chain, SCE claimed savings for implementing a cooling setup from 72 °F to 77 °F when the store was closed. This measure was not simulated by RER because in reality, any gain in cooling would probably be negated by an increase in refrigeration energy, due to interactivity of the HVAC and refrigeration systems. In fact, it appeared that SCE also recognized this fact because for one of the other chains, the early coupon documents included savings for this same measure that were not claimed in the final coupon. Results for one site of each supermarket chain are presented in Table D-8. Note that RER savings are higher than SCE savings for the two sites with VSD HVAC fans, for the reason previously explained.

Table D-8: Savings Differences for Refrigeration Sites

RER_SITE	Measure	SCE (kWh)	RER (kWh)	% of SCE
521C2	Anti-sweat Heater Control Cooling setup (ignored)	47,830	43,368	41.1
19C18	Anti-sweat Heater Control FHP Control VSD Refrig Condenser VSD HVAC Fan	320,787	404,450	126
562C52	Anti-sweat Heater Control FHP Control VSD Refrig Condenser VSD HVAC Fan	163,248	223,000	137

D.8 Special Sites

Two of the sites presented in Table D-2 are responsible for a large percentage of the overall program savings, as well as program savings differences. Due to their special impact on the overall savings differences, the analyses for these sites are discussed in detail below, even though they were previously discussed under other sections.

Site 66. This site is really two pumping stations that pump hydrocarbons to Las Vegas through large pipelines that run across the desert and over the mountains. SCE estimated savings at 10,429,008 kWh or about 19% of total SCE program savings for the surveyed sites. The measures were high efficiency motors at one site (66M1) and high efficiency motors and VSD control at the other site (66M2). Motor sizes and quantities are two at 2,000 hp and two at 3,500 hp, respectively. Although these sites have minimal or no floor area associated with them, a floor area of 10,000 ft^2 was used for expressing the energy intensities in order to make them more compatible with energy intensities for the rest of the survey sample.

RER savings for high efficiency motors for both sites were about 25% higher than SCEs estimate, due to a difference in calculation methods. SCE savings for this measure were calculated based on an average flow rate, whereas RER savings utilized the motor size, average load factor, and weekly operating hours, which is a much more accurate approach. In addition, RER savings were calculated after lining up the simulation to actual bills by adjusting the weekly operating hours.

However, RER savings for VSD control was only 64% of SCEs savings. SCE had very detailed VSD calculations in the coupon, which showed estimated *monthly* energy use for the VSD system. However, these SCE estimates were about 36% higher than the actual bills. However, since RER's initial calculation of savings was close to 64% of SCE's savings as adjusted for actual bills, SCE was given the benefit of the doubt and the RER VSD savings were simply adjusted to 64% of SCE's VSD savings. The final result of the analysis was a net RER savings for both sites of 71% of SCE savings.

Site 28M1. This is a 754,000 ft^2 hospital that underwent extensive improvements. Measures include high efficiency chillers, a multi-function EMS, high efficiency motors, resized pumps, and various VSDs. SCE savings were estimated at 8,034,666 kWh or about 15% of total SCE program savings for the surveyed sites.

RER's savings are only about 60% of SCE's savings. The biggest differences are the result of discrepancies in SCE documentation and the fact that no building simulations were performed to assess the savings from these highly interactive measures. Examples include:

- Savings for resized pumps were lumped into the chiller measure.
- Savings for the high efficiency motors were lumped into the VSD savings.
- There were no supporting calculations for the EMS savings, only a copy of an email and one page from a report with single, uninformative descriptions like "EMS from DOE-2 run" at 2,352,019 kWh and "Parametric EMS" at 1,038356 kWh. Supporting documentation may not have been copied from the original SCE documentation.

- There were no supporting calculations for the VSD savings, although savings appear to be in line with the usual MARS Motors calculations (which typically over-estimate savings). Again, supporting documents may not have been copied from the original SCE documentation.
- Chiller savings for the complex three-chiller system were performed using a simple spreadsheet and some assumed full load hours, which were the same for all three chillers.
- A similar simple spreadsheet approach was also used to assess the savings for the resized pumps.
- Reported savings yield an energy intensity of 10.7 kWh/ft^2. This is 32% of the current billed intensity and would have, if correct, represented savings of 25% of the pre-measure bills. Savings of this magnitude are possible but not probable.

The bottom line is that savings were inadequately assessed and, as a result, overestimated for this site. The building simulation performed by RER, which incorporates HVAC system data from the on-site survey, is probably a more accurate estimate of expected savings.

Appendix E

Weather Data

Appendix E is available in hard copy only.

Appendix F

On-Site Metered HVAC Data

This section contains a brief description of the on-site metered HVAC data for the 1997 SCE CEEI program evaluation. Contents of this appendix include:

- A table that shows which sites and end uses were metered.
- Plots showing average weekday/weekend load profiles.
- The on-site metered data saved on a CD-ROM.

F.1 Summary of On-Site Metered Sites

The sites and the end uses that were metered for each site are presented in Table F-1.

Table F-1: On-site Metered HVAC Sites

SiteID	VSD	EMS	CHILLER	ILIT
120	X			
14M1	X	X	X	
19C12	X			X
26			X	
28M1	X			
414		X		
451M1		X		
521C13		X		X

This table shows the following:

- Eight sites were metered for HVAC.
- VSDs were end use metered at four of the sites. VSD applications included air handlers, pumps, and chillers. Measurements were taken as amps but converted to kW for analysis purposes.

- EMS/temperatures were end use metered for four of the sites. Measurements were taken in °F.
- Large chillers were end use metered at two of the sites. Measurements were taken as amps but converted to kW for analysis purposes.

F.2 Summary Plots

Average weekday and weekend load profiles for the end use metered data are presented in the graphs contained in this appendix. Note for the label at the top of each graph that "WEEKEND=0" indicates a weekday and "WEEKEND=1" indicates a weekend. A few EXCEL graphs were also included two of the sites.

F.3 Electronic Data

The electronic data is contained on the CD (12.6 MB for files!) titled "On-Site Metered Data for the 1997 SCE CEEI Program Evaluation." A directory named for each site contains the end use metered data of that site. On-site metered data for lighting sites is also included on this CD. The numerous files for each site are stored as zip files that contain one or more of the following compressed files:

- The *.PRN files contain the raw, as-metered data in column-delimited format.
- The *.DOC file is the "Site Installation/Removal Form" which summarizes the installation and removal information for each monitored data point.
- The *.XLS files contain the final, massaged data in the engineering units required for analysis and presented on an hourly basis. This is the data used to generate the plots.

Appendix G

SITEPRO Reference

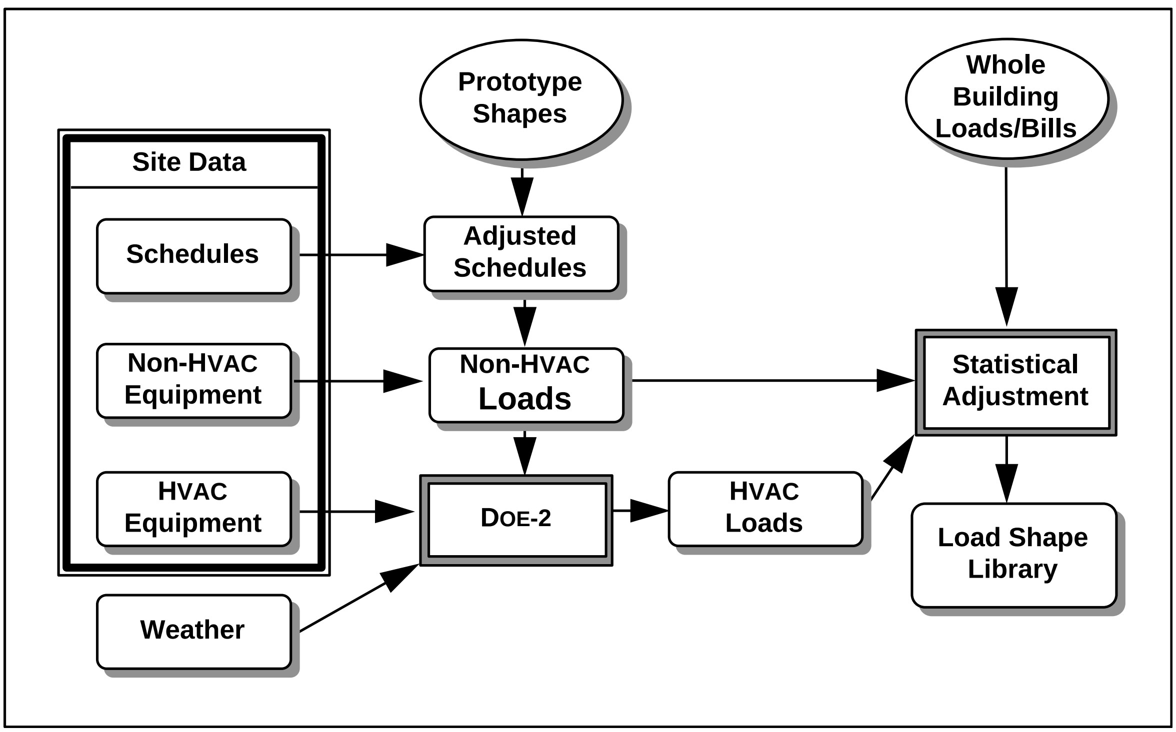
This section provides an overview of the SITEPRO system used by RER to perform its engineering savings estimates.

G.1 What is SITEPRO?

SITEPRO™ is a Windows program that has been designed specifically to translate on-site survey data into reconciled hourly load shape estimates for individual sites. The SITEPRO system embodies distilled versions of estimation and reconciliation algorithms that have been developed, refined, and tested in several prior projects of this type.

The SITEPRO modeling system is illustrated below in Figure G-1.

Figure G-1: SITEPRO Analysis Framework

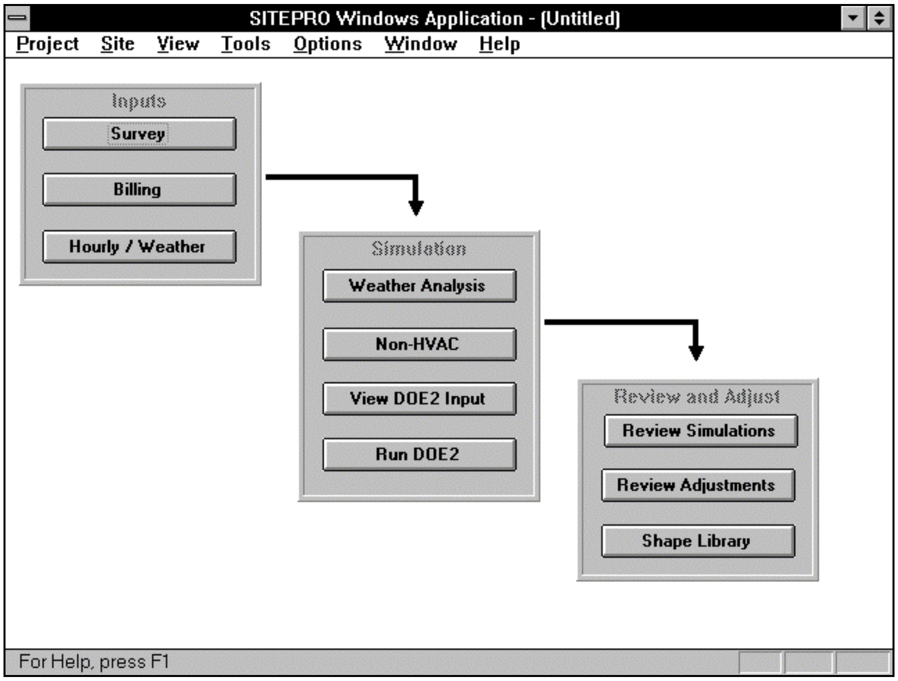


This framework is summarized as follows.

- Site data consist of information about business characteristics, building descriptions, inventories of HVAC and non-HVAC equipment, and building operating schedules. This information is gathered during an on-site survey and stored in an ACCESS database.
- Schedule information collected during the on-site survey is supplemented with or adjusted using prototype end-use shapes from the RER prototype building library. In cases where schedule information from the on-site survey are very limited, the prototype shapes are modified to incorporate the open and closed times recorded during the on-site survey. The result of this effort is a set of adjusted end-use schedules.
- The adjusted schedules and the connected loads for the non-HVAC equipment are combined to provide estimates of non-HVAC load shapes. Engineering algorithms developed by RER and incorporated into SITEPRO are used in this step.
- The non-HVAC load shapes, the HVAC equipment inventories and weather data for the selected area are input into DOE-2, which simulates the HVAC load shapes.
- The non-HVAC and HVAC load shapes are modified in a statistical-adjustment step to produce end-use load shapes that are consistent with the whole-building load shapes or monthly bills.
- Finally, reconciled load shapes are added to a building database load shape library. These site-level results can be retrieved and merged to create results on a building segment-level.

The SITEPRO Main Menu, shown in Figure G-2, illustrates the logic outlined in the previous section. Each button represents a step in the process of converting on-site survey data to load shapes. The functions connected to each button are described briefly below.

Figure G-2: SITEPRO Main Menu



G.2 Input Functions

SITEPRO inputs are illustrated by the *Survey*, *Billing*, and *Hourly / Weather* buttons on the Main Menu screen. Each of these inputs is described briefly below.

Survey Function. This button allows interactive review of the on-site survey data.

Billing Function. This button allows review and printing of calendarized, monthly billing data, and of comparisons of monthly billing data to whole building load research(WBLR) data, as illustrated in Figure G-3.

Hourly/Weather Function. This button is used to review hourly whole building load research data and hourly weather data, including dry-bulb, wet-bulb, and Temperature Humidity Index (THI) formats, as shown in Figure G-4.

Figure G-3: Example of Billing Data Screen

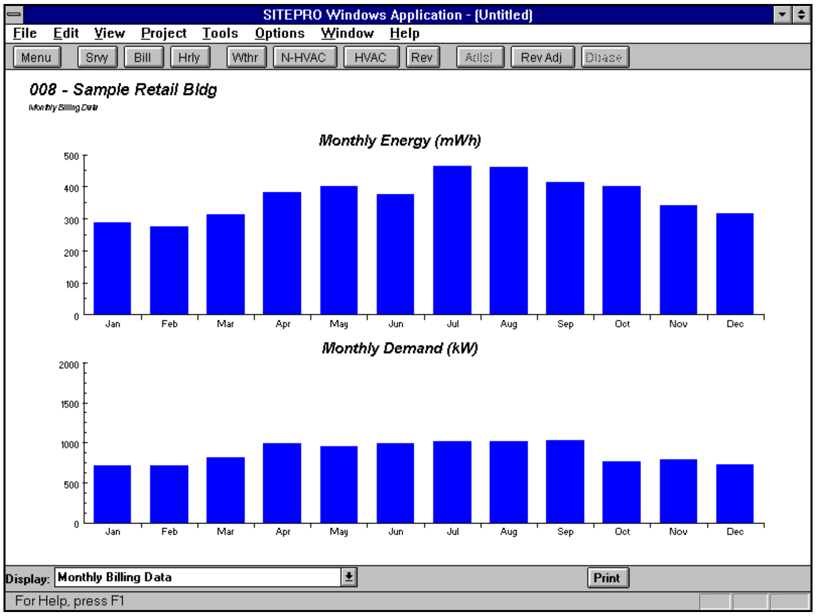
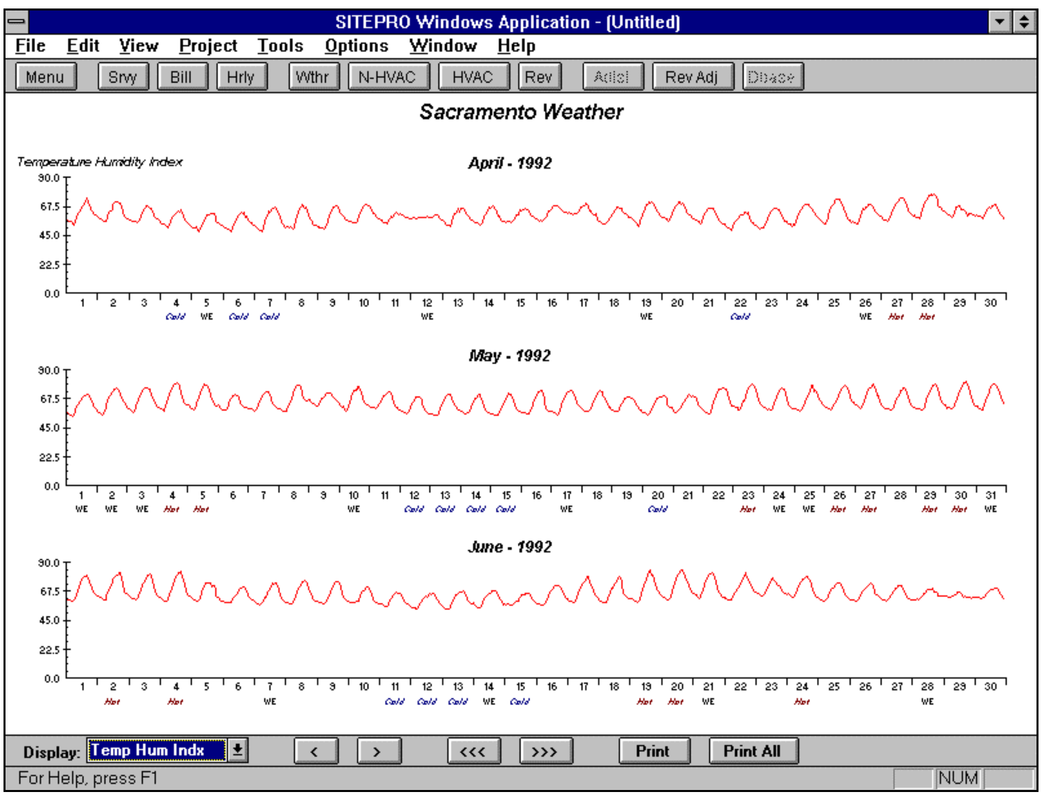


Figure G-4: Example of Weather Data Screen

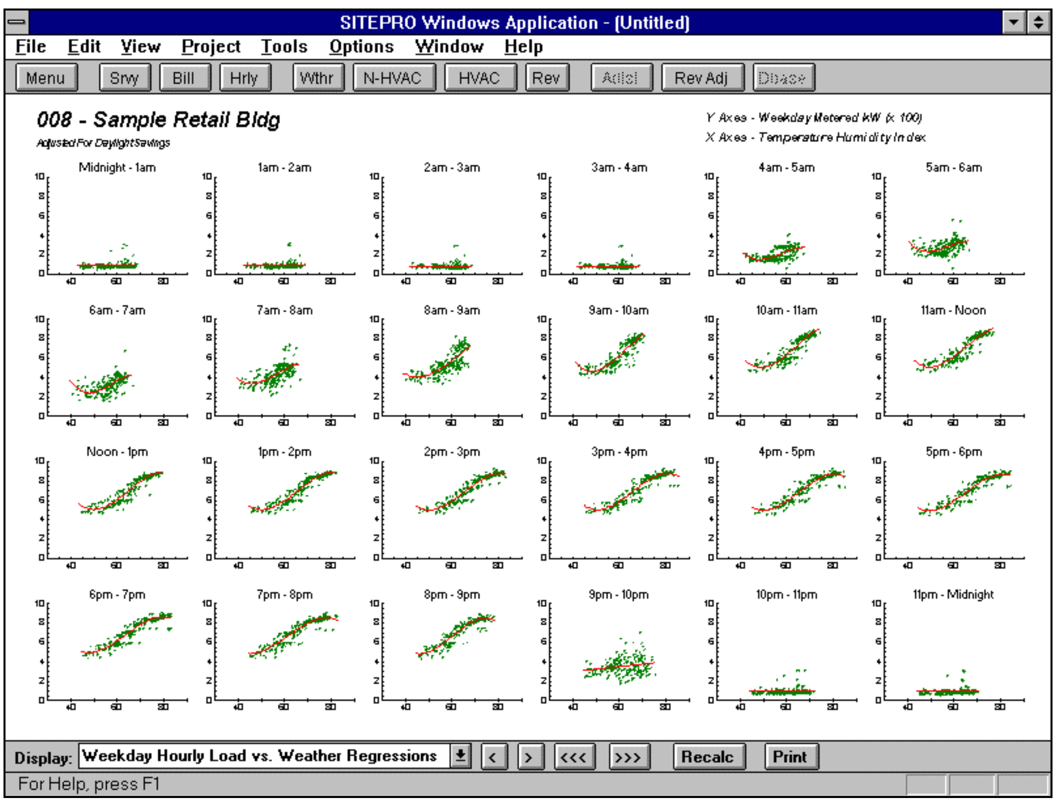


G.3 HVAC and non-HVAC Simulation Functions

SITEPRO simulation functions are illustrated by the *Weather Analysis*, *Non-HVAC*, *HVAC*, and *Review Simulations* buttons on the Main Menu. Each of these simulation steps is explained briefly below.

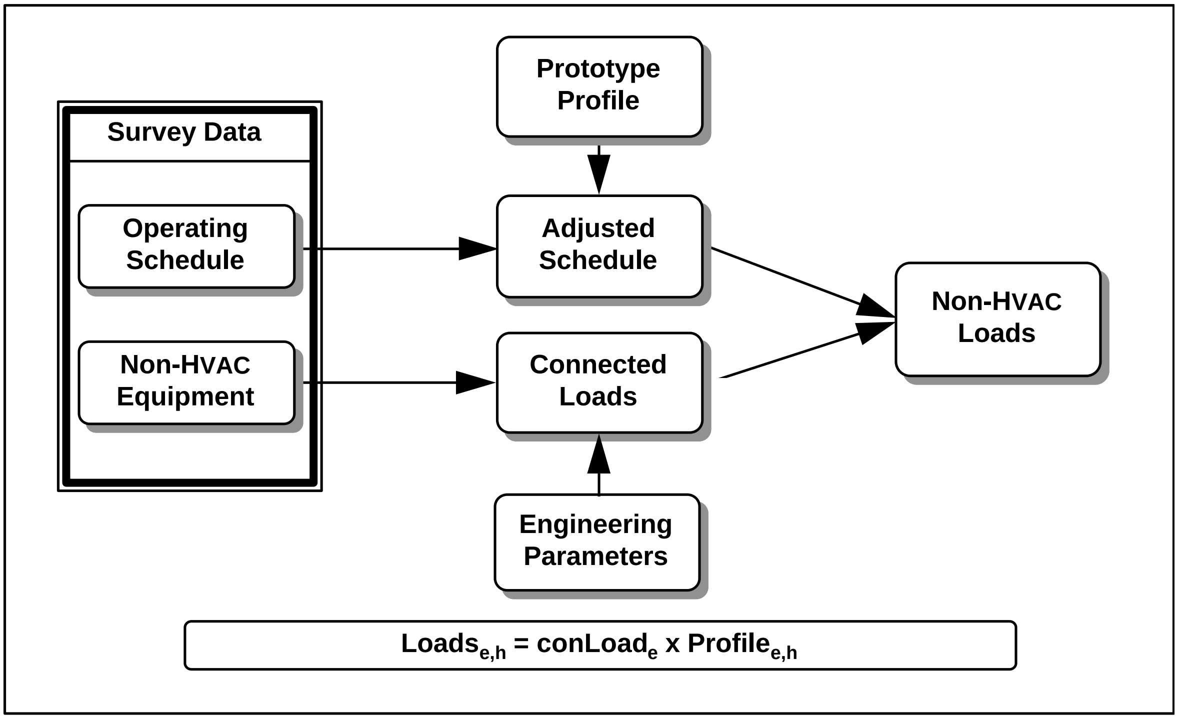
Weather Analysis Function. The weather analysis function is where WBLR data is separated into weather-sensitive and non-weather sensitive components. The information obtained from this analysis can be used in the Non-HVAC and Adjustment modules to modify the estimated end use loads for each building. An example of the screen used for this analysis is shown in Figure G-5. This figure shows a plot of building load versus temperature for each weekday hour. The vertical axes measure hourly energy use in Watts per square foot, while the horizontal axes measure Temperature Humidity Index (a function of dry bulb temperature and dew point).

Figure G-5: Regression Results for Whole-Building Metered Data



Non-HVAC Function. The framework for simulating non-HVAC load shapes is presented in Figure G-6. Non-HVAC end uses include water heating, cooking, refrigeration, outside lighting, inside lighting, office equipment, miscellaneous, mainframe computer, process, motor and air compressor uses. The non-HVAC simulation framework for each end use is summarized in three steps.

Figure G-6: Non-HVAC Simulation Framework



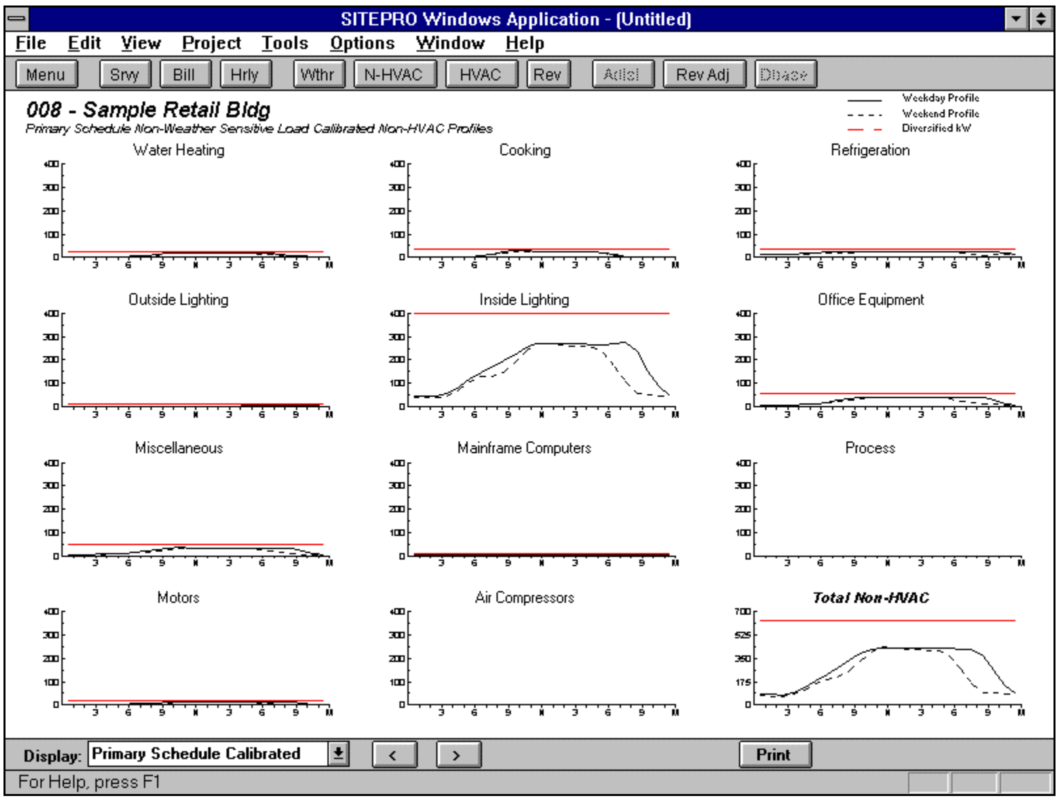
Step 1. Schedules. Ideally, the operating schedules obtained during the on-site survey provide information about the percent of equipment that is operating in each hour and daytype. Typically, this information is determined by auditor observation, examination of equipment controls, and discussion with the building operators. Key issues are the percentage of equipment that is on during the day, the percentage that is on during the night, and the transition profile between the two states.

Step 2. Connected Loads. Equipment inventories provide counts of the types and sizes of equipment found at the site. For example, for lighting, a lamp listing gives the number of lamps and the lamp Watts. Equipment inventories from the on-site survey are combined with engineering parameters to develop connected load estimates. Where appropriate, utilization factors are applied to the connected load values. Utilization factors provide a bridge between equipment rated capacity and expected average load when operating. These factors account for equipment cycling, wait-state energy requirements, usage patterns and diversity. These factors are important for office equipment, cooking, water heating, and other miscellaneous equipment. The result is a diversified connected load value.

Step 3. Diversified Non-HVAC Load Shapes. The diversified connected load is combined with the schedules for each end use to produce non-HVAC end use load shapes that peak at the diversified connected load.

An example of the final non-HVAC profile for a sample building is provided in Figure G-7.

Figure G-7: Example Non-HVAC End Use Profiles



HVAC Function. The HVAC simulation function executes DOE-2.1E to develop the preliminary HVAC load shapes. Figure G-8 summarizes the inputs required for this simulation. In computing HVAC shapes, DOE-2.1E accounts for the following factors:

(a) The distribution system type (e.g., single zone, multizone, fan coil, variable air volume, water-loop heat pump, etc.),

(b) The presence of terminal reheat coils,

(c) The presence of economizer cycles,

(d) The types of system controls and thermostat settings,

(e) The outside air percentages,

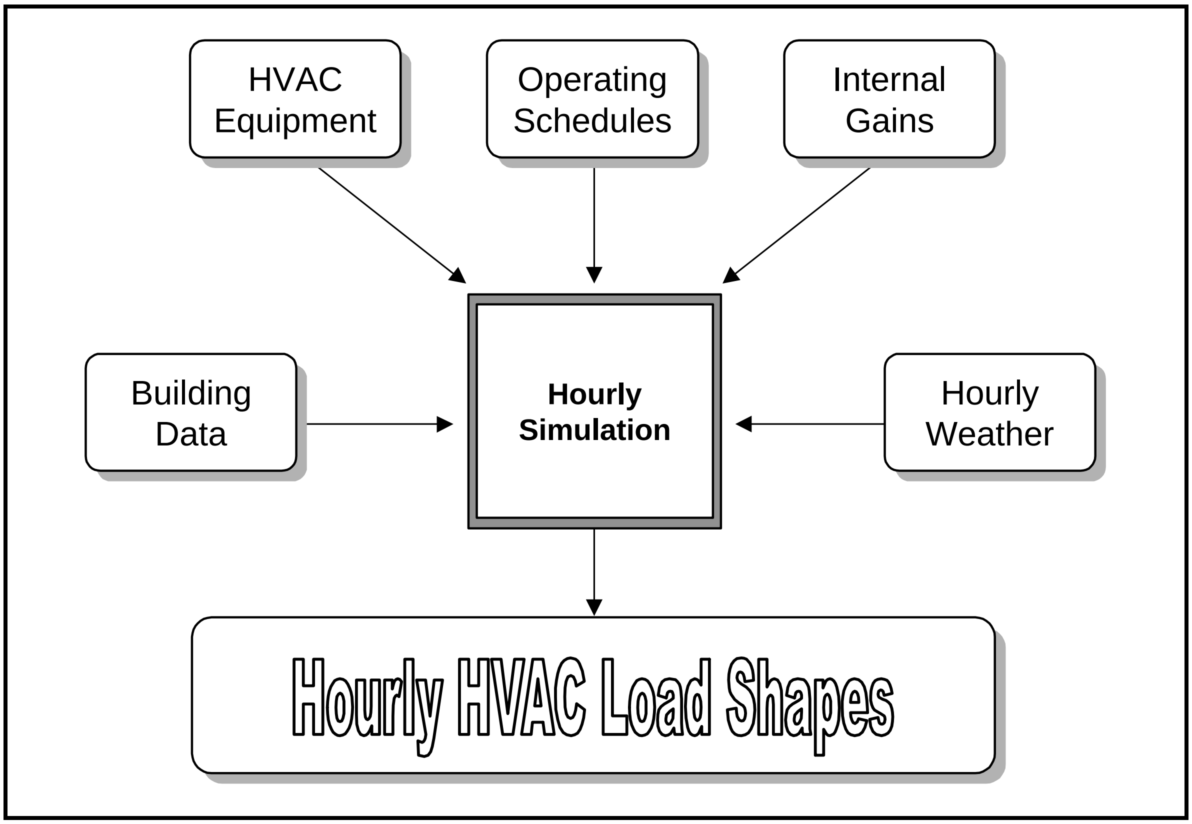
(f) Construction materials,

(g) Internal gains from lighting, equipment, and people, and

(h) Hourly weather conditions including temperature, humidity, and solar radiation.

Some of these data are available from the on-site surveys, and they are automatically translated by SITEPRO into the DOE-2.1E input file. For those factors for which on-site data are not available, default values borrowed from previous studies or DOE-2.1E defaults are used.

Figure G-8: HVAC Simulation Framework

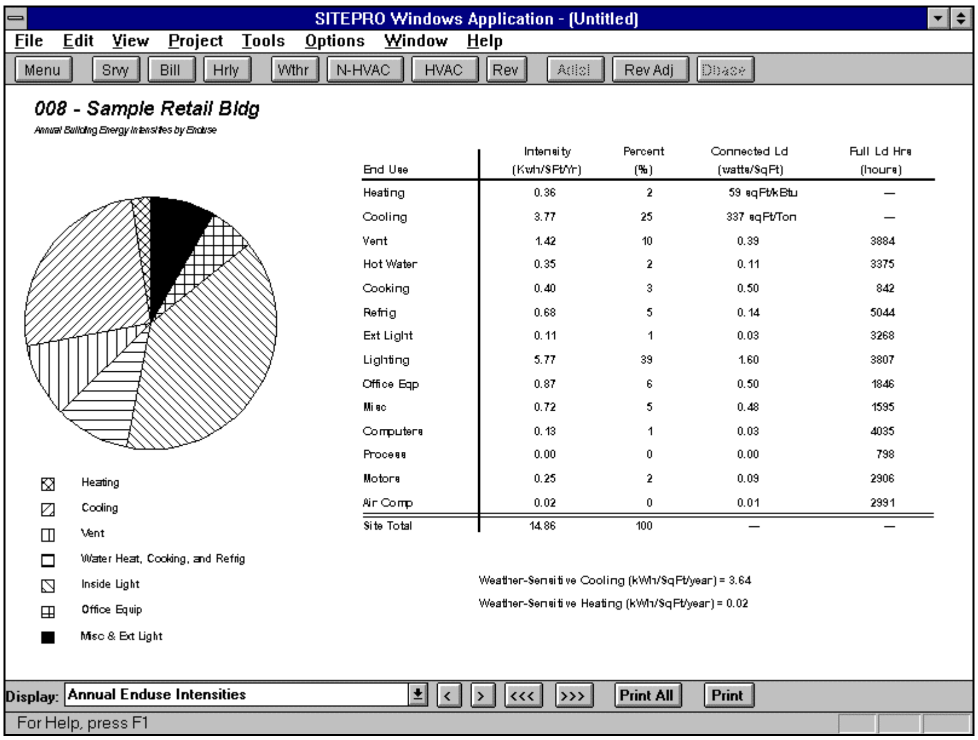


Review Simulation Function. This function allows the results of the non-HVAC and HVAC simulations to be reviewed prior to the reconciliation steps. Simulation results may be reviewed in a variety of ways:

- A summary of annual energy intensities (kWh/ft^2-yr) by end use as shown in Figure G-9.
- A monthly comparison of simulated results versus actual calendarized billing data as shown in Figure G-10.

- Whole-building simulation results versus hourly metered data in 16-day format as shown in Figure G-11.
- A comparison of hourly HVAC simulation results to the weather-regressed space cooling and space heating components of the calculated weather sensitive load in 16-day format, as shown in Figure G-12.
- Hourly whole-building simulation results (8,760 hours) versus hourly metered data, as shown in Figure G-13

Figure G-9: Summary of Annual Simulated Intensities by End Use



End Use	Intensity (Kwh/SFt/Yr)	Percent (%)	Connected Ld (watts/SqFt)	Full Ld Hrs (hours)
Heating	0.36	2	59 sqFt/kBtu	—
Cooling	3.77	25	337 sqFt/Ton	—
Vent	1.42	10	0.39	3884
Hot Water	0.35	2	0.11	3375
Cooking	0.40	3	0.50	842
Refrig	0.68	5	0.14	5044
Ext Light	0.11	1	0.03	3268
Lighting	5.77	39	1.60	3807
Office Eqp	0.87	6	0.50	1846
Misc	0.72	5	0.48	1595
Computers	0.13	1	0.03	4035
Process	0.00	0	0.00	798
Motors	0.25	2	0.09	2906
Air Comp	0.02	0	0.01	2991
Site Total	14.86	100	—	—

Weather-Sensitive Cooling (kWh/SqFt/year) = 3.64

Weather-Sensitive Heating (kWh/SqFt/year) = 0.02

Figure G-10: Comparison of Simulated and Monthly Billing Data

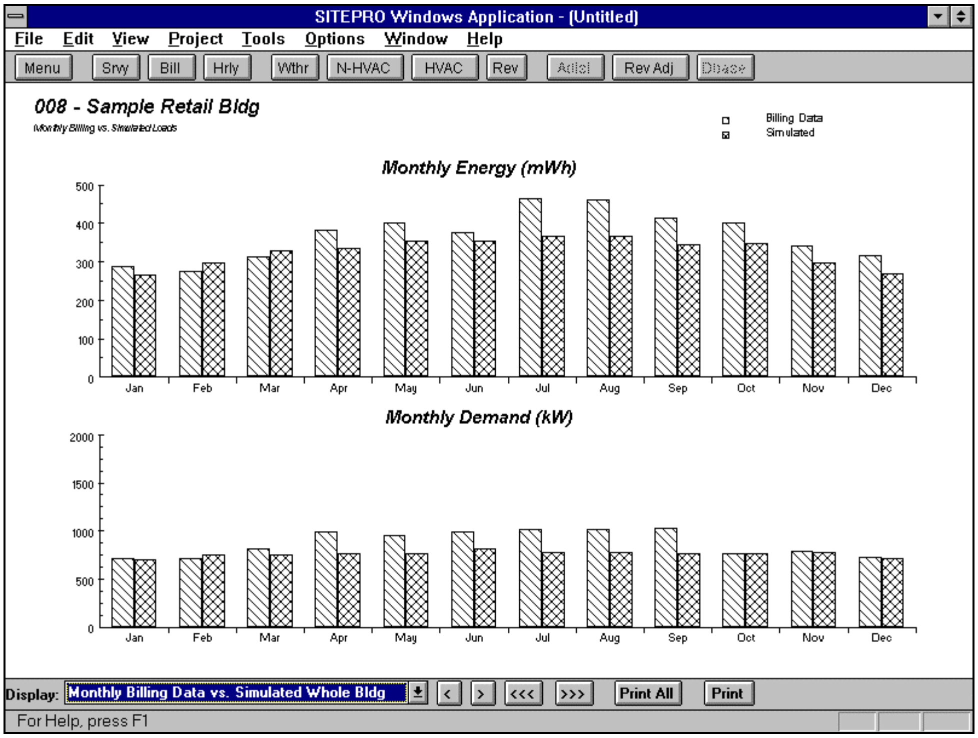


Figure G-11: Simulation Results versus Metered Loads in 16-Day Format

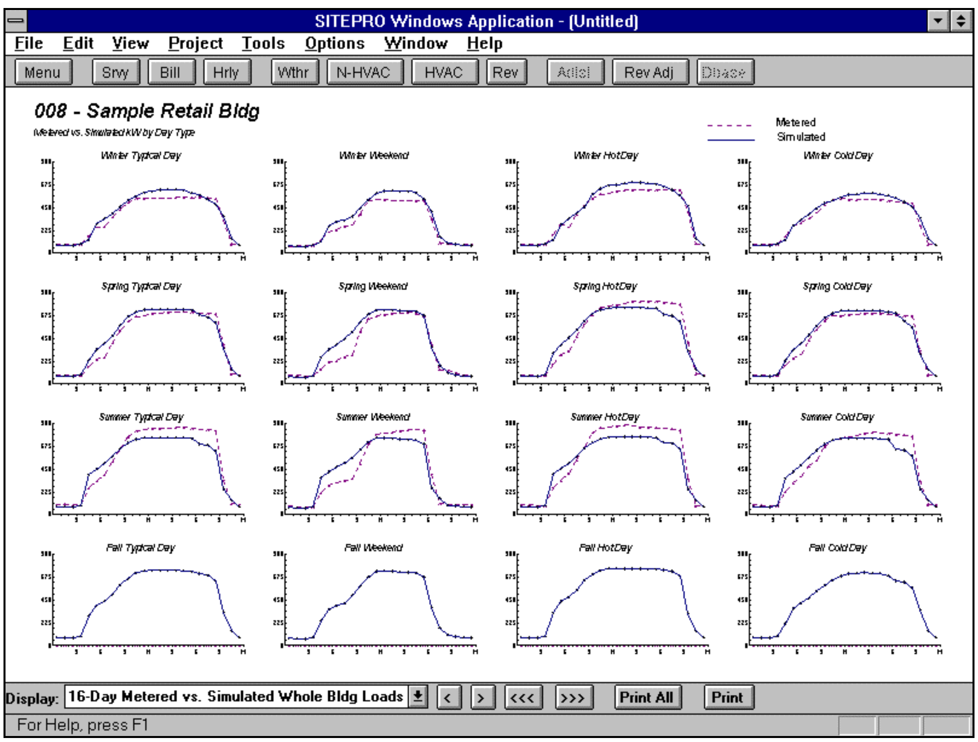


Figure G-12: Comparison of Simulated and Weather Sensitive Cooling

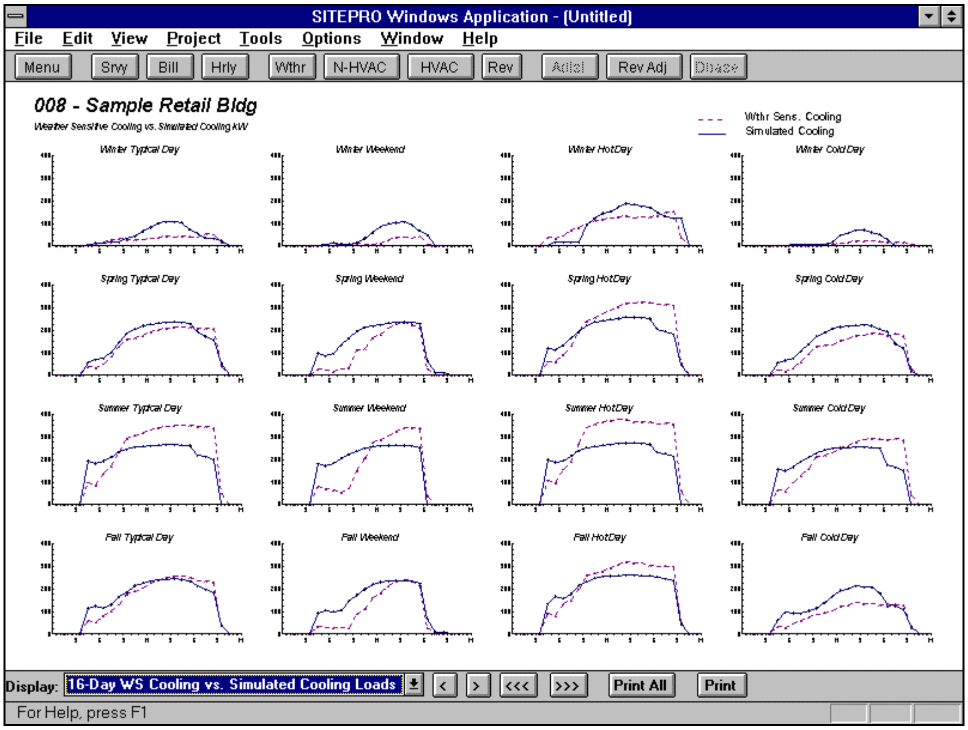
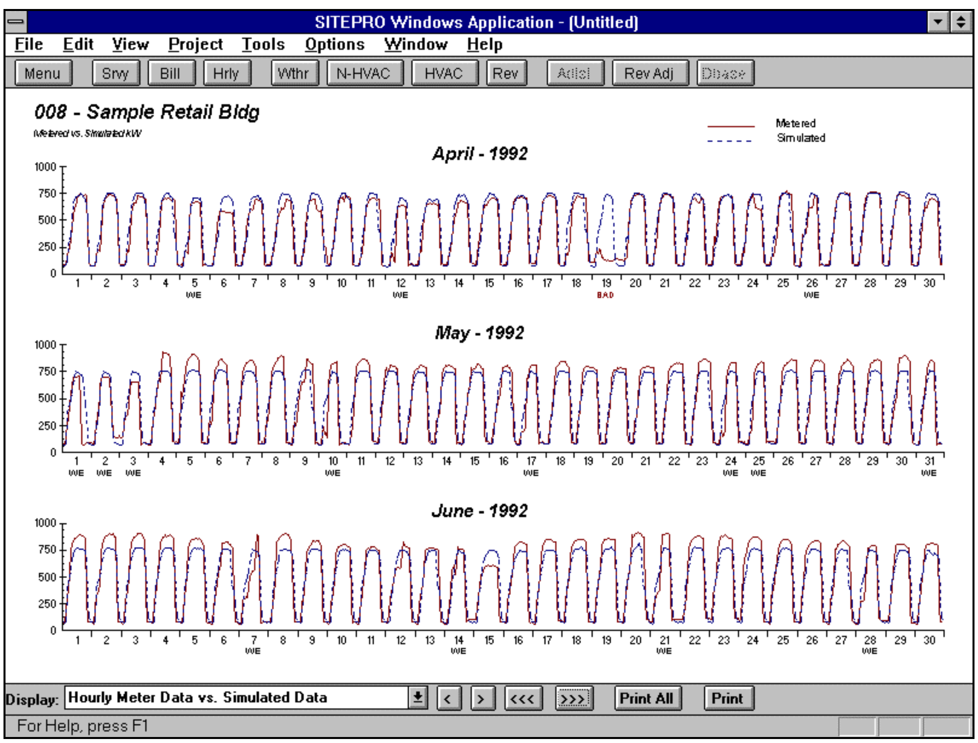


Figure G-13: Hourly Simulation Results versus Hourly Metered Loads



G.4 SITEPRO Simulation Results

The simulation results are stored in another ACCESS database referred to as the Load Shape Library. The data is stored as described below.

48-Day Hourly Shapes. SITEPRO results are stored as 48-day (Typical Weekday, Hot, Cold, Weekend), hourly end use shapes on a W/ft^2 basis. Additional information stored in the database includes customer name, floor area, percentage of conditioned floor area, weather data, building type, and full connected loads and peak loads for each end use.

Limited 8760 Shapes. SITEPRO also stores results on an 8760-hour basis, but the end uses are limited to cooling, heating, and Other, which is of course all non-cooling, non-heating energy use.

Appendix H

Regulatory Tables

Appendix H is available in hard copy only.