CALIFORNIA COMMERCIAL END-USE SURVEY

Chapters 1 to 5

CONSULTANT REPORT

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This report is dedicated to the memory of Alan Fields, who served as the project manager until his death on February 3, 2004. Alan was a valued colleague and dear friend. He will be missed by his associates at Itron, the California Energy Commission, and the energy industry.

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Publication CEC-400-2006-005APA contains the following 10 appendices that accompany this report:

CHAPTER 1: INTRODUCTION

1.1 Overview

This report presents the approach and findings of an extensive survey of the California commercial sector and an analysis of the way that sector uses energy. Itron, Inc. conducted the survey under contract to the California Energy Commission (Energy Commission). Subcontractors on the project team included KEMA (formerly Xenergy), ADM Associates, Volt VIEWTech, Inc., J.J. Hirsch and Associates, and SDV/ACCI. The survey was funded primarily by the California Public Goods Charge and partially by the Energy Commission.

The remainder of this introductory section provides a brief background for the study, reviews study objectives, summarizes the approach used to collect and analyze commercial data, and previews the remainder of the report.

1.2 Background

Historically, the Energy Commission has used customer characteristics data for a variety of purposes, including energy demand forecasting, market monitoring, and the assessment of energy efficiency opportunities. In the past, customer characteristics data were collected by the state's utilities, as required by the California Code of Regulations, Title 20, 1340 et seq. One of the major data collection efforts carried on by the utilities was a series of commercial end-use surveys. These surveys collected detailed information on commercial building energy use, thermal shell characteristics, equipment inventories, operating schedules, and other commercial building characteristics. The results of these surveys, along with results of other surveys of other customer classes, were provided to the Energy Commission to support its analysis needs.

However, in 1996, California Assembly Bill (AB) 1890 changed the way in which these customer data collection efforts were funded. AB 1890 instituted a Public Goods Charge (PGC) designed to finance energy efficiency program development and evaluation. The California Public Utilities Commission, which was charged with the oversight of the PGC, authorized the state's utilities to transfer two years of PGC-based funding to the Energy Commission in order to conduct a commercial survey commonly known as the Commercial End-Use Survey (CEUS). In early 2001, Itron, Inc. (then Regional Economic Research, Inc.) was selected to conduct the survey on behalf of the Energy Commission.

1.3 Project Objectives

In general, the study was designed to support the Energy Commission's end-use demand forecasting and energy efficiency market assessment activities. The specific analytical objectives of the project were:

- Develop estimates of end-use fuel shares, energy use by end use, and hourly load profiles for commercial market segments, at least partly to support the Commission's end-use forecasting process,
- Collect data on end-use energy efficiency to support the design and planning of energy efficiency programs and polices,
- Construct a flexible building energy demand analysis model to support the estimation of the hourly end-use load profiles, and
- Develop a means of estimating the hourly impacts of energy efficiency measures, load management strategies, building standards, alternative rate designs, and other programs and policies.

1.4 Summary of the Study

The project's general tasks included collecting commercial building characteristics data through on-site surveys, collecting electricity and natural gas use information on commercial facilities, developing a software system designed to facilitate the analysis of energy consumption patterns, using the software system to develop site-specific estimates of end-use load profiles, and developing overall commercial building-type characterizations. Itron's approaches to these tasks are summarized below.

Survey Design

The survey initially covered the service areas of California's four major investor-owned utilities: Pacific Gas & Electric Company (PG&E), Southern California Edison Company (SCE), Southern California Gas Company (SoCalGas), and San Diego Gas & Electric Company (SDG&E). It was eventually expanded to cover the Sacramento Utility District (SMUD) service area. Electric and natural gas billing data for commercial sector customers were provided by the utilities under agreements with the Energy Commission.

The primary sampling unit was the premise, defined as a single commercial enterprise operating at a contiguous location. A total sample size of 2,800 premises was targeted. The sample was stratified by utility service area, forecasting climate zone, building type, and size class. The sample design within utility service areas was optimized by using the Dalenius-Hodges approach for defining strata, and Neyman allocation of the samples across strata. The sample design is described in Chapter 2.

Collection of On-Site Survey Data

The first major component of the project was a comprehensive on-site survey to collect information on equipment stocks, operating schedules, efficiency levels, and shell characteristics of commercial buildings. The survey consisted of facility manager entry and exit interviews, building inspections, and inspection of site documents and records. For approximately 500 premises, time-of-use data loggers were used to monitor the operation of a sample of interior lighting systems and/or HVAC fans. The survey instrument used for recording CEUS participant information on site was relatively detailed, especially in the characterization of thermal HVAC zones within the premise. Data collection was conducted under an extensive set of protocols that standardized customer contact and recruitment procedures, interviews, building inspections, data logger installation and retrieval, and quality control. Survey design and implementation is described in Chapter 3.

Development of Energy Consumption Data for Sampled Sites

A primary task required for this study involved assembling information on energy usage for the surveyed sites. This information consisted of three basic types of data[1]:

- Utility billing records, consisting of information on billing determinants including energy use and, when available, time-of-use consumption and billing demand,
- Interval-metered electricity data collected by California's utilities as part of load research samples or as interval data used for billing of large customers, and
- Short-term metering data where the operation of a sample of HVAC and lighting systems for 500 premises was monitored with time-of-use data loggers.

Energy usage data for surveyed sites were used to inform the engineering analysis and to ensure the development of accurate estimates of end-use energy consumption and hourly load profiles. Billing records and interval-metered data were provided by the five utilities whose service areas were covered by the survey. Chapter 4 describes the procedures used to assemble consumption data.

Development of Demand Analysis System

The development of a comprehensive demand analysis system designed to facilitate the study team's and the Energy Commission's use of the engineering models to analyze commercial consumption patterns was a primary objective for the CEUS project. This demand analysis system is database-oriented and was designed for the following functions:

- Accommodate building simulations for individual sites,
- Facilitate batch simulations for sets of user-selected sites,

1 Utility customer information is confidential under the terms of Title 20 of the California Code of Regulations.

- View results graphically, including comparison of simulated results to utility billing data,
- Produce population estimates at the segment level using statistical weights,
- Produce population estimates for user-defined segments,
- Enable parametric simulations,
- Allow comparison of base case and alternative simulation results,
- Perform rate analysis using user-supplied rate schedules,
- Store simulation results in databases, and
- Allow export of results to spreadsheets and other common formats.

The demand analysis system, now called *DrCEUS*, consists of elements of two previously available software systems: SitePro, developed by Itron, and eQuest, developed by J.J. Hirsch and Associates[2]. eQuest, which is used as the framework for the analysis of weather-sensitive end uses, incorporates DOE 2.2 as a simulation engine. Chapter 5 provides a general description of the DrCEUS system and its capabilities.

Analysis of Premise-Level End-Use Energy Consumption

The next major phase of the study required the development of calibrated energy simulation models for all of the CEUS surveyed premises. These models generated energy consumption estimates at the end-use level for all 8,760 hours of the year. An attempt was made to conduct the simulation work within a reasonable time after completing the on-site survey. This facilitated the mitigation of problems identified in the survey data that were only realized during the modeling process. The analysis consisted of several discrete steps.

- First, survey data were entered into the DrCEUS system and initial building simulations were performed using actual historical weather from 2002. Simulated HVAC loads were developed using the DOE-2.2 engine incorporated into DrCEUS through eQuest. Non-HVAC end uses were calculated using algorithms that depended on survey information including occupancy schedules, equipment operating schedules, and connected loads. Simulation model output was summarized in several formats, including tabulation of end-use indices, 16-day[3] hourly end-use load profiles, and 8760 hourly load profiles.
- Second, simulation results were judgmentally calibrated against all available energy consumption information. It was necessary to first validate the list of

[2] DrCEUS is a proprietary product of these companies and is not available for distribution by the Energy Commission.

[3] The 16-day hourly shapes approach uses four day types—weekday, weekend, hot day (weekday), cold day (weekday)—for four seasons (winter, spring, summer, fall).

accounts and meters for the premise so an accurate history of energy use could be established. Billed usage (both energy and demand) was compared against the simulation results so that potential problems in the assumptions underlying the simulations could be identified. Wherever it was available, short-term metering data were also used to validate assumptions for lighting hourly use patterns and HVAC system operating schedules. Finally, if a site had interval-metered electricity data, it was used to construct 16-day hourly load profiles, which were then compared to the simulated profiles during the calibration process. The interval-metered data were invaluable for providing information on actual operation of the site.

- Third, simulation results were weather normalized by replacing the 2002 historical weather data with normalized weather data and rerunning the simulations. Itron developed normal weather data in DOE-2 compatible format for twenty weather stations specifically chosen for the CEUS project. A report describing the development of normal weather data is available separately from the Energy Commission.[4]

Chapter 6 describes the various steps of the simulation analysis in considerable detail.

Analysis of Segment-Level End-Use Energy Consumption

In the next step of the analysis, premise-level information (including simulated end-use load profiles) was used to characterize commercial segments. Projecting premise-level results to the population segment level was accomplished using an expansion module in DrCEUS, which applied expansion (case) weights developed from the final sample structure. For each service area and commercial building type segment, the following characteristics were estimated:

- Floor stocks,
- Fuel shares,
- Electric and gas energy consumption,
- Electric and natural gas end-use indices (EUI), which express the end-use energy consumption per square foot of floor stock with the end uses in question,
- Electric and natural gas energy intensities (EI), which express the end-use consumption per whole-premise square foot, and
- Hourly end-use load profiles.

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4 See Itron, Inc., *California Energy Commission Commercial End-Use Survey: Weather and Data Normalization*, November 14, 2003.

Chapter 7 defines these characteristics and discusses their calculation. Chapters 8 through 13 summarize the results of the study with respect to these commercial customer characteristics.

1.5 Organization of the Report

There are four primary sets of CEUS project documentation. They include this report, the appendices for this report, and two stand-alone supplemental reports. The organization of these elements is described below.

CEUS Report Structure

The remainder of this report is organized as follows:

- Chapter 2 describes the sample design for the on-site survey.
- Chapter 3 discusses the design and implementation of the survey, including the collection of short-term metering information.
- Chapter 4 discusses the development of electric and natural gas consumption data from utility billing records, as well as interval-metered electricity data.
- Chapter 5 describes the DrCEUS analysis system, covering both its overall design and its capabilities.
- Chapter 6 discusses the process of using DrCEUS to develop premise-level energy simulations, and calibrating the simulation models to actual historical energy consumption.
- Chapter 7 describes the development of segment-level results from the sampled premises, and defines the terms and concepts underlying the presentation of results.
- Chapter 8 presents results at the statewide level for all building types and end uses.
- Chapters 9 through 12 present utility-level results by building type and end use.
- Chapter 13 summarizes the study and provides recommendations for future research.

CEUS Report Appendices

Publication CEC-400-2006-005APA contains the following 10 appendices that provide additional technical detail on the project:

- Appendix A. Basic CEUS Survey Instrument
- Appendix B. Annotated CEUS Survey Instrument

- Appendix C. End-Use Equipment Mappings
- Appendix D. Recruitment Letter
- Appendix E. Recruitment Script
- Appendix F. Short-Term Metering Protocols
- Appendix G. Survey Database Layout
- Appendix H. Non-HVAC End-Use Algorithms
- Appendix I. Description of the Forecasting Climate Zone Results Database
- Appendix J. SIC Code to Building Type Mapping Table

Affiliated Reports from the CEUS Project

The following free-standing supplemental reports affiliated with the CEUS study provide more detailed information on weather and sample design issues. Both reports are available from the Energy Commission.

- California Energy Commission Commercial End-Use Survey: Weather and Data Normalization.
- Commercial End-Use Survey Sample Design Report.

CHAPTER 2: SAMPLE DESIGN

2.1 Overview

Development of the sample design for the CEUS project involved the investigation of a variety of different sample design approaches, as described in this chapter. There are four major elements of the sample design:

- Defining the Sampling Unit,
- Developing the Sample Frame,
- Identifying Sample Frame Stratification, and
- Developing a Sample Allocation Strategy.

Each element is discussed below, followed by a description of the final sample design. Some sections relate to the overall survey; others pertain to the two major elements of the survey: the survey of investor-owned utility (IOU) customers and the survey of SMUD customers. The latter survey was added to the workscope partway thorough the project, so its design was not subjected to the same level of consideration of alternative approaches as the design of the IOU survey. A full discussion of the sample design approaches for both the IOU surveys and the SMUD survey is contained in the *Commercial End-Use Survey Sample Design Report*.

2.2 Sampling Unit

The sampling unit for this study is a "premise." A premise is defined as a collection of buildings and/or meters serving a unique customer at a contiguous location. Therefore, a premise may have several buildings that are all occupied by the same customer, and each building may have several meters. Similarly, a premise may be a portion of a building such as one store in a strip mall, occupied by one customer and served by one meter.

SCE provided an indicator of premise in its billing frame. For the other utilities, an algorithm was developed to identify all meters associated with a single premise. The algorithm grouped all accounts/meters with matching service zip codes, the first 12 digits of the business name, and a compressed version of the service street number and name. The results from this process were then tested using the complete service address and the first three digits of the business name. Although this process is not a perfect premise identifier (typographical errors in the utility-supplied service address or business name not identified by the algorithm could create different premises), the majority of the accounts/ meters will be properly mapped. An overview of the premise aggregation algorithm is provided in the *Commercial End-Use Survey Sample Design Report*, which is one of the affiliated reports mentioned in Chapter 1.

2.3 Sample Frame for IOU Survey

Data for the nonresidential sample frame were supplied by the three electric IOUs (Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric). These account-level data were aggregated into 574,273 unique premises. Summary information developed for each premise includes the four potential stratification variables discussed below: utility, CEC forecasting climate zone, building type, and annual energy consumption for 2000. Table 2-1 provides the number of premises, percent of total premises, annual kWh for 2000, and percent of total annual kWh for 2000 by utility and building type. A more detailed discussion of the data provided by each utility and how these data were used to develop the frame is presented in the *Commercial End-Use Survey Sample Design Report*.

One note about building types and the ordering of building types: For all sample design discussions and tables, the Refrigerated Warehouse building type is presented last in the building type order, and “25.” is used as the identifying number. This designation is also coded into the site identifiers, e.g. P002*25*2001. However, in all discussions and presentations other than sample design, the Refrigerated and Unrefrigerated Warehouses are grouped together and presented in this respective order.

Table 2-1: Summary of Sample Frame

Utility	Building Type	Sample Frame	% of Sample Frame	Total kWh	% of Total kWh
pge	Total	234,548	100.0%	26,631,678,610	100.0%
pge	1. Small Office	75,733	32.3%	2,705,615,370	10.2%
pge	2. Large Office	1,674	0.7%	4,842,708,710	18.2%
pge	3. Restaurant	21,355	9.1%	2,152,749,139	8.1%
pge	4. Retail Store	32,995	14.1%	3,222,446,475	12.1%
pge	5. Food/Liquor	12,293	5.2%	2,830,486,642	10.6%
pge	6. Unref Warehouse	16,533	7.0%	1,579,011,394	5.9%
pge	7. School	6,460	2.8%	1,326,264,049	5.0%
pge	8. College	1,139	0.5%	823,561,664	3.1%
pge	9. Health Care	3,192	1.4%	1,561,817,961	5.9%
pge	10. Hotel	3,612	1.5%	1,013,920,214	3.8%
pge	11. Misc	58,708	25.0%	3,966,249,676	14.9%
pge	25. Refr Warehouse	854	0.4%	606,847,314	2.3%
sce	Total	256,724	100.0%	30,314,536,883	100.0%
sce	1. Small Office	83,438	32.5%	3,406,587,615	11.2%
sce	2. Large Office	1,736	0.7%	3,948,778,855	13.0%
sce	3. Restaurant	20,906	8.1%	2,738,791,595	9.0%
sce	4. Retail Store	39,889	15.5%	5,014,940,173	16.5%
sce	5. Food/Liquor	10,760	4.2%	3,295,534,621	10.9%
sce	6. Unref Warehouse	17,433	6.8%	1,886,686,022	6.2%
sce	7. School	5,032	2.0%	1,554,659,763	5.1%
sce	8. College	1,869	0.7%	827,897,421	2.7%
sce	9. Health Care	2,694	1.0%	1,814,666,549	6.0%
sce	10. Hotel	2,684	1.0%	1,125,621,479	3.7%
sce	11. Misc	69,760	27.2%	4,430,768,622	14.6%
sce	25. Refr Warehouse	523	0.2%	269,604,167	0.9%
sdge	Total	83,001	100.0%	8,325,536,210	100.0%
sdge	1. Small Office	39,304	47.4%	1,374,122,408	16.5%
sdge	2. Large Office	501	0.6%	1,303,496,943	15.7%
sdge	3. Restaurant	6,366	7.7%	692,389,265	8.3%
sdge	4. Retail Store	10,772	13.0%	1,032,429,584	12.4%
sdge	5. Food/Liquor	2,632	3.2%	620,001,352	7.4%
sdge	6. Unref Warehouse	4,714	5.7%	319,438,617	3.8%
sdge	7. School	1,407	1.7%	478,143,656	5.7%
sdge	8. College	511	0.6%	410,233,665	4.9%
sdge	9. Health Care	1,021	1.2%	512,072,925	6.2%
sdge	10. Hotel	865	1.0%	459,765,526	5.5%
sdge	11. Misc	14,610	17.6%	1,072,921,497	12.9%
sdge	25. Refr Warehouse	298	0.4%	50,520,772	0.6%

2.4 Sample Frame Stratification

The stratification of the frame had significant effects on potential sample allocations. The four variables used in stratifying the sample frame were; utility identifier, building type, size (annual kWh), and forecasting climate zone. Each of these variables is described in detail below.

- ***Utility Identifier.*** This variable identifies in which of the three utilities service territories (SDG&E, SCE or PG&E) the premise is located.
- ***Building Type.*** Twelve distinct commercial building types were identified jointly by Itron and the CEC. Building type assignments were based on SIC codes. The SIC code to building type mapping table used for the CEUS project is presented in Appendix J.[1]
  - Small Office
  - Large Office
  - Restaurant
  - Retail
  - Food/Liquor
  - Refrigerated Warehouse
  - Unrefrigerated Warehouse
  - School
  - College
  - Health Care
  - Hotel
  - Miscellaneous
- ***Size.*** Four size classes were developed, based on annual electric usage: Small, Medium, Large, and Census.
  - ***Census.*** The Census strata consist of all premises with annual kWh consumption above 12,868,956, or 0.02% of the total annual kWh for the three IOUs combined. They are denoted as “census” premises because every one of the premises in these strata was to be surveyed, hence there was no sampling involved. The Census premises were removed from the rest of the sample frame for the remainder of the segmentation process discussed below.

[1] Some thought was given to breaking out the miscellaneous category into sub groups (e.g. service stations). But it was ultimately decided, based on relative size (annual usage) and the potential use of the data by the CEC gained from adding these new building types, that these sub-groups did not warrant a new building type designation.

– ***Small, Medium, and Large.*** The remaining size strata were defined independently across building types using the Dalenius-Hodges approach.[2] A summary of the strata cutpoints identified for each building type using the Dalenius-Hodges approach is provided in Table 2-2.

Table 2-2: Building-Type Size Strata Cutpoints

Building Type	Cutpoints (Annual kWh)		
	Small	Medium	Large
1. Small Office	< 15,000	15,000 to 100,000	>= 100,000[3]
2. Large Office	< 2,000,000	2,000,000 to 4,750,000	>= 4,750,000
3. Restaurant	< 90,000	90,000 to 315,000	>= 315,000
4. Retail Store	< 80,000	80,000 to 900,000	>= 900,000
5. Food/Liquor	< 190,000	190,000 to 1,600,000	>= 1,600,000
6. Unrefrigerated Warehouse	< 85,000	85,000 to 1,000,000	>= 1,000,000
7. School	< 250,000	250,000 to 1,000,000	>= 1,000,000
8. College	< 400,000	400,000 to 3,750,000	>= 3,750,000
9. Health Care	< 450,000	450,000 to 3,000,000	>= 3,000,000
10. Hotel	< 300,000	300,000 to 2,200,000	>= 2,200,000
11. Misc	< 30,000	30,000 to 500,000	>= 500,000
25. Refrigerated Warehouse	< 500,000	500,000 to 3,000,000	>= 3,000,000

- ***Forecasting Climate Zone (FCZ).*** The Energy Commission's Forecasting Office uses 16 climate zones/planning regions, however only 11 of the 16 are represented in this study.[4] Table 2-3 presents a mapping of the forecasting climate zones to utility. Figure 2-1 presents a map of the forecasting climate zones. For more information on climate zones, see the *California Energy Commission Commercial End-Use Survey: Weather and Data Normalization* report.

[2] See Sampling Techniques third edition, William Cochran, John Wiley & Sons, New York, 1977 for a discussion of the Dalenius Hodges approach.

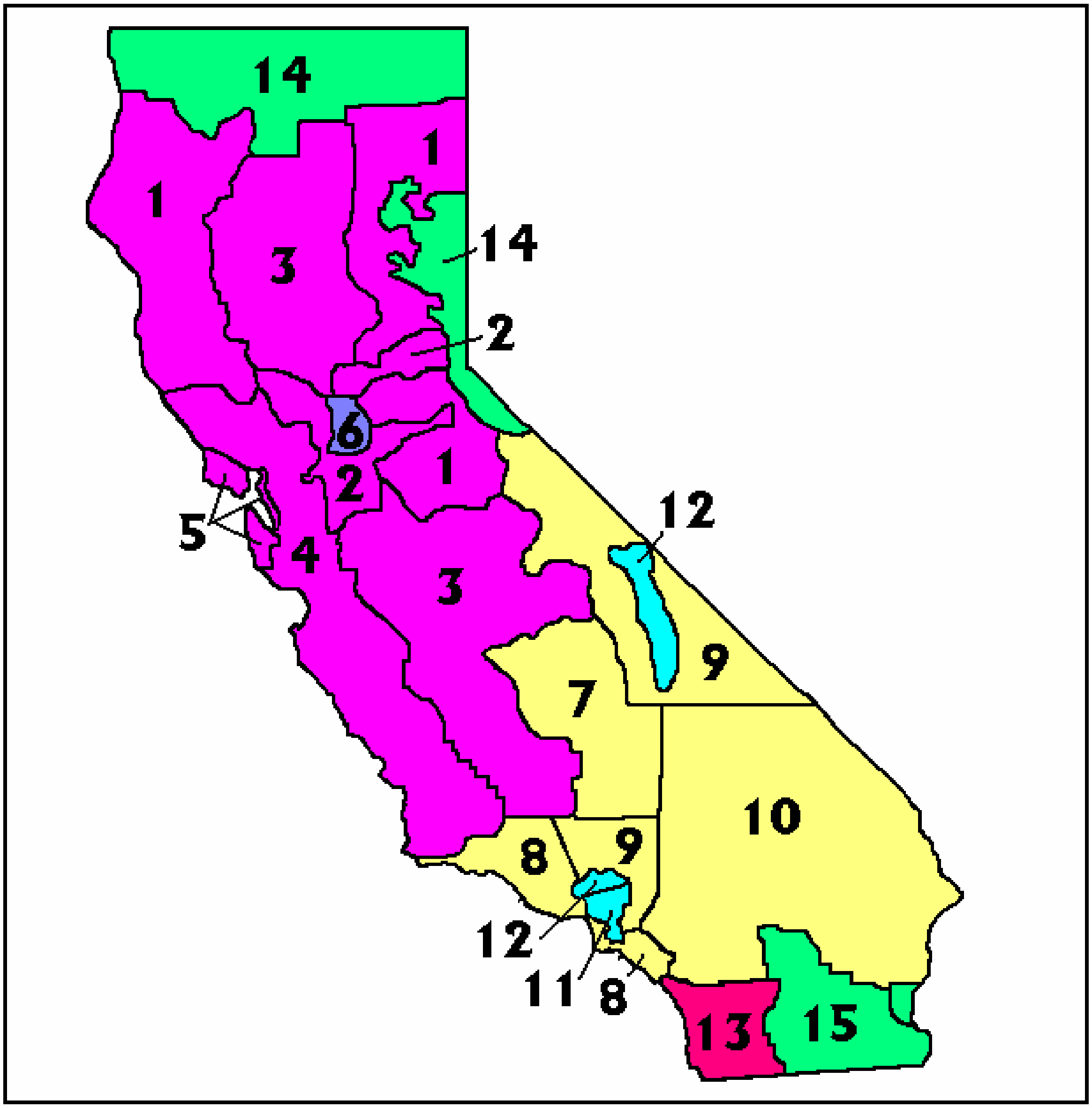
[3] The energy breakpoint for Small/Large offices was determined by assuming typical annual Large Office consumption of 20 kWh/ft^2-yr and a premise floor area of 50,000 ft^2, which yields an annual electricity use of 1,000,000 kWh.

[4] Forecasting climate zones are different from the climate zones used for California's Title 24 Energy Efficiency Standards (standards climate zones). A potential cause of confusion is that there are also 16 standards climate zones. The forecasting climate zones are based on both utility electric service area boundaries and climate, whereas the standards climate zones are based on climatic conditions and population centers, independent of utility service area.

Table 2-3: CEC Forecasting Climate Zone to Utility Mapping

Forecasting Climate Zones	Utility
1, 2, 3, 4, 5	PG&E
6	SMUD
7, 8, 9, 10	SCE
11, 12	LADWP
13	SDG&E
14, 15	Other
16	BGP[5]

Figure 2-1: CEC Forecasting Climate Zones[5]



[5] Due to its small size, BGP (Burbank, Glendale, Pasadena) is not represented on this figure. It is located along the northeastern/eastern edge of the LADWP 11/12 region.

2.5 Sample Size and Sample Allocation

Sample Size

The sample size for the initial portion of the project, which applied to the three investor-owned utilities, was pre-determined at 2,500. This number was based on assumptions about costs of completed surveys and available project budget.

Sample Allocation

There are many accepted methods of developing an allocation of sample targets across individual strata. Proportional, Neyman, and a combination of these allocation methods were evaluated for this project. These approaches, as well as the issues of minimum quotas and precision, are discussed below.

Proportional Allocation. Proportional allocation is relatively straightforward, allocating available premises across strata proportionally to some property. Proportional allocations by number of premises and by annual kWh were evaluated. Additionally, an overall proportional allocation and a proportional allocation by utility were evaluated. The formula for proportional allocation by annual kWh is presented below.

$$n_h = \frac{N * c_h}{C}$$

where:

n_h	=	Sample allocated to stratum *h*
N	=	Total sample available for the segmentation level
c_h	=	Annual kWh total for stratum *h*
C	=	Total annual kWh for segmentation level

Neyman Allocation. The Neyman allocation method minimizes the variance for a fixed sample, thereby optimizing the allocation of sample. This is essentially accomplished by weighting the allocation by the standard deviation. The general form for the Neyman allocation[6] is presented below.

$$n_h = n \frac{N_h S_h}{\sum_h N_h S_h}$$

[6] For a detailed discussion of the development of the Neyman allocation procedure, see Sampling Techniques third edition, William Cochran, John Wiley & Sons, New York, 1977.

where:

n_h	=	Sample allocated to stratum *h*
n	=	Total sample size
N_h	=	Total sample frame available for stratum *h*
S_h	=	Standard deviation of weighting variable (annual kWh) for stratum *h*

Alternative Allocation Approaches. Three sample allocation schemes were evaluated for this project. In all three schemes presented below, every premise in the population for the Census strata was targeted for inclusion in the sample. This approach is recommended by Hansen, Hurwitz, and Madow to take account of the large amount of information yielded by these premises because of their sheer size.[7]

- ***Proportional Allocation.*** The first allocation method evaluated is a proportional allocation based on total annual kWh across all strata.
- ***Overall Neyman Allocation.*** The second allocation method evaluated is a Neyman allocation across all strata.
- ***Proportional across Utility and Neyman Allocation within Utility.*** The final method is to initially distribute the sample proportionally by annual kWh across utility. Then, allocate sample targets across strata within each utility using the Neyman allocation. This variation of the Neyman allocation is designed to maximize the precision for estimating total commercial energy consumption for each utility service area, while maintaining the proportional distribution of sample points across utilities.

Minimum Quota Requirements. Once the sample is allocated into the defined strata, it is likely that several strata-specific samples will contain only one premise or no premises at all. Using two separate allocation schemes, at least one or two premises, if available, were allocated to each stratum. The relative error associated with each strategy was examined. This adjustment caused the total number of premises to rise above 2,500, so the total number of premises was then adjusted downward proportionally by utility until the overall target of 2,500 premises was achieved.

Precision. The precision of the estimate of total kWh is dependent upon the Relative Error of the estimate. The Relative Error with a 90% confidence for a stratified sample can be expressed as:

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7 Hansen, M. H., Hurwitz, W. N., and Madow,W. G. , Sample Survey Methods and Theory, John Wiley & Sons, New York, Vols. I and II, 1953.

$$RE = \frac{\sqrt{\sum_h \frac{N_h^2 S_h^2}{n_h}\left[1-\frac{n_h}{N_h}\right]}}{\sum_h N_h MEANkWh_h} * t-stat_{90,\infty}$$

where:

N_h	=	Sample frame for stratum *h*
S_h	=	Standard deviation for stratum *h*
n_h	=	Sample size for stratum *h*
$MEANkWh_h$	=	Mean annual kWh consumption for stratum *h*
$t\text{-}stat_{90,\infty}$	=	t-statistic for 90% confidence interval

2.6 Development of Final Sample Design for IOU Survey

Many options were considered in the creation of the final IOU survey sample design. These included, but were not limited to, sample allocation, stratification approaches, and minimum quota requirements. Each of these issues is discussed briefly below.

Allocation Methods

As discussed above, three allocation methods were evaluated.

- ***Method 1: Proportional Allocation.*** The first allocation method presented is a proportional allocation based on total kWh across all strata. This method, although quite simple, results in a relative error much higher than the other methods presented.
- ***Method 2: Overall Neyman Allocation.*** A Neyman allocation was developed across all strata. The Neyman allocation has a significant increase in precision compared to the proportional allocation. However, optimizing the allocation across utilities to maximize statewide accuracy yields a somewhat smaller than proportional sampling target for SDG&E, and therefore provides lower precision for the SDG&E service area. This is of concern since one of the primary objectives of the study was to make robust estimates of population characteristics at the building type level for each utility.
- ***Method 3: Neyman Allocation within a Proportional by Utility Distribution.*** This method has a slightly lower overall precision than Method 2, but does not suffer from the same sampling problems for SDG&E. It provides the flexibility to adjust the number of sample points for SDG&E upward so that adequate coverage could be obtained for all twelve building type categories.

Alternative Stratification Approaches

Several approaches to climate zone stratification were evaluated: no forecasting climate zone stratification, forecasting climate zone stratification, and additional climate zone stratification for SDG&E using the standards climate zone definitions.

- ***No Climate Zone Stratification.*** This method used only utility, building types, and size as the stratification variables.
- ***Forecasting Climate Zone Stratification.*** The sample frame was further stratified by forecast climate zone. In particular, each premise was mapped to a forecasting climate zone based on the ZIP code of the largest energy-using account. A potential disadvantage of this method is that it only assigns one climate zone to SDG&E, although there are several distinct climate regions.
- ***SDG&E Standards Climate Zone Stratification.*** Building on the approach of the forecasting climate zone method, each premise in SDG&E service territory was assigned one of two CEC Standards climate zones (coastal and inland) to acknowledge the varying climate regions within the service territory. Specifically, premises located in CEC Standards climate zones 6, 7, and 8 are grouped together into an "S7" climate zone and premises in CEC Standards climate zones 10, 14, or 15 are grouped together into an "S10" climate zone.
- ***Reduction of Minimum Quota Requirements from Two to One per Stratum.*** In an effort to maintain the geographical diversity of the sample that climate zone stratification provides without sacrificing precision, the minimum quota requirement for each stratum was lowered to one.

Summary-level results for each of these methods using the proportional by utility and Neyman allocation within utility are provided in Table 2-4. Key results to note include the following.

- ***No climate zone stratification provides the lowest relative error using a minimum of two premises per stratum***. This is not unexpected given the requirement of minimum quotas within stratum. That is, the minimum quota requirement of two was implemented only nine times using this method, as opposed to 143 for the forecasting climate zone method and 200 times for the SDG&E Standards climate zone method. This suggests that the other two methods tend to oversample certain stratum due the minimum quota requirement. This oversampling comes at the expense of overall precision.
- ***Introduction of standard climate zones within SDG&E lowers overall precision***. A similar situation exists when the additional climate zone stratification is added to SDG&E. Again, the minimum quota for certain stratum comes at the cost of overall precision.

- ***Reduction of minimum quota requirements increases overall precision***. Reducing the minimum quota requirement from two to one premise per stratum reduces the relative error to the level of the “no climate zone” method while maintaining the stratification by climate zone.

Detailed results for these four scenarios are included in the *Commercial End-Use Survey Sample Design Report*. Note that the three alternative allocation methods discussed earlier are also included in the results of the alternative stratification approaches in that appendix.

Table 2-4: Summary of Alternative Stratification Methods

Stratification Levels			Summary Statistics						Forecasting Climate Zones		No Climate Zones		2 SDG&E Standards Climate Zones, Minimum of 2 Premise per Stratum		2 SDG&E Standards Climate Zones, Minimum of 1 Premise per Stratum	
Utility	Climate Zone	Building Type	Sample Frame	% of Sample Frame	Total kWh	% of Total kWh	Average kWh	Standard Deviation	Sample Size	Relative Error	Sample Size	Relative Error	Sample Size	Relative Error	Sample Size	Relative Error
all			574,273	100.0%	65,271,751,703	100.0%	113,660	806,930	2,500	1.93%	2,500	1.90%	2,500	1.94%	2,500	1.90%
pge			234,548	40.8%	26,631,678,610	40.8%	113,545	845,517	1,020	3.02%	1,020	2.95%	1,020	3.02%	1,020	2.95%
sce			256,724	44.7%	30,314,536,883	46.4%	118,082	722,073	1,161	2.85%	1,161	2.81%	1,161	2.85%	1,161	2.82%
sdge			83,001	14.5%	8,325,536,210	12.8%	100,306	933,829	319	5.26%	319	5.26%	319	5.45%	319	5.30%
pge	1		17,176	3.0%	1,017,644,090	1.6%	59,248	302,918	74	15.70%	-	-	74	15.70%	54	16.78%
pge	2		17,384	3.0%	1,842,941,877	2.8%	106,014	518,940	97	11.29%	-	-	97	11.29%	79	11.82%
pge	3		50,308	8.8%	4,773,056,537	7.3%	94,877	670,598	188	7.36%	-	-	188	7.36%	191	7.18%
pge	4		60,171	10.5%	7,614,895,848	11.7%	126,554	1,006,882	266	5.60%	-	-	266	5.60%	275	5.48%
pge	5		89,509	15.6%	11,383,140,258	17.4%	127,173	931,709	395	4.57%	-	-	395	4.57%	421	4.39%
sce	7		12,874	2.2%	1,120,490,339	1.7%	87,035	402,750	78	13.95%	-	-	78	13.95%	54	15.67%
sce	8		105,616	18.4%	13,560,516,446	20.8%	128,395	731,191	480	4.20%	-	-	480	4.20%	495	4.12%
sce	9		85,356	14.9%	9,441,356,291	14.5%	110,612	788,618	356	5.13%	-	-	356	5.13%	363	5.06%
sce	10		52,878	9.2%	6,192,173,808	9.5%	117,103	647,753	247	6.51%	-	-	247	6.51%	249	6.41%
sdge	F13		83,001	14.5%	8,325,536,210	12.8%	100,306	933,829	319	5.26%	-	-	-	-	-	-
sdge	S7		61,471	10.7%	6,566,601,296	10.1%	106,824	1,054,338	-	-	-	-	226	6.20%	243	5.90%
sdge	S10		21,530	3.7%	1,758,934,914	2.7%	81,697	433,037	-	-	-	-	93	11.39%	76	11.98%
		1. Small Office	198,475	34.6%	7,486,325,393	11.5%	37,719	80,952	274	6.11%	284	5.98%	225	3.11%	282	5.99%
		2. Large Office	3,911	0.7%	10,094,984,507	15.5%	2,581,177	3,516,772	224	3.10%	213	3.06%	166	6.22%	219	3.04%
		3. Restaurant	48,627	8.5%	5,583,930,000	8.6%	114,832	149,886	166	6.21%	167	6.14%	393	5.84%	164	6.19%
		4. Retail Store	83,656	14.6%	9,269,816,232	14.2%	110,809	477,594	398	5.80%	418	5.66%	213	5.84%	414	5.67%
		5. Food/Liquor	25,685	4.5%	6,746,022,615	10.3%	262,644	836,707	213	5.83%	224	5.72%	187	9.41%	217	5.75%
		6. Unref Warehouse	38,680	6.7%	3,785,136,032	5.8%	97,858	494,752	187	9.39%	192	9.23%	112	8.35%	190	9.19%
		7. School	12,899	2.2%	3,359,067,469	5.1%	260,413	457,553	113	8.28%	111	8.28%	92	6.99%	108	8.34%
		8. College	3,519	0.6%	2,061,692,751	3.2%	585,875	5,317,897	86	7.15%	63	8.00%	164	6.96%	75	7.40%
		9. Health Care	6,907	1.2%	3,888,557,435	6.0%	562,988	2,285,785	162	6.96%	161	6.88%	112	9.60%	160	6.94%
		10. Hotel	7,161	1.2%	2,599,307,219	4.0%	362,981	1,197,268	109	9.64%	104	9.50%	499	6.19%	107	9.41%
		11. Misc	143,078	24.9%	9,469,939,796	14.5%	66,187	791,514	504	6.15%	526	6.01%	69	11.37%	520	6.04%
		25. Refr Warehouse	1,675	0.3%	926,972,254	1.4%	553,416	2,368,375	64	11.64%	37	14.32%	98	10.37%	44	13.64%
pge		1. Small Office	75,733	13.2%	2,705,615,370	4.1%	35,726	79,378	98	10.37%	104	10.03%	115	4.34%	103	10.05%
pge		2. Large Office	1,674	0.3%	4,842,708,710	7.4%	2,892,896	4,267,501	115	4.34%	108	4.30%	68	10.31%	112	4.23%
pge		3. Restaurant	21,355	3.7%	2,152,749,139	3.3%	100,808	140,431	68	10.31%	68	10.17%	132	10.03%	68	10.18%
pge		4. Retail Store	32,995	5.7%	3,222,446,475	4.9%	97,665	390,151	132	10.03%	143	9.64%	88	9.12%	142	9.65%
pge		5. Food/Liquor	12,293	2.1%	2,830,486,642	4.3%	230,252	591,124	88	9.12%	93	8.90%	78	14.63%	89	9.02%
pge		6. Unref Warehouse	16,533	2.9%	1,579,011,394	2.4%	95,507	496,874	78	14.63%	82	14.38%	48	13.80%	79	14.30%
pge		7. School	6,460	1.1%	1,326,264,049	2.0%	205,304	374,286	48	13.80%	47	13.60%	43	10.44%	46	13.70%
pge		8. College	1,139	0.2%	823,561,664	1.3%	723,057	5,458,080	43	10.44%	28	12.70%	65	11.80%	33	11.69%
pge		9. Health Care	3,192	0.6%	1,561,817,961	2.4%	489,291	1,744,559	65	11.80%	64	11.58%	45	16.08%	63	11.75%
pge		10. Hotel	3,612	0.6%	1,013,920,214	1.6%	280,709	961,904	45	16.08%	42	15.73%	208	9.39%	43	15.47%
pge		11. Misc	58,708	10.2%	3,966,249,676	6.1%	67,559	945,840	208	9.39%	221	9.08%	32	15.01%	218	9.12%
pge		25. Refr Warehouse	854	0.1%	606,847,314	0.9%	710,594	2,965,337	32	15.01%	20	17.29%	124	8.98%	24	16.30%
sce		1. Small Office	83,438	14.5%	3,406,587,615	5.2%	40,828	85,481	124	8.98%	128	8.83%	80	5.19%	127	8.84%
sce		2. Large Office	1,736	0.3%	3,948,778,855	6.0%	2,274,642	2,619,199	80	5.19%	76	5.10%	78	8.72%	79	5.05%
sce		3. Restaurant	20,906	3.6%	2,738,791,595	4.2%	131,005	158,469	78	8.72%	79	8.61%	219	7.82%	77	8.70%
sce		4. Retail Store	39,889	6.9%	5,014,940,173	7.7%	125,722	562,481	219	7.82%	228	7.66%	103	8.18%	227	7.66%
sce		5. Food/Liquor	10,760	1.9%	3,295,534,621	5.0%	306,276	1,102,266	103	8.18%	109	8.04%	93	13.22%	106	8.05%
sce		6. Unref Warehouse	17,433	3.0%	1,886,686,022	2.9%	108,225	528,876	93	13.22%	94	12.95%	50	11.81%	95	12.92%
sce		7. School	5,032	0.9%	1,554,659,763	2.4%	308,955	506,672	50	11.81%	49	11.97%	35	12.46%	47	12.08%
sce		8. College	1,869	0.3%	827,897,421	1.3%	442,963	3,226,577	35	12.46%	27	13.54%	74	9.44%	31	12.78%
sce		9. Health Care	2,694	0.5%	1,814,666,549	2.8%	673,596	2,823,824	74	9.44%	74	9.39%	45	14.49%	73	9.47%
sce		10. Hotel	2,684	0.5%	1,125,621,479	1.7%	419,382	1,224,878	45	14.49%	43	14.30%	234	9.10%	44	14.21%
sce		11. Misc	69,760	12.1%	4,430,768,622	6.8%	63,514	672,769	234	9.10%	243	8.92%	26	17.47%	241	8.95%
sce		25. Refr Warehouse	523	0.1%	269,604,167	0.4%	515,496	1,820,055	26	17.47%	11	27.48%	46	14.83%	14	26.11%
sdge		1. Small Office	39,304	6.8%	1,374,122,408	2.1%	34,961	73,514	52	13.91%	52	13.91%	30	8.56%	52	13.94%
sdge		2. Large Office	501	0.1%	1,303,496,943	2.0%	2,601,790	3,364,894	29	8.33%	29	8.33%	20	17.28%	28	8.65%
sdge		3. Restaurant	6,366	1.1%	692,389,265	1.1%	108,764	146,399	20	16.98%	20	16.98%	42	17.96%	19	17.49%
sdge		4. Retail Store	10,772	1.9%	1,032,429,584	1.6%	95,844	363,368	47	17.08%	47	17.08%	22	20.18%	45	17.32%
sdge		5. Food/Liquor	2,632	0.5%	620,001,352	0.9%	235,563	468,822	22	19.76%	22	19.76%	16	33.15%	22	19.84%
sdge		6. Unref Warehouse	4,714	0.8%	319,438,617	0.5%	67,764	327,082	16	32.46%	16	32.46%	14	22.30%	16	32.21%
sdge		7. School	1,407	0.2%	478,143,656	0.7%	339,832	574,178	15	21.08%	15	21.08%	14	12.72%	15	21.16%
sdge		8. College	511	0.1%	410,233,665	0.6%	802,806	9,502,978	8	14.84%	8	14.84%	25	19.40%	11	12.87%
sdge		9. Health Care	1,021	0.2%	512,072,925	0.8%	501,541	2,178,932	23	19.40%	23	19.40%	22	20.65%	24	19.01%
sdge		10. Hotel	865	0.2%	459,765,526	0.7%	531,521	1,812,848	19	21.37%	19	21.37%	57	19.21%	20	21.29%
sdge		11. Misc	14,610	2.5%	1,072,921,497	1.6%	73,437	615,881	62	18.25%	62	18.25%	11	48.63%	61	18.48%
sdge		25. Refr Warehouse	298	0.1%	50,520,772	0.1%	169,533	563,309	6	66.56%	6	66.56%	14	36.87%	6	69.81%

Final Sample Design

The study goals and how these goals impact the sample design goals guide the choice of a final sample design. In particular, the agreed upon study goal was to develop parameter estimates at the IOU service territory level. As such, precision at the IOU service territory level was assumed to take precedence. Given this goal and the alternative sample allocation methods and stratification approaches that were evaluated, the following sample design was chosen.

- ***Stratify the sample by utility, climate zone, building type, and annual usage.*** Using these variables to stratify the sample resulted in up to 1,584 strata (three utilities, 12 building types, 11 climate zones, and four usage levels). Note that no premises existed for some of the individual strata at this level of detail.
- ***Two CEC Standards climate zones for SDG&E stratification.*** Stratification by two CEC Standards climate zones for SDG&E was used. That is, PG&E and SCE were stratified by the CEC forecasting climate zones and additional CEC Standards climate zone breakouts for SDG&E were used, as discussed above. This approach provides lower precision at the utility level than if the sample were not stratified by climate zone, but allows for specific climate regions to be adequately represented for building simulations.
- ***Attempt to survey every premise in the Census usage strata.*** The Census strata consist of all premises with annual kWh consumption above 0.02% of the total annual kWh for the three IOUs combined. A census was attempted for these premises.
- ***Allocate the sample proportionally across the utilities and use Neyman allocation within each utility.*** The final design was to use an allocation method that proportionally allocates the sample across utilities by total annual kWh usage and uses a Neyman allocation within each utility.
- ***Use a minimum of one sample point for any one stratum.*** After performing the initial stratification, all strata with fewer than one sample point were increased to one sample point, if available. This adjustment caused the total number of premises to rise above 2,500. The total number of premises was then adjusted downward proportionally by utility until the overall target of 2,500 premises was achieved. Imposing a minimum of one sample point rather than two was consistent with the overall study goals to maximize precision at the utility service territory level.
- ***Oversample SDG&E to obtain minimum precision of ±5% relative error with 90% confidence (90/5 precision) for each utility.*** The sample allocation was refined to obtain a precision of at least ±5% relative error with 90% confidence (90/5 precision) for each utility. To obtain this desired result, the SDG&E sample was increased by 32 to 351. These 32 premises were taken proportionally from the other two utilities (15 from PG&E and 17 from SCE) to maintain the sample size goal of 2,500 premises.

- ***Selectively replace sampled sites with sites containing interval-metered electricity consumption data.*** It was highly desirable to maximize the number of sample points with interval-metered electricity data so that hourly usage information was available for calibrating the energy simulation models. A strictly random draw of premises would not yield many sites with interval data, so a method was devised to intentionally increase the number of these sites within the overall bounds of the sample design. SCE provided 752 commercial customer accounts with interval-metered data that were made available for substitution. Substitution could only occur for sites within the same building type and that have an annual energy consumption within 25% of each other. Although SDG&E and PG&E provided very limited lists of customers with interval-metered data for this process, closer examination revealed that the naturally occurring distribution of premises with interval-metered data for these two utilities was similar to that of SCE after adding interval-metered sites. Therefore, no further action was taken to increase the number of premises with interval-metered data for PG&E and SDG&E.

Table 2-5 presents a summary of three alternative sample designs along with the sample design that was ultimately adopted for the study. All four methods incorporate sampling the largest customers with certainty and imposing a minimum quota requirement of one for each stratum. The first two columns represent the sample distribution using a straight proportional allocation based on annual kWh consumption. The second set of two columns reflects a Neyman allocation across utilities, building types and non-certainty size classes. The third set of columns contains the proportional distribution allocation across utilities and Neyman allocation within utilities. The final set of columns presents the final sample design, which includes a minimum of one sample point per stratum (where available) and the oversampling of the SDG&E service territory.

Table 2-6 through Table 2-8 present sample design information by utility, building type, and size. The *Commercial End-Use Survey Sample Design Report* presents the detailed final sample design.

Table 2-5: Summary of Alternative and Final Sample Designs

Stratification Levels			Summary Statistics						Proportional by Energy Use		Overall Neyman Allocation		Neyman Allocation (Proportional by Utility)		Adjusted Neyman Allocation (Proportional by Utility)	
Utility	CZ	Building Type	Sample Frame	% of Sample Frame	Total kWh	% of Total kWh	Average kWh	Standard Deviation	Sample Size	Relative Error	Sample Size	Relative Error	Sample Size	Relative Error	Sample Size	Relative Error
all			574,273	100.0%	65,271,751,703	100.0%	113,660	806,930	2,500	2.06%	2,500	1.90%	2,500	1.90%	2,500	1.90%
pge	-		234,548	40.8%	26,631,678,610	40.8%	113,545	845,517	1,020	3.23%	1,021	2.95%	1,020	2.95%	1,005	2.98%
sce	-		256,724	44.7%	30,314,536,883	46.4%	118,082	722,073	1,161	3.02%	1,157	2.82%	1,161	2.82%	1,144	2.84%
sdge	-		83,001	14.5%	8,325,536,210	12.8%	100,306	933,829	319	5.72%	322	5.27%	319	5.30%	351	4.99%
pge	1		17,176	3.0%	1,017,644,090	1.6%	59,248	302,918	47	19.93%	54	16.78%	54	16.78%	54	16.78%
pge	2		17,384	3.0%	1,842,941,877	2.8%	106,014	518,940	75	12.92%	79	11.82%	79	11.82%	78	11.92%
pge	3		50,308	8.8%	4,773,056,537	7.3%	94,877	670,598	181	7.99%	191	7.18%	191	7.18%	188	7.24%
pge	4		60,171	10.5%	7,614,895,848	11.7%	126,554	1,006,882	286	5.83%	276	5.47%	275	5.48%	272	5.52%
pge	5		89,509	15.6%	11,383,140,258	17.4%	127,173	931,709	431	4.81%	421	4.39%	421	4.39%	413	4.44%
sce	7		12,874	2.2%	1,120,490,339	1.7%	87,035	402,750	52	16.91%	54	15.67%	54	15.67%	54	15.67%
sce	8		105,616	18.4%	13,560,516,446	20.8%	128,395	731,191	516	4.33%	493	4.13%	495	4.12%	487	4.16%
sce	9		85,356	14.9%	9,441,356,291	14.5%	110,612	788,618	358	5.45%	362	5.07%	363	5.06%	359	5.09%
sce	10		52,878	9.2%	6,192,173,808	9.5%	117,103	647,753	235	7.13%	248	6.42%	249	6.41%	244	6.48%
sdge	S7		61,471	10.7%	6,566,601,296	10.1%	106,824	1,054,338	246	6.30%	245	5.87%	243	5.90%	268	5.56%
sdge	S10		21,530	3.7%	1,758,934,914	2.7%	81,697	433,037	73	13.46%	77	11.88%	76	11.98%	83	11.30%
		1. Small Office	198,475	34.6%	7,486,325,393	11.5%	37,719	80,952	283	6.01%	281	6.00%	282	5.99%	284	5.98%
		2. Large Office	3,911	0.7%	10,094,984,507	15.5%	2,581,177	3,516,772	394	1.96%	219	3.04%	219	3.04%	219	3.04%
		3. Restaurant	48,627	8.5%	5,583,930,000	8.6%	114,832	149,886	210	5.57%	165	6.17%	164	6.19%	163	6.21%
		4. Retail Store	83,656	14.6%	9,269,816,232	14.2%	110,809	477,594	350	6.27%	413	5.68%	414	5.67%	412	5.69%
		5. Food/Liquor	25,685	4.5%	6,746,022,615	10.3%	262,644	836,707	253	5.86%	217	5.75%	217	5.75%	218	5.74%
		6. Unref Warehouse	38,680	6.7%	3,785,136,032	5.8%	97,858	494,752	149	10.66%	189	9.22%	190	9.19%	190	9.19%
		7. School	12,899	2.2%	3,359,067,469	5.1%	260,413	457,553	126	8.32%	109	8.30%	108	8.34%	108	8.34%
		8. College	3,519	0.6%	2,061,692,751	3.2%	585,875	5,317,897	74	8.82%	75	7.40%	75	7.40%	74	7.52%
		9. Health Care	6,907	1.2%	3,888,557,435	6.0%	562,988	2,285,785	159	7.66%	161	6.90%	160	6.94%	160	6.94%
		10. Hotel	7,161	1.2%	2,599,307,219	4.0%	362,981	1,197,268	106	9.91%	107	9.41%	107	9.41%	110	9.25%
		11. Misc	143,078	24.9%	9,469,939,796	14.5%	66,187	791,514	350	7.69%	520	6.04%	520	6.04%	519	6.05%
		25. Refr Warehouse	1,675	0.3%	926,972,254	1.4%	553,416	2,368,375	46	13.53%	44	13.64%	44	13.64%	43	13.96%
pge		1. Small Office	75,733	13.2%	2,705,615,370	4.1%	35,726	79,378	102	10.16%	103	10.05%	103	10.05%	102	10.10%
pge		2. Large Office	1,674	0.3%	4,842,708,710	7.4%	2,892,896	4,267,501	190	2.74%	112	4.23%	112	4.23%	110	4.30%
pge		3. Restaurant	21,355	3.7%	2,152,749,139	3.3%	100,808	140,431	80	9.57%	68	10.18%	68	10.18%	65	10.42%
pge		4. Retail Store	32,995	5.7%	3,222,446,475	4.9%	97,665	390,151	120	10.72%	142	9.65%	142	9.65%	138	9.80%
pge		5. Food/Liquor	12,293	2.1%	2,830,486,642	4.3%	230,252	591,124	106	9.29%	89	9.02%	89	9.02%	89	9.02%
pge		6. Unref Warehouse	16,533	2.9%	1,579,011,394	2.4%	95,507	496,874	62	16.77%	79	14.30%	79	14.30%	79	14.30%
pge		7. School	6,460	1.1%	1,326,264,049	2.0%	205,304	374,286	49	14.17%	46	13.70%	46	13.70%	45	13.85%
pge		8. College	1,139	0.2%	823,561,664	1.3%	723,057	5,458,080	34	12.76%	33	11.69%	33	11.69%	33	11.69%
pge		9. Health Care	3,192	0.6%	1,561,817,961	2.4%	489,291	1,744,559	65	12.95%	64	11.62%	63	11.75%	62	11.88%
pge		10. Hotel	3,612	0.6%	1,013,920,214	1.6%	280,709	961,904	41	16.99%	43	15.47%	43	15.47%	43	15.47%
pge		11. Misc	58,708	10.2%	3,966,249,676	6.1%	67,559	945,840	146	11.79%	218	9.12%	218	9.12%	216	9.18%
pge		25. Refr Warehouse	854	0.1%	606,847,314	0.9%	710,594	2,965,337	25	16.66%	24	16.30%	24	16.30%	23	16.92%
sce		1. Small Office	83,438	14.5%	3,406,587,615	5.2%	40,828	85,481	130	8.78%	126	8.88%	127	8.84%	125	8.92%
sce		2. Large Office	1,736	0.3%	3,948,778,855	6.0%	2,274,642	2,619,199	153	3.26%	79	5.05%	79	5.05%	79	5.05%
sce		3. Restaurant	20,906	3.6%	2,738,791,595	4.2%	131,005	158,469	104	7.59%	77	8.70%	77	8.70%	76	8.75%
sce		4. Retail Store	39,889	6.9%	5,014,940,173	7.7%	125,722	562,481	192	8.45%	226	7.68%	227	7.66%	223	7.74%
sce		5. Food/Liquor	10,760	1.9%	3,295,534,621	5.0%	306,276	1,102,266	124	7.98%	106	8.05%	106	8.05%	105	8.09%
sce		6. Unref Warehouse	17,433	3.0%	1,886,686,022	2.9%	108,225	528,876	75	14.81%	94	13.00%	95	12.92%	93	13.08%
sce		7. School	5,032	0.9%	1,554,659,763	2.4%	308,955	506,672	58	11.92%	47	12.08%	47	12.08%	47	12.08%
sce		8. College	1,869	0.3%	827,897,421	1.3%	442,963	3,226,577	30	16.03%	31	12.78%	31	12.78%	30	13.21%
sce		9. Health Care	2,694	0.5%	1,814,666,549	2.8%	673,596	2,823,824	72	10.41%	73	9.47%	73	9.47%	73	9.47%
sce		10. Hotel	2,684	0.5%	1,125,621,479	1.7%	419,382	1,224,878	45	14.29%	44	14.21%	44	14.21%	44	14.21%
sce		11. Misc	69,760	12.1%	4,430,768,622	6.8%	63,514	672,769	163	11.21%	240	8.97%	241	8.95%	235	9.08%
sce		25. Refr Warehouse	523	0.1%	269,604,167	0.4%	515,496	1,820,055	15	24.20%	14	26.11%	14	26.11%	14	26.11%
sdge		1. Small Office	39,304	6.8%	1,374,122,408	2.1%	34,961	73,514	51	14.11%	52	13.94%	52	13.94%	57	13.29%
sdge		2. Large Office	501	0.1%	1,303,496,943	2.0%	2,601,790	3,364,894	51	5.43%	28	8.65%	28	8.65%	30	8.15%
sdge		3. Restaurant	6,366	1.1%	692,389,265	1.1%	108,764	146,399	26	15.24%	20	17.05%	19	17.49%	22	16.19%
sdge		4. Retail Store	10,772	1.9%	1,032,429,584	1.6%	95,844	363,368	38	19.20%	45	17.32%	45	17.32%	51	16.25%
sdge		5. Food/Liquor	2,632	0.5%	620,001,352	0.9%	235,563	468,822	23	21.68%	22	19.84%	22	19.84%	24	18.98%
sdge		6. Unref Warehouse	4,714	0.8%	319,438,617	0.5%	67,764	327,082	12	37.97%	16	32.21%	16	32.21%	18	30.06%
sdge		7. School	1,407	0.2%	478,143,656	0.7%	339,832	574,178	19	19.24%	16	20.35%	15	21.16%	16	20.35%
sdge		8. College	511	0.1%	410,233,665	0.6%	802,806	9,502,978	10	16.12%	11	12.87%	11	12.87%	11	12.87%
sdge		9. Health Care	1,021	0.2%	512,072,925	0.8%	501,541	2,178,932	22	21.62%	24	19.01%	24	19.01%	25	18.24%
sdge		10. Hotel	865	0.2%	459,765,526	0.7%	531,521	1,812,848	20	22.57%	20	21.29%	20	21.29%	23	19.01%
sdge		11. Misc	14,610	2.5%	1,072,921,497	1.6%	73,437	615,881	41	23.61%	62	18.31%	61	18.48%	68	17.31%
sdge		25. Refr Warehouse	298	0.1%	50,520,772	0.1%	169,533	563,309	6	69.81%	6	69.81%	6	69.81%	6	69.81%

Table 2-6: Summary of Detailed Sample Design – PG&E

Stratification Levels			Summary Statistics						Proportional by Energy Use		Overall Neyman Allocation		Neyman Allocation (Proportional by Utility)		**Adjusted Neyman Allocation (Proportional by Utility)**	
Utility	Building Type	Size	Sample Frame	% of Sample Frame	Total kWh	% of Total kWh	Average kWh	Standard Deviation	Sample Size	Relative Error	Sample Size	Relative Error	Sample Size	Relative Error	Sample Size	Relative Error
pge	1. Small Office	1. Small	44,311	7.7%	240,720,100	0.4%	5,433	4,442	10	42.78%	12	38.53%	12	38.53%	12	38.53%
pge	1. Small Office	2. Medium	25,159	4.4%	923,595,335	1.4%	36,710	21,081	35	15.96%	32	16.68%	32	16.68%	32	16.68%
pge	1. Small Office	3. Large	6,263	1.1%	1,541,299,935	2.4%	246,096	153,350	57	13.48%	59	13.23%	59	13.23%	58	13.35%
pge	2. Large Office	1. Small	1,028	0.2%	1,239,943,332	1.9%	1,206,171	343,759	47	6.72%	23	9.84%	23	9.84%	22	10.08%
pge	2. Large Office	2. Medium	421	0.1%	1,257,033,089	1.9%	2,985,827	738,207	48	5.58%	21	8.93%	21	8.93%	20	9.19%
pge	2. Large Office	3. Large	182	0.0%	1,374,593,896	2.1%	7,552,714	2,164,867	52	5.50%	25	8.72%	25	8.72%	25	8.72%
pge	2. Large Office	4. Census	43	0.0%	971,138,393	1.5%	22,584,614	11,665,289	43	0.00%	43	0.00%	43	0.00%	43	0.00%
pge	3. Restaurant	1. Small	14,634	2.5%	624,825,617	1.0%	42,697	22,972	23	18.51%	20	19.85%	20	19.85%	19	20.32%
pge	3. Restaurant	2. Medium	5,421	0.9%	900,976,850	1.4%	166,201	65,973	33	11.36%	22	13.91%	22	13.91%	22	13.91%
pge	3. Restaurant	3. Large	1,300	0.2%	626,946,673	1.0%	482,267	313,962	24	21.74%	26	20.74%	26	20.74%	24	21.67%
pge	4. Retail Store	1. Small	27,332	4.8%	580,575,375	0.9%	21,242	18,522	20	32.18%	30	26.10%	30	26.10%	30	26.10%
pge	4. Retail Store	2. Medium	5,072	0.9%	1,309,167,447	2.0%	258,117	191,408	50	17.16%	60	15.66%	60	15.66%	58	15.93%
pge	4. Retail Store	3. Large	588	0.1%	1,280,617,070	2.0%	2,177,920	1,357,004	47	14.41%	49	13.91%	49	13.91%	47	14.23%
pge	4. Retail Store	4. Census	3	0.0%	52,086,583	0.1%	17,362,194	2,934,218	3	0.00%	3	0.00%	3	0.00%	3	0.00%
pge	5. Food/Liquor	1. Small	9,746	1.7%	638,940,602	1.0%	65,559	45,611	24	23.47%	27	21.97%	27	21.97%	27	21.97%
pge	5. Food/Liquor	2. Medium	2,000	0.3%	926,056,867	1.4%	463,028	368,259	34	22.08%	44	19.31%	44	19.31%	44	19.31%
pge	5. Food/Liquor	3. Large	546	0.1%	1,230,194,276	1.9%	2,253,103	554,141	47	5.65%	17	9.46%	17	9.46%	17	9.46%
pge	5. Food/Liquor	4. Census	1	0.0%	35,294,898	0.1%	35,294,898	0	1	0.00%	1	0.00%	1	0.00%	1	0.00%
pge	6. Unref Warehouse	1. Small	13,836	2.4%	263,754,193	0.4%	19,063	20,228	10	55.80%	18	40.93%	18	40.93%	18	40.93%
pge	6. Unref Warehouse	2. Medium	2,414	0.4%	584,680,157	0.9%	242,204	190,911	24	26.48%	28	24.40%	28	24.40%	28	24.40%
pge	6. Unref Warehouse	3. Large	279	0.0%	654,966,160	1.0%	2,347,549	1,831,474	24	23.89%	29	21.04%	29	21.04%	29	21.04%
pge	6. Unref Warehouse	4. Census	4	0.0%	75,610,885	0.1%	18,902,721	5,559,597	4	0.00%	4	0.00%	4	0.00%	4	0.00%
pge	7. School	1. Small	4,827	0.8%	327,707,608	0.5%	67,891	68,171	13	45.63%	20	36.82%	20	36.82%	19	37.75%
pge	7. School	2. Medium	1,415	0.2%	618,540,515	0.9%	437,131	171,894	22	13.62%	14	17.32%	14	17.32%	14	17.32%
pge	7. School	3. Large	218	0.0%	380,015,927	0.6%	1,743,192	852,882	14	20.12%	12	21.99%	12	21.99%	12	21.99%
pge	8. College	1. Small	980	0.2%	47,687,594	0.1%	48,661	74,114	5	133.74%	6	112.50%	6	112.50%	6	112.50%
pge	8. College	2. Medium	112	0.0%	135,708,988	0.2%	1,211,687	914,442	6	55.73%	8	43.90%	8	43.90%	8	43.90%
pge	8. College	3. Large	34	0.0%	226,547,705	0.3%	6,663,168	2,331,342	10	15.67%	6	23.53%	6	23.53%	6	23.53%
pge	8. College	4. Census	13	0.0%	413,617,377	0.6%	31,816,721	40,190,625	13	0.00%	13	0.00%	13	0.00%	13	0.00%
pge	9. Health Care	1. Small	2,679	0.5%	228,184,648	0.3%	85,175	108,505	9	70.50%	17	51.01%	17	51.01%	17	51.01%
pge	9. Health Care	2. Medium	393	0.1%	393,866,056	0.6%	1,002,204	584,392	16	23.09%	15	24.01%	14	24.99%	13	25.95%
pge	9. Health Care	3. Large	106	0.0%	695,963,786	1.1%	6,565,696	2,703,618	26	11.80%	18	14.70%	18	14.70%	18	14.70%
pge	9. Health Care	4. Census	14	0.0%	243,803,471	0.4%	17,414,534	4,912,003	14	0.00%	14	0.00%	14	0.00%	14	0.00%
pge	10. Hotel	1. Small	2,988	0.5%	229,815,936	0.4%	76,913	72,533	8	56.09%	13	42.78%	13	42.78%	13	42.78%
pge	10. Hotel	2. Medium	543	0.1%	373,446,227	0.6%	687,746	414,602	15	24.65%	14	25.69%	14	25.69%	14	25.69%
pge	10. Hotel	3. Large	77	0.0%	338,675,766	0.5%	4,398,387	2,216,557	14	20.03%	12	22.39%	12	22.39%	12	22.39%
pge	10. Hotel	4. Census	4	0.0%	71,982,286	0.1%	17,995,572	5,289,911	4	0.00%	4	0.00%	4	0.00%	4	0.00%
pge	11. Misc	1. Small	42,691	7.4%	413,212,761	0.6%	9,679	7,833	15	34.56%	21	29.22%	21	29.22%	21	29.22%
pge	11. Misc	2. Medium	15,114	2.6%	1,521,540,054	2.3%	100,671	89,500	57	19.31%	83	15.99%	83	15.99%	81	16.19%
pge	11. Misc	3. Large	876	0.2%	1,268,820,472	1.9%	1,448,425	1,642,634	47	26.37%	87	18.85%	87	18.85%	87	18.85%
pge	11. Misc	4. Census	27	0.0%	762,676,389	1.2%	28,247,274	32,084,579	27	0.00%	27	0.00%	27	0.00%	27	0.00%
pge	25. Refr Warehouse	1. Small	638	0.1%	74,300,452	0.1%	116,458	126,741	5	91.32%	7	71.46%	7	71.46%	7	71.46%
pge	25. Refr Warehouse	2. Medium	179	0.0%	215,964,505	0.3%	1,206,506	648,657	9	29.82%	9	29.82%	9	29.82%	8	32.42%
pge	25. Refr Warehouse	3. Large	34	0.0%	204,111,839	0.3%	6,003,289	2,159,342	8	18.78%	5	26.01%	5	26.01%	5	26.01%
pge	25. Refr Warehouse	4. Census	3	0.0%	112,470,519	0.2%	37,490,173	31,478,126	3	0.00%	3	0.00%	3	0.00%	3	0.00%

Table 2-7: Summary of Detailed Sample Design – SCE

Stratification Levels			Summary Statistics						Proportional by Energy Use		Overall Neyman Allocation		Neyman Allocation (Proportional by Utility)		**Adjusted Neyman Allocation (Proportional by Utility)**	
Utility	Building Type	Size	Sample Frame	% of Sample Frame	Total kWh	% of Total kWh	Average kWh	Standard Deviation	Sample Size	Relative Error	Sample Size	Relative Error	Sample Size	Relative Error	Sample Size	Relative Error
sce	1. Small Office	1. Small	45,067	7.8%	256,727,817	0.4%	5,697	4,417	10	40.89%	12	37.21%	13	35.65%	12	37.21%
sce	1. Small Office	2. Medium	30,184	5.3%	1,120,872,345	1.7%	37,135	20,980	43	14.15%	39	14.86%	39	14.86%	39	14.86%
sce	1. Small Office	3. Large	8,187	1.4%	2,028,987,452	3.1%	247,830	151,813	77	11.37%	75	11.52%	75	11.52%	74	11.60%
sce	2. Large Office	1. Small	1,179	0.2%	1,435,578,500	2.2%	1,217,624	353,114	55	6.28%	26	9.31%	26	9.31%	26	9.31%
sce	2. Large Office	2. Medium	402	0.1%	1,190,892,037	1.8%	2,962,418	723,266	45	5.65%	19	9.13%	19	9.13%	19	9.13%
sce	2. Large Office	3. Large	139	0.0%	982,882,313	1.5%	7,071,096	1,927,996	37	6.33%	18	10.21%	18	10.21%	18	10.21%
sce	2. Large Office	4. Census	16	0.0%	339,426,005	0.5%	21,214,125	6,262,550	16	0.00%	16	0.00%	16	0.00%	16	0.00%
sce	3. Restaurant	1. Small	11,608	2.0%	552,092,371	0.8%	47,561	23,592	21	17.76%	17	19.75%	17	19.75%	17	19.75%
sce	3. Restaurant	2. Medium	7,279	1.3%	1,203,671,656	1.8%	165,362	64,366	46	9.41%	28	12.07%	28	12.07%	28	12.07%
sce	3. Restaurant	3. Large	2,019	0.4%	983,027,568	1.5%	486,888	266,418	37	14.65%	32	15.68%	32	15.68%	31	15.92%
sce	4. Retail Store	1. Small	31,795	5.5%	724,254,781	1.1%	22,779	19,335	27	26.92%	38	22.60%	38	22.60%	38	22.60%
sce	4. Retail Store	2. Medium	7,078	1.2%	1,823,690,197	2.8%	257,656	196,706	69	15.04%	85	13.54%	86	13.46%	83	13.70%
sce	4. Retail Store	3. Large	1,005	0.2%	2,253,130,613	3.5%	2,241,921	1,504,426	85	11.42%	92	10.93%	92	10.93%	91	11.00%
sce	4. Retail Store	4. Census	11	0.0%	213,864,581	0.3%	19,442,235	9,983,216	11	0.00%	11	0.00%	11	0.00%	11	0.00%
sce	5. Food/Liquor	1. Small	8,348	1.5%	559,589,948	0.9%	67,033	45,226	21	24.18%	23	23.14%	23	23.14%	22	23.64%
sce	5. Food/Liquor	2. Medium	1,705	0.3%	808,808,947	1.2%	474,375	380,147	31	23.49%	40	20.56%	40	20.56%	40	20.56%
sce	5. Food/Liquor	3. Large	699	0.1%	1,699,353,219	2.6%	2,431,120	882,974	64	7.14%	35	9.48%	35	9.48%	35	9.48%
sce	5. Food/Liquor	4. Census	8	0.0%	227,782,507	0.3%	28,472,813	17,871,682	8	0.00%	8	0.00%	8	0.00%	8	0.00%
sce	6. Unref Warehouse	1. Small	14,200	2.5%	325,096,277	0.5%	22,894	20,341	13	41.04%	18	34.57%	18	34.57%	18	34.57%
sce	6. Unref Warehouse	2. Medium	2,928	0.5%	749,035,472	1.1%	255,818	198,996	29	23.71%	36	21.19%	37	20.89%	35	21.50%
sce	6. Unref Warehouse	3. Large	301	0.1%	730,177,971	1.1%	2,425,840	1,915,713	29	23.22%	36	20.47%	36	20.47%	36	20.47%
sce	6. Unref Warehouse	4. Census	4	0.0%	82,376,302	0.1%	20,594,076	7,968,810	4	0.00%	4	0.00%	4	0.00%	4	0.00%
sce	7. School	1. Small	3,123	0.5%	226,772,335	0.3%	72,614	71,380	8	57.21%	13	44.91%	13	44.91%	13	44.91%
sce	7. School	2. Medium	1,587	0.3%	740,627,426	1.1%	466,684	178,303	28	11.74%	17	15.11%	17	15.11%	17	15.11%
sce	7. School	3. Large	322	0.1%	587,260,002	0.9%	1,823,789	921,173	22	16.99%	17	18.93%	17	18.93%	17	18.93%
sce	8. College	1. Small	1,697	0.3%	76,817,436	0.1%	45,267	68,542	4	144.68%	8	90.05%	8	90.05%	8	90.05%
sce	8. College	2. Medium	125	0.0%	141,686,072	0.2%	1,133,489	746,585	7	41.65%	7	41.65%	7	41.65%	7	41.65%
sce	8. College	3. Large	38	0.0%	257,535,306	0.4%	6,777,245	2,309,377	10	16.42%	7	21.02%	7	21.02%	6	23.58%
sce	8. College	4. Census	9	0.0%	351,858,607	0.5%	39,095,401	22,006,182	9	0.00%	9	0.00%	9	0.00%	9	0.00%
sce	9. Health Care	1. Small	2,171	0.4%	202,020,498	0.3%	93,054	115,521	9	68.65%	15	52.48%	15	52.48%	15	52.48%
sce	9. Health Care	2. Medium	417	0.1%	427,536,436	0.7%	1,025,267	612,866	15	25.10%	16	24.15%	16	24.15%	16	24.15%
sce	9. Health Care	3. Large	76	0.0%	497,833,404	0.8%	6,550,440	2,676,789	18	14.09%	12	17.58%	12	17.58%	12	17.58%
sce	9. Health Care	4. Census	30	0.0%	687,276,211	1.1%	22,909,207	9,304,368	30	0.00%	30	0.00%	30	0.00%	30	0.00%
sce	10. Hotel	1. Small	2,029	0.4%	168,156,119	0.3%	82,876	74,290	7	55.61%	10	46.31%	10	46.31%	10	46.31%
sce	10. Hotel	2. Medium	541	0.1%	407,636,439	0.6%	753,487	467,754	16	25.21%	16	25.21%	16	25.21%	16	25.21%
sce	10. Hotel	3. Large	110	0.0%	474,895,222	0.7%	4,317,229	2,053,512	18	17.07%	14	19.94%	14	19.94%	14	19.94%
sce	10. Hotel	4. Census	4	0.0%	74,933,699	0.1%	18,733,425	6,667,686	4	0.00%	4	0.00%	4	0.00%	4	0.00%
sce	11. Misc	1. Small	51,118	8.9%	551,178,848	0.8%	10,782	7,949	20	27.11%	24	24.81%	24	24.81%	23	25.29%
sce	11. Misc	2. Medium	17,463	3.0%	1,827,889,533	2.8%	104,672	93,640	69	17.65%	100	14.64%	100	14.64%	98	14.79%
sce	11. Misc	3. Large	1,165	0.2%	1,586,251,848	2.4%	1,361,590	1,436,527	60	21.88%	102	16.42%	103	16.33%	100	16.59%
sce	11. Misc	4. Census	14	0.0%	465,448,394	0.7%	33,246,314	29,698,039	14	0.00%	14	0.00%	14	0.00%	14	0.00%
sce	25. Refr Warehouse	1. Small	445	0.1%	39,433,255	0.1%	88,614	110,241	4	115.86%	4	115.86%	4	115.86%	4	115.86%
sce	25. Refr Warehouse	2. Medium	53	0.0%	62,778,117	0.1%	1,184,493	614,043	4	43.29%	4	43.29%	4	43.29%	4	43.29%
sce	25. Refr Warehouse	3. Large	23	0.0%	124,007,357	0.2%	5,391,624	2,571,917	5	30.51%	4	37.20%	4	37.20%	4	37.20%
sce	25. Refr Warehouse	4. Census	2	0.0%	43,385,438	0.1%	21,692,719	3,166,297	2	0.00%	2	0.00%	2	0.00%	2	0.00%

Table 2-8: Summary of Detailed Sample Design – SDG&E

Stratification Levels			Summary Statistics						Proportional by Energy Use		Overall Neyman Allocation		Neyman Allocation (Proportional by Utility)		**Adjusted Neyman Allocation (Proportional by Utility)**	
Utility	Building Type	Size	Sample Frame	% of Sample Frame	Total kWh	% of Total kWh	Average kWh	Standard Deviation	Sample Size	Relative Error	Sample Size	Relative Error	Sample Size	Relative Error	Sample Size	Relative Error
sdge	1. Small Office	1. Small	22,042	3.8%	127,850,078	0.2%	5,800	4,384	5	56.16%	6	51.37%	6	51.37%	7	47.06%
sdge	1. Small Office	2. Medium	14,127	2.5%	517,016,050	0.8%	36,598	20,776	19	21.44%	18	21.99%	18	21.99%	20	20.87%
sdge	1. Small Office	3. Large	3,135	0.5%	729,256,280	1.1%	232,618	143,595	27	19.48%	28	19.11%	28	19.11%	30	18.45%
sdge	2. Large Office	1. Small	331	0.1%	389,456,426	0.6%	1,176,606	326,061	14	11.94%	7	17.06%	7	17.06%	7	17.06%
sdge	2. Large Office	2. Medium	109	0.0%	328,068,203	0.5%	3,009,800	740,397	12	11.15%	5	18.12%	5	18.12%	6	16.23%
sdge	2. Large Office	3. Large	51	0.0%	401,237,230	0.6%	7,867,397	2,149,933	15	9.72%	6	17.18%	6	17.18%	7	15.82%
sdge	2. Large Office	4. Census	10	0.0%	184,735,083	0.3%	18,473,508	8,895,880	10	0.00%	10	0.00%	10	0.00%	10	0.00%
sdge	3. Restaurant	1. Small	4,123	0.7%	173,842,536	0.3%	42,164	23,762	6	38.37%	6	38.37%	6	38.37%	7	35.23%
sdge	3. Restaurant	2. Medium	1,822	0.3%	294,342,966	0.5%	161,549	62,574	11	19.18%	7	24.12%	7	24.12%	8	22.48%
sdge	3. Restaurant	3. Large	421	0.1%	224,203,763	0.3%	532,551	258,141	9	26.39%	7	29.73%	6	32.10%	7	29.73%
sdge	4. Retail Store	1. Small	8,866	1.5%	186,527,052	0.3%	21,038	19,508	7	57.65%	11	45.96%	11	45.96%	12	44.07%
sdge	4. Retail Store	2. Medium	1,709	0.3%	404,935,948	0.6%	236,943	176,804	15	31.60%	18	28.77%	18	28.77%	21	26.63%
sdge	4. Retail Store	3. Large	197	0.0%	440,966,584	0.7%	2,238,409	1,387,656	16	24.16%	16	23.85%	16	23.85%	18	22.39%
sdge	5. Food/Liquor	1. Small	1,963	0.3%	118,736,396	0.2%	60,487	46,112	4	62.81%	6	51.39%	6	51.39%	6	51.39%
sdge	5. Food/Liquor	2. Medium	554	0.1%	265,602,006	0.4%	479,426	378,850	10	40.78%	13	35.66%	13	35.66%	14	34.39%
sdge	5. Food/Liquor	3. Large	115	0.0%	235,662,950	0.4%	2,049,243	452,442	9	11.78%	3	20.96%	3	20.96%	4	17.91%
sdge	6. Unref Warehouse	1. Small	4,092	0.7%	84,386,771	0.1%	20,622	20,035	3	93.05%	5	72.50%	5	72.50%	6	65.78%
sdge	6. Unref Warehouse	2. Medium	575	0.1%	132,446,809	0.2%	230,342	181,294	5	57.98%	7	48.88%	7	48.88%	7	48.88%
sdge	6. Unref Warehouse	3. Large	46	0.0%	87,487,296	0.1%	1,901,898	1,317,932	3	58.84%	3	58.84%	3	58.84%	4	50.42%
sdge	6. Unref Warehouse	4. Census	1	0.0%	15,117,741	0.0%	15,117,741	0	1	0.00%	1	0.00%	1	0.00%	1	0.00%
sdge	7. School	1. Small	899	0.2%	56,391,526	0.1%	62,727	66,666	3	99.72%	4	86.76%	3	99.72%	4	86.76%
sdge	7. School	2. Medium	392	0.1%	204,021,895	0.3%	520,464	202,287	8	22.41%	5	28.55%	5	28.55%	5	28.55%
sdge	7. School	3. Large	116	0.0%	217,730,235	0.3%	1,876,985	872,918	8	26.00%	7	27.85%	7	27.85%	7	27.85%
sdge	8. College	1. Small	456	0.1%	20,849,274	0.0%	45,722	70,104	2	207.51%	3	150.49%	3	150.49%	3	150.49%
sdge	8. College	2. Medium	40	0.0%	40,329,224	0.1%	1,008,231	753,469	2	111.66%	3	78.15%	3	78.15%	3	78.15%
sdge	8. College	3. Large	13	0.0%	83,649,687	0.1%	6,434,591	2,449,501	4	26.01%	3	34.03%	3	34.03%	3	34.03%
sdge	8. College	4. Census	2	0.0%	265,405,480	0.4%	132,702,740	102,417,895	2	0.00%	2	0.00%	2	0.00%	2	0.00%
sdge	9. Health Care	1. Small	865	0.2%	60,933,701	0.1%	70,444	98,369	3	133.30%	5	104.31%	5	104.31%	6	94.10%
sdge	9. Health Care	2. Medium	128	0.0%	146,727,388	0.2%	1,146,308	724,618	5	45.41%	6	41.39%	6	41.39%	6	41.39%
sdge	9. Health Care	3. Large	19	0.0%	119,849,202	0.2%	6,307,853	2,882,551	5	29.09%	4	34.84%	4	34.84%	4	34.84%
sdge	9. Health Care	4. Census	9	0.0%	184,562,635	0.3%	20,506,959	4,494,688	9	0.00%	9	0.00%	9	0.00%	9	0.00%
sdge	10. Hotel	1. Small	649	0.1%	53,238,819	0.1%	82,032	78,965	2	123.11%	3	91.95%	3	91.95%	4	78.87%
sdge	10. Hotel	2. Medium	170	0.0%	130,668,470	0.2%	768,638	479,602	5	45.16%	5	45.16%	5	45.16%	6	41.12%
sdge	10. Hotel	3. Large	40	0.0%	168,711,566	0.3%	4,217,789	2,241,332	7	32.42%	6	36.05%	6	36.05%	7	32.42%
sdge	10. Hotel	4. Census	6	0.0%	107,146,671	0.2%	17,857,778	4,800,225	6	0.00%	6	0.00%	6	0.00%	6	0.00%
sdge	11. Misc	1. Small	10,277	1.8%	103,410,002	0.2%	10,062	7,802	4	64.24%	4	64.24%	4	64.24%	6	52.16%
sdge	11. Misc	2. Medium	4,037	0.7%	407,374,318	0.6%	100,910	90,293	15	38.01%	23	30.61%	23	30.61%	24	29.96%
sdge	11. Misc	3. Large	290	0.1%	423,111,560	0.6%	1,459,005	1,622,943	16	44.71%	29	32.26%	28	32.89%	32	30.52%
sdge	11. Misc	4. Census	6	0.0%	139,025,617	0.2%	23,170,936	13,744,486	6	0.00%	6	0.00%	6	0.00%	6	0.00%
sdge	25. Refr Warehouse	1. Small	282	0.0%	20,805,947	0.0%	73,780	100,511	2	163.47%	2	163.47%	2	163.47%	2	163.47%
sdge	25. Refr Warehouse	2. Medium	12	0.0%	11,932,779	0.0%	994,398	447,060	2	56.24%	2	56.24%	2	56.24%	2	56.24%
sdge	25. Refr Warehouse	3. Large	4	0.0%	17,782,046	0.0%	4,445,512	1,331,590	2	36.53%	2	36.53%	2	36.53%	2	36.53%

2.7 SMUD Sample Design

The sample design for SMUD was undertaken after the design framework was implemented for the three IOUs. SMUD's premise aggregation, building-type size strata cutpoints, and sample design followed the final methods employed for the IOUs. The size cutpoints developed for the IOUs were used for SMUD rather than developing new size cutpoints in order to maintain consistency statewide. It is also worth mentioning that the SMUD sample was based on the 2003 commercial frame rather than the 2002 commercial frame used for the IOUs.

Sample Frame

Data for the commercial and industrial sample frame were supplied by SMUD. The account level data contained 50,888 accounts. Using SIC and NAICS codes, the data were divided into separate commercial and industrial frames. The sampling unit for SMUD was a "premise," or a collection of buildings and/or meters serving a unique customer at a contiguous location. The commercial accounts aggregated into 33,343 unique premises. Summary information developed for each premise included building type and energy consumption for 2003. Table 2-9 lists the number of premises, percent of total premises, annual kWh for 2003, and percent of total annual kWh for 2003 by building type.

Table 2-9: Summary of SMUD's Sample Frame

Building Type	Sample Frame	% of Sample Frame	Total kWh	% of Total kWh
Total	33,343	100.0%	3,633,986,980	100.0%
1. Small Office	18,506	55.5%	622,100,848	17.12%
2. Large Office	324	1.0%	885,104,047	24.36%
3. Restaurant	2070	6.2%	267,964,754	7.37%
4. Retail Store	3207	9.6%	438,932,570	12.08%
5. Food/Liquor	825	2.5%	290,336,861	7.99%
6. Unref Warehouse	1916	5.8%	150,110,488	4.13%
7. School	678	2.0%	197,045,143	5.42%
8. College	145	0.4%	78,324,193	2.16%
9. Health Care	398	1.2%	211,314,579	5.81%
10. Hotel	176	0.5%	86,300,543	2.37%
11. Misc	5067	15.2%	392,856,158	10.81%
25. Refr Warehouse	31	0.1%	13,596,796	0.37%

SMUD Sample Design

Table 2-10 presents a summary of the sample design implemented in SMUD's service territory. The sample design incorporates sampling the largest customers with certainty and imposing a minimum quota requirement of one for each stratum. The first two sample design columns represent the sample distribution using a straight proportional allocation based on annual kWh consumption. The second set of two columns reflects a Neyman allocation across building types and non-certainty size classes. For SMUD, it was not necessary to calculate the adjusted Neyman allocation. For the three IOUs, the adjustment factor was based on utility. A utility-based adjustment factor was not possible, given that SMUD's sample design was undertaken for only one utility. SMUD provided an identifier for meters with interval-metered data. There was no preferential treatment of these meters in the sample design.

Table 2-10: Summary of Detailed Sample Design – SMUD

Stratification Variables		Summary Statistics						Proportional		Overall Neyman	
		Sample Frame	% of sample frame	Total kWh	% of total kWh	Average kWh	Standard Deviation	Sample Size	Relative Error	Sample Size	Relative Error
All		33343	100.0%	3,633,986,980	100.0%	108,988	781,665	300	5.1%	300	4.6%
	1. Small	21692	65.1%	628,427,782	17.3%	28,970	125,289	57	14.7%	62	12.5%
	2. Medium	9591	28.8%	1,179,338,076	32.5%	122,963	276,691	103	9.9%	110	9.0%
	3. Large	2049	6.1%	1,530,987,305	42.1%	747,188	1,387,050	129	7.0%	117	6.7%
	4. Census	11	0.0%	295,233,816	8.1%	26,839,438	25,538,437	11	0.0%	11	0.0%
1. Small Office		18506	55.5%	622,100,848	17.1%	33,616	77,216	53	14.0%	61	13.0%
2. Large Office		324	1.0%	885,104,047	24.4%	2,731,803	6,248,403	64	3.7%	35	5.8%
3. Restaurant		2070	6.2%	267,964,754	7.4%	129,452	134,341	22	13.6%	15	16.0%
4. Retail Store		3207	9.6%	438,932,570	12.1%	136,867	382,872	36	17.5%	45	15.2%
5. Food/Liquor		825	2.5%	290,336,861	8.0%	351,923	718,808	25	14.5%	19	14.4%
6. Unref Warehouse		1916	5.7%	150,110,488	4.1%	78,346	321,521	13	35.9%	19	28.8%
7. School		678	2.0%	197,045,143	5.4%	290,627	464,554	17	21.3%	15	20.3%
8. College		145	0.4%	78,324,193	2.2%	540,167	3,090,989	7	18.7%	7	18.7%
9. Health Care		398	1.2%	211,314,579	5.8%	530,941	1,956,529	17	20.7%	17	16.9%
10. Hotel		176	0.5%	86,300,543	2.4%	490,344	1,002,562	8	24.2%	7	26.8%
11. Misc		5067	15.2%	392,856,158	10.8%	77,532	378,407	33	24.2%	55	18.1%
25. Refr Warehouse		31	0.1%	13,596,796	0.4%	438,606	1,079,242	5	38.8%	5	38.8%
1. Small Office	1. Small	11335	34.0%	58,022,965	1.6%	5,119	4,108	5	59.0%	7	49.9%
1. Small Office	2. Medium	5753	17.3%	213,637,406	5.9%	37,135	21,009	18	21.9%	19	21.3%
1. Small Office	3. Large	1418	4.3%	350,440,477	9.6%	247,137	154,163	30	18.5%	35	17.1%
2. Large Office	1. Small	222	0.7%	261,226,147	7.2%	1,176,694	333,294	22	9.4%	12	13.1%
2. Large Office	2. Medium	60	0.2%	172,888,343	4.8%	2,881,472	702,906	15	9.0%	7	14.3%
2. Large Office	3. Large	37	0.1%	265,584,414	7.3%	7,177,957	1,909,696	22	5.9%	11	11.1%
2. Large Office	4. Census	5	0.0%	185,405,143	5.1%	37,081,029	36,251,747	5	0.0%	5	0.0%
3. Restaurant	1. Small	1137	3.4%	52,799,496	1.5%	46,438	24,009	4	42.4%	4	42.4%
3. Restaurant	2. Medium	709	2.1%	116,757,960	3.2%	164,680	65,561	10	20.6%	7	24.6%
3. Restaurant	3. Large	224	0.7%	98,407,298	2.7%	439,318	123,819	8	16.1%	4	23.0%
4. Retail Store	1. Small	2367	7.1%	61,244,222	1.7%	25,874	20,161	5	57.3%	8	45.2%
4. Retail Store	2. Medium	747	2.2%	193,995,918	5.3%	259,700	192,697	16	30.2%	23	25.1%
4. Retail Store	3. Large	93	0.3%	183,692,430	5.1%	1,975,187	970,156	15	19.1%	14	19.9%
5. Food/Liquor	1. Small	611	1.8%	43,249,423	1.2%	70,785	47,228	4	54.7%	5	48.9%
5. Food/Liquor	2. Medium	137	0.4%	58,345,745	1.6%	425,881	315,742	5	53.5%	7	44.9%
5. Food/Liquor	3. Large	77	0.2%	188,741,693	5.2%	2,451,191	543,555	16	8.1%	7	13.1%

Table 2-10 (continued): Summary of Detailed Sample Design – SMUD

Stratification Variables		Summary Statistics						Proportional		Overall Neyman	
		Sample Frame	% of sample frame	Total kWh	% of total kWh	Average kWh	Standard Deviation	Sample Size	Relative Error	Sample Size	Relative Error
6. Unref Warehouse	1. Small	1628	4.9%	32,556,760	0.9%	19,998	20,891	3	99.1%	5	76.7%
6. Unref Warehouse	2. Medium	265	0.8%	63,090,633	1.7%	238,078	186,423	5	57.1%	8	44.8%
6. Unref Warehouse	3. Large	23	0.1%	54,463,094	1.5%	2,367,961	1,584,042	5	43.5%	6	38.6%
7. School	1. Small	447	1.3%	37,140,612	1.0%	83,089	78,420	3	89.3%	6	63.0%
7. School	2. Medium	193	0.6%	89,270,568	2.5%	462,542	176,388	8	21.7%	5	27.7%
7. School	3. Large	38	0.1%	70,633,963	1.9%	1,858,788	716,281	6	23.7%	4	30.0%
8. College	1. Small	126	0.4%	6,175,508	0.2%	49,012	66,610	2	156.8%	2	156.8%
8. College	2. Medium	15	0.0%	12,620,851	0.3%	841,390	529,719	2	68.2%	2	68.2%
8. College	3. Large	3	0.0%	25,406,665	0.7%	8,468,888	3,412,422	2	27.1%	2	27.1%
8. College	4. Census	1	0.0%	34,121,169	0.9%	34,121,169	.	1	.	1	.
9. Health Care	1. Small	331	1.0%	25,120,054	0.7%	75,891	100,210	2	153.1%	5	96.4%
9. Health Care	2. Medium	52	0.2%	44,970,860	1.2%	864,824	412,672	4	37.7%	3	44.0%
9. Health Care	3. Large	11	0.0%	81,743,703	2.2%	7,431,246	2,915,282	7	14.7%	5	21.3%
9. Health Care	4. Census	4	0.0%	59,479,963	1.6%	14,869,991	856,968	4	0.0%	4	0.0%
10. Hotel	1. Small	109	0.3%	9,741,937	0.3%	89,376	76,717	2	98.9%	2	98.9%
10. Hotel	2. Medium	57	0.2%	35,153,042	1.0%	616,720	273,010	3	40.9%	3	40.9%
10. Hotel	3. Large	10	0.0%	41,405,563	1.1%	4,140,556	1,468,674	3	28.2%	2	36.9%
11. Misc	1. Small	3353	10.1%	37,933,842	1.0%	11,313	8,001	3	67.1%	4	58.1%
11. Misc	2. Medium	1599	4.8%	173,706,120	4.8%	108,634	94,402	15	36.7%	24	29.0%
11. Misc	3. Large	114	0.3%	164,988,655	4.5%	1,447,269	1,395,304	14	39.7%	26	27.3%
11. Misc	4. Census	1	0.0%	16,227,541	0.4%	16,227,541	.	1	.	1	.
25. Refr Warehouse	1. Small	26	0.1%	3,216,817	0.1%	123,724	124,171	2	112.2%	2	112.2%
25. Refr Warehouse	2. Medium	4	0.0%	4,900,628	0.1%	1,225,157	1,168,442	2	78.4%	2	78.4%
25. Refr Warehouse	3. Large	1	0.0%	5,479,350	0.2%	5,479,350	.	1	.	1	.

CHAPTER 3: SURVEY DESIGN AND IMPLEMENTATION

3.1 Overview

This chapter describes the design of the on-site survey instrument and the implementation of the field survey effort for the Commercial End-Use Survey (CEUS) project. Key aspects of the on-site survey design and implementation are addressed including design issues, protocols, methods, training, pre-testing, full-scale survey implementation, and completed samples.

On-site survey design and implementation was an interactive process that involved the Itron team and Energy Commission staff. A significant feature of this effort was the "pre-test" phase, in which the initial products of the design effort were given a trial run, then evaluated and revised based on feedback from the team prior to "full-scale" implementation of the survey.

On-site survey design and implementation are described in detail in the rest of this Chapter. On-site survey design issues are covered in Section 3.2 through 3.5. Surveyor training and pretest implementation efforts are described in Section 3.6 and 3.7. The full-scale implementation process is described in Section 3.8. A summary of the targeted and completed samples for the on-site survey, interval-metered (IM) data and short-term metering is provided in Section 3.9.

3.2 Survey Instrument Design

The Itron/James J. Hirsch & Associates (JJH) project team worked closely with the Energy Commission staff in creating the survey instrument. The team started with the CEUS survey instrument from a previous CEUS survey effort. Several team meetings were held to discuss and finalize the requirements for both the energy modeling system and the survey instrument, since the two were interlinked. The initial version of the survey form was then pre-tested with some preliminary field surveys, then revised as needed based on feedback from the team.

Although many issues were discussed and addressed during the design phase, only the three most significant design issues are described here.

- ***Non-HVAC Equipment End-Use Mapping.*** To avoid any ambiguity of what type of equipment an end use encompassed, discrete lists of commonly found equipment were created for each of the 10 non-HVAC end uses used for this study.

- ***Energy Efficiency Measure Detail.*** Because the CEUS data would be used for measure analysis, it was important that the survey form capture enough detail to analyze measures of interest.
- ***Using the eQUEST Design Development Wizard (DDW).*** Of the three issues discussed, this is the most significant. Using the eQUEST DDW required major changes to the survey instrument. However, these changes were fully warranted because they addressed many modeling issues and, most importantly, allowed eQUEST, rather than DrCEUS, to handle construction of the building simulation model. The use of the eQUEST DDW and integration of its modeling concepts into the survey instrument is what differentiates this effort not only from previous CEUS surveys, but also from all other survey efforts involving the construction of building simulation models from survey data. More than any other survey instrument, the DrCEUS survey instrument does not merely inventory equipment, but also records key building simulation modeling inputs.

Copies of the final survey instrument are provided in Appendix A (which contains the basic survey instrument) and Appendix B (which contains an annotated version). Survey design issues are described in detail in the following subsections.

Non-HVAC Equipment End-use Mapping

Mapping of non-HVAC equipment to specific end uses was deemed a critical issue. Previous CEUS surveys often did not use a common set of end uses, and sometimes the same piece of equipment might be mapped to a different end use based on building type. This made comparing and contrasting results between the studies quite difficult. For instance, a microwave and coffee maker in an office would be mapped to the "Miscellaneous" end use, but this same equipment in a restaurant would be mapped to the "Cooking" end use.

This issue was addressed for the CEUS survey by using 10 non-HVAC end uses, which offers enough fidelity of end uses that the miscellaneous category would not become the catchall end use. More importantly, the equipment mapped to each end use is clearly delineated. These mappings are described in Appendix C. These mappings were incorporated into the survey instrument, and the equipment for a specific end use was generally confined to a single table, a single page, or, if multiple pages, grouped together sequentially.

Energy Efficiency Measure Detail

Assessing energy efficiency potential was one of the primary uses identified for the CEUS data. As such, it was imperative that the survey form be designed to gather the data needed to assess most of the measures commonly offered by utility energy efficiency programs. The first step in this process was to develop a list of measures. In developing the list, the team reviewed many sources (DEER 1994, DEER 2000, Savings-by-Design, eQUEST's Energy Efficiency Measure

Wizard, Assembly Bill AB 970, etc.). The final list of measures was then used to identify fields on the existing form that could be used to assess these measures. If the existing fields did not adequately characterize the measures, then the survey form was modified and additional data fields were added.

eQUEST Design Development Wizard Features

The most significant survey instrument design issue was integration of the modeling concepts of the eQUEST Design Development Wizard (DDW) into the survey form. In fact, the eQUEST DDW and integration of its modeling concepts into the survey instrument distinguishes the California Energy Commission CEUS survey instrument not only from previous CEUS surveys, but from most other survey efforts involving the construction of building simulation models from survey data. This is because the surveyor records many of the inputs required for creating the model.

Using the eQUEST DDW accomplished many of the project objectives. Using the wizard (boilerplate) accommodated the modeling of issues like footprint shapes, thermal zoning schemes, defaults by building type, and the inclusion of multiple buildings in a single DOE2 model. This was a synergistic effort by Itron, JJH, and the Energy Commission and involved not only survey instrument design, but also resulted in enhancements of eQUEST concepts and features.

Some of the key features of the eQUEST DDW incorporated into the survey instrument include the following.

- ***Building Shell Component and Component Multiplier Concepts.*** eQUEST DDW's building shell component, or more simply "component," concept enabled the simulation of campuses, multiple buildings, and single buildings with multiple footprints within a single building simulation file. Each building, part of a building, or sub-sampled area could be represented as a "component." Each component has a component multiplier, which can be used to scale up the floor area and equipment to represent the entire building or other buildings like it on the campus. These concepts incorporated into the survey instrument enabled a single survey form to be used for campus situations and resulted in not having to manually scale up sub-sampled equipment.
- ***Building Footprint Templates.*** A large number of common building footprint shape templates made it possible to specify realistic building shapes, rather than a simple rectangle for all buildings. All of these templates can be simply defined with no more than six dimensions.
- ***Thermal Zoning Conventions.*** Thermal zoning was one of the most discussed survey design issues. eQUEST's thermal zoning conventions—one-per-floor, perimeter/core, zone-by-activity-area—encompassed the most common types of zoning schemes expected to be found at the surveyed

premises. The zone-by-activity-area zoning scheme, used for places such as restaurants where zoning is by activity type (for instance, kitchen and dining area), was synthesized from the CEUS effort.

- ***Construction Types/Features.*** eQUEST's large library of construction types and materials were used wherever possible, including building type defaults.
- ***HVAC Systems and System Assignment Conventions.*** The eQUEST DDW included a pre-defined set of complete HVAC systems (rooftop HVAC, four-pipe fan coil, etc.) and combined those with HVAC system assignments based on the thermal zoning convention selected for a particular component. This was entirely consistent with the approach used by Itron in dealing with HVAC systems. This made it easy to map the DrCEUS HVAC systems to eQUEST HVAC systems and then assign those systems to thermal zones (perimeter, core, bottom floor, etc.).

The use of a wizard approach to creating the building simulation models was critical to performing building simulations en masse, as required by this project. By integrating some key aspects of the eQUEST DDW and DOE-2.2 into the survey form, much more of the building simulation modeling work could be automated. This made the survey somewhat more difficult for the surveyors to complete because they had to understand some of the key building simulation concepts. However, this was countered with well documented protocols, training manuals, surveyor training sessions, and pre-test sessions that ensured surveyors understood what was required.

Tight protocols not only ensured consistency, accuracy, and efficiency in the collection of data, but also provide information to potential users of the data about the specific practices followed during the survey. Protocols developed for the survey were wrapped into an on-site survey training manual, which includes sections on conducting the survey, survey form building simulation concepts, detailed instructions for filling out the survey form, and appendices containing useful reference information.

3.3 Customer Recruitment Protocols

Introduction

This section describes the protocols followed by the data collection subcontractors (KEMA, ADM, and VIEWtech) in recruiting customers for the on-site surveys. These protocols included customer contact procedures, documentation, and disposition of recruitment phone calls, and tracking/reporting requirements. The protocols for soliciting and recruiting commercial customer sites to participate in the CEUS project included the following elements:

- Recruitment letter,

- Recruitment phone calls, and
- Recruitment disposition report requirements.

These elements are described in detail in the following subsections.

Recruitment Letter

The recruitment letter was the first step taken in contacting customers. This letter explained the purpose of the project, introduced the on-site survey subcontractor involved, solicited survey participation, and provided information that customers could use to verify the project's legitimacy. This information included the address of the Energy Commission website, which provided a project synopsis, the Energy Commission toll-free hotline, and a contact for the local utility.

Recruitment letters were sent out in staged batches at least one week before calling. The send dates of each batch of letters were tracked to ensure that the follow-up recruitment phone call was made within a week after sending. The recruitment letter was tailored for each of the respective utility service areas. An example is provided in Appendix D.

Recruitment Phone Calls

The second step involved a telephone call to each customer. Each subcontractor used a centralized approach for recruiting customers. The advantages of the centralized approach were significant for the following reasons.

- ***Careful and Consistent Treatment of Customers.*** The centralized approach was carried out by two or three people. These individuals were trained in recruitment techniques and had previous experience performing this task. The use of a small number of centralized recruiters ensured that the customers were contacted in a consistent manner. There were cases where one contact person was responsible for multiple sites (for instance, school district facilities manager or chain stores). Centralized recruiters ensured that these contacts would not receive more than one letter of introduction or multiple telephone calls.
- ***Daily Scheduling Updates.*** With a centralized approach, all the scheduling information was maintained in one place. Periodically (typically weekly), all information was compiled and transmitted to the Itron project manager.

Recruitment protocols and the script used in recruiting customers are described in the following subsections.

Telephone Recruiting Protocol

As noted in Chapter 2, the overall sample was stratified by utility, climate zone, building type, and size. Each unique combination of segmentation variables was assigned a unique strata number to facilitate the tracking of progress. The following recruiting protocol, which involves up to six callbacks, was followed. Specifically, given a targeted number of completed on-site surveys equal to *n* for each stratum:

- Subcontractors were given a "primary" sample containing *n* sites and a secondary or backup sample containing 3*n* sites.
- For the sites in the primary sample:
  - No less than six attempts (initial call plus five callback attempts) were to be made to recruit these sites before they were substituted with a replacement site from the secondary/backup sample.
  - No more than two attempts in a single day were permissible. This provided the necessary time diversity to ensure that a reasonable effort was made to make contact.
- If the recruiter was unsuccessful in recruiting or contacting a primary sample site after six attempts, or the site failed the general screening criteria outlined in Appendix E, the site was replaced with the next *sequential* site from the secondary/backup sample.
- Replacement sites were to be contacted no fewer than four times (three callback attempts) before they could be substituted with the next *sequential* replacement site from the secondary/backup sample. As with the primary sample, no more than two call attempts in a single day were permissible.
- This procedure was followed until the stratum target of completed surveys was achieved.

Each subcontractor had to report a disposition for each sample site each week, as described in Section 3.4.4 below.

Telephone Recruitment Script

Because of the sensitivity of the individual utilities and the Energy Commission concerning customer relationship management, it was important that the telephone recruiters use a recruiting script that contained the message the utilities wished to communicate to their customers. Appendix E contains the specific script developed to accomplish this objective.

All survey subcontractors on this project were required to use this script along with any other dialog they chose to use in recruiting. During the recruiting call, the subcontractor was required to confirm the utility customer name and address, as well as implement additional screens such as the "minimum building" and accessibility requirements established for the study. The actions required in the recruitment script are summarized below.

- Recruiters were to make telephone contact with the customer and verify the appropriate person for discussing participation in the study. Recruiters then explained the purpose of the project and verified that they received the recruitment letter and, if they did not, immediately faxed a copy to the customer.
- Recruiters briefly interviewed the customer about key site features, such as facility type, size, etc. If the respondent was not able to answer the questions, recruiters then probed to find a contact person knowledgeable about these features.
- If during these interview questions it was revealed that the facility is a non-building site and does not meet the minimum building requirements, the recruiter thanked the customer for his/her time and explained that the site at the service address was outside the project's scope. Sites identified as having a different building type classification than was expected from the utility billing information were still recruited into the survey.
- Recruiters solicited participation in the on-site survey, indicating the amount of time needed during the visit from the contact person, or from other individual(s) knowledge about the facility and business operations.
- A mutually acceptable time to conduct the survey was arranged. In setting up the visit, recruiters took care not to schedule the visit during important activities at the facility. Arrangements for any necessary security clearances were also made at this time.
- Recruiters requested that selected information be available for the surveyor to review. This information included copies of blueprints, facility listings, and nonparticipating utility energy bills, if appropriate.

Recruitment Disposition Report Requirements

Subcontractors were responsible for developing their own on-site survey recruitment and tracking system, which was used to create disposition reports. Regardless of the system used for tracking recruitment, weekly disposition reports were due to Itron by close of business each Thursday. These disposition reports were used for the following purposes:

- To determine and evaluate response rates, for instance, the percent of customers who can be reached that agree to the survey,
- To monitor general progress and *adherence to the recruiting protocol*, i.e., requirements that must be met before replacing a primary site with a site from the secondary/backup sample,

- To evaluate the impact of the minimum building and accessibility screening criteria, and
- To identify any underlying systematic problems with the sample/frame data (incorrect phone numbers, contact names, outside lighting or street lighting accounts showing up, etc.).

Both a site-level and a summary report had to be provided. Each report had to include both the current week's progress and the cumulative progress over the course of the project. These reports were required to be delivered in electronic spreadsheet format. Figure 3-1 presents an example of the site-level report.

Figure 3-1: Site-Level Disposition Report Example

Premise ID	Business Name	Recruit Letter Sent	Call #1		Call #2		==>	Notes/Comments
			Date/Time	Call Disposition	Date/Time	Call Disposition		
1000005	Customer A	2/14/02	2/23 AM	no answer	2/23 PM	no answer		
1000006	Customer B	2/14/02	2/23 AM	non-building site				pumping station
1000007	Customer C	2/14/02	2/23 AM	survey scheduled	2/23 AM	survey scheduled		
1000008	Customer D	2/14/02	2/23 AM	not interested				
1000009	Customer E	2/14/02	2/23 PM	wrong number				number disconnected
1000010	Customer F	2/14/02	2/23 PM	business moved				
1000011	Customer G	2/14/02	2/23 PM	busy signal	2/23 PM	not interested		
1000012	Customer H	2/14/02	2/23 PM	left message/call back	2/23 PM	left message/call back		
1000013	Customer I	2/14/02	2/24 AM	language barrier				
1000015	Customer J	2/14/02	2/24 AM	left message/call back	2/24 AM	left message/call back		
1000016	Customer K	2/14/02	2/24 AM	survey scheduled				
1000017	Customer L	2/14/02	2/24 AM	survey scheduled				
1000018	Customer M	2/14/02	2/24 AM	survey scheduled				conflict need to reschedule

The site-level disposition report was required to include the following fields:

- Premise ID number of contacted premise,
- Business name, and
- Date that the recruitment letter was sent.

For <u>each call attempt made</u> (i.e., up to six attempts for primary sample sites), the following was required:

- Date and time that the contact attempt was made,
- Disposition of each call, categorized as follows:
  - No answer/unable to leave message
  - Scheduled callback
  - Call back later
  - Survey scheduled
  - Not interested/mid-terminate

  - Wrong number
  - Different business/customer (business moved out)
  - Busy signal
  - Left message
  - Language barrier
  - Non-commercial site (<50% commercial)
  - Non-building site (<100 ft^2 of occupied space)
  - Limited access (i.e., <50% of site accessible for survey)
- Notes/comments.

Additional fields that could be included on the tracking system, but not required for the recruitment disposition report, were as follows:

- Contact name,
- Contact telephone,
- Appointment date,
- Appointment time,
- Surveyor assigned,
- Completed date and initials,
- Cancel date,
- Quality control check date and initials, and
- Data entry date and initials.

Figure 3-2 presents an example summary report. The summary disposition report was a simple tally of the dispositions per call.

Figure 3-2: Recruitment Summary Disposition Report Example

Disposition Codes	CALL 1	CALL 2	CALL 3	Total as of W/E 2/18
01 - Left Message	2375	1535	1236	5146
02 - Not Interested/ Mid Terminate	671	360	269	1300
03 - Scheduled Survey	244	345	22	611
04 - Disconnected	690	4	11	705
05 - Wrong #	2002	147	85	2234
06 - Busy Signal	118	86	53	257
07 - Initial Refusal	78	26	27	131
09 - Call Back Later	207	118	10	335
10 - Language Barrier	127	48	24	199
11 - No Answer/ Unable to Leave Message	535	375	315	1225
12 - Non Commercial Site	93	48	38	179
Totals	**7140**	**3092**	**2090**	**12322**

3.4 Survey Protocols

Introduction

An extensive set of survey data collection protocols was developed for the implementation of the survey. The survey protocols, which are detailed in the on-site survey training manual, were intended to provide the surveyors with guidance for handling most buildings that were surveyed. These protocols covered the following topics:

- The definition of the survey site as the entire customer premise at the service address, and examples of how to configure forms for specific situations,
- A methodology for linking meters to premises,
- Defining component survey areas,
- An explanation of how to determine business type,
- Suggestions for dealing with large sites and limited access,
- The details to be recorded to describe mechanical systems and equipment for HVAC and non-HVAC end uses,
- The physical characteristics of the site, including construction materials, building geometry, and other characteristics relevant to estimating HVAC loads,
- The appropriate techniques for recording the technical information,

- Key elements in business operations including operating hours, system control settings, and estimated equipment usage levels and usage profiles,
- The appropriate interview techniques for eliciting information about business characteristics and operations, and
- Quality-control procedures that must be exercised by the surveyors before the survey is considered “complete.”

Each of these topics is described in more detail below.

Premise as the Unit of Analysis

As noted in Chapter 2, the unit of analysis in this study was the premise. In theory, the premise was defined as a “single contiguous customer.” However, in practice, because premises are assembled from the utility billing frame, the methods for assembling a premise sometimes yielded something other than this ideal. As such, *it was of utmost importance* that surveyors understood the proper definition of a premise so they could decide in the field if the survey area needed to be something other than that identified on the Customer Contact sheet. Several practical rules of thumb were developed to help surveyors understand what a premise should be.

Protocols for Linking Meters to Premises

Given the use of billing data to guide the calibration of estimates of end-use consumption for the premise, the verification of natural gas and electricity meters serving the premise was clearly one of the most important steps taken in the on-site survey. A major effort was undertaken to aggregate meters to the premise level. Itron recognizes that the process used to develop premise-level data from billing records is imperfect and varies considerably across utilities. As a result, special emphasis was placed on the accurate identification of meters at the surveyed sites. The on-site survey training manual contains many examples of survey area configurations and the appropriate approach for surveying the premises and recording the information on the survey instruments.

Defining Component Survey Areas

One of the most challenging aspects of this project was the proper identification of component survey areas within a premise. A *Component Survey Area* is a building simulation concept used for subdividing a premise into two or more areas unique enough to warrant individual simulation. This could be due to HVAC zoning schemes, different construction properties, or operating characteristics. The first eight forms of the on-site survey are premise-specific forms that are to be completed for the premise as a whole. The remaining forms must be completed for each component survey area identified. Dividing the premise into component survey areas is a way to isolate distinct building construction types, locations, or activities and examine each area individually. Defining component survey areas generally applies to larger, more complex sites. Although definitions will vary for each premise, there are some general guidelines to follow while segmenting the premise into component survey areas. Each guideline is described below.

Areas with Unique HVAC Zoning Schemes

If a premise has two or more areas that are zoned differently, the premise should be split into two components. An example of this would be a multi-story office building with retail on the first floor. The offices are zoned perimeter/core, but the retail area is zoned by activity area. In this example, the office tower would be one component and the first floor retail space would be a second component.

Areas with Unique Footprints/Building Construction Materials

Typically, each area with a unique footprint or construction type should be a separate component survey area. An example of this would be a hotel that has a tower for guest rooms and a larger footprint convention center on the first floor. In this case, the convention center would be one component, the first floor lobby area would be a second component (following the next guideline), and the tower (floors 2 and up) would be the third component.

Areas with Unique Operating and Equipment Schedules

If a portion of a premise operates on a schedule that is different from the rest of the premise, it should be a separate component survey area. Taking the hotel example above, the lobby area most likely functions 24/7, the guest rooms have a more residential schedule, and the convention center operates on an entirely different schedule than the other two areas. Therefore, these should be treated as separate components. Remember that the survey form only allows for up to three schedule sets, so component survey areas were selected carefully to adhere to this limitation. As a different example, an office building operates at normal business hours. It has a computer room that operates 24/7. In this example, the computer room would not be a separate component, but would instead be an activity area within a component. The distinction is made here based on comparing the potential gain in modeling accuracy with the additional effort involved in defining separate components. The activity area approach still allows for 24/7 operation of HVAC systems and computer equipment

Separate Buildings in a Multi-Building/Campus Premise

Campuses or multi-building premises can be divided into component survey areas that represent all similar buildings. Using a college campus as an example, dormitories would be one component survey area, classrooms may be another, and administrative offices may be a third. Refer to the protocols for campuses for more detailed information on the procedure for segmenting the campus into individual buildings.

Floor Types within a Component

An important concept to note here is the recording of floor types. If a component is defined as floors 2-10 of a 10-story office tower, then the ground floor for the component will be the second floor, which is adiabatic or defined as having no heat transfer capabilities. The middle floors will be floors 3-9 and the top floor will be floor 10.

Protocols for Determining Business Type

At times, determining business type is not entirely straightforward. There may be multiple business activities at the site, or business activities may not fit the pre-specified options as neatly as one would like. The Itron team attempted to minimize problems in determining business type in two ways. First, Itron designed the survey to allow the specification of both the primary and component business types. Second, Itron developed rules of thumb to aid surveyors in characterizing business activities in a consistent manner.

Protocols for Dealing with Large Sites and Limited Access

Three special problems may be confronted in the course of the on-site survey. First, a premise may consist of several buildings, each with different functions. Second, a site may be a very large single-tenant building. Third, some areas in the premise may not be accessible. The means of dealing with many of these situations is to divide the premise into different component survey areas, as described above. Additional surveying methods appropriate to each situation are described below. At the end of this chapter, subsampling guidelines are provided for surveying these types of premises.

Campus Situations. Multi-use buildings can be covered by the survey form, which allows the identification of sub-areas within the building, the assignment of equipment to these areas, and the assignment of operating schedules for each area. However, even with the flexibility provided by the proposed multi-area form, there are campus situations where it is necessary to develop separate component survey areas for individual buildings at the premise. This occurs when buildings are constructed from different materials, when they have different types of HVAC systems, or when the operating hours are significantly different. In any of these cases, multiple component survey areas and multiple energy simulations are required to develop appropriate premise characteristics data and accurate energy-use estimates. With this in mind, distinct component survey areas can be used to describe unique building types in a campus situation.

For large campuses, the cost of developing separate forms and engineering simulations for each building on the campus is prohibitive. As a result, some form of subsampling is usually invoked, in order to keep the data collection costs at a reasonable level.

Multi-building and campus locations are typically handled as follows. For schools, colleges, hospitals and other health, lodging, and miscellaneous buildings that have demand levels higher than some critical value (say, 500 kW), detailed data are collected for the largest building at the location and square footage and data on fuel use by end use for all other buildings at the location are also collected. An energy analysis is performed for the surveyed building, and the results are scaled upward to represent energy use for the premise as a whole.

The Itron project team used a more complete subsampling procedure for the multiple building and campus sites. With this approach, the following steps were executed at large sites flagged as potential multiple-form locations.

- An initial inspection of the site was made, which included a review of campus maps and building inventory listings. Following this inspection, the surveyor notified the Itron project manager about the site layout and provided a listing of buildings at the site, including a building type indicator and an initial estimate of square footage for each building.
- After reviewing the surveyor's description of the site layout along with the billing information, the Itron project manager determined if additional forms were necessary to capture the site information adequately. The Itron project manager also identified the building-type groupings to be recorded on the additional survey forms.

  The general rule for grouping buildings is straightforward. Each survey form represents a group of similar buildings. For instance, a large college may be broken into classrooms/offices, dormitories, gymnasiums, and food service facilities. There is one survey form for each of these building types. Before implementation, the Itron project manager reviewed the building-type groupings with the subcontractor's field manager.
- Once Itron approved the strategy for the site, random sampling techniques were applied to select the exact buildings to be surveyed. The Itron project manager provided this information to the surveyor, who proceeded with the survey work.

At the conclusion of this effort, the multiple survey forms were entered into the building database, along with the premise weight and a subsampling weight indicating the inverse probability of selection for that specific building within its use group. For example, if the surveyed classroom space at a campus represents 20% of the total classroom space, then the subsampling weight will be 5.

In the energy analysis step, a separate engineering analysis and DOE-2 simulation was executed for each building surveyed at the campus. Subsampling weights were used to expand the estimated energy use numbers upward to an estimate of total premise energy use, and this total was calibrated against total premise bills or hourly loads, if available.

Very Large Single Tenant Buildings. Some extrapolation of survey data is required for very large buildings. The largest buildings could require several days of auditing to gather detailed lighting, air handling system, and plug loads for the entire site. In some cases, it was simply not possible to gain access to certain spaces in a building. For large buildings, the plan was to collect detailed information on a sampled portion of a building and extrapolate the results to the whole building(s) based on relational occupancy types and amount of floor space. In the case of a large multi-story office building, the surveyor selected a representative number of floors that predominately contained office space and collected data on the lighting, plug loads, and HVAC equipment located on and serving each selected floor. Information was gathered on all equipment in areas with unique space types such as the main lobby, cafeteria, computer room, or parking garage. Building shell data and equipment serving the *entire* building, such as central chiller/boiler plants, elevators, and exterior lighting were also surveyed.

Premises with Restricted Access. Some premises (for example, certain military sites) may not be open to the public. These premises simply could not be included in the final sample. Other premises may be open to surveyors, but have specific areas with restricted access. This is typically true in research sites, where labs may be off-limits. There are few good options available for the treatment of areas with restricted access. Surveyors were trained to probe to the extent possible for information about the types of activities conducted in the restricted area and for rough estimates of connected loads and operating schedules. Moreover, surveyors requested site layouts in order to ascertain square footage, lighting connected loads, and other structural characteristics of the restricted areas.

Additional Subsampling Guidelines. In the above cases, the threshold for sampling depends on two factors: the size of the premise and the homogeneity of its space utilization. The contractor used sampling when there was a minimum of 100,000 square feet of the same type of space utilization within the premise, and would sample only within spaces of this type.[1]

- ***Example 1.*** A 200,000 square foot office building with a single tenant. A lobby and a cafeteria on the first floor, a 25,000 square foot parking garage, and seven floors of office space. The contractor would survey the first floor, the parking garage, central HVAC facilities, and two of the seven floors of office space.

[1] It is assumed for these examples that the space in question contains a single premise. Only premises originally selected for the sample were surveyed even if there were multiple premises in a location,.

- ***Example 2.*** A 12-story, 800,000 square foot office building with retail space on the first floor (under the same account) and 11 floors of offices. The contractor would survey the entire retail space, any central HVAC facilities, and three of the 11 floors of office space.
- ***Example 3.*** A 300,000 square foot hotel with common areas including a lobby, a restaurant, and meeting rooms, with three types of guest rooms. The contractor would survey the lobby, restaurant, meeting rooms, HVAC plant, and a sample of two or three of each type of guest room.

Describing HVAC Zoning, Mechanical Systems and Equipment for HVAC and non HVAC End Uses

HVAC is typically one of the major end uses at a premise. Therefore, it is very important to properly identify the HVAC zoning scheme(s) at a premise and properly assign HVAC systems and equipment to their respective zone. A great deal of effort was expended to create survey forms versatile enough to handle almost every situation encountered in the field, while still being simple enough to be completed in a timely manner.

HVAC Thermal Zoning Schemes

There are four thermal zoning scheme types available on the survey form: Perimeter/Core, Multi-Perimeter/Core, One per Floor, and Zone by Activity Area. Each zoning type is described below.

Perimeter/Core and Multi-Perimeter/Core. These two zoning types are described together here due to the similarity between them. Perimeter/Core refers to a component that has one or more HVAC systems for the perimeter areas of the component/building and one or more HVAC systems for the core. This is a very common zoning scheme in larger office buildings where there is a larger internal heat gain at the core of the building than at the perimeter. Often times the core will require cooling year round, while the perimeter requires heating in winter.

Multi-Perimeter/Core is a special case of Perimeter/Core in which the perimeter is divided into many separate zones. A very common example of this is a hotel, where each guest room is a separate HVAC zone.

One per Floor. This zoning type is the most straightforward of all, consisting of one HVAC zone for each floor of a component or building. There should be only one thermostat on the floor.

Zone by Activity Area. This zoning type is the most difficult of all, but it results in accurate thermal zoning for those buildings that are zoned based on activity type rather than building geometry. A restaurant is the perfect example, where the kitchen area will have a separate HVAC system than the dining area, and there may be some unconditioned space used for storage. Assuming one zone per floor would spread out the internal heat gains from the cooking equipment across the entire dining area, resulting in a much lower overall load shape for the HVAC end use. Using Zone by Activity Area allows each unique Activity Area to become a thermal zone without requiring the use of separate components. In addition to restaurants, Zone by Activity Area will be commonly used for grocery stores, warehouses, and some retail establishments.

HVAC Mechanical Systems

HVAC systems were addressed in six basic equipment categories: Single Zone (SZ) systems, Multiple Zone (MZ) systems, central plants (for example, boilers, chillers), auxiliaries (heat rejection and circulation pumps), exhaust fans, and make-up air fans. Single-zone systems are those HVAC systems that serve only a single thermal zone, and they are typically unitary/package systems. Multiple-zone systems are those HVAC systems that serve multiple, independently controlled thermal zones. These are typically, although not exclusively, built-up type systems. Single-zone and multiple-zone systems are defined more explicitly in the on-site survey training manual and the survey forms.

All distribution systems (SZ and MZ) are linked to zone types and/or area IDs, while central plants are linked to distribution systems, and auxiliaries are linked to central plants. A combination of direct observation and review of site plans was used to gather as much information about the HVAC systems as possible. If access to equipment or plans was denied, an attempt was made to obtain the information from the site contact. If the information could not be provided by the site contact, then the data was estimated and comments about the situation were recorded on the survey form so that energy simulation modelers could adjust their analysis accordingly.

Site Physical Characteristics

The survey form captured key construction characteristics of the building shell for each component survey area, including floor, roof, ceiling, window, and wall construction. Blueprints and/or construction plans were utilized whenever they were available, and surveyors were careful to verify that the plans reflected the true “as-built” configuration. Where a building was constructed of more building materials than allowed in the survey form, surveyors recorded the predominant building material. Other building materials were recorded in the comments section, along with amounts of each building material used (square feet, percent of total wall area, etc.).

Roof Construction

Only one roof type can be described for each component survey area. If more than one type was present, surveyors recorded the type that accounted for the largest share of enclosed floor space and described others in the comments section.

Exterior Wall Construction

Exterior wall refers to walls exposed to the outside environment. Again, only one wall type can be associated with a component survey area. If a component survey area had more than one wall type, surveyors recorded only the predominant type. Other types present and their approximate percentages were noted in the comments section. This information was obtained via direct observation, from site plans, or from the site contact.

Below-Grade Wall Construction

Below-grade walls refer to walls that are completely below grade. Only one below-grade wall type can be described per component survey area. If a component survey area had more than one wall type, surveyors recorded only the predominant type. Other types and their approximate percentages were noted in the comments section. This information was be obtained via direct observation, from site plans, or from the site contact.

Floor Construction

Only one floor type can be associated with a component survey area. If more than one floor type was present, the predominant type was described.

Windows/Skylights/Fenestration

Up to three types of windows may be described for the component survey area. Window descriptions include glazing type, frame type. Two types of skylight can be described, but only one type can be associated with each component.

External Doors

Up to three types of doors may be associated with each component survey area. Door descriptions include design type, material type, and dimensions. This chapter applies only to exterior doors in the component survey area.

Window Percentages and Door Locations

Windows and doors are linked to the four footprint plan orientations (not compass or true directions). Windows are specified by indicating the percentage of gross wall area that is occupied by windows for each wall orientation. Doors are specified by indicating the number of doors located on each orientation of wall.

Recording Technical Information

All responses and field entries were entered into a database. Therefore, many entries were coded. As much as possible, the appropriate codes were included as part of the question or in the response fields themselves. In some cases, codes were provided at the bottom of the form. When recording responses or data values, the following guidelines were used:

- All zeroes were written with an overstrike (Ø) to differentiate them from the letter O.
- The number seven and last letter of the alphabet were written as 7 and Z, respectively.
- Decimals (1.25) were used, instead of fractions (1¼), when recording values.
- Surveyors were instructed to print legibly so that the data entry personnel would not have to struggle to read the data.
- Some of the response or data fields were limited in length, indicated by a series of lines (__ __ __.) Surveyors were instructed to write only one character per line.

Supplemental Information

Many additional sources of information were used to supplement the interview and the walkthrough. For example, the following sources are very useful:

- Facility or campus maps (schools, office complexes, hospitals, resorts, etc.),
- School calendars, and
- Site plans or maps.

Surveyors requested copies of these or other materials whenever possible. The Site ID number was added to each one, along with the surveyor's initials, and these additional materials were then attached to the survey instrument.

Key Elements of Business Operations

Some of the key elements include schedules and operating hours, system control settings, and estimated equipment usage levels and usage profiles. Each element is described below.

Schedules

The main schedules define the weekly and annual operation of the component survey area and the equipment at the site. Because a single set of schedules must often be used to represent the operation of multiple areas and various pieces of equipment, the surveyor needed to consider carefully about the schedules that are specified. Often, it is necessary to average the schedules for multiple areas or several pieces of equipment.

Schedules were specified in whole-hour increments. Therefore, the start hour for each time interval in a schedule was rounded to the nearest whole hour. In addition, a 24-hour clock was used to designate time (1:00 p.m. would be 13). For example:

- If the schedule applied to equipment typically operating from 8:35 a.m. to 2:25 p.m., the appropriate entries were 9 and 14 (2 p.m.), respectively.
- Similarly, if the equipment operated from 9:15 a.m. to 1:45 p.m., the appropriate entries were 9 and 14 (2 p.m.), respectively.

System Control Settings

There are two types of system control settings commonly used in the survey forms. The first is for cooling and heating temperature setpoints. The other is for on/off operation of equipment such as fans, pumps, and motors. Each is addressed separately.

For each component survey area, one cooling temperature setpoint and one heating temperature setpoint were to be defined. Additionally, there should only be one value for occupied hours and one value for unoccupied hours. For responses that varied, the response that corresponded to the majority of the component survey area was selected.

On/off control options for equipment such as fans, motors, and pumps were listed for each unique equipment type. If multiple control options were present, the control type that applied to the majority of the equipment was selected. For example, the control options for a single-zone HVAC distribution system are manual (on/off), time clock, programmable thermostat, always on, and EMS. In addition, the fan may also be set to None, Auto, or On. In both cases, all options were presented on the survey form. If a control existed that was not present on the survey form, the surveyor recorded the control type on the comments form along with a detailed description of the control.

Equipment Usage Levels

Equipment usage levels were typically recorded as “Average Hours per Week On.” For all equipment, this refers to the number of hours that the equipment is on and available. Operating profiles were applied during analysis to account for standby and operating hours.

Interview Techniques

After all identification issues were handled, the surveyor interviewed the site contact about general site operations and characteristics. The interview portion roughly corresponds to Form 1 through Form 7 of the survey instrument, although pertinent information for other forms was often revealed during the interview. Interviews generally lasted between 20 and 30 minutes.

Surveyors had to be sensitive to the site contact’s time constraints. If the site contact had limited availability, the most critical questions were asked first (for example, occupancy levels, schedules, and location of major equipment). If this was an issue, building plans and documentation potentially available at the site were requested. In some cases, the site contact was only available after the walkthrough was completed. If this occurred, questions were organized before the interview was conducted.

Quality-Control Procedures for Field Surveyors

The survey firms and Itron monitored all incoming surveys to ensure the quality of the responses. In the first stage of quality control, the survey firm executed the following procedure for each site.

- Surveyors had access to basic energy use information before traveling to the site and were required to perform a variety of "sanity checks" before leaving the survey site. This information was summarized on a "customer information sheet," which is described in more detail in Chapter 4. These checks include the following:
  - Computing overall electric intensity.
  - Computing selected equipment densities, including square feet per ton of cooling equipment and Watts per square foot of lighting equipment.

  If the data did not pass these initial checks, this usually indicated an inconsistency between the site data and the billing data. In this case, the surveyor continued at the site to clear up obvious discrepancies.
- The survey form was delivered to the surveying firm's project manager. The project manager reviewed the form and the sanity checks performed by the surveyor. The project manager and the surveyor resolved any missing data or apparent inconsistencies.

Once the survey data passed review of the surveying firm's project manager, they were forwarded to Itron for data entry. Once entered, they were then processed by Itron's energy analysis software, DrCEUS. The Itron project manager then reviewed the energy analysis results and compared these against the monthly bills and hourly load research data. Large discrepancies between the simulated results and the actual billing data that could not be explained by data-entry errors were returned to the survey firm for resolution.

Follow-Up to Collect Missing or Incorrect Data

Based on the results of the comparison between simulation results and billing data, follow-up steps may have been necessary in order to collect missing data or re-visit data that appeared to be inaccurate from the initial data collection effort. Itron's experience has been that limited follow-up is typically required for less than 10% of the survey cases, and that most follow-up is easily accomplished through telephone contacts. Any necessary follow-up (by telephone or a second visit to the site) was conducted by the surveyor who conducted the initial survey work or by the surveying firm's project manager, depending on the specific circumstances of the case.

3.5 Short-Term Metering Protocols

Overall STM Objectives

Reliable estimates of hourly energy use depend strongly on surveyor estimates of equipment operating hours and usage patterns (i.e., percent of equipment on), as captured in the on-site survey form schedules. However, schedules are usually the most subjective and difficult site characteristics to assess. In an attempt to improve the accuracy of the schedules for inside lighting and HVAC systems – which are significant end uses for almost all building types – TOU data loggers were used to gather short-term metering (STM) data for these two end uses for a small subset of the on-site survey premises. The STM data were used to improve, or at least qualitatively evaluate, the operation schedules reported on the survey form, which are ultimately incorporated into the building simulation models. A detailed description of how STM data was used for calibration is contained in Chapter 6.

In addition to improving schedules using the STM data alone, a special effort was made to examine the effectiveness of using STM data in conjunction with whole-building interval-metered data. Conventional practice might suggest screening interval-metered premises from the pool of sites eligible for STM, on the assumption that more information about premise-level operation can be gleaned from the interval-metered data than from STM data. However, as an experiment, the Energy Commission requested that at least 10% of the STM premises also have interval-metered data, in order to examine if operation information gleaned from the STM data could be used to complement and supplement observations from the interval-metered data.

Short-term metering was to be conducted for 500 premises. Details of the short-term metering effort are addressed in the following sections.

- ***Section 3.5.2. STM Targets.*** This chapter presents the STM targets by building type and size, and contains a description of how the STM targets were determined.
- ***Section 3.5.3. General Issues/Protocols.*** General issues and protocols applicable to the overall STM process and both end uses are presented in this chapter.

Additional detail regarding the STM protocols can be found in Appendix F. A description of how the STM data was used for calibration is contained in Section 6.3 Calibration Data Sources.

STM Targets

Targets by building type and size are presented in Table 3-1. The OVERALL column presents the total number of STM sites required. The KEMA and ADM columns present the targets for each survey team. The Interval-Metered Sites column denotes the number of STM sites expected to be interval-metered sites, based on the statistics of interval-metered (IM) sites within the primary and secondary recruitment samples, as shown in Table 3-2. The criteria used to establish these targets, as developed in consultation with the Energy Commission, were as follows.

- Five hundred premises will be sampled.
- STM targets, presented in Table 3-1, were distributed following the process described below:
  - Census premises were excluded,
  - Large hospitals (health care-large) and hotels (hotels-large) were excluded, and
  - STM targets were distributed proportionally to the remaining on-site targets.

  The initial proportional distributions were further modified as follows:
  - Excluded small and medium hotels and reduced the number of large miscellaneous targets from 50 to 10 premises,
  - Re-allocated the targets from the two steps above (54 total—10 hotels and 40 large miscellaneous points) proportionally to all other small and medium sized categories, and
  - Overall targets were proportioned out to KEMA and ADM targets.
- The Energy Commission requested that approximately 10% of the STM sites (i.e., 50 sites) should be known interval-metered data premises. As mentioned in the overview, this effort was being pursued as an experiment to determine whether STM data can be used to complement the interval-metered data. This requirement was not strictly enforced as a hard target. Instead, based on the presence of interval-metered sites in the recruitment sample (16%), it was hoped that this requirement would be met naturally by random sampling.
- Although the STM targets were not established on a climate zone basis, a "balanced approach" with regards to climate zone was still desired. However, the logistics of extracting loggers from remote areas was recognized and, as such, loggers were not installed in remote areas of the state.
- Itron provided a modified sample on which known interval-metered sites were "tagged," so that a premise's IM status could be appropriately tracked. This was necessary in order to request the IM data to be used for analysis in DrCEUS.

- An STM tracking system was needed to track dispositions related to STM metering for STM sites, including information related to installation, extraction, processing, and receipt of these data. These data were used to create a status report for the STM efforts.

Table 3-1: Short-Term Metering Targets

BldgType	Size	OVERALL	KEMA	ADM	Interval-Metered Sites
1. Small Office	1. Small	9	6	3	1
1. Small Office	2. Medium	25	14	11	4
1. Small Office	3. Large	37	20	17	1
2. Large Office	1. Small	15	8	7	5
2. Large Office	2. Medium	12	7	5	6
2. Large Office	3. Large	11	7	4	6
2. Large Office	4. Census	0	0	0	0
3. Restaurant	1. Small	12	8	4	1
3. Restaurant	2. Medium	17	10	7	1
3. Restaurant	3. Large	14	8	6	1
4. Retail Store	1. Small	21	12	9	3
4. Retail Store	2. Medium	44	24	20	2
4. Retail Store	3. Large	35	18	17	12
4. Retail Store	4. Census	0	0	0	0
5. Food/Liquor	1. Small	15	11	4	0
5. Food/Liquor	2. Medium	27	18	9	1
5. Food/Liquor	3. Large	13	7	6	3
5. Food/Liquor	4. Census	0	0	0	0
6. Unref Warehouse	1. Small	11	7	4	1
6. Unref Warehouse	2. Medium	19	12	7	1
6. Unref Warehouse	3. Large	16	10	6	7
6. Unref Warehouse	4. Census	0	0	0	0
7. School	1. Small	9	6	3	0
7. School	2. Medium	9	6	3	1
7. School	3. Large	8	5	3	4
8. College	1. Small	4	3	1	0
8. College	2. Medium	6	4	2	1
8. College	3. Large	3	2	1	1
8. College	4. Census	0	0	0	0
9. Health Care	1. Small	11	8	3	0
9. Health Care	2. Medium	9	5	4	2
9. Health Care	3. Large	0	0	0	0
9. Health Care	4. Census	0	0	0	0
10. Hotel	1. Small	0	0	0	0
10. Hotel	2. Medium	0	0	0	0
10. Hotel	3. Large	0	0	0	0
10. Hotel	4. Census	0	0	0	0
11. Misc	1. Small	13	8	5	1
11. Misc	2. Medium	55	33	22	4
11. Misc	3. Large	10	6	4	2
11. Misc	4. Census	0	0	0	0
25. Refr Warehouse	1. Small	4	3	1	0
25. Refr Warehouse	2. Medium	4	3	1	1
25. Refr Warehouse	3. Large	2	1	1	1
25. Refr Warehouse	4. Census	0	0	0	0

Table 3-2: Interval-Metered Data Site Statistics

BldgType	Size	Interval-Metered Sites Primary	Interval-Metered Sites Secondary	Interval-Metered Sites Total	On-Site Target	On-Site %	IntvMtrd % Of On-Site
1. Small Office	1. Small	5	13	18	31	11%	17%
1. Small Office	2. Medium	22	30	52	91		16%
1. Small Office	3. Large	11	8	19	162		3%
2. Large Office	1. Small	20	44	64	55	9%	33%
2. Large Office	2. Medium	16	64	80	45		51%
2. Large Office	3. Large	22	72	94	50		54%
2. Large Office	4. Census	42	-	42	69		17%
3. Restaurant	1. Small	4	9	13	43	7%	9%
3. Restaurant	2. Medium	6	8	14	58		7%
3. Restaurant	3. Large	6	4	10	62		5%
4. Retail Store	1. Small	11	23	34	80	16%	12%
4. Retail Store	2. Medium	11	12	23	162		4%
4. Retail Store	3. Large	44	136	180	156		33%
4. Retail Store	4. Census	3	-	3	14		6%
5. Food/Liquor	1. Small	2	3	5	55	9%	3%
5. Food/Liquor	2. Medium	4	13	17	98		5%
5. Food/Liquor	3. Large	12	31	43	56		22%
5. Food/Liquor	4. Census	-	-	-	9		0%
6. Unref Warehouse	1. Small	4	4	8	42	8%	5%
6. Unref Warehouse	2. Medium	6	6	12	70		5%
6. Unref Warehouse	3. Large	24	76	100	69		41%
6. Unref Warehouse	4. Census	2	-	2	9		6%
7. School	1. Small	-	-	-	36	4%	0%
7. School	2. Medium	4	11	15	36		12%
7. School	3. Large	15	44	59	36		47%
8. College	1. Small	-	-	-	17	3%	0%
8. College	2. Medium	4	9	13	18		21%
8. College	3. Large	3	7	10	15		19%
8. College	4. Census	2	-	2	24		2%
9. Health Care	1. Small	-	-	-	38	6%	0%
9. Health Care	2. Medium	4	17	21	35		17%
9. Health Care	3. Large	14	40	54	34		45%
9. Health Care	4. Census	17	-	17	53		9%
10. Hotel	1. Small	-	1	1	27	4%	1%
10. Hotel	2. Medium	5	10	15	36		12%
10. Hotel	3. Large	17	39	56	33		48%
10. Hotel	4. Census	6	-	6	14		12%
11. Misc	1. Small	6	13	19	50	21%	11%
11. Misc	2. Medium	29	19	48	203		7%
11. Misc	3. Large	44	147	191	219		25%
11. Misc	4. Census	28	-	28	47		17%
25. Refr Warehouse	1. Small	-	-	-	13	2%	0%
25. Refr Warehouse	2. Medium	1	6	7	14		14%
25. Refr Warehouse	3. Large	6	9	15	11		39%
25. Refr Warehouse	4. Census	2	-	2	5		11%

General Issues/Protocols

These protocols do not address instructions governing the actual installation, extraction, and downloading of data from the loggers, which was left up to the CEUS survey team members. Only the targets, high-level objectives, protocols, and deliverables are addressed below.

General issues and protocols include the following:

- The surveyor was given a great deal of leeway in deciding on the best way to install the loggers in order to optimize the lighting and HVAC operation information that could be captured for a premise. This is in recognition that the protocols could not specifically address every unique situation.
- General guidelines for how many loggers to use for each end use included, but were not limited to, the following:
    1) Six loggers were to be used for every premise, unless operation could be characterized using fewer loggers (i.e., for very small sites or single-control point sites).
    2) The number of lighting loggers needed to obtain adequate representation of non-continuous (i.e., not always on) lighting was determined, and the balance was used for HVAC fans.
    3) Typically, every premise had at least one of each type of logger, unless a premise was completely unconditioned or HVAC system logging was not useful (see detailed protocols below). However, there were some instances where only HVAC loggers were warranted (for example, 7/24 lighting by an HVAC system/fan that cycles on/off as space conditioning is needed).
- Loggers were not installed on lighting or HVAC systems that were EMS or time clock controlled if operation could be verified with a high-level of confidence. In situations where the EMS/time clock operation was suspect, loggers were used to validate the system functionality and settings.
- Loggers were left in place a minimum of two weeks to obtain at least two good days of data for each day of the week. If loggers were installed during a holiday or vacation period, then the monitoring period was extended by as many days as the holiday or vacation.
- Loggers were not installed if most of the premise was closed during the <u>entire</u> monitoring period, such as schools on winter/spring break. However, if a premise had a seasonally varying schedule and both schedules could be captured during the logger installation period, those distinct periods were noted on the final data set.
- For multi-component sites, the focus was on the primary objective—gaining some insight into the premise-level lighting and HVAC schedules—to determine where loggers should be placed for maximum usefulness.

- Every strata (BldgType X Size) for which a non-zero target number of sites is specified in Table 3-1 had to have loggers applied to at least one site, even if the detailed lighting and HVAC fan protocols dictated otherwise. Itron was to be consulted immediately if it was shown for any strata that the protocols would prevent installing loggers on any of the premises within that strata (for example, all premises have EMS systems or 7/24 operation). Actions that were taken included the following:
    1) Ignoring the detailed lighting and HVAC protocols that would normally prohibit logger installation (EMS, 7/24, etc.) for more than just one site.
    2) Reallocating a portion of the targets for such strata to another strata.
- Itron worked with KEMA and ADM on a case-by-case basis on the implementation of this protocol.

Specific protocols for lighting loggers and HVAC fan loggers are provided in Appendix F.

3.6 Surveyor Training

Surveyor training was provided at two points in the study. Training was centered on the principles outlined in the on-site survey training manual. The first surveyor training coincided with the pretest of the survey instrument and was an important element of the pretest process. It was held at Itron's offices in San Diego. The training consisted of two elements: survey instrument training and data entry training. These elements are described here in more detail.

The surveyor training occurred over a four-day period. Each subcontractor sent two individuals to attend. These individuals were to be the lead surveyors for each subcontractor. These surveyors were ultimately responsible for training additional surveyor staff at their respective companies. Individuals were required to supply their resumes detailing their prior training and experience as building surveyors to the Energy Commission project management team for approval. The Energy Commission project management team attended the formal training session.

Day 1

The first day was a formal classroom session and was conducted by Itron staff. The survey instrument was introduced and its elements described. In addition to reviewing the survey instrument, survey protocols were discussed. This discussion included the type of information that needed to be tracked and reported back to Itron each week, what lines of communication to use when issues and questions arose, and how to handle sample recruiting and replacements.

Day 2-3

Over the next two days, the three surveyor teams used the survey forms in an actual survey setting. Each team surveyed two sites from the project sample in the San Diego area. The plan was to conduct one survey per group per day. The surveyed premises were part of the SDG&E sample and included a mix of building types. Small sites were surveyed on Tuesday and larger sites on Wednesday. The Itron trainers accompanied the teams in the field to provide guidance and to answer any questions.

Day 4

On the morning of the fourth day, the surveyors returned to the classroom to review the completed survey forms with the Itron trainers. An important element of the training and pretesting of the survey forms was the data entry into the survey database. In the afternoon of the fourth day, the data entry system was introduced and the surveyors practiced using the system with the survey forms they completed earlier in the week.

After this formal training, the trained surveyors were responsible for training the additional members of their survey teams at their respective companies. Just as before, each trainee from each subcontractor team was required to supply the Energy Commission project management team with resumes of their prior training and experience for approval.

During the course of the project, it became apparent that additional surveyor training was necessary. There had been considerable turnover in the surveyor teams, and the survey instrument proved fairly complex for most surveyors. As a result, Itron trainers traveled to each of the subcontractor's facilities to provide additional training support.

3.7 Survey Pretests

The pretest of the survey questionnaire involved selecting a subsample of cases and executing the entire data collection and review procedure with these cases before beginning full-scale fieldwork. This pretest coincided with the first round of surveyor training and had the following features.

- The pretest involved 60 sites in total, with approximately an equal number of sites for each of the 12 building type segments in the study. An attempt was made to include both large and small sites in each building segment, and at least one campus or multi-building premise. An approximately equal number of sites was chosen from each IOU service area although holding the training in San Diego resulted in a slight bias toward the SDG&E service area.
- The pretest surveys were conducted over a five-week period. The first six surveys were conducted as part of the formal surveyor training in San Diego;

the remaining 54 sites were conducted over a four-week period following the formal training in the survey team's respective areas.

- The survey form was tested for a variety of potential implementation problems:
  - To ensure the instructions were adequate and validate survey form flow/layout,
  - To ensure that the questions in the interview phase were phrased properly,
  - To guard against non-response, and
  - To ensure that the necessary data were gathered and compiled correctly.
- The pretest also assessed the adequacy of the information provided to the surveyors on the Customer Contact and Site Information sheets, which included premise ID, business name, contact name, contact phone number, premise address, SIC designation, appointment details, service type(s), rate type(s), account number(s), electric and gas meter number(s), and billing history (at the premise level).
- The pretest was used to refine quality control procedures, and consisted of a survey form review, feedback on missing and incomplete data, the use of the data entry system, and data cleaning procedures.
- The pretest evaluated the adequacy of the entire survey-to-simulation process, including the following steps: survey performance, quality control, data entry, data cleaning, submission of data to Itron, and the generation of inventory reports.

3.8 Survey Implementation Process

Overall Process

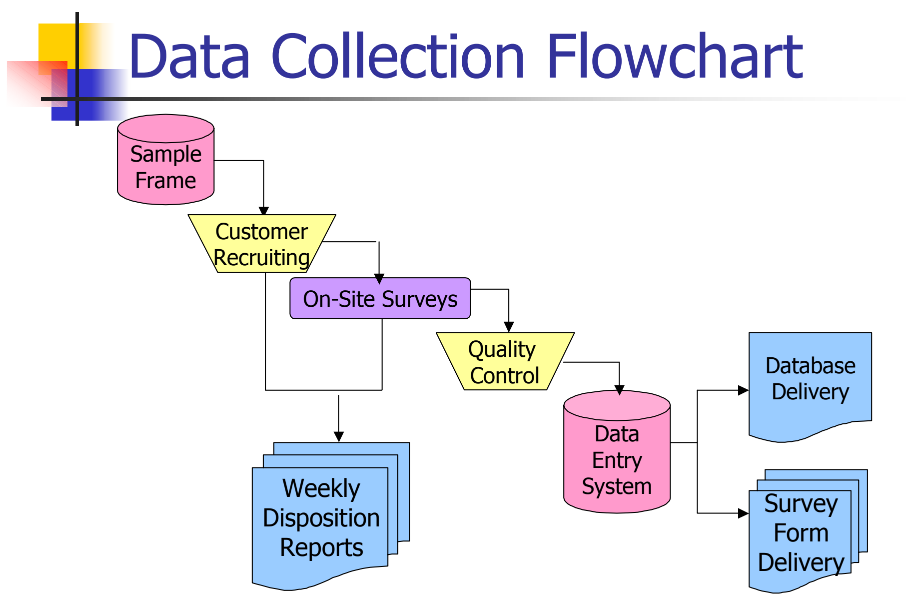
Figure 3-3 presents a high-level overview of the data collection process. The remainder of this section provides detail on the following topics.

- ***Delivery of sample to subcontractors.*** The 2,500 on-site surveys were completed from a sample of approximately 10,000 premises divided up among the subcontractors based on pre-determined allocation of work effort.
- ***Survey recruitment disposition tracking.*** Each subcontractor was responsible for recruiting participant sites and tracking the disposition of each site contacted through this project, regardless of whether an on-site survey was scheduled.
- ***Provide weekly disposition reports for on-site surveys and end-use metering.*** During the completion of the required on-site surveys and end-

use metering, each subcontractor delivered a disposition report to Itron by close of business on Thursday of each week.

- ***Conduct quality control procedures for on-site surveys.*** Each subcontractor was responsible for conducting quality control for all on-site surveys completed.
- ***Complete data entry for on-site surveys.*** Each subcontractor was responsible for completing data entry for all on-site surveys completed. Itron provided a Microsoft Access database to be used for data entry.
- ***Delivery of on-site surveys to Itron.*** Once the on-site survey was data-entered, the subcontractors made a copy for their own records and delivered the original to Itron.

Figure 3-3: Data Collection Flowchart



Initial Sample

The initial sample was delivered to each subcontractor in a Microsoft Access database along with a list of sampling targets by stratum. This initial sample was comprised of a primary sample consisting of listings of sites equal to the stratum targets, and a secondary sample consisting of listings of sites equal to three times these respective targets. The initial sample was stratified by utility, climate zone, building type, and size. Each unique combination of segmentation variables was assigned a unique strata number to facilitate the tracking of progress. Information on the initial sample consisted of the variables described in Table 3-3.

Table 3-3: Sample Variables and Descriptions

Variable Name	Type	Length	Description
SiteID	Text	10	Unique Site Identifier
BusName	Text	50	Customer Name
Street	Text	35	Service Address
City	Text	50	Service City
State	Text	2	Service State
Zip	Text	5	Service Zip Code
Zip4	Text	4	Service 4-digit Zip Extension
Contact	Text	35	Contact First Name
ContactLast	Text	35	Contact Last Name
Title	Text	25	Contact Title
Phone	Text	14	Contact Telephone Number
PhoneExt	Text	4	Contact Telephone Extention
stratum	Number (Long)	4	Strata Number
site_cz	Number (Long)	4	Climate Zone
SIC4	Number (Long)	4	SIC Code

Recruiting Protocol

Itron provided each subcontractor with a recruiting protocol during the training period. This protocol, described in Section 3.3, detailed the requirements for recruiting customers for on-site surveys, including customer contact procedures, documentation of call status, and scheduling.

Site Information Sheets

Itron developed and provided a Microsoft Access database containing detailed information for each premise. The database was designed to allow each subcontractor to print site information sheets as appointments were made. The site information sheets contained information that had to be transferred to the on-site survey form, like account number(s), meter number(s), and rate types. These site information sheets were attached to the survey form and returned to Itron with the on-site survey. A sample site information sheet is provided in Appendix J.

Weekly Disposition Reports

As noted in Section 3.3, subcontractors were responsible for developing their own on-site survey recruitment and tracking systems. Weekly disposition reports were due to Itron by close of business each Thursday. Each report was a cumulative process, including both the current week's progress and the cumulative progress over the course of the project.

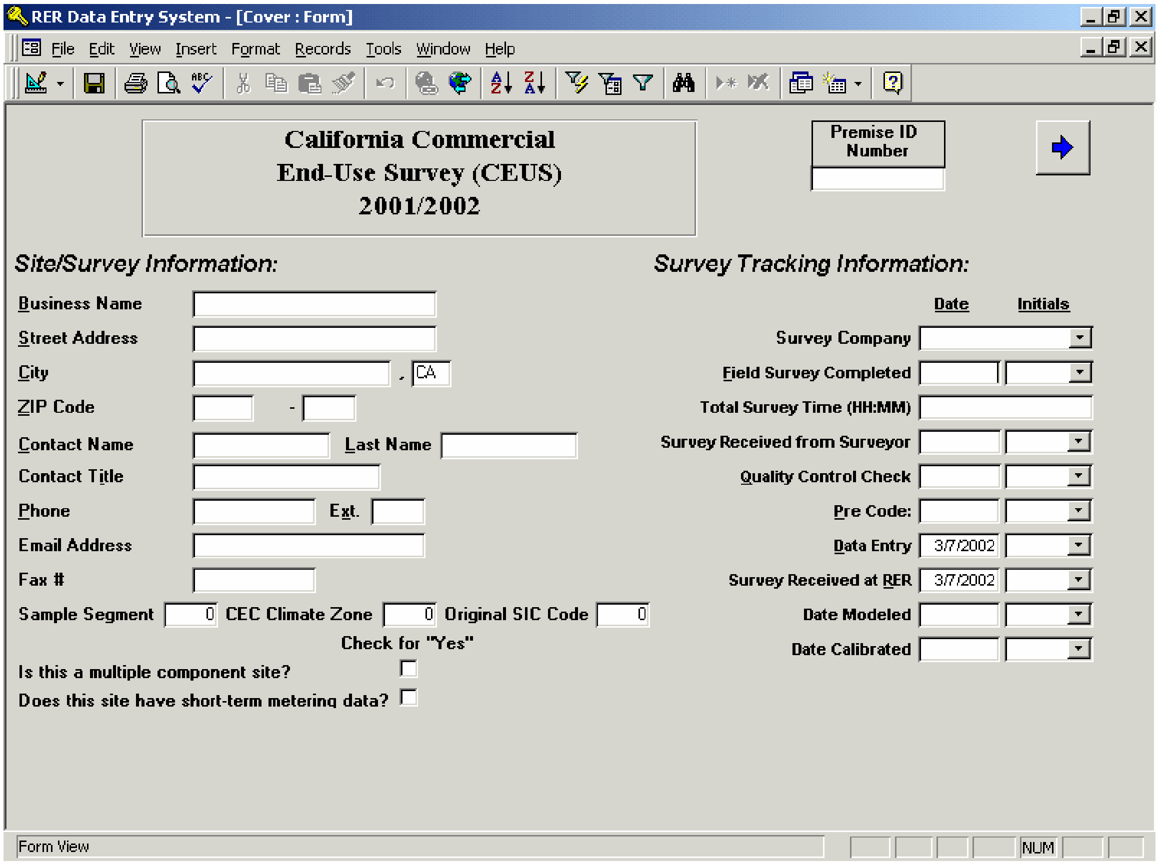
Quality Control Procedures

Once the on-site survey was completed and submitted to the subcontractor, each survey underwent a quality check to identify deficiencies. Details of the quality control procedures were developed in the data collection protocols during training. Potential deficiencies included but were not limited to equipment model numbers, area dimensions, mapping of equipment ID numbers to area ID numbers, etc. This step required communication with the surveyor and sometimes the site contact. .

Data Entry

Data entry was performed by the three survey subcontractors. Due to the decentralized nature of this process, the need for a common database was considered very important. Therefore, Itron designed the data entry system in Microsoft Access 97 using forms that very closely resembled the paper forms used for data collection. Each page in the on-site audit instrument had a corresponding form in the data entry system. The first eight forms related to the entire site and were linked by site ID. An example page from the data entry system is provided in Figure 3-4. The remaining forms were specific to individual component survey areas and linked by a combination of site IDs and component survey area IDs. This allowed data entry to take place in a manner consistent with the way the on-site audit forms were organized, thereby reducing systematic data entry errors. Figure 3-5 provides an example of a form that used both site ID and component survey area ID.

Figure 3-4: Site-Level Data Entry Form


RER Data Entry System - [Cover : Form]

File Edit View Insert Format Records Tools Window Help

California Commercial
End-Use Survey (CEUS)
2001/2002

Premise ID Number

Site/Survey Information:

Business Name

Street Address

City , CA

ZIP Code -

Contact Name Last Name

Contact Title

Phone Ext.

Email Address

Fax #

Sample Segment 0 CEC Climate Zone 0 Original SIC Code 0

Check for "Yes"

Is this a multiple component site?

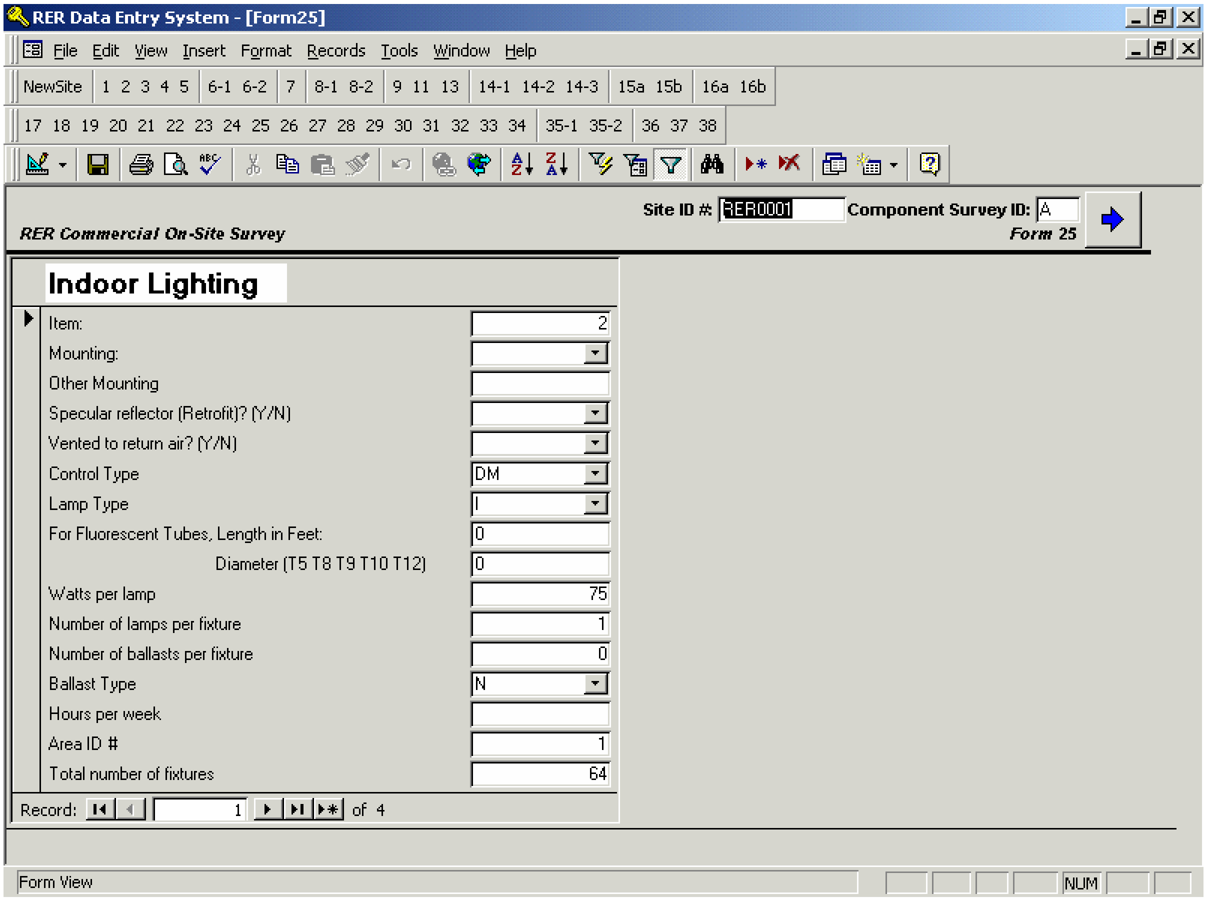
Does this site have short-term metering data?

Survey Tracking Information:

	Date	Initials
Survey Company		
Field Survey Completed		
Total Survey Time (HH:MM)		
Survey Received from Surveyor		
Quality Control Check		
Pre Code:		
Data Entry	3/7/2002	
Survey Received at RER	3/7/2002	
Date Modeled		
Date Calibrated		

Form View NUM

Figure 3-5: Shell Component-Level Data Entry Form



The data entered into each form was saved to one or more tables in Access. General premise information was stored in the same table, while end-use specific information (for instance, indoor lighting equipment) was stored in another table. At the premise level, each item was uniquely identified by a combination of the premise identification number and the item number. Additionally, each item in tables specific to component survey areas was uniquely identified by a combination of premise ID, component ID, and item number.

Several controls were implemented to minimize the data cleaning effort. The most important control was the separation of numeric fields and the units corresponding to that field. Setting the property of certain fields to numeric served two purposes: the entry had to be numeric to proceed (character values could not be entered) and a range of appropriate values was required. The latter control was only implemented where an appropriate range was easily identifiable. For some fields, there was both a text box to enter a value and a pull-down menu to select the units associated with this value. This reduced the effort after data entry to verify that units for each field were consistent. Additionally, some fields were set up to utilize pull-down menus where a discreet list of options was appropriate.

Data Cleaning

Initial data cleaning was performed by each subcontractor. Upon delivery of the completed data entry databases, all tables were imported into SAS for secondary data cleaning. Copies of the raw survey data and the uncleaned data entry system were preserved so that issues that arose during subsequent analysis tasks could be properly resolved. Several data cleaning algorithms were developed. The examination of the contents of these fields allowed the identification of outliers. Many of the outliers were a result of either data entry error or stoichiometry (unbalanced units, for instance, W instead of kW or kBtu instead of tons). These cases were addressed by examining the raw survey form, the data entry system, and often the equipment manufacturer product literature. On a larger scale, an engineering review of each site was performed to ensure that HVAC systems and components were compatible and plausible. This step was performed on an individual basis and based on engineering principles and staff experience.

On-Site Survey Form Delivery

After the on-site survey forms were completed, subcontractors made copies of the forms for their own records. Originals were sent to Itron, along with all of the above reports and databases. Itron used the original on-site survey forms to randomly validate data entry and to answer questions that arose during the building simulation task.

Inventory Reports

Once the database was cleaned, the data were imported into an empty version of the data entry database that contained a reporting algorithm. This algorithm summarized, at the site level, all the major energy-using equipment found at the site. Equipment was summarized according to end use, such as HVAC, lighting, office equipment, cooking equipment, refrigeration, etc. For large sites where sub-sampling occurred, the inventory reports reflected only the equipment that was sampled and not the estimated equipment using multipliers. These inventory reports were used to check results from the building simulations.

3.9 Completed Samples

The following tables show the distribution of premise surveys compared with various targets set up by the sample design protocols. As mentioned in Section 1.4.1, the targeted sample size was 2,800 premises. The definition of a premise is described in Section 2.2. These targets are presented alongside the actual survey counts by utility and building type. Also presented is the distribution of premises with interval-meter data and the distribution of premises with short-term metering (STM). A brief discussion accompanies each table.

On-Site Survey Sample Targets and Actual Counts

Table 3-4 shows the targeted sample and the actual surveys performed by utility and building type. Also shown are the distributions by overall total buildings and by utility. Note that the building type classifications in this table are based on the SIC code identifier from the utility frame, and not on the actual activity occurring at the premise.

Table 3-4 shows that 2,790 actual surveys[2] were performed and accepted for inclusion into the DrCEUS database. No one building type was affected inordinately from the reduction in the number of surveys performed from the target of 2,800. Overall, by building type the actual number of surveys compared to the sample targets was off by no more than ±5 premises. By utility, the actual number of surveys as compared to the targets was no more than ±4 premises. When looking by utility and by building type the differences are even smaller.

[2] Over 2850 premises were actually surveyed, but during the quality control process some of these were determined to be incomplete and they were eliminated from the final sample of sites.

Table 3-4: On-Site Survey Sample

Description	PG&E		SCE		SDG&E		SMUD		Total Sample Targets	Total Actual Surveys
	Sample Target	Actual Surveys	Sample Target	Actual Surveys	Sample Target	Actual Surveys	Sample Target	Actual Surveys		
Small Office	102	101	125	127	57	57	61	61	345	346
Large Office	110	109	79	77	30	28	35	35	254	249
Restaurant	65	65	76	76	22	23	15	15	178	179
Retail Store	138	139	223	226	51	50	45	46	457	461
Food/Liquor	89	90	105	109	24	23	19	19	237	241
Refrigerated Warehouse	23	24	14	15	6	5	5	5	48	49
Unrefrigerated Warehouse	79	76	93	92	18	17	19	19	209	204
School	45	45	47	47	16	17	15	15	123	124
College	33	31	30	28	11	11	7	7	81	77
Health Care	62	62	73	69	25	24	17	16	177	171
Hotel	43	43	44	43	23	23	7	7	117	116
Miscellaneous	216	216	235	236	68	67	55	55	574	574
Grand Total	**1005**	**1001**	**1144**	**1145**	**351**	**345**	**300**	**300**	**2800**	**2791**

Premises with Interval-Metered Data Available

Table 3-5 shows the distribution of premises where interval-metered data were made available by the utilities. The source of this data was the utilities' load research samples, as well as large customer's meters that record interval data. No formal sample design was created for the interval-metered sites. The last column of Table 3-5 shows that approximately 17% of surveyed sites had interval-metered data.

Table 3-5: Premises with Interval-Metered Data

Description	PG&E	SCE	SDG&E	SMUD	Grand Total	% of Surveyed Sites
Small Office	1	1	4	1	7	2%
Large Office	60	17	19	10	106	43%
Restaurant	1	1	2		4	2%
Retail Store	25	45	14	3	87	19%
Food/Liquor	5	29	5	2	41	17%
Refrigerated Warehouse	5	5	1	1	12	24%
Unrefrigerated Warehouse	9	23	3	0	35	17%
School	3	11	6	2	22	18%
College	12	3	2	3	20	26%
Health Care	23	11	8	5	47	27%
Hotel	11	6	11	0	28	24%
Miscellaneous	24	20	19	2	65	11%
Grand Total	**179**	**172**	**94**	**29**	**474**	**17%**

Premises with Short-Term Metering Data

Table 3-6 shows the distribution of premises where short-term meters were installed. As mentioned in Section 3.5, the overall objective was to meter 500 premises with short-term lighting and/or HVAC loggers. The purpose was to obtain additional information that could be used to verify surveyor schedule data, and could also be used for calibration. In addition, there was a special interest by the Energy Commission in examining the effectiveness of having both short-term and interval-metered data for calibrating the building simulations. As shown in Table 3-6, 17% of the STM sites also had interval-metered data.

Table 3-6 brings together the distribution of STM premises by utility and building type. The table also shows the distribution of premises with both types of metering by building type. A description of how the STM data were used for calibrating sites is contained in Chapter 6.

Table 3-6: Premises with Short-Term Metering

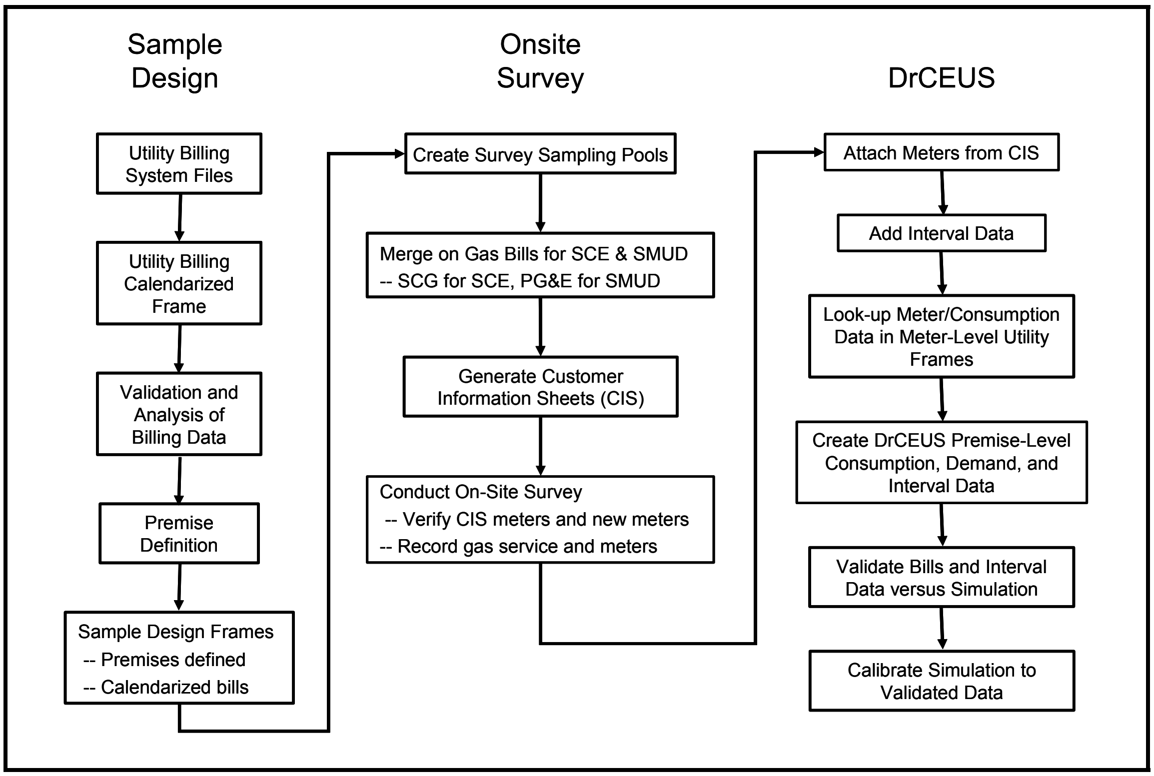
Description	PG&E	SCE	SDG&E	Grand Total	Targets	% of Surveyed Sites	Site with Interval Meters	% of Short Term Meters with Interval Meters
Small Office	17	28	12	57	71	16%	2	3.5%
Large Office	15	22	5	42	38	17%	16	38.1%
Restaurant	6	16	5	27	43	15%	2	7.4%
Retail Store	25	72	7	104	100	23%	22	21.2%
Food/Liquor	14	26	2	42	55	17%	9	21.4%
Refrigerated Warehouse	4	4	0	8	10	16%	3	37.5%
Unrefrigerated Warehouse	17	27	5	49	46	24%	12	24.5%
School	11	11	5	27	26	22%	6	22.2%
College	4	5	0	9	13	12%	2	22.2%
Health Care	8	10	1	19	20	11%	2	10.5%
Hotel	2	1	0	3	0	3%	1	33.3%
Miscellaneous	42	48	8	98	78	17%	6	6.1%
Grand Total	**165**	**270**	**50**	**485**	**500**	**17%**	**83**	**17.1%**

CHAPTER 4: ELECTRIC AND NATURAL GAS CONSUMPTION DATA

4.1 Overview

This section describes the approach used to clean and process raw utility energy consumption data into a form usable for calibration of the energy simulation models. A flowchart of the process is shown in Figure 4-1.

Figure 4-1: Consumption Data for DrCEUS Flowchart



The process is briefly described as follows:

- ***Sample Design.*** As described in detail in Chapter 2 of this report, the raw utility billing system files were organized, calendarized, and cleaned for the sample design analysis. This part of the process included the critical step of aggregating account-level records up to the premise level.
- ***On-Site Survey.*** The first step in the survey process was to select the candidate sites to be surveyed. Survey sampling pools – the lists of premises that were targeted for recruitment as CEUS participants – were extracted from the sample design utility frames. For electric-only utilities, calendarized gas service accounts from the IOU gas providers were merged with the existing electric customer accounts to consolidate energy use

information. The calendarized consumption data and other utility customer information were used to generate a customer information sheet (CIS) that provided the surveyors with a list of electric and gas meters associated with a premise, as well as an estimate of premise-level consumption. Surveyors used the CIS as a guideline for defining the survey area, for meter verification, and for evaluation of a site's overall energy use characteristics.

- ***DrCEUS.*** After completion of the on-site survey, the meters listed on the CIS were compared to meters found by the survey. The reconciled list of meters was used to extract consumption data from the calendarized sample frames and create premise-level consumption, demand, and interval-metered data for use in DrCEUS. During the calibration process of comparing historical consumption against output of the simulation models, additional problems with the energy use data were sometimes uncovered and corrected.

Several key steps in this process are discussed in more detail in the subsequent sections of this chapter. The utility data validation and calendarization steps of the Sample Design process are discussed in Sections 4.2 and 4.3. Key elements of the Onsite Survey process are described in Sections 4.4 through 4.6. The remaining Sections 4.7 through 4.9 discuss the final meter and consumption data reconciliation process.

4.2 Validation and Analysis of Billing Data

Each utility participating in the CEUS project was asked to provide a full calendar year's worth of energy use data. The IOUs provided multiple years of data (2000-2002). For SMUD, data for 2003 were provided because this component of the study did not begin until early 2004. In addition, PG&E provided 2003 gas information for the SMUD service area.

Each utility has a unique data format and methodology for recording consumption and demand data. A general approach to validating and analyzing utility billing data was developed, and then adapted to accommodate the unique characteristics of each utility's billing system. Numerous data validation procedures were used to develop uniform energy consumption histories for simulation modeling. To provide the reader with some sense of the difficulty of this task, specific examples of issues encountered while working with utility billing system data are summarized below:

- For one utility, billing information was only provided for customers that were active at the end of the calendar year. For example, if only a customer's business name changed mid-year and not the actual operation of the business, it would still trigger the assignment of a new account number in the utility's billing system. Consequently, Itron would not have received billing data for the first half of the year since the old account number was no longer active at the end of the calendar year. In these cases, additional information was requested from the utility and then had to be manually merged to complete the consumption records.

- One billing data set was split into two separate files, each covering a different portion of the year. Merging these files and annualizing consumption without double counting proved to be a significant challenge.
- One utility changed the structure of its entire billing system midway through the study. This change resulted in an incomplete match between old and new key identifiers that had to be reconciled.
- Several billing data inconsistencies were discovered during the calendarization process, such as missing billing records or key variables, each resulting in additional requests having to be made to the utilities for revised billing data.
- Several non-building rates were included in the billing data, such as natural gas vehicle refueling, outdoor lighting, and pumping. Sites consisting of *only* these types of meters were screened from the sampling pools because they did not meet the minimum requirements for a premise. For example, an outdoor lighting meter for a sign that is not part of building would get screened. However, these records were still retained in the billing frame.
- For one utility, the meter identifier in the frame was not the number physically stamped on the meter in the field but was instead a descriptive code. For example, meters that tracked multiple variables (kW, kVAR, etc.) were only identified in the frame as being "COMBO" meters. It was necessary to obtain a reference table from the utility and then replace the descriptive codes with the true meter numbers.
- In several instances for the gas utilities, gas billing data for apartment leasing offices and assisted-living developments were not provided in the commercial billing system files. The premises were considered to be multi-family establishments, and as such had a residential multi-family gas rate classification. For these sites, gas bills were not available and calibration to gas use was not possible.

4.3 Calendarization of Consumption Data

The meter-level consumption and demand data were passed through a calendarization routine to produce accurate monthly energy histories. This was necessary because the standard practice of reading meters in the field for billing purposes occurs at irregular times. For monthly consumption readings, each observation was divided into daily values for every day in the billing cycle. The daily values were then summed for each month to create the calendarized energy use for that month. Calendarized demand values were calculated as the proportional average based on the number of days in the billing month that fall in the calendar month. In other words, demand values were calendarized by weighting the maximum demand of any billing period by the number of days that period overlapped the month of interest. An example of the raw billing data and the resulting calendarized data is presented in Figure 4-2.

Figure 4-2: Calendarized Consumption Data Example

Raw Billing Frame Data

ReadDate	BillDays	kWh	Max kW	Avg Daily kWh	Days In March
2/26/2002	32	209400	624	6543.8	0
3/28/2002	30	206400	576	6880.0	28
4/25/2002	28	216600	594	7735.7	3

Calendarized Data for March

Month	Days	kWh	kW
March	31	215847	577.7

An additional algorithm was applied only to January and December to account for missing information from just these months. If at least 10 days of usage was available for January or December, the daily results were expanded up to a *complete* month of consumption. However, if there was less than 10 days worth of usage, the consumption for that month was left alone and flagged in the database. This approach was used so that the shortage of data would be obvious to the simulation modelers who would know not to calibrate to that month's data.

The January/December algorithm was not used for other months that appeared to be incomplete as this was usually an indication of actual operation, rather than the result of missing data. Instead, the billing data was used as-is and the simulations were just calibrated to the available monthly billing data. For example, if only six months of bills – e.g. July through December – were available for a premise because it opened in the middle of the year, then the simulation would be calibrated to yield the best match on a monthly basis to the existing data. In this case, it would not make sense to expand 6 months of billing data to 12 months of data.

4.4 Developing Sample Recruitment Pools

The stratified random sample design used for the CEUS required creating several lists of premises from which to recruit potential survey participants. These recruitment lists or "sampling pools" are drawn from the entire commercial population represented in the sample design frame. For each utility, primary and secondary sample pools were initially created. The design called for exhausting the primary pool under a strict set of protocols before recruiting participants from the secondary pool. The protocols helped to ensure that the sample draw remained random and that no bias was introduced into the study from the recruitment process. The primary sampling pool contained the same number of premises required to populate each cell defined by the stratification variables (utility, building type, consumption level, and climate zone). The secondary sample pool was composed of three back-up premises for every premise in the primary pool. Additional tertiary and quaternary sample pools were also prepared for some strata, as the survey teams exhausted the primary and secondary samples without meeting the strata quotas. The specific sample draw that a premise came from is actually encoded into the first letter of the Site ID (P=Primary, S=Secondary, T=Tertiary, Q= Quaternary).

Meter-level energy consumption data was compiled for all premises in the sampling pools. For the SCE and SMUD sites, obtaining gas consumption required an additional step, as described in the next section.

4.5 Gas Consumption for SCE and SMUD Premises

Since SDG&E and PG&E provide both electric service and gas service, gas consumption for premises in these service areas could easily be obtained from a single billing system file. However, for the electric-only utilities (SCE and SMUD), gas consumption had to be obtained separately from SCG and PG&E.[1]

Since merging two different utility data sets would not produce a complete record of customer accounts, surveyors were required to identify gas service and gas meters for premises served by SCE and SMUD during the on-site survey. However, in the interest of providing the surveyors with all available meter and consumption information, an attempt was made to compile existing gas meters for the SCE and SMUD premises *before* going into the field. Service addresses for the electric utility customers where compared to those of the gas utility customers to try and consolidate the account-level meter information. The process of reconciling meters after the survey is described in Section 4.9.

For reference, Table 4-1 illustrates the different combinations of utilities serving individual premises in the CEUS survey.

Table 4-1: Mapping Electric and Gas Utility Combinations

Electric Utility	Gas Utility
PG&E	PG&E, SCG, Propane
SCE	SCG, LBGD, Propane, SWG
SDG&E	SDG&E, SCG, Propane
SMUD	PG&E, Propane

Note that there are several gas utilities – Southwest Gas (SWG) and Long Beach Gas (LBGD) – for which no requests were made to obtain gas consumption data.

[1] PG&E provided an additional 2003 gas billing frame for the SMUD service area.

4.6 Customer Information Sheet (CIS)

The Customer Information Sheet (CIS), illustrated in Figure 4-3, is a key part of the meter reconciliation process. The billing information provided on the CIS represents the meters and consumption associated with the premise, as derived from the sample design process and the addition of gas use information for the electric-only utilities. The meter and billing information presented on the CIS is described in further detail below.

Accounts/Meters. A listing of the accounts and meters associated with each premise is presented in the lower left corner of the CIS. These are the accounts/meters identified from the energy utility's billing system for the premise. One of the first and most critical steps in the onsite visit is the verification and disposition of the account/meter information listed on this sheet, since these are the meters associated with the premise. However, it is ultimately up to the surveyor to correctly identify the premise – and therefore the appropriate area to survey – and to match the account/meter information and the appropriate businesses to the premise survey area.

Monthly kWh, Peak kW, Therms (Monthly Energy Use and Demand). In the upper right-hand corner of the CIS, the *premise-level* calendarized monthly electric use in kWh, peak kW, and gas use in therms values are presented. The monthly energy values are the sum of the monthly meter-level values presented in the Accounts/Meters section of the CIS. Note that if the premise is not a demand-metered site and there is no gas service or no gas meters could be identified for the site, the kW and Therms columns were blank.

Figure 4-3: Sample Customer Information Sheet

California Commercial End-Use Survey (CEUS) 2002/2003

Customer Information Sheet

Site Information

Site Id	_RER0001
Business Name	ABC BUSINESS
Street	123 MAIN ST
City, State	SAN FRANCISCO, CA
Zip	95570
Site Contact	JOHN DOE
Contact Title	
Phone	(123) 1234567 **Ext.**

Special Instruction

CHECK IN AT FRONT DESK

Appointment Detail

Date	5/5/2005
Time	12:00 PM
Surveyor	MARK C
Estimated Time of Site Visit	4 HOURS
Electric Utility	pge
4-Digit SIC Code	9999

	kWh	*Peak kW*	*Therms*
January	1,705	5	6,574
February	1,587	4	5,987
March	1,748	5	4,562
April	1,566	4	3,520
May	1,607	5	2,688
June	1,473	5	1,112
July	1,566	5	756
August	1,604	6	729
September	1,595	5	802
October	1,615	4	1,815
November	1,654	5	3,790
December	1,659	5	5,150

Account Number	Service Type	SIC Code	Meter Number	Rate	Service Address	January	February	March	April	May	June	July	August	September	October	November	December
ABC9876543	KBTUH	9999	METER1	GNR1	123 MAIN ST	6,574	5,987	4,562	3,520	2,688	1,112	756	729	802	1,815	3,790	5,150
ABC9876543	KWH	9999	METER2	ALTOU	123 MAIN ST	1,705	1,587	1,748	1,566	1,607	1,473	1,566	1,604	1,595	1,615	1,654	1,659

4.7 Meter Reconciliation Issues

One of the key steps in any on-site survey is the verification of meters present at the site. While premises were initially defined in terms of groups of meters and accounts for the entire frame, the aggregation results are imperfect. Reconciling meters to premises after the site visit was a manual process that precluded automation. This process was far more difficult and time consuming than previous on-site survey efforts for several reasons. First, due to the length of time from the original sample design to the end of the study, there was a higher than normal turnover of commercial businesses and changes to existing businesses.

Second, meter reconciliation was further complicated by the massive meter change-outs driven by assembly bill AB29X,[2] as shown in Table 4-2. The result was that many of the meters expected to be found in the field had been replaced by newer meters.

Table 4-2: AB29X Interval Meter Installation Quotas for IOUs and SMUD

Utility	# of Meters to be Installed
Southern California Edison	12,000
Pacific Gas & Electric	5,900
San Diego Gas & Electric	1,380
Sacramento Municipal Utility District	300

For the IOUs, the original sample frame was developed using year 2000 as the basis. The frame was updated in 2001 and again in 2002 to account for businesses that closed and for meter change-outs. These updates did not account for all possible events and introduced a certain amount of unavoidable errors to the revised frames. However, the end result of performing the updates was justified by having a more representative frame at the time of on-site data collection.

4.8 Mapping Interval-Metered Data to Premises

Interval-metered data were received from all of the electric utilities in varying formats throughout the active data collection period. Table 4-3 provides a very brief description of the format of the interval data that were received by Itron and the manipulation required to create the maximum hourly kW values needed by DrCEUS.

2 AB29X "provided $35 million from the state General Fund to the California Energy Commission to install either time-of-use or real-time electric meters for utility end-use customer accounts with peak electric demand levels of 200 kilowatts (kW) or greater." California Energy Commission Report P400-02-004F, June 2002.

Table 4-3: Outline of Interval Meter Data Formats by Utility

Utility	Interval Data Units	Interval Period	Method Used to Convert to Maximum Hourly Demand
SCE	kWh	1 hour average	Utility provided *average* instead of *maximum* kW for each hour; could not be converted so used data as-is and just noted this during calibration.
PG&E	kW	15-min max	Used the maximum value from each hourly group of four 15-min interval values
SDG&E	kWh	15-min average	Summed each 15-min interval in hourly groups of four interval values
SMUD	kW	1 hour max	No adjustment necessary, already in the required format.

In general, the interval data were reasonably clean and the most difficult task was to match the interval data back to the associated premise. Partial-year data was not modified so no attempt was made to fill in missing values or expand incomplete data up to a full year. However, even interval data for part of a year could be used for the judgmental calibration of a site. Additionally, some sites had only partial coverage (contained both standard meters and interval meters). Data for these situations was used to the extent possible, especially in cases where the majority of consumption at the site was recorded by the interval meters. In general, the interval-metered data provided substantial benefits for the calibration process including the following:

- Validation of business hours,
- Characterized usage during unoccupied hours, such as indicating whether a substantial portion of equipment was operating after the business closed and/or on weekends,
- Explained seasonal time-of-use variations and changes in operation, and
- Identified intermittent operation of large pieces of equipment (like irrigation pumps for golf courses or outside lighting at car lots).

4.9 Post-Survey Meter Reconciliation

Surveyors were provided with the CIS, which contained a list of the electric and gas meters and the associated monthly premise-level consumption for each site. Surveyors located and recorded all meters serving the premise and documented all discrepancies between the CIS meter list and the observed meters. Disposition codes on the survey form (Add, Delete, Verified, Not Verified, etc.) were used to identify meters that were to be added or removed from the CIS meter set. This process was further complicated by the issues previously discussed in section 4.7. The final set of reconciled meters was matched to the utility billing information by the energy simulation modelers to obtain revised meter-level and premise-level consumption and demand.

For demand values, both a *total* demand and a *maximum* demand were calculated. The *total demand* for each month was the sum of demand values from *all* meters that had demand values. The *maximum demand* for each month was the maximum single meter demand value. In reality, the monthly demand for a premise should occur somewhere between these two values because the individual meter demand readings are not coincident. As such, both of these values are displayed in DrCEUS and considered during the building simulation calibration process.

Once the final consumption and demand values were obtained and entered into the DrCEUS survey database, the results were checked for reasonableness against the simulation and survey data. For example, the annual electric whole-building intensity could be checked using the surveyed floor area. If the whole-building intensity was too low or too high for the particular building type, then a simulation modeler might investigate the meter assignments further.

CHAPTER 5: SIMULATION MODELING SOFTWARE

5.1 Introduction

The primary purpose of the CEUS project was to support end-use demand forecasting at the California Energy Commission (Energy Commission). Yet, beyond that basic requirement was the need to develop tools to take advantage of the rich source of information typically collected in a CEUS study. The Energy Commission receives numerous requests from the Governor and Legislature, other government agencies, energy consulting firms, utilities, universities, and the public to characterize how various segments of the commercial sector use energy. The design of this latest CEUS project was fundamentally driven by the need to be able to respond to these requests quickly and effectively. The DrCEUS system—or more simply, DrCEUS—is a flexible building simulation tool that meets these very needs.

DrCEUS automates the creation of energy simulation models from the on-site survey data collected for the CEUS project. It supports the estimation of end-use load profiles, as well as the evaluation of hourly impacts of energy efficiency measures, load management strategies, building standards, and other program policies. DrCEUS can also be used to weight and aggregate premise-level results up to the population level for specific user-defined segments of the commercial sector. DrCEUS also facilitates comparing the effects of energy rate schedules, weather parameters, and many other scenarios against baseline usage patterns or conditions.

The DrCEUS system was used to develop both engineering simulations of energy consumption for all surveyed sites and segment-level end-use load profiles for all the major commercial building types. The purpose of this Chapter is to provide a general overview of the DrCEUS system and its capabilities.

5.2 DrCEUS System Design Overview

In the past, CEUS projects have always provided an efficient means of producing population estimates for specific characteristics such as square footage, construction types, connected loads, fuel saturations, and the like. What was not available was an efficient means of providing detailed estimates of electricity and natural gas consumption on an hourly basis at the end-use level. Advancement of energy simulation software and in raw computing power have made it possible to not only develop energy simulation models for every sample point in the study, but have allowed the creation of a system to efficiently manage large-scale energy simulation analysis. This approach is a major improvement over the Energy Commission’s historical reliance on using a very limited number of prototypical building models for simulation research and forecasting model input development. Together, the DrCEUS system and the CEUS survey database can effectively yield a working representation of the commercial sector in California.

The DrCEUS system is a powerful tool for simulating electric and gas energy use for buildings; it combines features of Itron's SITEPRO software with J.J. Hirsch and Associates' eQUEST and DOE-2.2[1] programs. DrCEUS has the capability to develop segment-level profiles from the individual site-level data. Included in the system are error-checking procedures to debug common simulation problems and full color graphics to facilitate reporting of results at the site and segment levels. Input data required by the system are developed from survey characteristics data, utility billing records, and other industry accepted sources. These input data include the following:

- ***On-Site Survey Data.*** The on-site survey data include building characteristics, equipment inventories and connected loads, and operation schedules.
- ***Technology Data Tables.*** These tables provide default values for data entries missing from the survey. The technology tables supply values for parameters required by DOE-2 that were beyond the scope of this study.
- ***Weather Data.*** Weather files for the simulations include historical and normalized weather data in DOE-2 compatible format, which are discussed in Section 6.2.
- ***Utility Billing Data.*** The utility billing data contain information on electric and gas consumption and electric demand. Chapter 4 describes how utility billing data was used.
- ***Expansion Weights.*** Each site in the sample is assigned a weight for expanding site-level characteristics up to the population for a segment within the commercial sector. These weights were developed during the sample design process and are discussed more fully in Section 7.2.

The DrCEUS System has two distinct modes of operation.

- ***Site Processing Mode*** is used for creating calibrated premise-level building simulation models from the survey data. This mode can be run interactively, for a single site, or in batch mode for a group of sites. Simulation model input assumptions were adjusted within the Site Processor until the standards for calibration were achieved. Once weather normalized, these models collectively represent end-user characteristics and baseline energy consumption for the commercial sector. The Site Processor also allows the user to create subsets of sites that can be used for more focused analyses, such as small offices or all buildings in a specific utility service area or

[1] The software is a proprietary product of these companies and is not available for distribution by the Energy Commission.

climate zone. The Site Processor can also be used to conduct energy efficiency measure analyses and limited billing rate structure analyses as described in subsequent sections of this chapter.

- ***Segment Processing Mode*** is used for aggregating or expanding site-level results up to the population level. The user can define segments based on any combination of site characteristics. Results can be viewed graphically or stored to Microsoft Excel workbooks for further analysis. It is in this mode that the user can compare results between segments. The capabilities of the Segment Processor maximize the usefulness of the CEUS database in ways that have never been available in the past.

Each of these modes is described in more detail in the next sections.

5.3 Site Processing Mode

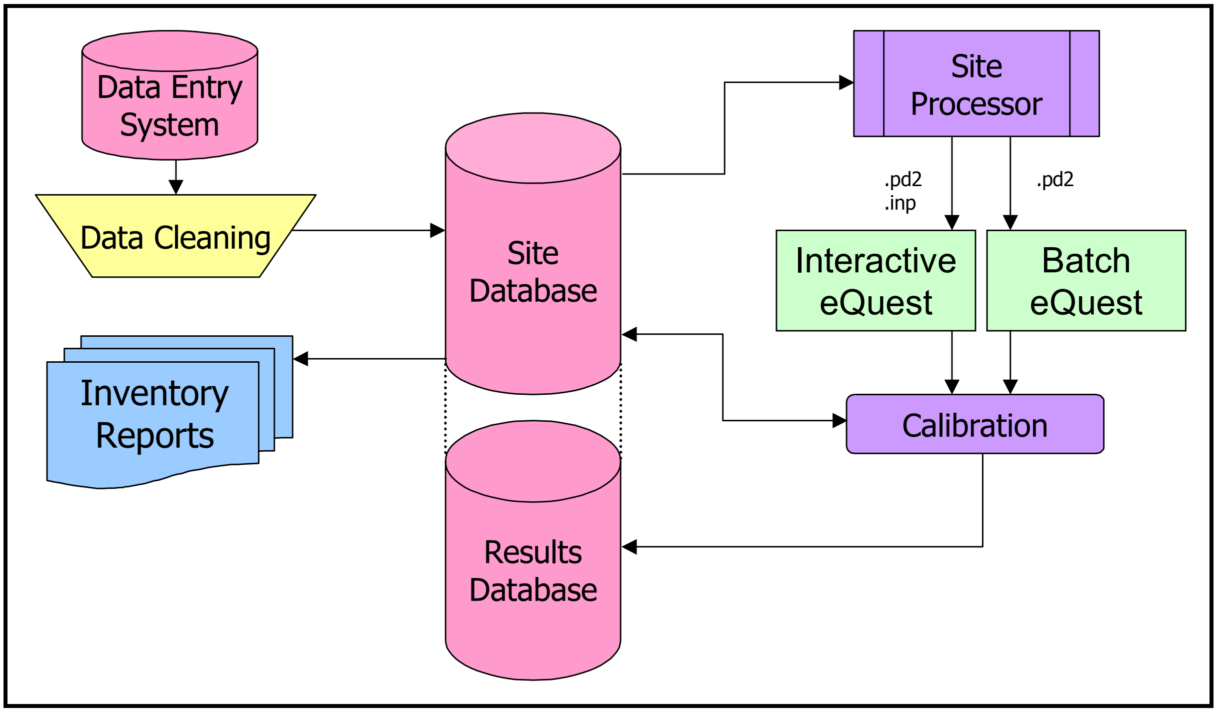
Site Processor Structure

Figure 5-1 presents a flowchart of the DrCEUS site processing system. The three major components of the site processing system are described briefly below.

- ***Survey Data Processing System*** encompasses the Data Entry System, Data Cleaning, and Inventory Report elements on the left side of Figure 5-1. In this phase of processing, the survey data are entered, quality checked, and then printed in summary format.
- ***Master (Site/Results) Database*** encompasses the Site Database and Results Database elements in the middle of Figure 5-1. For the CEUS project, the premise-level survey data and simulation results are kept in a single "master" database. These data are stored in a relational data management system (RDMS) and contain both the survey inputs after cleaning as well as the results from site processing.
- ***Site Processing System*** encompasses the Site Processor, Interactive eQUEST, Batch eQUEST, and Calibration elements shown on the right side of Figure 5-1. The site processor system consists of a set of programs designed to manage, process, and review information about each site. DOE-2.2 and eQUEST are the respective simulation engine and "front-end" interface that are used to process the survey data and develop energy usage for the sites. The survey data are used to create an eQUEST Design Development Wizard input file (a **.pd2* file). eQUEST then uses this file to create and run the DOE-2 BDL input file (**.inp*). For the Batch eQUEST mode, creation of the .pd2 and .inp files is automatic. For the Interactive eQUEST mode, either the .pd2 and or .inp file are altered directly by the user. The interactive mode would be used only for situations outside the

capabilities of the eQUEST Design Development Wizard, where the full capabilities of DOE-2.2 are required.

Figure 5-1: Site Processing Mode Flowchart



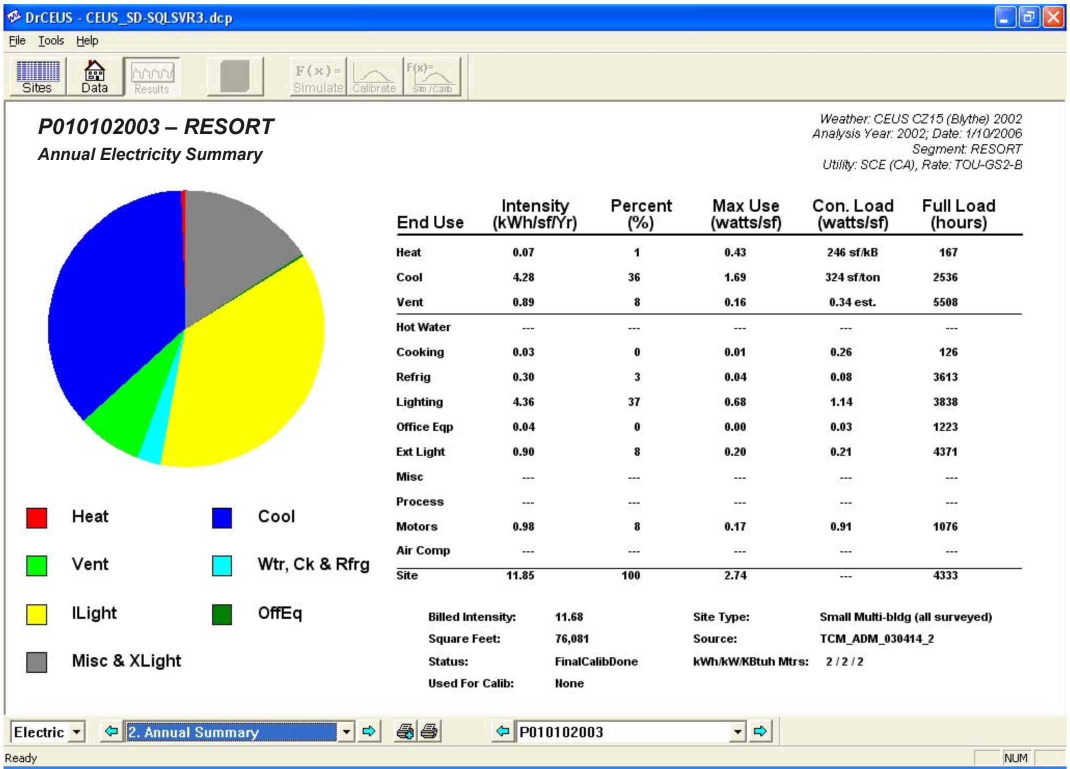
Site Processor Results

DrCEUS reports a number of useful simulation results that can be displayed graphically or stored electronically. These include the following:

- Annual end-use energy intensities,
- End-use peak load factors,
- 16-day results by end use,
- Monthly end-use peak loads, electricity and gas usage,
- 365-day whole-building gas use,
- 8760-hourly electric whole-building energy usage, and
- A premise-level 3D rendering of the building simulation model from eQUEST.

Figure 5-2 through Figure 5-4 present a sample of the graphical simulation results available from DrCEUS. Figure 5-5 provides an example of the premise-level 3D rendering of the building simulation model produced by eQUEST. It should be noted that eQUEST is accessible directly from the Site Processor. This capability allows the user to open eQUEST from the Site Processor and examine the eQUEST wizard inputs directly.

Figure 5-2: DrCEUS Results – Annual Electric Summary



End Use	Intensity (kWh/sf/Yr)	Percent (%)	Max Use (watts/sf)	Con. Load (watts/sf)	Full Load (hours)
Heat	0.07	1	0.43	246 sf/kB	167
Cool	4.28	36	1.69	324 sf/ton	2536
Vent	0.89	8	0.16	0.34 est.	5508
Hot Water	---	---	---	---	---
Cooking	0.03	0	0.01	0.26	126
Refrig	0.30	3	0.04	0.08	3613
Lighting	4.36	37	0.68	1.14	3838
Office Eqp	0.04	0	0.00	0.03	1223
Ext Light	0.90	8	0.20	0.21	4371
Misc	---	---	---	---	---
Process	---	---	---	---	---
Motors	0.98	8	0.17	0.91	1076
Air Comp	---	---	---	---	---
Site	11.85	100	2.74	---	4333

Figure 5-3: DrCEUS Results – 16-Day Hourly Electric Stacked End Use

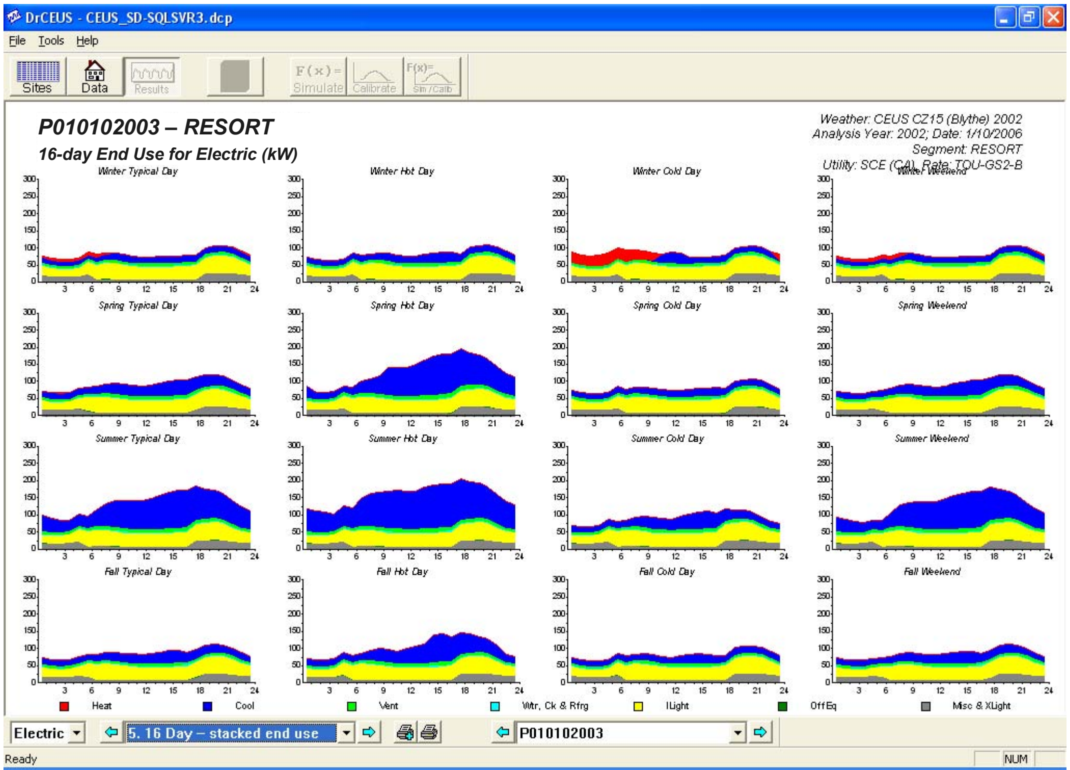


Figure 5-4: DrCEUS Results – Actual Billing versus Simulation

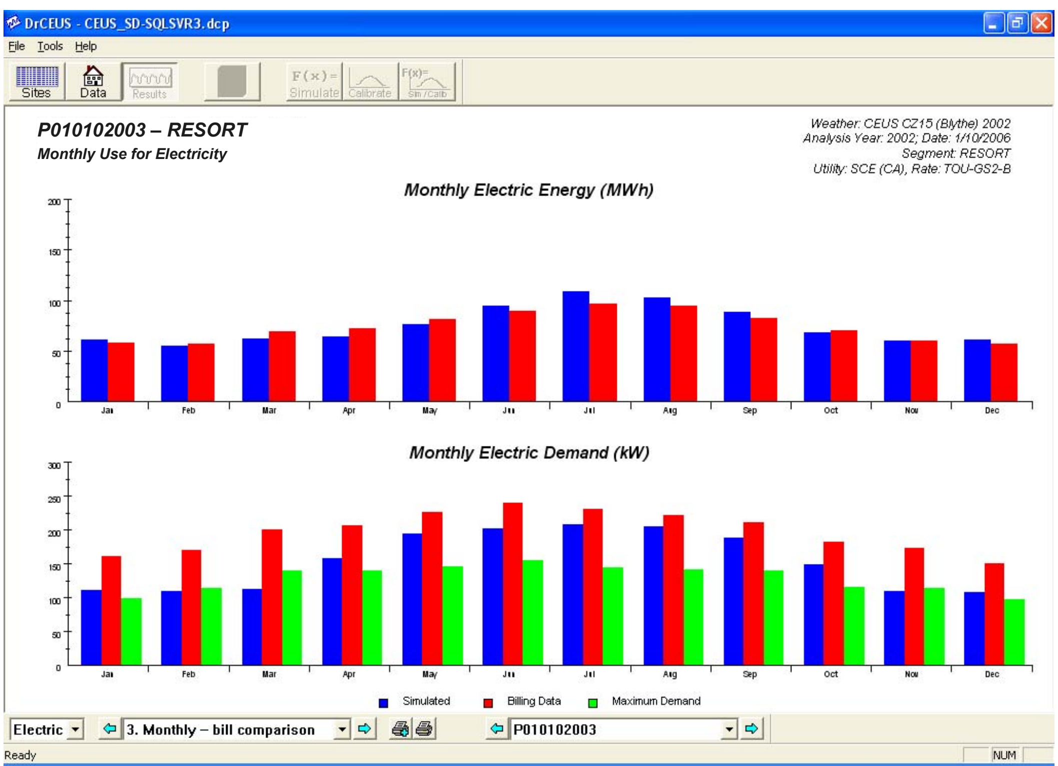
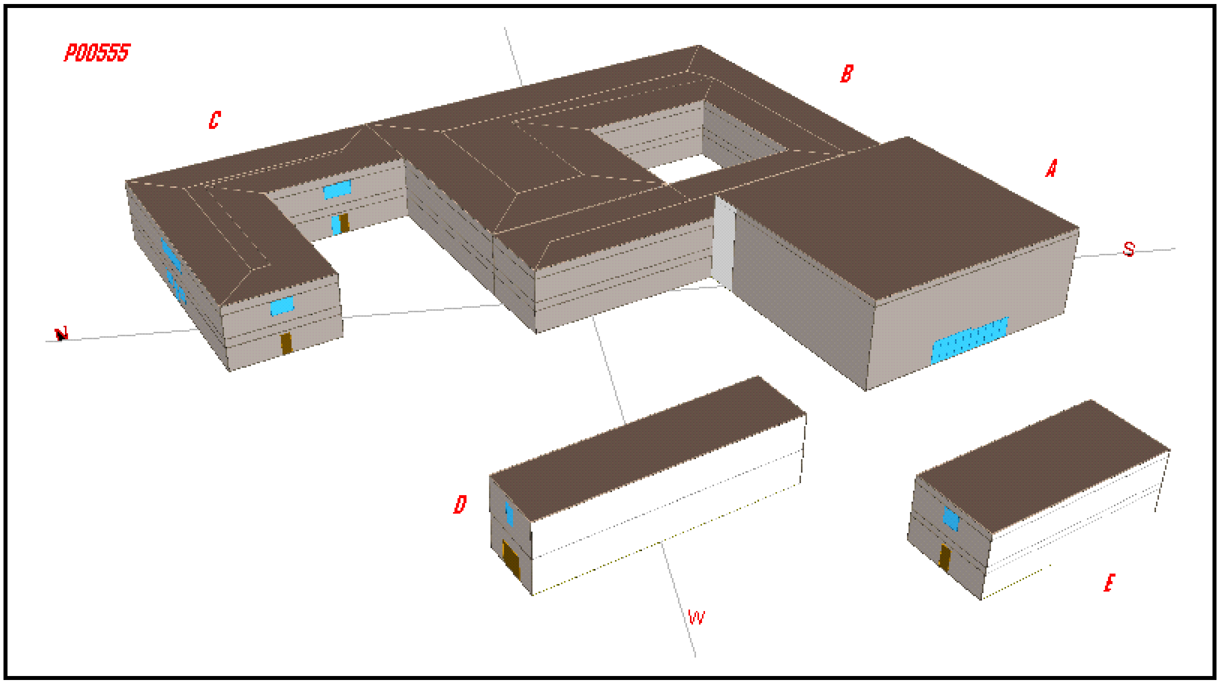


Figure 5-5: eQUEST 3D View of Premise-Level Building Simulation Model



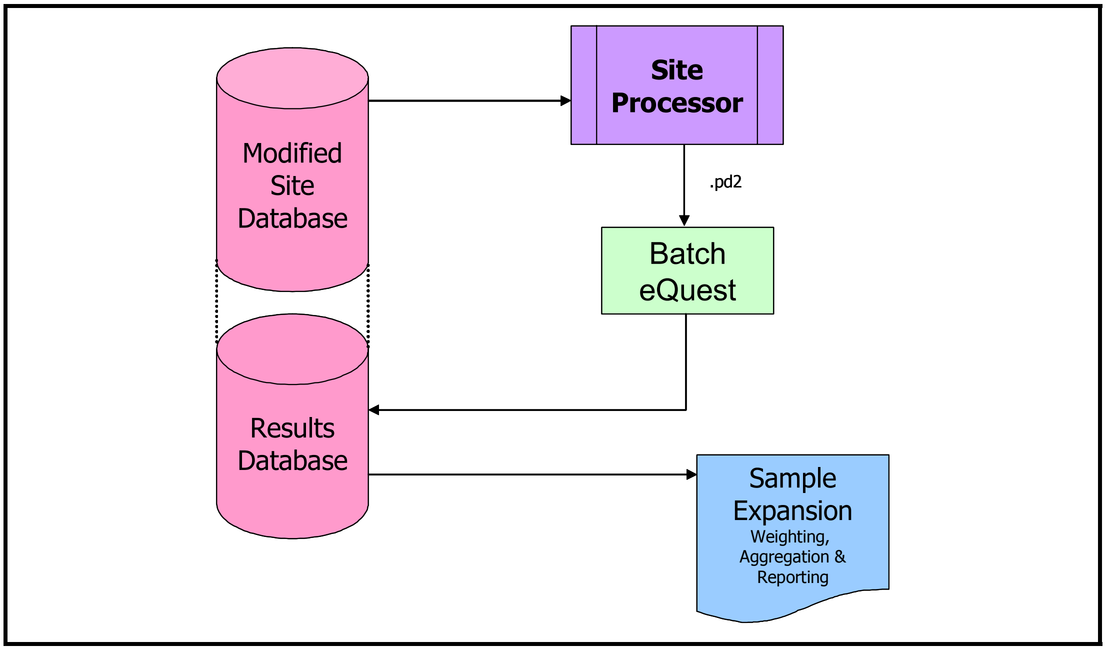
Energy Efficiency Measure Analysis in the Site Processor

The DrCEUS system can also be used to conduct energy efficiency measure analysis. The general approach for conducting measure analysis in the DrCEUS system is as follows:

- Identify the sites to be used for the analysis and save them in a subset (the “base case” subset),
- Make copies of the selected sites and add them to another subset (the “measure” subset),
- Modify equipment data parameters - such as SEER, lamp watts, motor efficiency - in the copied sites to reflect the measure configuration,
- Batch run the building simulations for the copied sites, and
- Compare the difference between the base subset and the measure subset results via graphical summaries (in the Segment Processor) and/or Excel workbooks.

Figure 5-6 illustrates the parts of the DrCEUS system that are used for this process. Note that these are the same system components that are used to perform the standard building simulations.

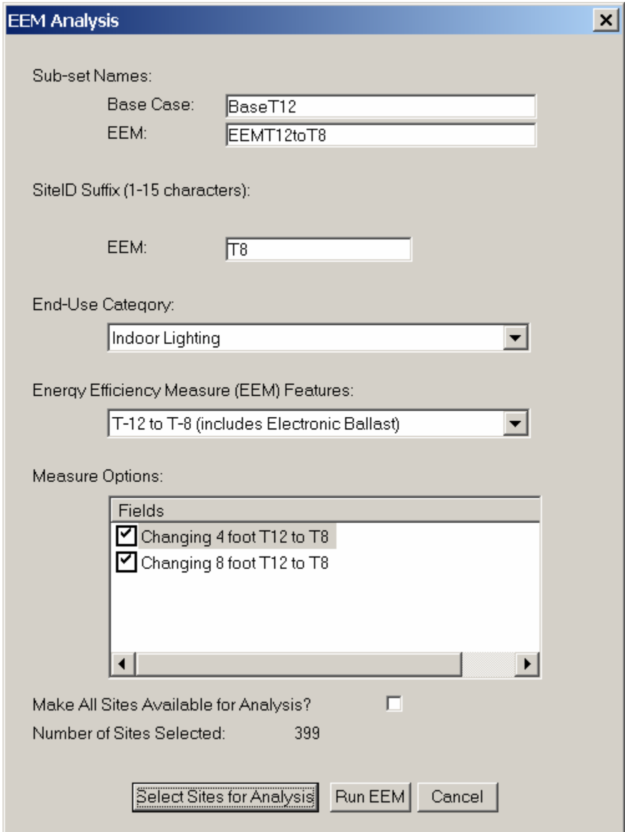
Figure 5-6: Energy Efficiency Measure Analysis Flowchart



Two methods can be used to conduct energy efficiency measure analysis. The first and most flexible way is to manipulate the survey data directly in the Access database. This process involves making copies within the Site Processor of all the sites that are to be analyzed. The energy efficiency measure is then incorporated into these copied sites by changing the survey data that characterizes the measure *directly in the Access database* (typically via an Access query). The copied sites are then simulated in the Site Processor, and the results can then be compared to the original sites. This is a labor-intensive process and care must be taken not to overwrite original survey data. It is, however, a very powerful tool when analyzing multiple energy efficiency measures.

The second method involves using the Energy Efficiency Measure Analysis Wizard (EEM Wizard), a function available within the Site Processor that automates the measure analysis process. The EEM Wizard can be used to perform energy efficiency analysis for approximately 80 pre-defined measures, which include most of the measures commonly offered by utility energy efficiency programs. Measure analysis is accomplished through the EEM Wizard dialog, shown in Figure 5-7, which allows the user to select the sites to be analyzed, to specify the names for the base and measure subsets, and to select what energy efficient measures to apply to these sites.

Figure 5-7: EEM Analysis Wizard Dialog



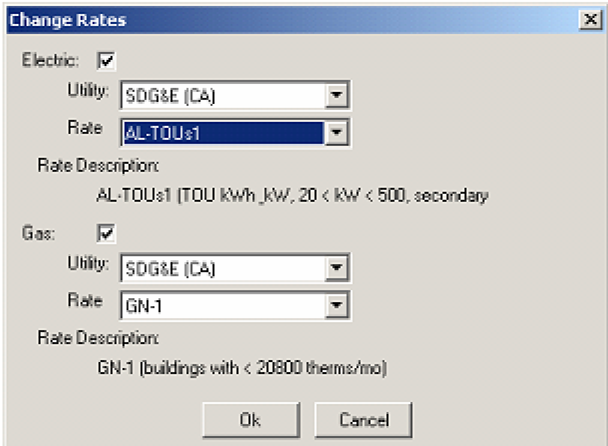
The EEM Wizard includes limited measures for the following end-use categories; building shell, indoor and outdoor lighting, water heating, remote refrigeration, packaged single zone HVAC systems, built-up HVAC systems, chillers, space heating boilers, circulation pumps, and HVAC supply and return fans. Each end-use category typically includes several possible measure options; Figure 5-7 illustrates the options for the Indoor Lighting, T-12 to T-8 energy efficiency measure.

Utility Billing Analysis in the Site Processor

The Site Processor also has the capability to assess rate change impacts. The process for performing a rate analysis is similar to that for energy efficiency analysis. The user first makes copies of the sites to be analyzed and adds them to a subset. The Change Rates dialog shown in Figure 5-8 is then used to change the electric and/or gas rate codes for *all* sites in the subset to the ones selected on the Change Rates dialog[2].

[2] Note that each site in the database has only a single electric and gas rate associated with it. For premises with multiple meters and rates, the electric and gas meters with the largest annual consumption were used in assigning the predominant utility billing rate code.

Figure 5-8: Change Rates Dialog



Once the billing rates have been replaced, the sites must be simulated again to calculate the new bills. Upon completion of the simulations, the individual sites can be compared to the original bills in the Site Processor.[3]

5.4 Segment Processing Mode

The Segment Processor is a powerful tool that is used for aggregating or expanding site-level results up to the population level. It is used to create and view results for groups of premises, or “segments.” Segments can be created from within the Segment Processor using any combination of available site characteristics. Segments can also be created from existing subsets in the Site Processor database. It is also in this mode that results for any two segments can be compared. Note that no energy simulations are performed within the Segment Processor; instead, simulation results are extracted from a Site Processor database. For example, to produce load profiles, it reads and aggregates the 8,760 end-use level electricity and gas consumption from the Site Processor for each premise in the segment. The Segment Processor applies the expansion weights calculated from the sample frame to individual site load profiles to produce population estimates for the segment.

There are two major components of the Segment Processor:

- ***Master (Site/Results) Database*** is the Site Database and Results Database elements in the middle of Figure 5-1 and/or Figure 5-6, as described previously.
- ***Sample Expansion Module*** is used to weight, aggregate, expand, view, and export the segment level results, whether from the baseline calibrated models or from measure runs.

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3 Billing calculations are performed by eQUEST as part of the building simulation, and as such, calculations are only performed for rates that are defined in eQUEST.

The Segment Processor uses filtering and querying capabilities to create segments from all sites in the CEUS database. Segments can also be constructed using simple manual selection and copying functions. Pre-existing segments can be modified by adding or removing sites as desired. The system produces a comprehensive set of graphics for summarizing results. All data generated for the selected segment can be exported to a tabbed Microsoft Excel workbook for easy access and further analysis.

The following figures show a portion of the available graphics in the Segment Processor. Figure 5-9 shows an example of the Monthly Day-Type chart that displays end-use load profiles for weekdays, Saturdays, Sundays, and the peak day for each month. Figure 5-10 shows the electric 8760-hourly energy usage chart for the segment. Three monthly charts are displayed at a time and the user can scroll through the charts to view the entire year.

Figure 5-9: Segment Processor – Results Example

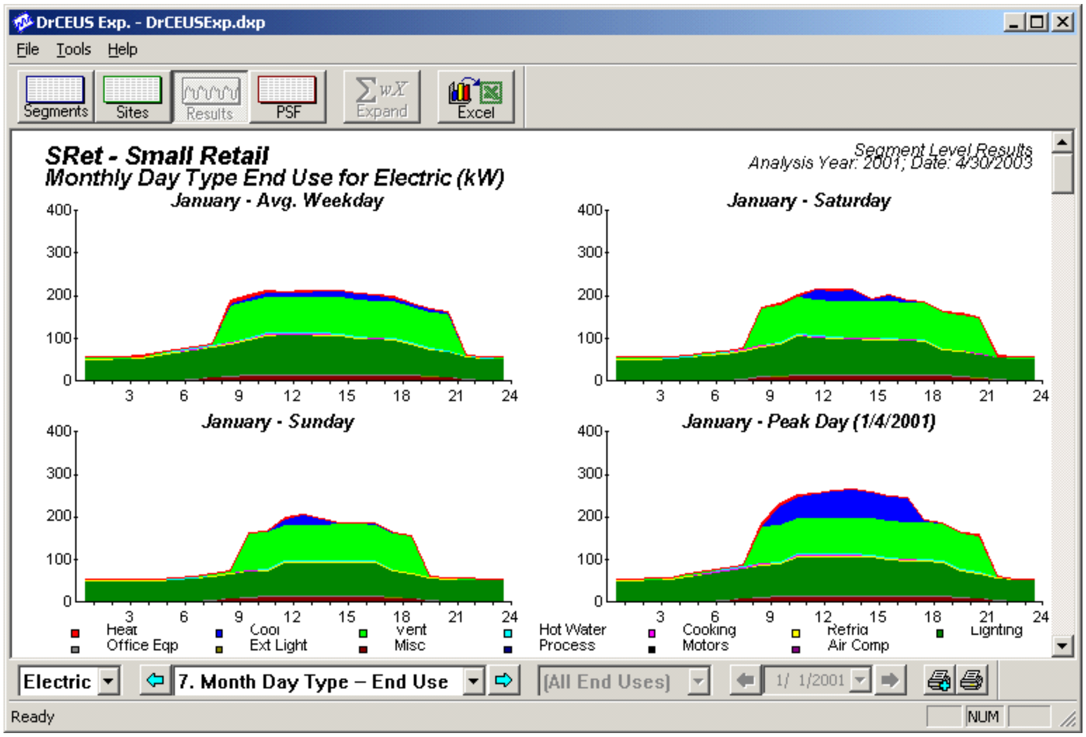
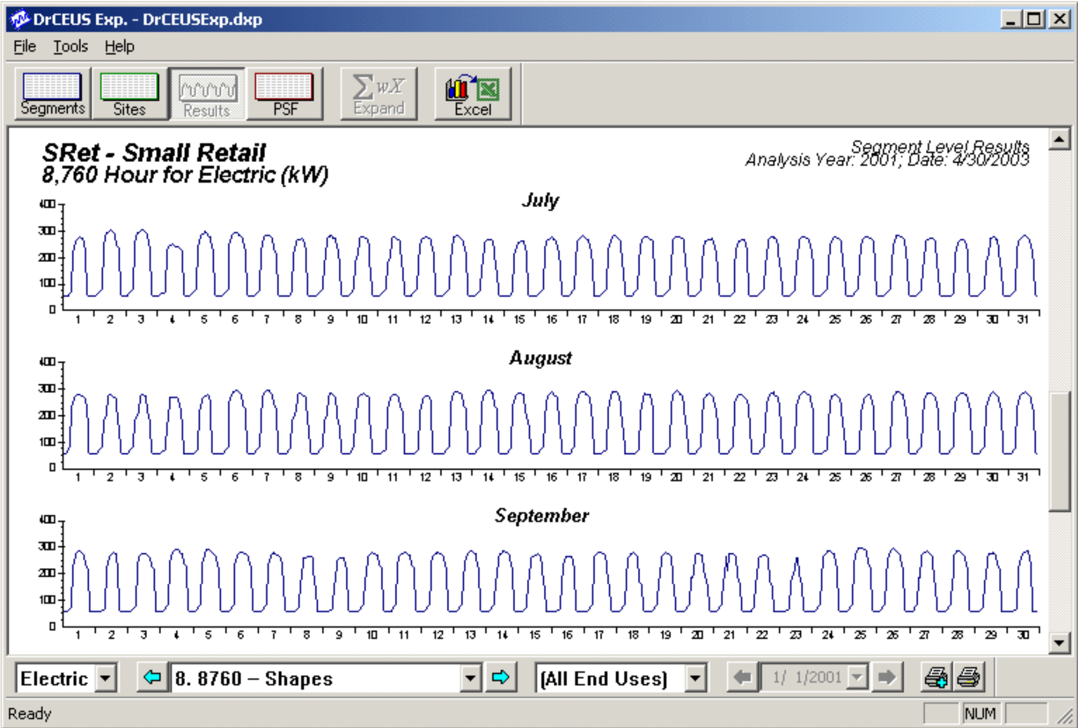


Figure 5-10: Segment Processor – Electric 8760 Usage Example



5.5 Applications of the CEUS Database and DrCEUS

The survey databases and DrCEUS framework developed for the CEUS study provide an integrated system that can support a variety of commercial end-use energy analysis. Several key applications for this system are described briefly below.

End-Use Demand Forecasting. The Energy Commission's commercial forecasting model is a combined engineering and econometrics based end-use forecasting model that projects energy use for 12 building types, 10 end uses, and three fuel types over 16 climate zones. Much of the data needed to support this model are derived from the statewide CEUS, which has been periodically updated since the late 1970s.

The floor space portion of the commercial model uses the estimates of square footage by building type, vintage, and climate zone developed from the CEUS as a baseline from which future floor space is estimated. The baseline square footage is used along with annual floor space additions and economic and demographic drivers to estimate the future additions to floor space. In addition to floor space, the estimates of baseline fuel saturation and energy use at the end-use level for each building type by vintage and climate zone used within the commercial model are developed from the data collected in the CEUS.

Energy Efficiency Measure Potential Savings Analysis Support. California has recently completed a significant amount of work in the analysis of demand-side management technical, economic, and market electric and gas savings potential for the commercial and residential sectors.[4,5] These efforts are data intensive, requiring baseline applicability, saturation, and density information for each major end-use equipment type and measure. In addition, these data need to include specific information on the presence, characteristics, and per unit savings of high efficiency equipment and measures.

The data collected from the CEUS study are a rich resource for these required studies, and in fact, were used in part for the latest statewide potential study effort.[6] For instance, information on end-use equipment saturations (such as percent of square feet cooled by packaged air conditioners) as well as the presence of high efficiency measures, can be derived from the data. It also provides the ability to break out these features for any number of classifications including utility service area, building type, climate zone (forecasting or Title 24), vintage, and ZIP code.

Assessment of Rate Impacts. Using the billing analysis capabilities of DrCEUS, the effects of different rate structures for a particular site or segment can be analyzed. Since there is only one predominant rate assigned to each site, the analysis cannot completely represent situations where sites have multiple accounts on different rate structures. It is, however, a useful way of looking at the effects of different rates given a common load profile.

Characterization of Commercial Sector End Users. Another beneficial use of the DrCEUS modeling system and CEUS databases is the development of tailored market profiles on an as-needed basis. For instance, Energy Commission staff often receive requests to develop energy use profiles for very specific market sectors (for example, high schools in a specific geographical area), or “what if” scenarios relating to the installation of specific equipment in these market sectors (for example, high efficiency air conditioning in middle schools). The Energy Commission has had a very limited ability to respond to these types of data requests since the end user segments did not match the twelve building type categories used for forecasting. The DrCEUS system will allow the Energy Commission to provide timely feedback to these requests with a level of precision dependent upon the number of premises fitting the specified market of interest.

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4 Itron, Inc. *Energy Efficiency Potential Summary Study.* Prepared for Pacific Gas & Electric. Draft report. Publication pending 2006.

5 Xenergy, Inc. *California Statewide Commercial Sector Energy Efficiency Potential Study. Volume 1 of 2.* Prepared for Pacific Gas & Electric. Study ID SW039A. 2003

6 Itron, op cit. *EE Potential Study.* 2006.