CALIFORNIA COMMERCIAL END-USE SURVEY

Executive Summary

CONSULTANT REPORT

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Prepared By:
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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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ABSTRACT

The California Commercial End-Use Survey (CEUS) is a comprehensive study of commercial sector energy use, primarily designed to support the state's energy demand forecasting activities. Itron performed the survey under contract to the California Energy Commission. The survey captures detailed building systems data, building geometry, electricity and gas usage, thermal shell characteristics, equipment inventories, operating schedules, and other commercial building characteristics.

A stratified random sample of 2,800 commercial facilities was targeted from the service areas of Pacific Gas & Electric, San Diego Gas and Electric, Southern California Edison, Southern California Gas Company and the Sacramento Municipal Utility District. The primary sampling unit was the *premise*, defined as a single commercial enterprise operating at a contiguous location. The sample was stratified by utility service area, climate region, building type, and energy consumption level.

Specialized software developed for the CEUS project generates energy simulation models automatically from the on-site survey data. Simulated energy use for each survey participant was calibrated to actual historical energy consumption from utility billing records. The software creates end-use load profiles and electricity and natural gas consumption estimates by end-use for user-defined commercial market segments. Its capabilities allow evaluation of energy efficiency measure installation, energy rate schedules, weather parameters, and many other scenarios against baseline usage patterns or conditions.

For each utility service area, floor stocks, fuel shares, electric and natural gas consumption, energy-use indices (EUIs), energy intensities, and 16-day hourly end-use load profiles were estimated for twelve common commercial building type categories.

KEYWORDS

Commercial, CEUS, Commercial End-Use Survey, end use, energy use, building type, energy forecasting, survey, fuel shares, saturations, EUI, building simulation, demand, load profiles, load shapes, California, electricity, gas, DOE-2, building, characteristics data

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EXECUTIVE SUMMARY

E.1 Introduction

Overview

This report presents an analysis of the way the California commercial sector uses energy. The analysis is based on an extensive commercial on-site survey conducted by Itron, Inc. 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 (PGC) and partially by the Energy Commission.

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.

However, in 1996, California Assembly Bill 1890 instituted a Public Goods Charge (PGC) designed to finance energy efficiency program development and evaluation. The California Public Utilities Commission, the agency overseeing 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). Itron, Inc. (then Regional Economic Research, Inc.) was selected to conduct the survey on behalf of the Energy Commission.

Project Objectives

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

- Develop estimates of end-use saturations, energy use by end use, and hourly load profiles for commercial market segments, at least partly to support the Energy 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.

E.2 Summary of the Project Scope and Methods

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 include the Sacramento Utility District (SMUD) service area. The utilities provided critical customer identifiers such as name, address, contact information, Standard Industrial Classification code, energy consumption records, and other information 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 service area, forecasting climate zone, building type, and size class.

Collection of On-Site Survey Data

The first major component of the project entailed 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 some premises, the survey also entailed the collection of time-of-use logger data on interior lighting and/or HVAC fans.

Collection of Information on Energy Usage for Sampled Sites

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

- Utility billing records, consisting of account and meter numbers, rate codes, meter read dates, monthly electric and gas consumption, and when available, time-of-use consumption and maximum demand values,
- Interval-metered electricity data collected by California's utilities as part of load research samples, as well as interval-metered data used for billing of large customers, and
- Short-term metering data, where the operation of a sample of HVAC and lighting systems for a target of 500 premises was monitored with time-of-use data loggers.

Usage data for surveyed sites informed the engineering analysis and ensured the development of accurate estimates of end-use energy consumption and hourly load profiles. The five utilities whose service areas were covered by the survey provided billing records and interval-metered data[1].

Development of Demand Analysis System

A comprehensive demand analysis system (DrCEUS) manages the energy simulation models developed for each premise in the survey. The DrCEUS system facilitates model calibration to historical energy use, control of batch simulation runs for segments within the entire database of sites, choice of weather station, energy efficiency measure analysis, and a comprehensive set of graphics. 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 the simulation engine.

Analysis of Hourly End-Use Energy Consumption at the Premise Level

The next major phase of the study required the development of calibrated energy simulation models for all of the CEUS premises. These models generated energy consumption estimates at the end-use level for all 8,760 hours of the year. The simulation work generally occurred within a reasonable time of 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 corresponding to the billing period. Simulated HVAC loads were developed using the DOE-2.2 engine incorporated into DrCEUS through eQuest. Non-HVAC end uses

1 These data are confidential under the terms of Title 20 of the California Code of Regulations.
2 DrCEUS is a proprietary product of these companies and is not available for distribution by the Energy Commission.

were calculated using a variety of algorithms that used survey information to estimate 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 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. Short-term metering data, when available, was also used to validate assumptions concerning 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 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. More information on this process can be found in the *California Energy Commission Commercial End-Use Survey: Weather and Data Normalization* report.

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 energy-use indices, which express the end-use energy consumption per square foot of floor stock with the end uses in question,

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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).

- Electric and natural gas energy intensities, which express the end-use consumption per whole-premise square foot, and
- Hourly end-use load profiles.

This report provides considerable detail on project methods and conventions. A comprehensive set of appendices describes additional technical details for key project elements. Two freestanding supplemental reports affiliated with the CEUS study are also available from the Energy Commission:

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

E.3 Overview of Statewide Energy Usage

Definitions

This section provides an overview of the electricity and natural gas consumption of commercial buildings for most of California. In this context, "statewide" refers to the combined electric service areas of the utilities participating in the CEUS: PG&E, SCE, SDG&E and SMUD. Service areas of the Los Angeles Department of Water and Power and a number of small municipal utilities were not part of the project scope. Several key terms used in this presentation are defined below:

Floor Stock. This term is used to describe the "stock" or amount of floor area or floor space. In this report, floor stock represents the total premise floor area for a segment, and is typically expressed in units of thousands of square feet (kft^2), or billions of square feet. Floor stock for a particular segment of the population of commercial buildings is estimated by summing the product of the surveyed premise floor areas and the corresponding expansion weights.

End-Use Definitions. Thirteen distinct end uses were used for this study; three are HVAC end uses and ten are non-HVAC end uses. Six of the end uses can be both electric and natural gas, while the remaining seven are electric-only end uses. The HVAC end uses are as follows:

- Space Heating – Electric and Gas
- Space Cooling – Electric and Gas
- Ventilation

The non-HVAC end uses include the following:

- Water Heating – Electric and Gas
- Cooking – Electric and Gas
- Refrigeration
- Inside Lighting
- Office Equipment
- Outdoor Lighting
- Miscellaneous Equipment – Electric and Gas
- Process – Electric and Gas
- Motors
- Air Compressors

End-Use Floor Stock (End-Use ft^2). It is also useful to define a concept that relates only to the portion of the floor stock in which a specific end use and fuel type are present. For all *non-HVAC end uses*, the end-use floor stock is defined as the *premise-level* floor stock associated with the end use *and* fuel in question. As a result, the end-use floor stock for gas water heating, for example, is based only on the floor area of premises in which gas water heaters are present.

Fuel Shares. Associated with the concept of end-use floor stock is the definition of an end-use and fuel-specific "share." For any end use and fuel, a fuel share is defined as the proportion of total floor stock that uses the fuel-specific end use in question. It is simply computed as the ratio of end-use floor stock to total floor stock in the segment. If a premise has equipment of both fuel types for a single end use, then the end-use floor area is associated with *both* fuel types.

Energy-Use Indices (EUIs). For the analysis of energy usage patterns, it is very useful to develop indicators of energy usage per square foot at the end-use level. Two such indicators are used in the analytical literature. The first of these is an energy-use index (EUI). An EUI is defined as the annual energy usage for a specific fuel and end use per square foot of *end-use floor stock* (area served by the fuel and end-use in question).

As with all energy estimates produced for this study, simulation results represent the total end-use consumption at a premise, rather than just purchases from the electric or gas utility. For electricity, simulations include all portions of electric usage satisfied through self-generation. For gas, simulated usage is restricted to end-use consumption, and excludes the use of gas for self-generation.

Energy Intensities (EIs). The second indicator is an energy intensity (EI), defined as the total fuel-specific consumption per square foot of total floor stock. EIs can be expressed at the segment or building-type level, at the premise level, or at the end-use level. For example, the energy intensity for electric end uses is referred to as an "electric end-use EI", and for gas end uses it is referred to as a "gas end-use EI". The difference between an EI and an EUI is in the floor stock used to develop the estimate; the EUI is based on end-use floor stock, while the EI is based on segment total floor stock.

Results

Table E-1, Figure E-1 and Figure E-2 depict the estimates of statewide floor stock, energy intensities, and energy usage by building type. Energy intensities and annual usage are weather-normalized, and refer to end-use consumption rather than purchases from utilities or other energy service providers.

As shown, total commercial floor stock in the covered electric service areas is estimated to be just over 4.9 billion square feet. The building types with the highest shares of total commercial floor stock are Miscellaneous (with approximately 22% of the total), Retail (14%), and Large Offices (13%).

Total commercial electric consumption is 67,707 GWh annually. The largest shares of total electricity consumption are in Large Offices (17%), Miscellaneous (16%), and Retail (15%). Natural gas usage (again, in the covered electric service areas) is roughly 1,279 million therms (Mtherms) per year. Three building types account for over 54% of natural gas usage: Restaurants (24%), Miscellaneous (20%) and Health (14%).

Figure E-3 and Figure E-4 depict estimates of electric and gas usage percentages by end use in the covered electric service areas. The primary electric end uses are interior lighting (29%), cooling (15%), refrigeration (13%), and ventilation (12%). The primary natural gas end uses are space heating (36%) and water heating (32%).

Electric and gas usage by end use for each building type are presented in Table E-2 through Table E-5. End-use electric EIs are shown in Table E-3. As indicated, the highest overall end-use electric intensity is interior lighting (3.92 kWh per square foot), followed by cooling (2.04), refrigeration (1.83), and ventilation (1.63). According to Table E-5, the highest natural gas intensities in the commercial sector are space heating (9.5 kBtu per square foot), water heating (8.3), and cooking (5.9).

Similar results, as well as EUIs, are presented in the report for individual utility service areas.

Table E-1: Overview of Energy Usage in the Statewide Service Area

Building Type	Floor Stock (kft^2)	Annual Energy Intensities: Electricity (kWh/ft^2)	Annual Energy Intensities: Natural Gas ($therms/ft^2$)	Annual Energy Intensities: Natural Gas ($kBtu/ft^2$)	Total Annual Usage: Electricity (GWh)	Total Annual Usage: Natural Gas (Mtherms)
All Commercial	4,920,114	13.63	0.26	25.99	67077	1278.60
Small Office (<30k ft^2)	361,584	13.10	0.11	10.54	4738	38.10
Large Office (>=30k ft^2)	660,429	17.70	0.22	21.93	11691	144.80
Restaurant	148,892	40.20	2.10	209.98	5986	312.60
Retail	702,053	14.06	0.05	4.62	9871	32.50
Food Store	144,209	40.99	0.28	27.60	5911	39.80
Refrigerated Warehouse	95,540	20.02	0.06	5.60	1913	5.30
Unrefrigerated Warehouse	554,166	4.45	0.03	3.07	2467	17.00
School	445,106	7.46	0.16	15.97	3322	71.10
College	205,942	12.26	0.34	34.24	2524	70.50
Health	232,606	19.61	0.76	75.53	4561	175.70
Lodging	270,044	12.13	0.42	42.40	3275	114.50
Miscellaneous	1,099,544	9.84	0.23	23.34	10817	256.60
All Offices	1,022,012	16.08	0.18	17.90	16430	182.90
All Warehouses	649,706	6.74	0.03	3.44	4380	22.40

Figure E-1: Commercial Electricity Use by Building Type

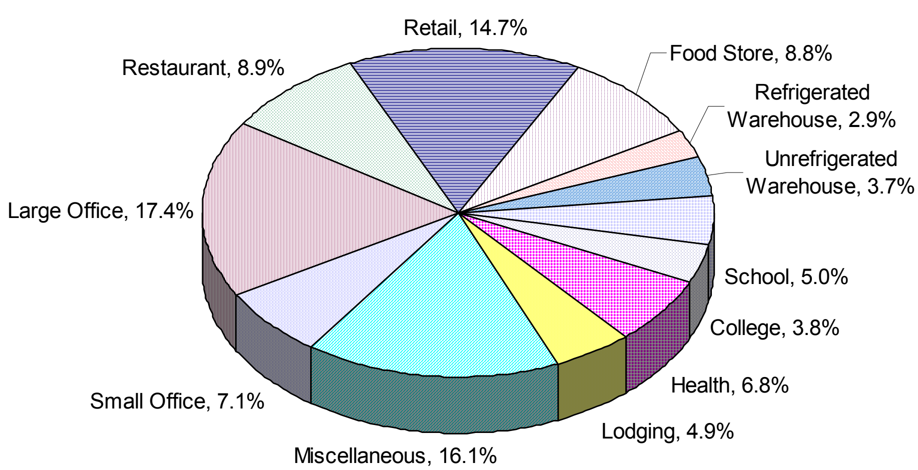

Figure E-2: Commercial Gas Usage by Building Type

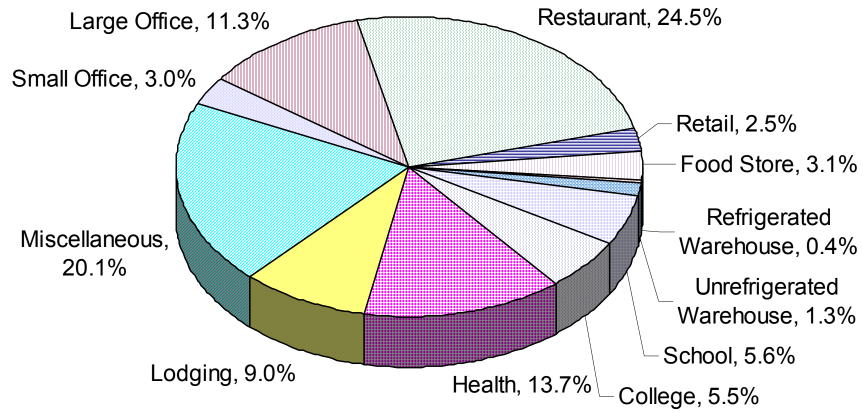

Figure E-3: Electric Usage by End Use

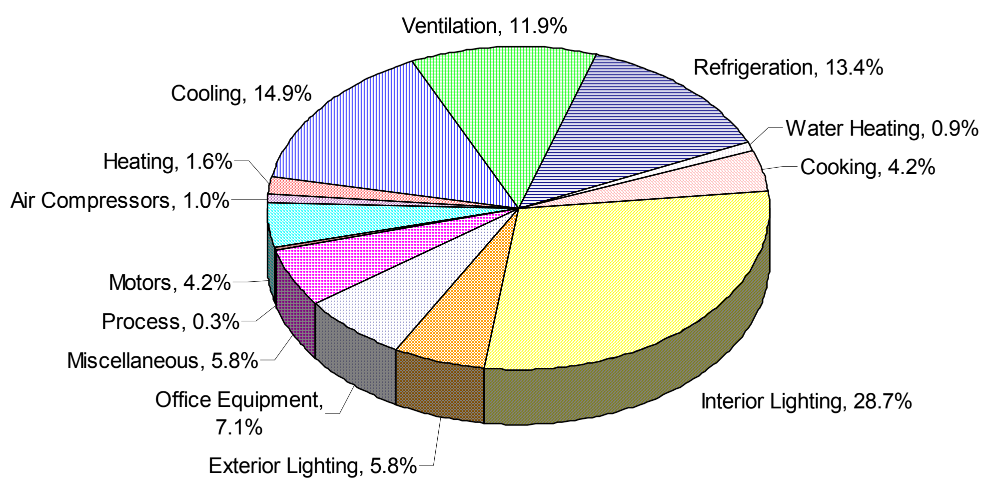

Figure E-4: Natural Gas Usage by End Use

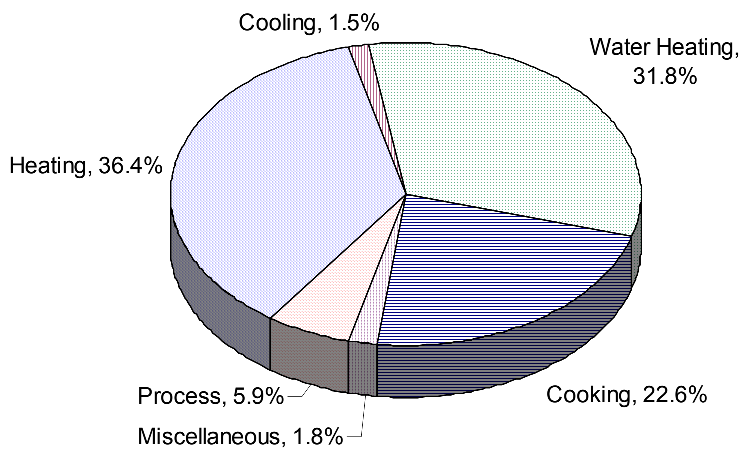

Table E-2: Electric Usage (GWh) by Building Type and End Use

Building Type	Heat	Cool	Vent.	Refrig.	WH	Cook	Int. Ltg.	Ext. Ltg.	Office Equip.	Misc.	Air Comp.	Motors	Proc.	Total
All Commercial	1,087	10,017	8,000	9,014	611	2,805	19,265	3,916	4782	3924	204	2811	642	67,077
Small Office	72	943	467	208	90	38	1,386	343	793	283	1	79	36	4,739
Large Office	322	2358	2,019	268	80	77	2,945	324	2365	383	18	474	60	11,691
Restaurant	7	858	482	1,469	56	1,546	961	300	94	168	1	41	3	5,986
Retail	55	1553	1,267	726	96	157	4,246	644	343	483	37	201	64	9,871
Food Store	12	415	372	3,233	20	266	1,233	137	54	138	1	26	6	5,911
Refrigerated Warehouse	2	31	23	1284	3	3	262	33	17	55	4	174	22	1,913
Unrefrigerated Warehouse	20	183	156	154	26	12	1,223	145	131	215	9	162	32	2,467
School	56	520	429	225	43	78	1,281	330	206	110	1	37	7	3,322
College	159	393	423	95	25	55	790	188	148	100	2	119	28	2,524
Health	166	901	940	166	18	101	1,119	132	200	586	1	181	50	4,561
Lodging	114	650	483	244	9	185	945	165	46	301	0	128	6	3,275
Miscellaneous	104	1,212	941	942	145	287	2,874	1,175	386	1103	129	1190	330	10,817
All Offices	393	3,301	2,485	476	171	115	4,331	666	3157	666	19	553	95	16,430
All Warehouses	22	214	179	1,438	28	15	1,485	178	148	270	13	336	54	4,380

Table E-3: Electric Energy Intensities (kWh/ft^2-yr) by Building Type and End Use

Building Type	Total	Heat	Cool	Vent.	Refrig.	WH	Cook	Int. Ltg.	Ext. Ltg.	Office Equip.	Misc.	Air Comp.	Motors	Proc.
All Commercial	13.63	0.22	2.04	1.63	1.83	0.12	0.57	3.92	0.80	0.97	0.80	0.04	0.57	0.13
Small Office	13.10	0.20	2.61	1.29	0.58	0.25	0.10	3.83	0.95	2.19	0.78	0.00	0.22	0.10
Large Office	17.70	0.49	3.57	3.06	0.41	0.12	0.12	4.46	0.49	3.58	0.58	0.03	0.72	0.09
Restaurant	40.20	0.05	5.76	3.24	9.87	0.38	10.38	6.45	2.02	0.63	1.13	0.01	0.27	0.02
Retail	14.06	0.08	2.21	1.81	1.03	0.14	0.22	6.05	0.92	0.49	0.69	0.05	0.29	0.09
Food Store	40.99	0.08	2.88	2.58	22.42	0.14	1.85	8.55	0.95	0.37	0.95	0.01	0.18	0.04
Refrigerated Warehouse	20.02	0.02	0.33	0.24	13.44	0.03	0.04	2.74	0.35	0.17	0.57	0.04	1.82	0.23
Unrefrigerated Warehouse	4.45	0.04	0.33	0.28	0.28	0.05	0.02	2.21	0.26	0.24	0.39	0.02	0.29	0.06
School	7.46	0.13	1.17	0.96	0.50	0.10	0.18	2.88	0.74	0.46	0.25	0.00	0.08	0.01
College	12.26	0.77	1.91	2.05	0.46	0.12	0.27	3.84	0.91	0.72	0.49	0.01	0.58	0.14
Health	19.61	0.71	3.87	4.04	0.71	0.08	0.43	4.81	0.57	0.86	2.52	0.01	0.78	0.22
Lodging	12.13	0.42	2.41	1.79	0.90	0.03	0.68	3.50	0.61	0.17	1.11	0.00	0.48	0.02
Miscellaneous	9.84	0.09	1.10	0.86	0.86	0.13	0.26	2.61	1.07	0.35	1.00	0.12	1.08	0.30
All Offices	16.08	0.38	3.23	2.43	0.47	0.17	0.11	4.24	0.65	3.09	0.65	0.02	0.54	0.09
All Warehouses	6.74	0.03	0.33	0.28	2.21	0.04	0.02	2.29	0.27	0.23	0.42	0.02	0.52	0.08

Table E-4: Natural Gas Usage (Mtherms) by Building Type and End Use

Building Type	Heat	Cool	WH	Cook	Misc.	Proc.	Total
All Commercial	465.50	19.10	406.70	289.10	23.00	75.20	1278.60
Small Office	31.20	0.00	6.00	0.50	0.10	0.40	38.10
Large Office	113.70	3.60	17.20	1.50	0.70	8.10	144.80
Restaurant	11.50	0.00	72.40	228.20	0.00	0.50	312.60
Retail	21.20	0.00	5.50	3.60	1.90	0.30	32.50
Food Store	13.70	0.00	11.00	14.90	0.00	0.10	39.80
Refrigerated Warehouse	0.80	0.00	0.80	1.20	0.00	2.70	5.30
Unrefrigerated Warehouse	14.80	0.00	1.80	0.10	0.20	0.10	17.00
School	44.60	0.60	20.90	4.70	0.10	0.30	71.10
College	40.80	7.10	17.30	3.40	1.80	0.00	70.50
Health	76.10	3.60	73.00	7.80	3.40	11.80	175.70
Lodging	19.70	0.20	78.20	11.90	3.90	0.70	114.50
Miscellaneous	77.40	4.00	102.70	11.20	10.90	50.30	256.60
All Offices	144.90	3.60	23.20	2.00	0.80	8.40	182.90
All Warehouses	15.60	0.00	2.60	1.20	0.20	2.80	22.40

Table E-5: Natural Gas Energy Intensities (kBtu/ft^2-yr) by Building Type and End Use

Building Type	Total	Heat	Cool	WH	Cook	Misc.	Proc.
All Commercial	26.00	9.50	0.40	8.30	5.90	0.50	1.50
Small Office	10.50	8.60	0.00	1.70	0.10	0.00	0.10
Large Office	21.90	17.20	0.50	2.60	0.20	0.10	1.20
Restaurant	210.00	7.70	0.00	48.60	153.30	0.00	0.30
Retail	4.60	3.00	0.00	0.80	0.50	0.30	0.00
Food Store	27.60	9.50	0.00	7.70	10.30	0.00	0.10
Refrigerated Warehouse	5.60	0.80	0.00	0.80	1.20	0.00	2.80
Unrefrigerated Warehouse	3.10	2.70	0.00	0.30	0.00	0.00	0.00
School	16.00	10.00	0.10	4.70	1.10	0.00	0.10
College	34.20	19.80	3.50	8.40	1.70	0.90	0.00
Health	75.50	32.70	1.60	31.40	3.40	1.40	5.10
Lodging	42.40	7.30	0.10	29.00	4.40	1.40	0.30
Miscellaneous	23.30	7.00	0.40	9.30	1.00	1.00	4.60
All Offices	17.90	14.20	0.40	2.30	0.20	0.10	0.80
All Warehouses	3.40	2.40	0.00	0.40	0.20	0.00	0.40

E.4 Recommendations

Recommendations for future work in this area are categorized as either project-specific "lessons learned" or as general commercial sector research issues. Lessons learned are recommendations that could help ensure an effective follow-on CEUS project. General commercial sector issues are those related to improving the data development.

Lessons Learned

The CEUS study was an extremely large undertaking, involving intensive work over a period of four years. The project team learned a considerable amount in the course of the study. Some of the major lessons are discussed below.

Developing Initial Sampling Frames. The development of sampling frames was a time-consuming and frustrating process. Requests for non-residential billing data were made of the three electric IOUs early in the project, and several months passed before final consistent frame databases could be constructed. To some extent, this was due to substantially different formats of the frames received by Itron. A common format probably should have been requested from all utilities. The need for Itron to put confidentiality agreements in place with the IOUs exacerbated the problem. This process cost several additional months and wasted project resources. The administrative mechanism for exchanging data between the utilities and contractors working for regulatory agencies needs to be further developed.

Updating Frames. The initial sample design was based on 2000 billing data, with the intention that analysis would also be done with 2000 data. Given a variety of delays in getting the survey under way, it eventually became apparent that the analysis should use more recent data, and the year 2002 was chosen as the analysis year. Switching base years required Itron to make additional requests for 2002 consumption data from the utilities, and this process took a substantial amount of additional time. In retrospect, sample design in an extensive project like this one should follow a number of other steps, including the design of the survey instrument and perhaps even the pre-testing of the instrument.

Conducting Survey Fieldwork. Survey fieldwork took far longer than anticipated. To some extent, this was due to early delays in getting utility billing system data and changes made to the survey form after the pre-test survey. Subcontractors understandably reassigned surveyors temporarily to other activities, so in a sense the project had to bear a certain amount of start-up costs for a second time. In addition, the complexity of the unique survey instrument, which incorporates several building simulation concepts, aggravated the problem. This affected the need for more intensive surveyor training than is typical for an on-site survey effort, because the survey was more than just a census of equipment; it involved understanding some of the basic building simulation concepts as well. Moreover, as the needs of the survey became clearer, it became apparent that the fieldwork was under-budgeted. Subcontractors found it difficult to complete the survey in the time they had anticipated, and this in turn made it necessary to re-contact many site managers to clarify and/or confirm information. The interaction between Itron and the fieldwork subcontractors was extensive and time-consuming. In future efforts like this, it will be necessary to simplify some aspects of the survey or to recognize the need for higher survey budgets.

Reconciling Meters. 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, a higher than normal turnover of commercial business and changes to existing businesses occurred.

Second, meter reconciliation was further complicated by the massive meter change-outs driven by Assembly Bill 29X. This bill provided state money to utilities for replacing older technology meters with newer time-of-use meters on a very large scale. Unsurprisingly, surveyors discovered that many of the meters expected to be found in the field had been replaced. Closer cooperation with utilities early in the project would help minimize the time to resolve meter assignments.

Interval Data for Calibration of Energy Simulation Models. Equipment operating schedules are usually the most difficult information to obtain from an on-site survey. Building owners and operators frequently cannot characterize equipment operation in the detail necessary for simulation modeling, and information is not always available from building control systems. Assumptions made during the energy simulation process regarding schedules directly affect the shape of load profiles at the whole-building and end-use levels. Therefore, it is essential to maximize the number of premises included in the sample that have interval-metered electricity data so that calibration of the simulation models is based on known building performance. The number of premises with interval-metered data for this study was significantly limited and future efforts should take full advantage of the wealth of data available.

Recommendations for Additional Commercial Sector Research

Itron offers several recommendations for further commercial sector research to build on the current effort.

Updating the Current Study. While the CEUS project was an extremely ambitious undertaking, it does not exhaust the need for commercial sector information. Some means of refreshing the CEUS database will need to be determined, whether this entails statewide surveys like this one or surveys conducted periodically by individual utilities.

Enhancing New Construction Information. By agreement with the Energy Commission, the CEUS sample design did not entail oversampling of new construction. Even though the total sample size is large enough to contain a significant number of new sites (depending, of course, on the definition of this vintage), the importance of differences between new and existing construction for forecast and other purposes may warrant collecting additional information on new construction. Ideally, this information would be collected with the same survey instrument (albeit perhaps simplified in some areas) as used in this study, and subjected to the same kind of simulation analysis.

Improving the Simulation of Remote Refrigeration. It was agreed early in the project not to use DOE 2.3 (a detailed remote refrigeration system simulation tool) for the simulations, in that it was still being developed by J.J. Hirsch & Associates and VaCom Technologies. However, DOE2.3 could yield improved results versus the DrCEUS remote refrigeration algorithm, which was also developed with the assistance of VaCom. As such, it may be useful to modify DrCEUS at some point to use DOE2.3, at least for supermarkets and refrigerated warehouses.

Refining Commercial Building Types. The summary of CEUS results contained in Chapters 8 through 12 makes use of the traditional commercial building types. However, the CEUS database is large enough that it could easily be used to develop a finer resolution of building types. For instance, the miscellaneous building type (24% of all CEUS premises) could be further disaggregated into churches, gas stations, prisons, movie theaters, and a variety of other significant customer segments. This might have a number of useful applications, including refining end-use forecasts and allowing closer targeting of key sectors by energy efficiency programs.

Refining HVAC End Uses. The analysis conducted under this project makes use of fairly traditional HVAC end-use definitions: space heating, space cooling, and ventilation. The system could be enhanced to use a finer resolution of HVAC end uses, consistent with the DOE-2 HVAC end use distinctions of heat rejection and pumps/auxiliary energy.