California Energy Commission

CONSULTANT REPORT

2022 California Commercial End-Use Survey (CEUS): Final Report

Prepared for**: California Energy Commission**
Prepared by: **ADM Associates, Inc.**

February 2024 | CEC-200-2023-017

California Energy Commission

Primary Author(s):

Sasha Barioant

Daniel Mort

Taghi Alereza

Don Dohrmann

ADM Associates, Inc.

3239 Ramos Circle

Sacramento, CA 95827

(916) 363-8383

www.admenergy.com

Contract Number: 200-2023-017

Prepared for:
California Energy Commission

Mohsen Abrishami
Project Manager

Heidi Javanbakht
Branch Manager
DEMAND ANALYSIS BRANCH

Aleecia Gutierrez
Director
ENERGY ASSESSMENTS DIVISION

Drew Bohan
Executive Director

ACKNOWLEDGEMENTS

The authors have been beneficiaries of the institutional knowledge of California Energy Commission's Demand Analysis Office staff, who provided guidance and perspective during this project. Mohsen Abrishami provided invaluable leadership and comprehensive guidance and continuous technical feedback throughout the project. Sabaratnam Thamilseran provided technical and conceptual guidance and collaboration. Steven Mac, Le-Huy Nguyen, Sean Pruitt, and Sabaratnam Thamilseran supplied vital management support as CAMs of the project. Kristen Widdifield, Siva Gunda, Mark Ciminelli, and Linda Schrupp assisted with contract amendments and work authorizations. Numerous staff at participating California utility companies acted as liaisons with their forecasting departments and call centers and provided essential customer meter data. The authors are indebted to policy makers and industry professionals that conceived, commissioned, and assisted this CEUS, and made the data available for public use.

The members of our Technical Advisory Committee (TAC) provided deep industry insights and experience to develop the relevant questions this CEUS asked and answered. ADM would like to acknowledge the services of Wim Bos, Tim Vonder, Bob Patchen, Bob Ramirez, Chris Kavalec, Kristen Widdifield, Le-Huy Nguyen, Martha Brook, Mohsen Abrishami, Rachel Salazar, Sabaratnam Thamilseran, Sean Pruitt, Don Dohrmann, and Taghi Alereza.

The CEUS team would like to thank all survey participants who voluntarily provided site access, key site-specific operational knowledge, and documentation required to successfully complete the survey.

PREFACE

The California Energy Commission's (CEC) Energy Assessments Division provides energy demand forecasts to policy makers and utilities by collecting and analyzing data on electricity peak demand and consumption, natural gas consumption, and transportation fuel use. California Code of Regulations Title 20[1] places ongoing data collection and reporting requirements on major California electric and gas utility companies and the CEC related to energy usage, efficiency, and related information. The Commercial End Use Survey is an important part of the Title 20 compliance effort for participating utility companies. This broad energy survey of California's commercial sector was funded by the Electric Program Investment Charge (EPIC) and other funding sources. The survey covered the electric service territories of Pacific Gas and Electric Company, San Diego Gas and Electric Company, Southern California Edison, Los Angeles Department of Water and Power, and Sacramento Municipal Utilities District, and the gas service territory of Southern California Gas Company. The CEUS team collected data on over 24,000 buildings in these service territories between 2018 and 2022 and presents results in this report.

The CEC is committed to ensuring public participation in its research and development that promote greater reliability, lower costs, and increase safety and include:

- Providing societal benefits
- Greenhouse gas emissions mitigation and adaptation in the electricity sector at the lowest possible cost
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply
- Supporting low-emission vehicles and transportation
- Providing economic development
- Using ratepayer funds efficiently

For more information about the Energy Assessments Division and the California Commercial End-Use Survey, please visit California Commercial End-Use Survey or contact the CEC Project Manager, Mohsen Abrishami, at mohsen.abrishami@energy.ca.gov.

1 California Code of Regulations Title 20; Division 2; Chapter 3; Article 2; Section 1343

ABSTRACT

The 2022 California Commercial End-Use Survey (CEUS) was a comprehensive study of commercial sector energy use, primarily designed to support the state's energy demand forecasting activities. ADM Associates, Inc. (ADM) performed the survey under contract to the California Energy Commission. The survey focuses on selective building systems data, electricity and gas usage, equipment inventories, occupancy schedules and primary business activities, and other commercial building characteristics.

A stratified random sample of nearly 27,000 commercial facilities was targeted from the service areas of Pacific Gas & Electric Company (PG&E), San Diego Gas and Electric (SDG&E), Southern California Edison (SCE), Southern California Gas Company (SoCalGas), Los Angeles Department of Water and Power (LADWP), and the Sacramento Municipal Utility District (SMUD). The primary sampling unit was the survey-site, defined as a single commercial entity operating in a contiguous commercial space (i.e., all or part of one or more commercial buildings that are not separated by other buildings, or by public roads). The sample was stratified by utility service area, Forecast Zone, Building-type, vintage (existing & new), and energy consumption level.

The 2022 CEUS was the first instance of the CEUS to use paperless survey forms. This survey used a web-based application (app) specifically designed for this CEUS survey to address the unique characteristics of this survey. The app is called the "CEUS Tool" and was a major part of this data collection effort.

For each utility service area, floor stocks, fuel shares, electric and natural gas consumption, energy use, and hourly whole building load profiles were estimated for the twelve commercial Building-type categories.

Keywords: California Energy Commission, CEUS, commercial, Commercial End-Use Survey, end-use, energy use, Building-type, Forecast Zone, survey-site, survey, CEUS Tool, fuel shares, saturations, demand, electricity, gas, statewide, survey-wide

Please use the following citation for this report:

Baroiant, Sasha, Daniel Mort, Taghi Alereza, Don Dohrmann (ADM Associates, Inc.). 2023. *2022 California Commercial End-Use Survey (CEUS)*. California Energy Commission. Publication Number: CEC-200-2023-017.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Introduction

Overview

This report presents findings from the 2022 Commercial End-Use Survey (CEUS). Key findings include estimates for electric and gas usage in the commercial sector as a function of floorspace, business activity, and geographic location. The survey has collected data from over 24,000[2] commercial facilities in California, primarily through on-site surveys and inspections. The California Energy Commission (CEC) contracted with ADM Associates to conduct the CEUS. Subcontractors on the project team were Matrix Energy Services and Davenergy Solutions. The survey was funded primarily by the CEC's Electric Program Investment Charge (EPIC) Program, but also by the Energy Resources Programs Account (ERPA) and the Petroleum Violation Escrow Account (PVEA). This section provides an overview of CEUS project including project objectives, a summary of survey design and data collection methodology and high-level results (Statewide energy and floorspace data).

Background

The CEC uses building characteristics and energy consumption data to inform energy demand forecasting, to assess energy efficiency opportunities, and to inform research related to rulemaking. The CEC's demand forecasts rely heavily on estimates of total floorspace for 12 commercial subsectors called *Building-types (*e.g., *Retail, Small Office, School,* etc.*)*, as well as electric and gas fuel saturations and energy usage for 10 different end-uses for each Building-type. All of these have historically been quantified separately for 16 geographical zones known as *Forecast Zones*. In 2015, the CEC started to disaggregate demand forecasts into 20 Forecast Zones that are associated with resource planning areas used by the California Independent System Operator (CAISO) to manage the state's electricity grid. The desire to disaggregate energy demand forecasts into smaller geographical regions was the primary design driver of this CEUS.

While previous CEUS efforts lacked enough sample points to make robust population estimates at the Forecast Zone level, this project was charged with the task of developing that capability at an even finer level of granularity. To this end, the 2022 CEUS targeted over 24,000 sample points across the service territories of the five largest electric utilities in California: Los Angeles Department of Water and Power (LADWP), Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas and Electric (SDG&E), and Sacramento Municipal Utility District (SMUD), and the gas service territory of SoCalGas (SCG).

---

2 While the project team conducted over 24,000 surveys, the net result was 22,933 distinct sample points. After inspection of data, analysts decided to combine 664 pairs of sites which were recognized to satisfy the definition of a single Survey Site, even though they were separate sample points in the sample frame. Another 697 sites (2.9% of total) were removed due to various considerations such as noncommercial activities found on site or uncertainty in data (particularly for online surveys). Please see CHAPTER 6: Results, for a full discussion.

Project Objectives

The goals of the project are to:

- Increase the sample size for on-site surveys significantly above that of historical levels to support disaggregation of energy demand forecasts.
- Calculate end-use fuel saturations, commercial floorspace, gas and electricity usage at the Forecast Zone level by Building-type.
- Develop annual whole-building hourly load profiles at the Forecast Zone level by Building-type.
- If practicable, oversample newly constructed commercial facilities.
- Assess the feasibility of potential for using purchased commercial real estate data to benefit the CEUS design or as a means of collecting commercial end-user characteristics.
- Accurately characterize building economic activity and assess North American Industry Classification System's (NAICS) code misclassification.
- Develop CEC staff expertise in the evaluation of sample design alternatives, construction of sampling frames and recruitment pools, computation of sample weights and population estimation techniques.

Summary of the Project Scope and Methods

The 2022 CEUS is the largest volume survey in the history of the CEUS. The EPIC-funded portion of the survey targeted nearly 20,000 completed surveys of electric power customers from PG&E, SDG&E, and SCE. The non-EPIC funded portion of the survey targeted 5,800 surveys of electric power customers of LADWP and SMUD, as well as 1,200 additional sites for PG&E, SDG&E, and SCE. Participating utility companies provided customer information systems data, billing data, and at times assisted the CEC and ADM project team (the CEUS team) in recruiting high-value customers for the survey. Southern California Gas provided gas usage information for commercial customers, which allowed the CEUS team to compute natural gas usages for surveyed SCE and LADWP electric customers. The project conducted over 24,000 surveys in the electric service territories of LADWP, PG&E, SCE, SDG&E, and SMUD, making it the largest survey of its kind.

Survey Design

The survey sought to maximize the sample size while maintaining only the data fields that are essential to project goals. CEC and ADM staff specifically designed the survey instrument for efficient data collection and transmission for immediate validation and downstream analysis. The sample design stratified along Building-types and Forecast Zones, as defined in the CEC's forecasting process, and also included two vintages: buildings constructed before 2006, and newer buildings. The survey oversampled newer buildings, and following recommendations from the previous CEUS study, also oversampled the relatively heterogenous *miscellaneous* Building-type which includes disparate facility types such as auto repair, amusement parks, prisons, and dry cleaners.

Data Collection

For the first time in the history of the CEUS, the survey was carried out in a "paperless" fashion. Surveyors used tablet computers and a web-based survey tool to perform on-site data collection. The survey tool, referred to as the CEUS Tool, included real-time validation logic, drop-down lists to standardize input data, and provided a means to automatically link photographs taken by surveyors with corresponding survey-sites. Data collection included a walk-through of the facility to measure floorspace and to collect information on the presence of major equipment and their fuel sources. Surveyors interviewed site-contacts to assess primary business activities and building usage patterns and to inquire about past building additions and renovations. Billing data provided by participating utilities supplemented data collected on site. The majority of on-site data collection occurred during calendar year 2019. The project team completed 50 to 100 surveys per business day during this period. To cope with the extreme pace of data acquisition, the team automated key aspects of sample management, scheduling, data aggregation, validation, and quality control. In March 2020, the team transitioned to remote surveys in response to the COVID pandemic. Approximately 2,500 surveys were conducted remotely through email, telephone, and video chat, and another 600 surveys were completed by participants in an online survey form.

Analysis of Segment-Level End-Use Energy Consumption

After reconciling site-level data with utility billing data, the project team constructed a number of key metrics by Building-type and Forecast Zone. Some of these are listed below:

- Floor stocks
- Fuel shares (% gas, electric, solar, etc.) of major equipment
- Penetrations or saturations of equipment or end-use
- Electric and natural gas energy intensities, which express whole-facility energy consumption per square foot
- Weather-normalized hourly load profiles

Mining the 2022 CEUS Dataset

The CEC's vision for this study was to enable research at a finer granularity than possible with previously available data. It is possible to subdivide the CEUS dataset far beyond the design stratification, while maintaining statistical significance. As part of non-EPIC funded work for this project, ADM has developed two tools to facilitate CEC Research with the CEUS data.

Poststratification Tool

The poststratification tool quickly recalculates and presents the summary tables and plots in this project report, but for unique data divisions created by users. For example:

- What if the Forecast Zones grow in number to 50, or are defined at the county or zip-code level?
- What if the warehouse and refrigerated warehouse Building-types were combined?
- What if the miscellaneous or office Building-types were split into several other types?
- What if the number of vintages increased to four, or eleven?

The poststratification tool can perform all necessary data manipulation and calculations and presents summary statistics for each newly defined stratum. The tool will provide the relative precision at a given confidence level, the number of surveyed sites in each new stratum, and their associated weights. The poststratification tool is developed in R/Shiny and can output data in HTTP and spreadsheet formats.

Data Modeling Tool

The poststratification tool discussed above can enable CEC forecasters to compare basic attributes of the Commercial Forecast Model with CEUS Data. These include floorspace, fuel saturations by end-use, and employment within commercial sectors. It is also possible to estimate from the CEUS data, the relative contributions to annual energy usages associated with an array of predictor attributes. These attributes may include:

- Building-type or NAICS code
- Vintage (either new or existing as defined in the 2022 CEUS, or other user-defined schemes)
- Forecast Zone (or other geographical zone that can be defined by users)
- Site square footage and heated and cooled square footage (and by fuel type)
- Presence of commercial cooking equipment (and % electric/gas)
- Presence of commercial refrigeration or refrigerated floorspace
- Presence (and capacity) of IT server equipment
- Total employment in FTE
- Annual business hours of operation
- Number of Hospital Beds/Meals Served/Students for Hospitals/Restaurants/Schools

Possible applications of this model may include potential load disaggregation by end use, solar or other generation induced demand studies (e.g., do customers become less efficiency conscious once they have solar power?), and a validation or cross comparison tool for the Commercial Forecast Model. The relative importance of predictor attributes can also guide the development of future commercial sector survey instruments. The data modeling tool is developed in R/Shiny and can output data in HTTP and spreadsheet formats.

Overview of Statewide Energy Usage

Definitions

This section provides an overview of statewide electric and gas consumption of commercial buildings. The term statewide in this report, unless otherwise indicated, means to pertain to the entirety of California. The CEUS survey did not survey the entire state. The CEUS project's sample frame consisted of electric utility accounts that are expected to be associated with commercial entities based on NAICS codes in customer information system (CIS) databases of LADWP, PG&E, SCE, SDG&E, and SMUD, and therefore did not cover 100% of the state. Therefore, it is important to note the following sources of exclusions to the CEUS survey:

- Forecast Zones 0, 14, 15, 18, 19, and 20 were not surveyed (see Figure 3)
- Customers that had other electric service providers than the five participating electric utilities were not surveyed (e.g., Silicon Valley Power or Roseville Electric, etc.)

- Commercial customers that had not been classified as commercial entities due to a lack of valid NAICS codes (referred to as "unclassified NAICS codes[3]" in the report)

The CEUS team used data from the CEC's Quarterly Fuel and Energy Report (QFER) data tables to construct scale factors to account for the above sources of commercial energy usage. With these scale factors, the CEUS team presents statewide results.

Some key terms used in the following discussion are defined below:

Floor Stock: This term describes the total amount of floorspace. At the statewide level, units of thousand square feet (kft^2) or even millions of square feet are appropriate. Floor Stock for any given commercial subsector (Building-type) and Forecast Zone is calculated as the product of the survey-site level square footage for sampled buildings within the Building-type and Forecast Zone, and their corresponding expansion weights.

Energy Intensities (EIs): Energy Intensities are defined as the ratio of total fuel-specific annual energy usage for a given set of buildings to the total floor stock for those buildings. For one building, the electric energy intensity is its annual electric consumption divided by its floorspace in units of square feet.

Results

Table 1 shows estimates of statewide floor stock, energy intensities, and energy usage by Building-type, while Figure 1 and Figure 2 show the overall electricity and gas usages in the commercial sector respectively, broken out into the 12 separate Building-types.

Based on survey data, the total commercial sector floor stock in California is estimated at 8,810,237 kilo-square feet, and total electricity usage is 98,888 GWh, and total natural gas usage is 2,379 million therms (Mthm)[4].

3 The survey has assigned 2017 NAICS codes to all sites. Utility CIS include several generations of NAICS codes (e.g., 2002, 2007, 2012, 2017). We use the term "unclassified NAICS" to represent utility accounts where an economic activity has not been identified.

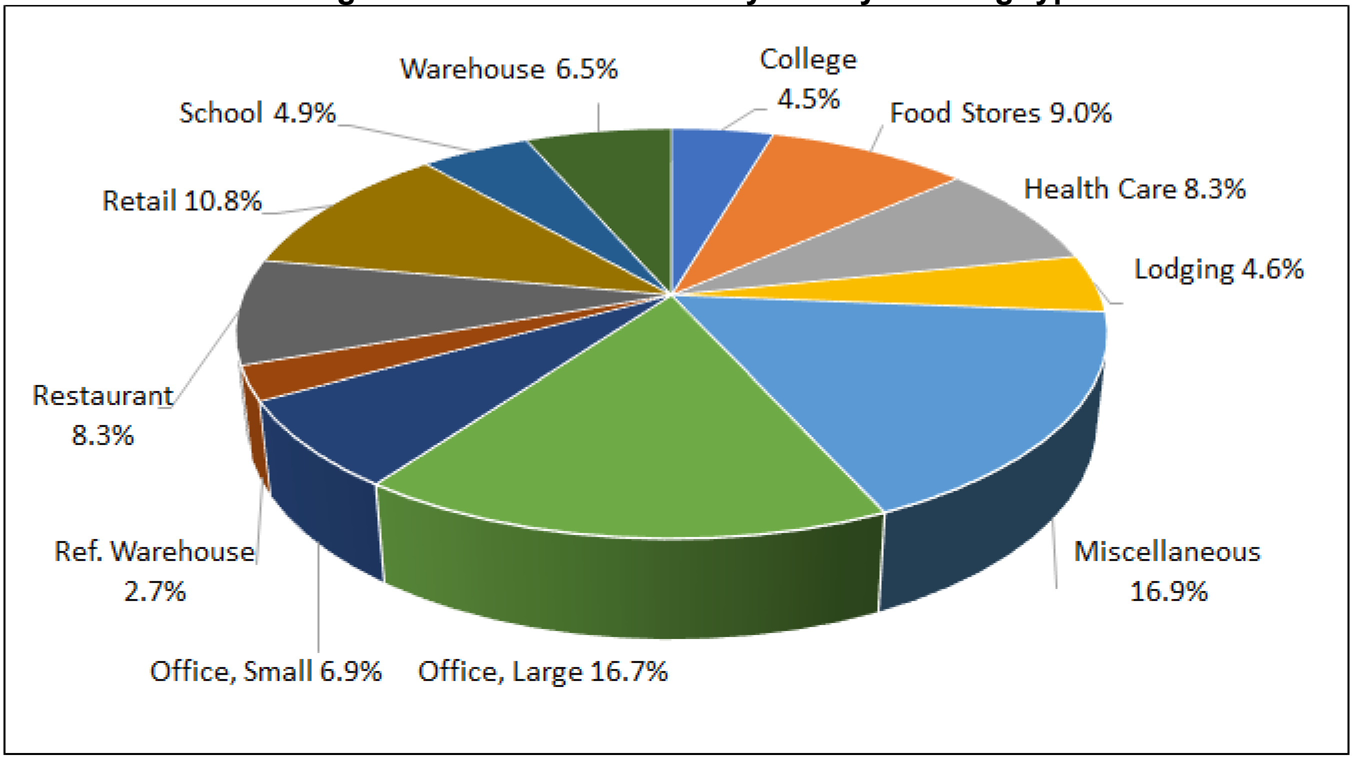
4 The CEUS team determined customer energy usage primarily from billing data provided by the five electric and one gas participating utilities. Billing data included up to two years of usage per customer and depending on the utility spanned between December 2015 and October 2018. All data had calendar year 2017 in common. The team used all available data for a given customer to calculate energy usage.

Table 1: Overview of Statewide Energy by Building-type

Building-type	Floor Stock (kft^2)	Annual Electric Intensity (kWh/ft^2)	Annual Electric Usage (GWh)	Annual Gas Intensity ($kBTU/ft^2$)	Annual Gas Usage (Mthm)
College	384,440	11.6	4,476	56.2	202.5
Food Stores	241,676	36.7	8,864	57.4	138.8
Health Care	480,002	17.0	8,179	61.8	281.3
Lodging	471,706	9.6	4,516	33.9	159.2
Miscellaneous	1,704,294	9.8	16,714	32.7	551.2
Office, Large	1,321,787	12.5	16,558	18.0	236.9
Office, Small	771,141	8.9	6,871	18.4	142.0
Refrigerated Warehouse	145,619	18.0	2,622	3.6	5.2
Restaurant	223,831	36.8	8,229	206.7	462.7
Retail	1,126,373	9.5	10,650	7.1	78.3
School	686,285	7.0	4,801	10.5	72.1
Warehouse	1,252,308	5.1	6,428	4.1	49.6
All Commercial	**8,809,461**	**11.2**	**98,909**	**27.5**	**2,379.7**
All Office	**2,092,928**	**11.2**	**23,430**	**18.2**	**378.9**
All Warehouse	**1,397,927**	**6.5**	**9,050**	**4.0**	**54.7**

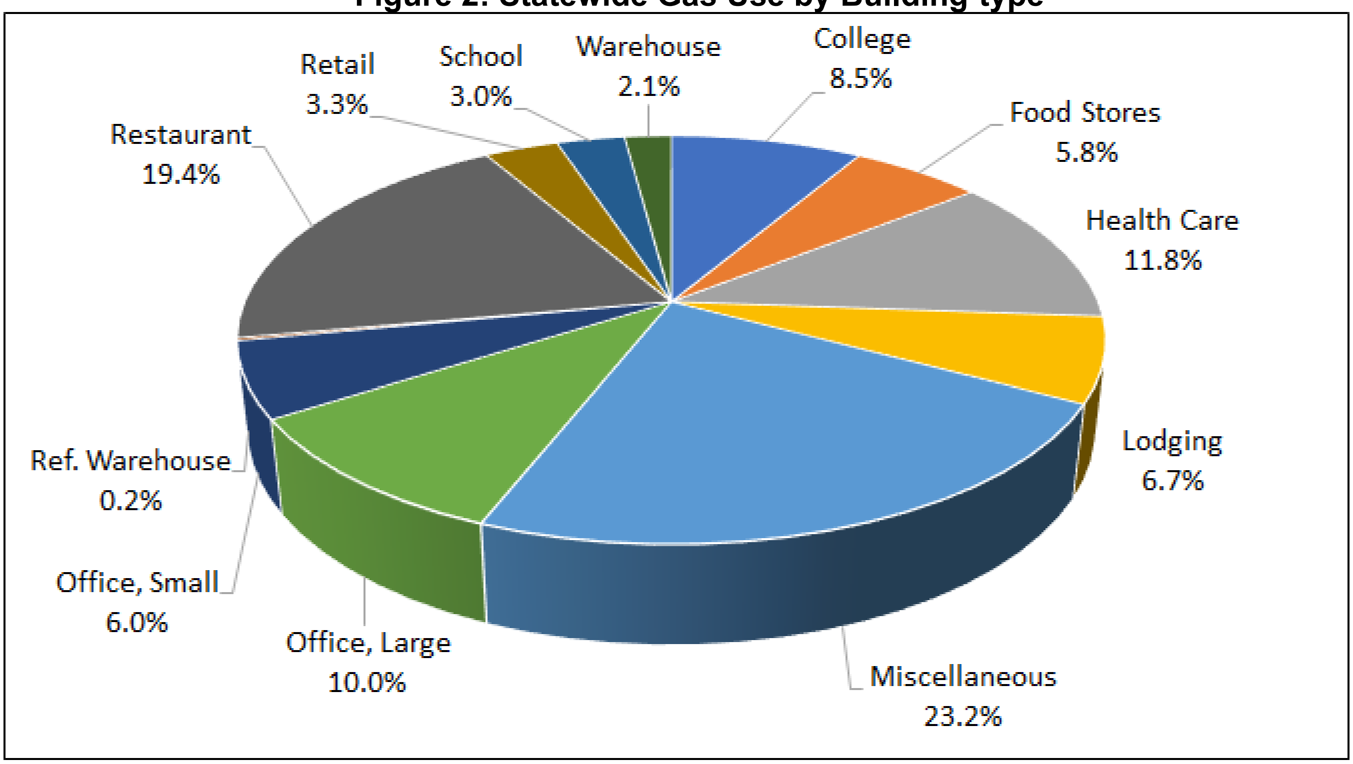
Source: 2022 CEUS

Figure 1: Statewide Electricity Use by Building-type



Source: 2022 CEUS

Figure 2: Statewide Gas Use by Building-type



Source: 2022 CEUS

Comparison of Energy Use in 2006 and 2018

Both the 2006 CEUS and 2022 CEUS surveyed PG&E, SCE, SDG&E, and SMUD, and this report provides comparisons of key energy metrics between the 2006 CEUS and the 2022 CEUS for those service territories. The 2022 CEUS includes estimates of energy metrics from 2018, the base year characterized by the survey sample frame, and also results adjusted to reflect 2022 values.

Overall commercial floorspace grew by 21% from 2006 to 2018. Electric energy usage increased 13% statewide while electric intensity decreased by 7% statewide, although the CEUS team observed anecdotal evidence of increased energy usage in computing-intensive business activities, such as data centers and analytical services. Gas usage, on the other hand, increased by 33% driven primarily by increased floorspace, but also due to a 9% increase in gas energy intensities. The CEUS team noted that likely causes for the increase in gas EI include price elasticity and heating interactive effects associated with decreased electric loads in gas-heated spaces. While the team found anecdotal evidence of CHP and fuel cell installations over the last 15 years, it is difficult to gauge whether these installations outweighed the natural expiration of such generators over the same time period.

Comparison of Energy Use in 2018 and 2022

Overall commercial floorspace grew by 4% from 2018 to 2022. Electric energy usage decreased 7% statewide while electric intensity decreased by 11% statewide. Gas usage decreased by 6% driven by a 10% reduction in energy intensity, but unevenly among Building-types. The main decrease in energy usage is associated with commercial cooking, while commercial space heating energy intensities appear to have increased between 2018 and 2022.

Lessons Learned

The CEUS project was funded by several funding sources, each with different initiation and expiration dates. Project initiation was delayed until all major funding sources could be secured, but the CEUS team had to race to complete all EPIC-funded work prior to the funding expiration date of June 2020. The short duration between January 2018 and March 2020 was a major challenge to the project team. To ensure maximum utilization of EPIC funds, staff that would have been assigned to collect data in LADWP service territory focused on EPIC-funded data collection in SCE instead. While the team managed to complete the EPIC-funded portion of the study prior to the funding expiration, the delay in on-site data collection in LADWP service territory proved problematic as the COVID-19 pandemic caused statewide shutdowns exactly as the team launched the LADWP survey effort.

Recommendations

Recommendations presented in CHAPTER 9: Recommendations, include lessons learned from carrying out the 2022 CEUS and ideas for future research, and are summarized below.

Secure and Synchronize Project Funding Sources

Our primary recommendation related to project timing is to attempt to synchronize funding sources and to gain early participation commitments from utilities to allow the project to proceed at or near the designed data collection rate. A secondary recommendation is to extend the duration of funding sources for large and long-term projects such as CEUS to accommodate potential delays and unforeseen events.

Electric and Gas Meter Reconciliation

Due to the large sample size, it was a challenge to match gas meters with survey-sites that have different gas and electric providers. The CEUS team developed successful strategies for matching gas meters and associated energy usage to survey-sites that previously had only electric usage information available (primarily sites in SMUD, LADWP, and SCE service territory), and for validating those matches. These involved fuzzy matching of text and numeric fields between different utility databases and statistical modeling to discern genuine matches, as well as manual review of sites that had anomalous energy usage intensities (kWh/ft2 and kBTU/ft2) relative to facilities with the same NAICS code.

Using Commercial Real Estate Data to Identify Newly Constructed Buildings

The CEUS team found that the primary benefit of commercial real estate data was to enhance the sample frame with building construction dates, thereby enabling the survey to oversample newly built facilities. While oversampling new construction added value to the project, there was a significant labor cost associated with matching over 600,000 unique sample points derived from utility CIS data to a comparably sized list of properties based on street address or geographical coordinates. However, some of the automation schemes developed in the effort helped in the gas and electric meters reconciliation effort described above. In retrospect, it may have been more effective to formulate mid-survey data requests to utilities for such newly created accounts or premises.

Develop a Parametric Modeling Framework Informed by CEUS Data

Building energy simulation models can be used to estimate potential impacts of energy efficiency measures such as window shading schedules, ventilation control schemes, "smart" thermostats, as well as more basic, but impactful changes such as gas to electric space heating or cooking retrofits. Some of the research conducted at the CEC involves characterization of large populations of buildings, which could involve utilization of hundreds or even thousands of building simulation models. A parametric building energy simulation modeling framework, with the ability to specify and batch-run hundreds of models, could facilitate this type of research. With this modeling framework, CEC researchers can run thousands of individual models and aggregate results into meaningful measure-level impacts both at the individual customer level (for example, medium, low-bound, and high-bound per-customer savings from a given measure or code enhancement), as well as localized or aggregated grid-level impacts for any hour of a typical year.

Track Emerging Technologies

This CEUS survey collected information related to behind-the-meter generation, battery storage, and electric vehicle charging. Battery storage and electric vehicle charging are nascent but rapidly growing fields, and a concern is that data collected prior to 2020 would not be representative of California five or ten years from now. The authors recognize that CEC staff are engaged in multiple efforts that focus on electric vehicle charging infrastructure, electrification, and distributed generation. Since many of these technologies are closely related, and relevant to forecasting and other demand side management efforts, the recommendation is to continue to collect data, and to maintain data in a unified and readily accessible format.

Develop a Forever Cohort

A subset of 2022 CEUS participants could be recruited into a cohort that can be asked to complete a modified version of the CEUS form online on an annual basis for years to come. The survey can serve to track important trends in building and transportation electrification, behind the meter generation, battery storage, and changes in commercial space utilization. Another benefit from this approach is that participants in this cohort could be recruited for other purposes, such as end-use metering, more detailed data collection, or focus group studies.

CHAPTER 1: Introduction

Overview

This report presents methods and findings of the largest commercial sector building energy usage survey conducted in California to this date. ADM Associates conducted the survey under contract to the California Energy Commission. Matrix Energy Services and Davenergy Solutions were subcontractors to ADM Associates in this effort. The survey was funded primarily by the CEC's Electric Program Investment Charge (EPIC) Program and the Energy Resources Programs Account (ERPA) and the Petroleum Violation Escrow Account (PVEA).

Background

The CEC uses data related to building energy usage characteristics to inform energy demand forecasting, to assess energy efficiency opportunities, and to inform research related to rulemaking. Energy demand forecasts rely heavily on estimates of total floorspace for 12 commercial subsectors known as Building-types, as well as electric and gas fuel saturations and energy usage for ten different end-uses for each Building-type. All of these quantities have historically been quantified separately for 16 geographical zones known as Forecast Zones. In 2015, the CEC started to disaggregate demand forecasts into 20 Forecast Zones that are associated with resource planning areas used by the California Independent System Operator (CAISO) to manage the state's electricity grid. The desire to disaggregate energy demand forecasts into smaller geographical regions was the primary design driver of this Commercial End-Use Survey (CEUS). While many previous CEUSs did not have enough sample points to make robust population estimates at the Forecast Zone level by Building-type, this project was charged with the task of developing that capability at an even finer level of granularity. In December of 2015, the CEC issued a request for proposals (RFP), that identified project objectives and sought a third party to implement the CEUS survey. In spring of 2016, ADM Associates, Inc. was selected to conduct the survey on behalf of the CEC.

Project Objectives

Through agreement number 300-15-011, the California Energy Commission (CEC) has contracted with ADM Associates, Inc. (ADM) for the Commercial End-Use Survey (CEUS). The goals of the project, according to the RFP developed by the CEC are:

- Increase the sample size for on-site surveys significantly above that of historical levels to support disaggregation of energy demand forecasts.
- Calculate end-use fuel saturations at the Forecast Zone level by Building-type.
- Calculate commercial floorspace estimates at the Forecast Zone level by Building-type.
- Calculate annual whole building energy use estimates at the Forecast Zone level by Building-type.
- Develop annual whole-building hourly load profiles at the Forecast Zone level by Building-type.

- Develop a potential methodology, and evaluate the pros and cons, for over-sampling newly constructed commercial facilities so that statistically significant population estimates can be made of the most recent building stock vintage.
- Examine the potential for using purchased commercial real estate data to benefit the CEUS design or as a means of collecting commercial end-user characteristics.
- Accurately characterize building economic activity and assess North American Industry Classification System's (NAICS) code misclassification.
- Develop CEC staff expertise in the evaluation of sample design alternatives, construction of sampling frames and recruitment pools, computation of sample weights and population estimation techniques.

Summary of Study

The 2022 CEUS is the largest volume survey in the history of the CEUS. The team conducted over 24,000 surveys of electric power customers from Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E), Southern California Edison (SCE), Los Angeles Department of Water and Power (LADWP), and Sacramento Municipal Utility District (SMUD).

The general scope of work included on-site surveys to collect information on building floor-space, business activities, operation schedules, and fuel saturations by end-use. Data were collected primarily through tablet computers and transferred to ADM's Sacramento headquarters for validation and processing. However, the project team conducted remote surveys from March 2020 to the end of the project in response to the COVID-19 pandemic. The project team also conducted additional research activities as directed by CEC staff. These tasks included:

- Develop a Poststratification Tool in R/Shiny to enable CEC researchers to stratify survey data into different groupings than the project sampling strata.
- Develop a statistical modeling tool in R/Shiny to model building energy usage as a function of key quantitative data fields collected by the survey.
- Update the Hourly Electric Load Model (HELM 2.0) [5], which originally accommodated PG&E, SCE, and SDG&E, to include SMUD and LADWP.
- Conduct ongoing maintenance for the HELM 2.0 and add a load profile to characterize behind-the-meter storage.

The overall approach to the survey is summarized below.

Survey Design

The survey covered the electric service territories of LADWP, PG&E, SCE, SDG&E, and SMUD, and the gas service territory of SCG. All participating utilities provided customer information systems information, including business identification and physical location, annual energy usages, and business classification through the North American Industrial Classification System (NAICS). The

---

5 The 2.0 version of the Hourly Electric Load Model (Baroiant, 2019) was developed with EPIC-funding in 2019 and converts annual electric demand forecasts by end use to hourly end-use demand forecasts.

utility data formed the basis of the project sample frame, with the primary sampling unit defined as a *survey-site.* The survey-site is a key concept to this project, and is defined below:

Survey-Site: Defined as a single commercial entity operating in a contiguous commercial space (i.e., all or part of one or more commercial buildings that are not separated by other buildings, or by public roads).

The survey sought to maximize the sample size while maintaining only the data fields that are essential to project goals.

Sample Design

The most prominent feature of the CEUS sample was its large size. The initial target sample size was 26,516 sites, although since 2020, the project faced major logistical and budgetary challenges caused by the COVID pandemic. As a result, the target sample size was reduced to 24,956. With such a large sample size, sample design considerations focused on multiple project goals such as preserving the ability to post-stratify along finer geographical and business subsector delineations, oversampling new construction and importantly, on developing a sample design that can be monitored and executed at rates of 50-100 on-site visits per week. The sample was stratified by utility service territory, Forecast Zone, Building-types, and two building vintages. Within those categorical strata, there were two to five usage-based strata. Chapter 2 describes the sample design process in greater detail.

Survey Implementation

Survey implementation accommodated a large sample size relative to the time and budget available for the survey. The overall sampling algorithm placed each candidate survey-site into one of three categories associated with recruitment mode. The largest facilities, and those that were under a centrally controlled organization, such as corporate chains, state universities, or health management organizations, were assigned to senior project staff for recruitment. All other survey-sites were eligible to be recruited by call center staff. Smaller facilities with general public access were also eligible for recruitment through door-to-door canvassing by CEUS surveyors. The project team had offices in Sacramento, Fremont, and San Diego. Overall travel was minimized by hiring and training local staff, who typically completed two to three surveys per workday. After March 17,2020, all surveys were conducted remotely to minimize the chance of COVID transmission.

On-Site Data Collection

Surveyors used tablet computers and a web-based app (CEUS Tool) developed for this project to perform on-site data collection. The CEUS Tool included real-time validation logic, drop-down lists to standardize input data, and provided a means to automatically link photographs taken by surveyors with corresponding survey-sites. Data collection included a walk-through of the facility to collect information on the presence and fuel sources of major equipment, and to measure floorspace, and sub-spaces served by various combinations of heating, ventilation, air conditioning (HVAC) and refrigeration equipment. Surveyors interviewed site-contacts to assess primary business activities, to inquire about past building additions and renovations, and to collect information on facility occupancy, operation schedules, and other factors that can influence energy usage.

Remote Data Collection

The project team developed two modes of remote data collection to avoid social contact during the COVID pandemic. The first mode of remote data collection involved a combination of interviews, email communications, and electronic data transfer between survey participants and project staff. This mode of data collection was particularly suited to large and complex survey sites with knowledgeable facilities' staff, such as universities and hospitals. ADM also conducted 600 online surveys with an online survey campaign directed at smaller facilities.

Data Validation

The survey included several layers of data validation. The initial level of validation took place in the tablet computer, at the time of data entry. Inconsistent, or unreasonable values were either prohibited, or used to generate specific warning messages to surveyors. A site could not be submitted if there were significant data gaps. Surveyors were encouraged to submit sites within one or two business days of the on-site visit and were allowed to maintain a queue of at most 12 partially completed sites that may need follow-up data collection activities. This practice ensured that analysts were able to access survey data and address data validation issues in a timely manner. ADM and CEC staff jointly developed over 100 distinct quality control (QC) criteria, which were algorithmically applied on each completed survey-site. These QC algorithms generated follow-up items for ADM analysts and surveyors. Remediation efforts could include correction of clerical errors, follow-up calls to survey participants for clarification and in some cases, a follow-up visit to confirm measurements or equipment characterizations. In addition, following the completion of data collection, CEC and ADM staff held weekly quality control working meetings in the final months of the project to ensure data quality and comprehensiveness. In this process CEC staff reviewed over 400 key data fields for 23,000 surveys and over 100,000 photographs taken on site, and provided actionable feedback to ADM. Quality control is particularly important for this CEUS survey since the extremely large sample size imposed practical limitations to time available to surveyors on site. Moreover, all surveys from mid-March 2020 to the end of data collection were conducted remotely, and therefore required thorough review prior to inclusion in the final survey data.

Survey Data Analysis

Although the 2022 CEUS was a high-level survey, the digital data collection process resulted in a staggering number of primary data fields. The ultimate data set included thousands of data fields, many of which were associated with physical partitions of buildings, fuel saturations, meters, occupancy schedules, and end-use equipment characterizations. ADM staff processed the primary data by aggregating numerous data fields associated with individual operation schedules, building partitions, and fuel saturations, into useful site-level variables such as the total gas-heated square footage, annual full-time equivalent (FTE) labor, weekly and annual hours of operation, etc. The resulting data set enabled the joint QC effort described above, and when coupled with site-level expansion weights, facilitated construction of charts and tables presented throughout this report.

Sector-Level Results

The CEUS data set can be used for numerous research and analysis purposes. As part of the project, ADM developed a means to quickly access the CEUS data and develop user-specified metrics, at user-specified levels of stratification. In this report, the following characteristics are estimated at the Forecast Zone and Building-type level:

- Floor stocks,
- Saturations or penetrations for various end-uses,
- Fuel shares,
- Electric and gas energy consumption
- Electric and natural gas energy intensities (EI), which express total energy consumption per premise square foot, and
- Hourly whole-building load profiles.

Report Organization

There are four main documents available to describe the 2022 CEUS survey. This report summarizes survey methodology and key findings. The appendices to this report are presented as a separate document. The CEUS Research Plan was a standalone supplemental report, and discussed survey design and implementation considerations, motivated the sample design, and drew from lessons learned from a limited implementation effort to "pretest" project operations and infrastructure. The CEUS Sample Design Report was a standalone document that explains the CEUS sample design.

CEUS Report Structure

This report is organized as follows:

- Chapter 1 introduces the survey and guides the reader through the rest of the report.
- Chapter 2 describes the survey sample design.
- Chapter 3 discusses survey design, training, pretest, and implementation.
- Chapter 4 discusses the attribution of electricity consumption to each survey-site. This includes aggregation of meters and buildings into survey-sites, meter reconciliation, and weather normalization of energy usage data.
- Chapter 5 discusses key definitions and concepts related to data analysis.
- Chapter 6 summarizes the survey results.
- Chapter 7 discusses trends in commercial building energy usage
- Chapter 8 discusses NAICS code correspondence between utility data and the CEUS survey
- Chapter 9 discusses lessons learned and recommendations for future work
- References and a list of acronyms follow the Appendices.

CEUS Report Appendices

The CEUS report (CEC publication CEC-200-2023-017) contains the following appendices:

- Appendix A – CEUS Survey Instrument
- Appendix B – Annotated CEUS Survey Instrument
- Appendix C – Recruitment Letters
- Appendix D – Recruitment Script

- Appendix E – Data Collection Protocols
- Appendix F – CEUS Database Dictionary
- Appendix G – NAICS to Building-type Map
- Appendix H – Detailed Sample Tables
- Appendix I – Quality Control
- Appendix J – Expansion Weights (Spreadsheet)
- Appendix K – Results at Building-type and End-Use Levels (Spreadsheet)
- Appendix L – BTM Generation and Electrification
- Appendix M – Scale Factors
- Appendix N – Unscaled Results at Building-type and End-Use Levels (Spreadsheet)
- Appendix O – Comparison of as-found to utility-assigned NAICS codes (Spreadsheet)
- Appendix P – Comparison of Saturations, Penetrations, and Fuel Shares (Spreadsheet)

Affiliated Reports

The CEUS Research Plan motivated and designed the 2022 CEUS Survey. The report is available from the CEC. The CEUS project also funded capability enhancements for the CEC's HELM 2.0 model, which is described in CEC publication CEC-500-2019-046.

CHAPTER 2: Sample Design

Introduction

The project team considered several sampling scenarios before finalizing the project sample design. All alternate sample designs shared common definitions of the sampling unit and the sample frame but differed in approaches to stratification and sample allocation. The overall goal was to develop a sample design that was consistent with study goals and was reasonably achievable. Key design considerations included the following:

- Increase the sample size for on-site surveys significantly above that of historical levels to support disaggregation of energy demand forecasts.
- Calculate all key metrics at the Forecast Zone level by Building-type.
- Develop a potential methodology, and evaluate the pros and cons, for over-sampling newly constructed commercial facilities so that statistically significant population estimates can be made of the most recent building stock vintage.
- Examine the potential for using purchased commercial real estate data to benefit the CEUS design or as a means of collecting commercial end-user characteristics.
- Incorporate realistic response rate assumptions into the sample design.
- Use survey design elements to minimize oversampling of strata that may occur at high data collection rates.
- Surpass, by significant margins, the statutory sampling precision target of ±5% at the 95% confidence level.

Sampling Unit

The definition of the sampling unit is connected to the choice of the sample frame. The CEUS survey benefits from the availability of comprehensive customer information systems (CIS) data from utility companies [6]. Most utilities have clustering algorithms that assign accounts and meters to one related cluster of meters or buildings, which are called *premises*, *service addresses*, or *service points*. In the previous CEUS, the term premise was used to refer to sampling units. In the current CEUS, the term *survey-site* represents a physical site that corresponds to a sample point. The project team used a simple algorithm to cluster meters and accounts into survey-sites, rather than relying on utility clustering algorithms or premise definitions. This was done in part to maintain consistency with past efforts, and in part to put sampling units from different utility service territories on equal footing. The algorithm is defined as follows:

6 Similar surveys in other regions are challenged by impracticalities in obtaining standardized CIS data from scores of utilities that may serve a geographical region similar in size to California.

- Standardize business and street names through the following steps:
  - Term substitution (e.g., "California" or "Calif" → "CA")
  - White space removal
  - Removal of special characters such as +, /, -, etc.
  - Capitalize all letters
  - Retention of the first 15 characters
- Standardize Street Names
  - Term substitution (e.g., "BLVD" or "Boulevard" → "BL")
  - Removal of special characters such as +, /, -, etc.
- Search within ±20 in street number, after matching customer and street name
- Search only on same side of the street (odd vs. even street numbers)

The above algorithm is essentially the functional definition of a survey-site. That is, a survey-site is defined for CEUS as *a contiguous location, served by a collection of meters, and controlled by a single utility account holder*. A contiguous location is defined as a cluster of adjacent buildings that are not separated by public roads.

Sample Frame for the Survey

The utility CIS and billing data comprise the basis of the sample frame. These data sets tend to have the following structure:

- One row per utility meter
- One or more meters per account
- One or more accounts per customer, and per utility premise (similar to our survey-sites, as described above)

For each row of data, utilities provide information that allows the development of qualitative and quantitative strata for sampling purposes. Some important examples of these fields include:

- Customer electricity and gas usages on a monthly basis
- Customer contact information, service address
- At least one NAICS code for each customer

In addition to the above fields, approximately 70% of utility records are matched to third party real estate data. For these buildings, the real estate data provides additional information such as total property square footage, a Building-type assignment, building construction dates, and any dates associated with major building additions or renovations. The construction dates in particular allowed the CEUS team to identify and to oversample newly constructed facilities.

Geographical Areas Covered by CEUS

The electric service territories of LADWP, PG&E, SCE, SDG&E, and SMUD are included in the 2022 CEUS. In this chapter, the term "survey-wide" is used to pertain to electricity customers of LADWP, PG&E, SCE, SDG&E, and SMUD, which are expected to be commercial entities based on their NAICS codes on file with their electric service provider. The term survey-wide differs from statewide in the following ways:

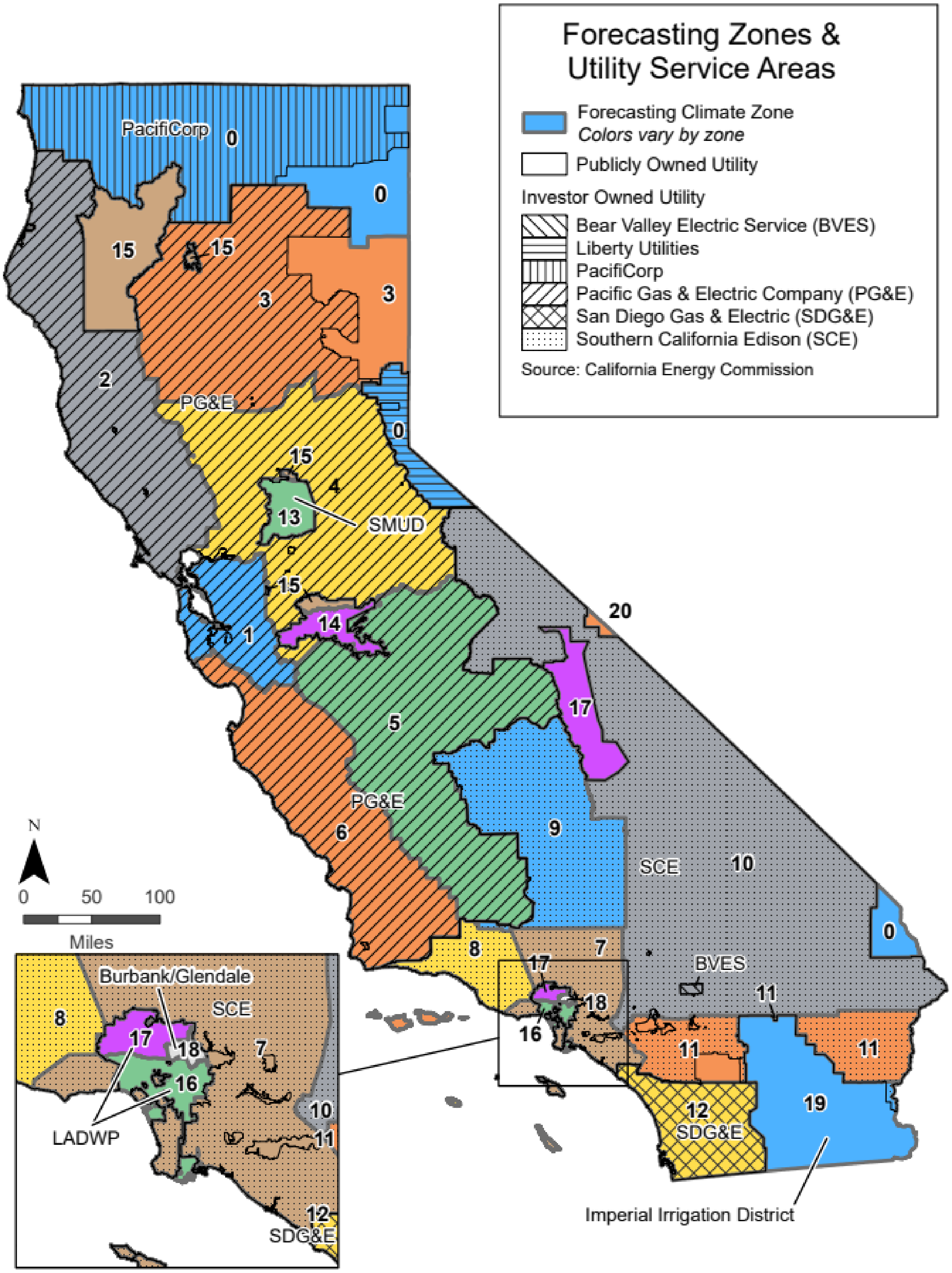
- Survey-wide does not include commercial customers of LADWP, PG&E, SCE, SDG&E, and SMUD that did not have associated NAICS codes at the time that the CEUS team developed the sample frame in 2018 (Unclassified NAICS).
- Survey-wide does not include customers of nonparticipating electric utilities.
- Survey-wide does not include customers in Forecast Zones 0, 14, 15, 18, 19, and 20.

Geographical Strata in Energy Commission Forecast Model

Since 2015, the CEC has used 20 Forecast Zones, as shown in Figure 3 below. Geographical stratification in the 2022 CEUS follows present CEC Forecast Zone definitions, with one modification: Forecast Zone 12 for SDG&E was split into inland and coastal components. SDG&E has four native subzones in its CIS: Coastal, Inland, Mountain, and Desert. The Coastal subzone has a larger population than all other subzones combined. For the CEUS survey, the remaining three subzones were combined into a general *Inland* zone, and Zone 12 was thus separated into 12c (12 coastal) and 12i (12 inland) zones.

Note that in Figure 3, colors are used to differentiate adjacent Forecast Zones, but do not otherwise indicate a relationship between similarly-colored Forecast Zones.

Figure 3: Map of California Energy Commission Forecast Zones[7]



Credit: CEC Staff

[7] Zone Zero is served by utilities based outside of California and is not formally a part of CEC's forecast.

Building-types in Energy Commission Forecast Model

The CEC's Commercial Forecast Model disaggregates the commercial sector into 12 subsectors, which are represented by the 12 Building-types below. These subsectors are determined as groupings of NAICS codes, with the current NAICS to Building-type assignments provided in Appendix G. Large and small offices have identical NAICS codes, but are differentiated by floorspace, with large offices defined as buildings above 30,000 square feet in area. Since floorspace was not known in advance of sampling, large and small designations for the office Building-type are approximated through inspection of annual energy usage, with 500 MWh/year acting as the threshold between small and large offices[8].

- College
- Food/Grocery
- Health Care
- Hotel
- Miscellaneous
- Large Office
- Small Office
- Refrigerated Warehouse
- Restaurant
- Retail
- School
- Warehouse

Vintages in Energy Commission Commercial Forecast Model

As of the start of the 2022 CEUS, the Commercial Forecast Model included ten vintages, with the characteristics of each building vintage defined by building standards requirements and construction practices of that era. The vintages are defined as pre-1979, 1979-1983, 1984-1991, 1992-1997, 1998-2000, 2001-2004, 2005-2008, 2009-2013, and 2014-2016, and with the most recent one at the time of the survey design covering the years 2017 through 2019. Although the CEUS survey has not previously sampled along vintages, the CEC identified the potential over-sampling of newly constructed buildings as a study goal.

Sample Frame Stratification

The project team considered several alternative stratification schemes. The merits and risks for various sample schemes were discussed in Technical Advisory Committee (TAC) meetings. Alternative stratifications are briefly discussed at the end of this section. The standalone CEUS Sample Design Report includes a deeper discussion of the pros and cons of various sampling schemes.

8 The 500 MWh threshold is approximately equal to the average energy usage of a 30,000 square-foot office, based on the previous CEUS survey.

Considerations for Sample Frame Stratification

With an ambitious target sample size, it was possible to address numerous sampling goals without sacrificing adequate overall precision. The main goals addressed by stratification were:

- Increase the sample size for on-site surveys significantly above that of historical levels to support disaggregation of energy demand forecasts.
- Develop floorspace estimates and end-use fuel saturations at the Forecast Zone level by Building-type, with adequate sampling coverage to enable post-stratification such as:
    - Increase the number of distinct Building-types.
    - Dissect the data into finer geographical zones.
    - Increase the number of vintages, maintaining adequate representation for each vintage.
- Oversample new construction.

The project team considered a number of options related to stratification and sample allocation by developing hundreds of simulated samples, using CIS data provided by IOUs. For each simulated run, key target metrics such as sampling precision at the survey-wide, planning area, and zonal levels were compiled, along with practical considerations such as the necessary response rates, overall number of strata, and number of sites in the must-have or certainty strata.

Stratification Design

The final stratification scheme included qualitative strata to account for Building-types, geographical zones, and vintages. Within these qualitative strata, there were two to five strata that were based on annual energy usage.

Geographical

The geographical stratification was largely along CEC Forecast Zones. The PG&E service territory included six Forecast Zones, the SCE service territory included five Forecast Zones, SDG&E's Zone 12 was further disaggregated into 12-inland and 12-coastal. LADWP service territory included two Forecast Zones, and SMUD service territory was comprised of one zone.

NAICS Groupings

In keeping with past CEUS efforts, the 12 Building-types in the Commercial Forecast Model are taken as qualitative strata for sampling purposes. However, in an effort to increase survey resolution with respect to business activity, the survey form accommodated a weighted superposition of up to three distinct Building-types for each survey-site, in addition to a primary NAICS code.

Vintages

Prior CEUS efforts did not stratify along vintages. One of the CEC's goals for this survey was to evaluate the potential of oversampling newly constructed buildings. The rationale for oversampling newly constructed buildings was to gather statistically significant information to inform the newest vintages of buildings in the CEC's Commercial Forecast Model. In this effort, ADM used billing frame data from IOUs and ran simulated samples which oversample new construction in varying degrees. Expected survey-wide precision levels showed insignificant degradation even if those facilities that are known to be newly constructed were oversampled by

200% to 300%. Oversampling new construction does not impact overall results in a significant manner because fewer than 4% of all extant buildings are known to be constructed after 2005. This was in part due to a dramatic and sustained downturn in new construction in the years 2008-2015, and in part because only 70% of buildings in the frame have known construction dates. The project team decided to construct two vintages, and to define all buildings constructed in 2006 or later as the *new* vintage. Facilities that were not known to be constructed in this period were placed into the *existing* vintage. The year 2006 was selected as the threshold to define the new vintage because later dates would result in too few buildings in the sample frame that correspond to the new vintage, and also because the year corresponded to when the 2005 code change would start to impact building efficiency.

Quantitative Strata

Each Building-Zone combination in the *Existing* vintage has four quantitative sampling strata, potentially with a fifth *Certainty* stratum that contained sites with exceedingly high energy usage. Each Building-Zone combination in the *New* vintage has two quantitative sampling strata, potentially with a third *Certainty* stratum. In rare cases, there may be just one or two buildings of a type and vintage, in a given zone. In these cases, a census was attempted. The boundaries between quantitative strata can be set in a number of ways. The team researched methods such as manual boundary determination, geometric determination (Gunning and Horgan, 2004), cumulative root determination (Dalenius and Hodges, 1959), and iterative algorithmic optimization (Lavallee and Hidiroglou, 1988). The CEUS team used the iterative approach of Lavallee and Hidiroglou, as it tended to outperform other methods and was no more difficult to implement in the *Stratification* package available in the R statistical computing framework [9].

Alternative Stratifications Considered

The project team considered increasing the number of strata to include building sub-types, geographical sub-zones (similar to what was done for Zone 12) and including three or more building vintages. Each of these approaches, while offering advantages, presents a common risk: The number of distinct strata quickly grow to many thousand, rendering execution of the survey unmanageable. The final stratification included 1,305 distinct strata, with an average of approximately 21 sample points per stratum. The team also considered reducing the number of strata to cover just Building-types or just Forecast Zones. In these cases, although a perfectly random sample would achieve equivalent results to the base sample design, there was an increased chance of underrepresenting or over-representing certain geographical market sectors.

More Building-types

The team considered an expansion of Building-types by disaggregating the miscellaneous, small office, large office, and health care sectors into subsectors. This could increase survey resolution with respect to specific business activities. The main practical limitation to this approach was that a more detailed NAICS to Building-type classification system did not exist, and a new categorization may have involved numerous stakeholders and potentially delayed the project.

---

9 The R software (R Core Team, 2018), R-Studio (RStudio Team, 2016), and the Stratification package (Baillargeon and Rivest, 2017) are available free of charge online.

Furthermore, the stratification would necessarily be based on initial NAICS coded in CIS data. Initial NAICS codes are key to the sampling process but increasing the number of Building-types would create over-reliance on these codes. The TAC decided that additional Building-types are better addressed through post-stratification, using verified NAICS codes that result from the survey. Rather than increasing the number of Building-types, the team decided to add data collection flexibility to the survey form. As a result, any site could be described as a superposition of up to three Building-types, while retaining a primary NAICS code for the site. The project team also recognized that the *miscellaneous* Building-type is the most heterogeneous type, in that it has numerous and disparate NAICS codes and oversampled this Building-type to enable potential subdivision into smaller, more homogeneous sets. The relative heterogeneity of this Building-type was addressed in the overall sampling algorithm described in the section titled Sampling Algorithm.

More geographical zones

The team considered increasing the number of geographical sub-zones within Forecast Zones. Increased geographical zones would provide more homogeneous geographical coverage. However, there was a tradeoff between overall sampling precision and zonal precision. This option was selected for Zone 12, but not for other zones.

More vintages

In addition to the existing and new vintages, the team considered using all nine vintages that are in the Commercial Forecast Model. The main challenge with this approach was that the overall number of strata grew to nearly 4,000. While the project team developed automated measures to minimize oversampling of strata, the team acknowledged that such a large number of sampling strata would render the survey unmanageable. The main reason for this is that there would be thousands of strata with small sample targets (i.e., fewer than five sites). The field effort, however, was expected to yield over 50 surveys per business day. Given that survey-sites could be recruited in multiple, concurrent modes, the detrimental effects of oversampling of strata became too great a risk.

Overall Sample Size

The initial target sample size for the survey was nearly 27,000 surveys. The target sample size was determined at the time that the ADM team responded to the CEC's RFP. Since that time, the scope of the survey instrument expanded to include additional data fields. Although the additional data collection activities tend to increase time spent on site, the team was confident that other cost-cutting opportunities would present themselves during the course of the survey and maintained the target sample size of 27,000. The project tracked closely to the allotted budget through the first quarter of 2020 but suffered significant decreases in productivity after the COVID-19 pandemic. As a result, the project team downsized the target to nearly 25,000 sample points. The downsize included significant cuts to LADWP's sample target since data collection in that service territory occurred entirely during the pandemic and Los Angeles County was acutely affected by the pandemic.

Sample Point Allocation

Sample point allocation is the exercise of dividing the overall pre-determined sample size of 27,000 into the various strata. Initial sample design experiments indicated that a number of potentially viable sample designs and allocation schemes would achieve overall survey-wide precisions near ±1.2%, at the 95% confidence level. The team compared aspects of survey achievability and geographical homogeneity among multiple candidate sample designs, as discussed below.

Post-Stratification Considerations

The commercial facility energy usage distribution is positively skewed, with the top 2% of electricity users comprising about half of the total energy usage. If the best survey-wide precision were the sole consideration, the allocation would necessarily focus on these highest users. Indeed, initial sampling trials with pure Neyman allocation (that is, allocation to a given stratum in proportion to the product of the total energy usage and its coefficient of variation) resulted in nearly all sample points concentrated among high-use customers, particularly in greater Los Angeles and the San Francisco Bay Area. The rest of the state, however, had relatively poor coverage. The primary tradeoff in this sample design is between overall survey-wide precision and precision for subpopulations, whether those subpopulations are defined by geography, commercial subsector, or building vintage. The CEC has emphasized the desire to achieve comprehensive and representative geographical coverage in anticipation that future research efforts would require increasingly finer geographical segmentation. As a result, the project team developed initial precision targets by Forecast Zone and Building-type, which were later adjusted based on availability of any remaining sample points, and by sample execution considerations.

Sample Execution Considerations

Given that the CEUS is a voluntary survey, it is necessary to factor in expected response rates in the sample design. The sample designs that exhibited the best precisions tended to have the highest assumed response rates. The project team decided to plan for a 20% response rate, but with higher response rates for a limited number of strata that present the best opportunities to increase sample precision.

Many survey designs include a number of certainty strata, or strata in which 100% of customers are to be surveyed. If the response rate can approach 100%, then such certainty strata tend to dramatically improve statistical precision. On the other hand, if a survey design calls for a large number of *certainty sites* (or sites in the certainty strata), but only a small fraction of them ultimately respond to the survey, then the achieved sampling precision ends up far worse than the planned sampling precision. The project team opted to include certainty strata, while avoiding overreliance on certainty sites. A total of 392 certainty sites were targeted, which is comparable to the number of targeted certainty sites in the previous CEUS effort.

The overall number of distinct strata was also of concern, as tending to many hundreds or thousands of distinct sampling strata, each with its own quota, is an organizational challenge. The ultimate sample design yielded 1,305 distinct strata, which is considerably higher than the 491 distinct strata in 2006 CEUS [10]. The primary drivers for the increase are the project goals of greater focus on local precision and oversampling new construction. To address the former, the team devised specific energy usage thresholds by zone *and* by Building-type to differentiate sites, as opposed to survey-wide thresholds at the Building-type level. To address the latter goal, the team included vintage-based strata.

Allocation Methodology

The project team investigated various allocation methodologies, including subjective determination of sample points to each stratum, *equal allocation* (equal sample points in each stratum), *Neyman allocation* (in this context, sample points proportional to the product of a stratum's total energy usage and its coefficient of variation), *proportional allocation* (sample points in proportion to stratum population) and *power allocation*, which is a flexible form of allocation that can provide allocation schemes that range from equal to Neyman allocation (Hidiroglou and Srinath, 1993). The team found that equal allocation tends to result in the most even distribution of sample points, which is a key consideration for post-stratification. Neyman allocation results in the best precision, provided the response rates can be raised above the working 20% value for certain strata. Subjective allocation is often used for simplicity, but with over 1,000 strata, proves impractical to this effort. Proportional allocation, on the other hand, does not achieve desired precision levels in large part due to the high positive skew in the commercial facility energy usage distribution. Power allocation is attractive in that it can be tuned to balance efficiency and sampling homogeneity. The team applied both equal and Neyman allocation in an iterative fashion, as described below.

Sampling Algorithm

The project team developed a sampling algorithm to iterate over all strata and to optimize precision given a budget of sample points for each planning area, and rules for identifying certainty sites, limiting sample ratios to achievable response rates, and oversampling new construction. In the following discussion, a combination of a vintage, Building-type, Forecast Zone, and size-based stratum definition is referred to as a *sample cell*, as these are the most elemental building blocks of the sample design.

1. Define qualitative strata along zones, Building-types, and New and Existing vintages.
2. Designate certainty if they each exceed a certain percent of the qualitative strata MWh:
    a. 6 percent for the miscellaneous Building-type
    b. 8 percent for large offices or health care
    c. 10 percent for all other Building-types
3. Limit the number of certainty sites to five or fewer per qualitative stratum.
4. Develop four sampling strata with Lavalee-Hidroglou method (two strata for New vintages) with equal allocation. Strata are numbered in order of increasing energy usage.
5. Allocate initial points with equal allocation.
    a. Assign relative precision targets of ±8 percent with the following modifications:

10 California Commercial End-Use Survey, Itron, 2006, Table 2-10.

    b. Oversample the New vintage by a factor of two.
    c. Oversample the miscellaneous Building-type by 25 percent.
6. After initial allocation, iterate over cells and adjust sample sizes as follows.
    a. Reduce sample sizes, if necessary, for any sample cell with a sampling ratio greater than 20 percent
    b. For any stratum 4 (largest sampled buildings) in the miscellaneous Building-type, increase the sample rate up to 0.4.
    c. For any stratum 4 (largest sampled buildings) in the health care or large office Building-type, increase the sample rate up to 0.3.
7. Use Neyman allocation (optimized at the survey-wide level to distribute remaining sample points across all cells) while maintaining oversample rates for the miscellaneous Building-type, and for the New vintage.

Allocation Among Utilities

The CEUS team started sample design studies as early as possible to enable the start of field work within one month of CIS data receipt from each utility. It was possible to conduct these studies in advance of formal CIS data receipt because the CEC shared, with utility consent, slightly older CIS data from PG&E, SCE, and SDG&E with ADM. SMUD made their data available early to allow for the *CEUS Pretest* in Q1 of 2018. SDG&E data was taken as a proxy for LADWP, as the overall energy usage and number of geographical zones were similar to SDG&E.

During initial sample design runs, the sampling algorithm allocated approximately 10,000 points to PG&E and SCE, nearly 3,000 points each to SDG&E and LADWP, and just over 1,000 points for SMUD. The project team and TAC members questioned whether the algorithmic allocation resulted in adequate emphasis to planning areas, as planning area is not formally considered in the algorithm described above. Furthermore, SMUD data in particular would be used as a proxy for non-SMUD *Northern California Non-California-ISO* (NCNC) planning area. The project team ran a number of simulated samples that suggested a transfer of sample points from PG&E and SCE to other utilities would result in significant improvements for their planning areas (particularly for SMUD), without substantial degradation of results survey-wide, or for PG&E or SCE. Table 2 shows sample points by service territory as initially determined by the algorithm (labeled as Survey-wide Neyman), and two alternatives manually balanced samples. Table 3 shows the expected relative precisions at the 95% confidence level, with those three allocation schemes. After consulting the TAC, the team decided on the *Balanced 2* allocation scheme, and then ran the sampling algorithm with specific sample budgets for each planning area. The Balanced 2 sample was selected because it exhibited better overall balance than the Balanced 1 sample (it had the lowest standard deviations in utility sample sizes and target precisions, and it had the best precision for the smallest utility). The ultimate sample size was slightly smaller than 27,000 in part because the iterative process does not result in exact target sample sizes (unless one runs many iterations), and in part because a small number of sample points were reserved for manual assignment to optimize precision after most of the survey has been completed, and to include any sites that should be considered on the basis of very high gas usage, but may not have been sampled on the basis of electricity usage.

Table 2: Three Sample Size Allocation Methods by Service Territory

Allocation Method	PG&E	SCE	SDG&E	SMUD	LADWP	Total
Survey-wide Neyman	10,225	10,050	2,750	1,125	2,850	27,000
Balanced 1	9,100	9,100	3,275	2,150	3,375	27,000
Balanced 2	8,950	8,950	3,300	2,450	3,350	27,000

Source: 2022 CEUS

Table 3: Expected Relative Precisions at the 95% Confidence Level

Allocation Method	PG&E	SCE	SDG&E	SMUD	LADWP	Total
Survey-wide Neyman	2.26%	2.27%	2.56%	3.67%	2.55%	1.23%
Balanced 1	2.27%	2.28%	2.51%	3.50%	2.50%	1.23%
Balanced 2	2.27%	2.29%	2.52%	3.48%	2.50%	1.23%

Source: 2022 CEUS

Sample Allocation

The CEUS team obtained all data necessary to complete sampling in late 2018, and successively ran the clustering and sampling algorithms on each data set. Table 4 summarizes results by utility and Forecast Zone. Detailed sample tables are available in Appendix H.

The expected precisions in Table 4 are similar to those achieved with the proxy CIS data in Table 3. Differences are due primarily to the fact that the proxy CIS data was not clustered for the three IOUs, and that SDG&E data was used as a proxy for LADWP data. The project team recognized that the targets and precisions in Table 3 are very ambitious – in particular, that achieving the stated precisions was highly dependent on securing response rates of 100% for large Stratum 5 facilities and response rates of up to 40% for large Stratum 4 facilities – a difficult task given the project timeline and the lack of monetary incentives for survey participation. At the same time, it was recognized that the study design goals would easily be met if the survey field effort could even approximate the sample design shown below.

Table 4: Sample Summary by Utility and Forecast Zone

Utility	Forecast Zone	Total MWh	Population Size	Target Sample Size	Relative Precision at 95% Confidence Level
PG&E	1	13,508,009	97,924	3,740	3.7%
PG&E	2	2,030,833	26,262	886	3.6%
PG&E	3	651,919	9,463	453	4.5%
PG&E	4	3,688,522	38,421	1,336	4.0%
PG&E	5	4,197,223	36,334	1,485	3.6%
PG&E	6	2,134,184	26,167	911	4.2%
PG&E Total		**26,210,690**	**234,571**	**8,811**	**2.10%**
SCE	7	18,378,811	152,625	5,188	2.1%
SCE	8	2,117,160	21,215	800	3.1%
SCE	9	1,096,146	11,899	554	5.1%
SCE	10	4,375,656	33,265	1,327	5.6%
SCE	11	3,167,446	24,845	1,015	4.3%
SCE Total		**29,135,219**	**243,849**	**8,884**	**1.66%**
SDG&E	12-coastal	6,362,734	45,848	2,196	3.3%
SDG&E	12-inland	2,576,749	23,241	1,002	3.4%
SDG&E Total		**8,939,483**	**69,089**	**3,198**	**2.52%**
SMUD	13	4,291,788	29,837	2,361	3.08%
SMUD Total		**4,291,788**	**29,837**	**2,361**	**3.08%**
LADWP	16	5,225,511	41,523	2,280	4.06%
LADWP	17	1,556,632	17,252	982	3.25%
LADWP Total		**6,782,143**	**58,775**	**3,262**	**3.22%**
Survey-Wide Total		**75,359,324**	**636,121**	**26,516**	**1.07%**

Source: 2022 CEUS

Expansion Methodology and Post-Stratification

Site-level characteristics are extrapolated to the stratum-level through multiplicative scaling with expansion weights. In any given stratum, the expansion weight is defined as the ratio of total stratum annual electricity usage to the total annual electricity usage of sampled sites within that stratum. Appendix J includes expansion weights for all strata in a spreadsheet format. In addition to Appendix J, ADM has developed a poststratification tool to facilitate future research by CEC staff. This tool simplifies development of alternative stratification schemes. For example, a researcher may wish to break out the miscellaneous Building-type into subsets that have NAICS codes which start with digits 5,7,8, and 9. The poststratification tool, developed in the R programming language, will quickly compile post-stratified results, along with resulting precisions.

Sample Modifications in Response to Pandemic-Induced Stresses

While the final survey instrument was much more complex and comprehensive than the one envisioned during the RFP stage, the team also found ways to reduce project costs through increased automation and real-time implementation of quality control procedures and reduction of travel-related expenditures from hiring and training competent local staff. As a result, in early 2020 the project was tracking closely to the budget and target survey count, trending toward 27,000 surveys at the end of the project with nearly 20,000 surveys completed.

Up through 2019 the project team faced occasional challenges to data collection. These included localized fires and flooding, and significant cancellations due to public safety power shutoffs in fall of 2019. The project team attempted to maintain productivity during these occurrences by redeploying local field staff to nearby unaffected regions or by assigning off-site analytical work to surveyors in affected region. Unlike previous challenges, COVID-related stay-at-home orders affected the entire state and greatly diminished the team's ability to recruit participants and to conduct surveys. Many of the smaller commercial customers were facing significant uncertainty and economic challenges and were more difficult to reach and to recruit. As a result, both survey refusal rates and costly survey cancellation rates increased dramatically. The stoppage of on-site surveys meant that door-to-door canvassing – previously the most time-efficient and cost-effective means of customer recruitment – was ruled out. At the same time, the project team incurred significant costs related to training staff to conduct remote surveys by telephone, video conference, and email, and by scaling down the survey effort to a near pause, hoping to conserve project budget until site visits and door-to-door canvassing could resume.

By the middle of 2020, the weekly survey rates had dropped by a factor of eight, while the project cost-per-survey had increased by a factor of four. It was clear that the initial design targets were no longer feasible with the remaining budget and time. The project team considered the following options and strategies to conserve the budget and to complete as many surveys as possible.

Pause the Project

In the early months of the COVID pandemic there was uncertainty about the potential duration of social isolation measures. At the same time, budgetary projections showed that the post-COVID customer recruitment and survey completion rates would result in total expenditure of project funds by the time 22,000 surveys were completed. The team considered pausing the project to preserve the remaining budget until economic conditions improved. While this was the clearest and most immediate way to preserve the budget, the option included significant drawbacks. Pausing the project would necessitate furloughing or laying off essentially all surveyors and recruiters. The related risk was that the project team would incur significant costs in terms of the amount of money and time required to hire and train staff when economic conditions improved. Another risk was that, with significant uncertainty regarding the trajectory of the COVID pandemic, stopping work altogether risked the expiration of funds that were allotted to the project.

Downsize the Project

While stopping work was not deemed as a viable option, the project team recognized that it was imperative to preserve project funds. The team was downsized to approximately 20% of the pre-COVID staffing through a series of layoffs and staff reassignments. This significantly reduced the project spend rate to about 25% of pre-COVID times. The team retained only a few field staff and recruiters based on their potential to contribute to the ongoing effort.

Extending the Project Timeline

CEC staff recognized that a smaller, slower CEUS offered the best chance at achieving a balanced and representative sample. To this end, they worked with CEC management to secure a one-year project extension. This allowed the project team to reduce the weekly spend rate beyond what would have been possible had the project deadline remained March 30, 2021.

Launch Online Surveys for Small and Simple Facilities

Online surveys completed by participants can potentially be much more cost-effective than remote surveys which require significant involvement from both surveyors and recruiters. The project team recognized that online surveys were not appropriate for relating information about complex sites such as universities, hospitals, or large offices, but could suffice for smaller sites. ADM developed an alternate online survey instrument and launched a series of online survey campaigns. While the online surveys ultimately were more cost effective than other data collection modes (with the possible exception of surveys conducted through canvassing), the overall number of completed online surveys fell well short of the target. The team experimented with multiple types of email campaigns, including alternate messaging and varying incentive amounts and schemes. While higher incentives proved to raise response rates, the impact was not as pronounced as hoped. While the team felt that the length of the survey was the primary impediment to participation, there was a competing desire to maintain maximum correspondence between the online surveys and the original survey instrument.

Seek Additional Funding

While additional funding could not solve the fundamental problems related to customer recruitment, it could mitigate the impact of losses already incurred by mid-2020 and could offset increased costs associated with planning and designing a post-COVID solution. ADM significantly increased its "match share" commitment to the project, primarily through in-kind labor and secondarily through e-gift cards offered to participants of online surveys.

Adjust the Sample Design

The measures described above helped to mitigate the budgetary and temporal impacts of customer recruitment and surveying challenges during the pandemic, but significant project risks remained. By summer of 2020, it became evident to the team that the initial sample target was no longer achievable. The project team ran through several alternate scenarios, considering survey achievements relative to design goals to date, expected participation rates in online surveys, and the importance of key sites and strata to overall zonal precisions. By mid-2020, the surveys for PG&E, SCE, and SDG&E were in acceptable standing, having neared overall sample targets, albeit missing some key high-value participants – particularly in the health care and higher education sectors. The project team had delayed the LADWP (last utility to agree to participate in CEUS) survey launch and focused on the three investor-owned electric utilities to utilize the full amount of EPIC funding before it expired in mid-2020. As a result, the team was only able to achieve a handful of on-site visits in Los Angeles before social isolation measures were in place. Table 5 compares the initial and adjusted samples. The adjusted sample represented a more accurate depiction of achievable results than the initial design not just due to the overall reduction in sample size, but because it reflected decreased response rates among commercial customers during the initial stages of the COVID pandemic. The project adjusted quotas up and down to optimize precision using the accumulated knowledge about the survey effort. For example, a particular stratum or zone needed to increase sample points to compensate for key customers' refusals to participate. Given that essentially 100% of data collection occurring post-COVID for LADWP, the sample targets for their service territory were reduced more than for any other utility. Note that the increase in the target precision for SMUD, from 3.1% to 8.2%, is not due to a marked reduction in sample size. Rather, by the time of the sample redesign the team had learned that one large stratum 5 site was noncommercial, and its removal decreased the precision gain afforded by that certainty stratum. The team also consolidated strata 4 and 5 in cases where not all stratum 5 sites were able to be recruited and reflected the associated impacts on precision in the updated sample design table.

Table 5: Initial and Adjusted Sample Design Summary

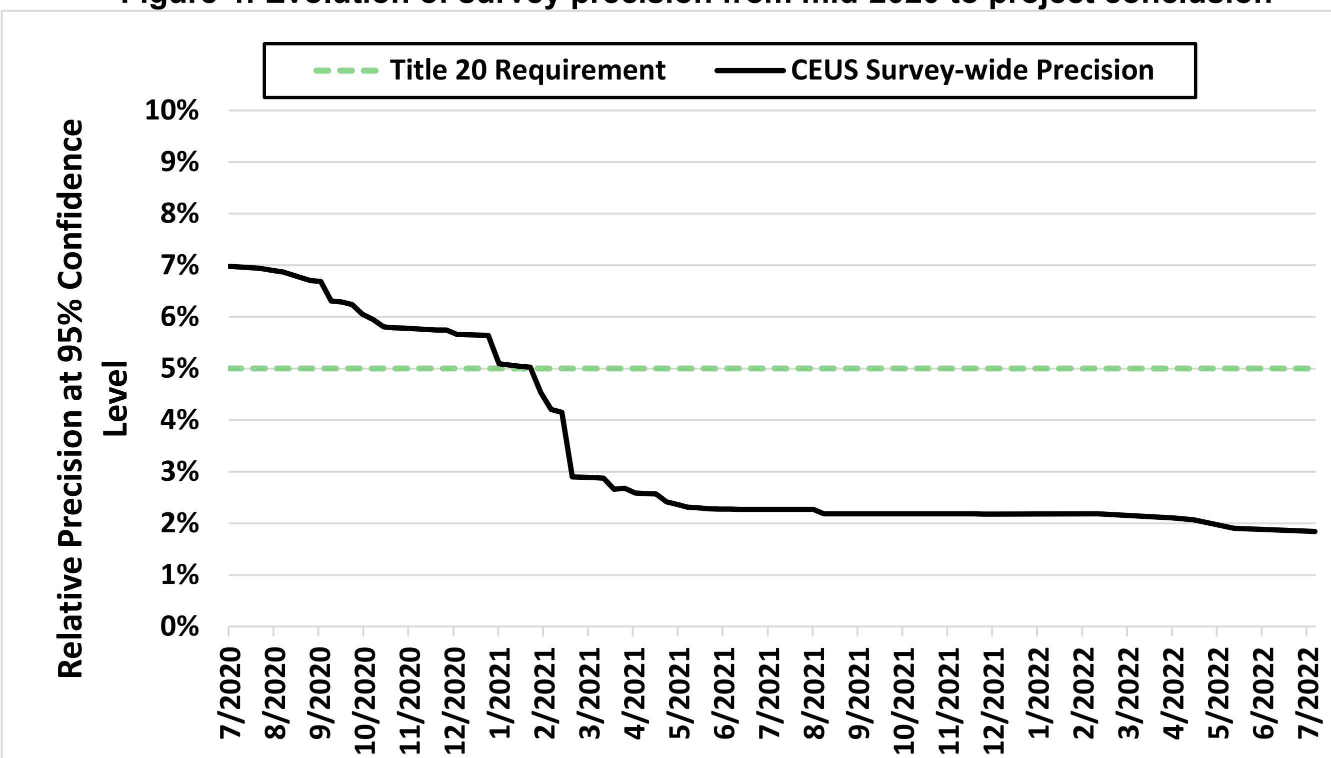
Utility	Forecast Zone	Initial Target Sample Size	Relative Precision at 95% Confidence Level	Adjusted (Post-COVID) Target Sample Size	Final Target Relative Precision at 95% Confidence Level
PG&E	1	3,740	3.7%	3,477	6.7%
PG&E	2	886	3.6%	993	8.0%
PG&E	3	453	4.5%	472	6.6%
PG&E	4	1,336	4.0%	1,332	8.7%
PG&E	5	1,485	3.6%	1,412	6.5%
PG&E	6	911	4.2%	908	6.7%
PG&E Total		**8,811**	**2.1%**	**8,594**	**4.0%**
SCE	7	5,188	2.1%	4,996	3.4%
SCE	8	800	3.1%	907	5.2%
SCE	9	554	5.1%	516	9.5%
SCE	10	1,327	5.6%	1,322	5.4%
SCE	11	1,015	4.3%	951	7.8%
SCE Total		**8,884**	**1.7%**	**8,692**	**2.5%**
SDG&E	12-coastal	2,196	3.3%	2,043	5.3%
SDG&E	12-inland	1,002	3.4%	930	6.0%
SDG&E Total		**3,198**	**2.5%**	**2,973**	**4.2%**
SMUD	13	2,361	3.1%	2,158	8.2%
SMUD Total		**2,361**	**3.1%**	**2,158**	**8.2%**
LADWP	16	2,280	4.1%	1,732	6.7%
LADWP	17	982	3.3%	807	4.8%
LADWP Total		**3,262**	**3.2%**	**2,539**	**5.3%**
Survey-Wide Total		**26,516**	**1.07%**	**24,956**	**1.87%**

Source: 2022 CEUS

Maintain Focus on Key Sites

While the large overall sample size was an important design element for the survey, overall survey precision was far more dependent on key sites that accounted for significant portions of the energy usage in a given zone and market segment. In mid-2020, the project team developed a business process that involved weekly ranking of sampling strata according to their contributions to sampling uncertainty and assigning specific high-value sites to project staff for recruitment. As shown in Figure 4 below, this process resulted in significant gains in survey precision and allowed the project to reach the revised survey-wide target relative precision of 1.85% at the 95% confidence level. This strategy proved successful, and the survey ultimately surpassed the revised survey-wide relative precision target of 1.87% even though the final survey count was well short of 24,956.

Figure 4: Evolution of survey precision from mid-2020 to project conclusion



Source: 2022 CEUS

Final Survey Count and Statistical Precision

The CEUS data collection effort concluded after conducting a total of 24,294 commercial surveys. The net number of surveys used to calculate sampling precision is 22,933. However, data from 23,597 surveys inform sector-level results because the main source of the reduction in count is post hoc consolidation of two or more survey sites into one larger survey site. This process retains data collected in all surveys but consolidates multiple sample points into one. Sources of survey count reduction are discussed below.

Consolidating Survey-Sites

In this study, a survey-site is defined as a single commercial entity operating in a contiguous commercial space (i.e., all or part of one or more commercial buildings that are not separated by other buildings, or by public roads). In approximately 2.7% of cases, a survey-site was recognized to belong to the same entity as an adjacent survey-site, and therefore the two sites together constituted one survey-site, even though they were separate sample points in the sample frame. While developing the sample frame, the team developed and applied algorithms to identify and cluster together utility accounts or premises that belonged to a single commercial entity. The algorithm was not 100% effective at recognizing records that belong to the same entity. The most common reasons for the algorithm's lack of recognition are business entity names or addresses (provided by utilities) that are too different from each other to be recognized as belonging to the same entity. Survey quality control analysts consolidated data from such pairs of sites into a single site, keeping track of this activity in the CEUS Tool so that the project manager could make corresponding adjustments to the sample frame. The net result is a reduction of 664 in the achieved sample count, although data from those 664 surveys still informed survey results.

Noncommercial Survey-Sites

Determination of primary NAICS codes is often straightforward but a small minority of cases pose difficulties often associated with weighing the importance of multiple business activities that may occur at a single survey-site. A total of 307 (1.3% of cases) survey-sites were deemed to be noncommercial after quality control review. In almost all cases, the surveyors discovered both commercial and noncommercial activities occurring on site. The most common examples are:

- Retail sales of cellular phones and accessories (a commercial activity) paired with sales of cellular phone plans (an activity that maps to transportation, communication, and utilities (TCU) according to the CEC's NAICS to Building-type map).
- Manufacturing of goods (a noncommercial activity) accompanied by storage and distribution of goods (a commercial activity).

Candidate survey-sites were discarded if the project team determined that the primary activity was the noncommercial one. Such decisions took careful deliberations and close coordination with CEC staff.

In addition to the above cases, the CEC decided after completion of data collection that NAICS codes 115111,115112, 115113, 115114, and 115116 should be reclassified as agricultural buildings rather than commercial. The CEUS team surveyed 18 such sites during the survey. The team discarded these survey sites and purged the sample frame of all sites with the listed NAICS codes.

Unusable Pretest Sites and Other On-Site or Remote Surveys that Failed Quality Control

A total of 220 on-site surveys, or 0.9% of all surveys, were found to have inconsistent or lacking data which could not be remediated during the quality control process. Of these surveys, 89 were conducted during the survey pretest period. Therefore, although the surveys could not ultimately be utilized in the final sample count, they provided useful feedback to the team regarding data collection methods and associated training. The remaining sites tended to occur randomly throughout the survey. The major factors that prevented remediation were that the site contact refused or was unable to provide the requested information, or the entity went out of business in the period between the initial survey and the follow-up attempt.

Online Surveys that Failed Quality Control

A total of 170 online surveys (0.7% of all surveys) were found to be lacking critical data or had irreconcilable inconsistencies between related data fields. While remediation may have been possible for some of these surveys, the online surveys occurred near the end of the project and the team opted to focus time and effort on completing high-value (stratum 4 and 5) surveys instead.

Final Survey Count and Achieved Precision

Table 6 lists the total number of surveys at stages of data collection and analysis as described above. Table 7 lists the targeted and achieved numbers of surveys for each Forecast Zone. While the total number of surveys were 8% below the target overall and significantly below target for LADWP, the achieved sampling precisions aligned with targets. This is primarily due to the project team’s focus on recruiting and surveying high-value survey sites.

Table 6: Survey Count at Various Data Collection and Validation Steps

Data Collection and Validation Activity	Survey Count
Initial Surveys Completed	24,294
Consolidation Survey-sites	23,630
Remove Non-Commercial Sites	23,323
Remove Unusable Pretest Sites and Sites that Failed Quality Control	23,103
Remove Online Surveys that Fail Quality Control	22,933
Final Survey Count	**22,933**

Source: 2022 CEUS

Table 7: Final Relative Precisions by Forecast Zone

Utility	Forecast Zone	Target Sample Size	Relative Precision at 95% Confidence Level	Final Survey Count*	Achieved Relative Precision at 95% Confidence Level
PG&E	1	3,477	6.7%	3,390	6.8%
PG&E	2	993	8.0%	1,016	7.9%
PG&E	3	472	6.6%	467	9.4%
PG&E	4	1,332	8.7%	1,356	6.5%
PG&E	5	1,412	6.5%	1,383	6.0%
PG&E	6	908	6.7%	916	7.4%
PG&E	**Total**	**8,594**	**4.0%**	**8,528**	**3.9%**
SCE	7	4,996	3.4%	4,962	2.9%
SCE	8	907	5.2%	895	5.6%
SCE	9	516	9.5%	488	9.4%
SCE	10	1,322	5.4%	1,266	7.6%
SCE	11	951	7.8%	923	7.7%
SCE	**Total**	**8,692**	**2.5%**	**8,534**	**2.4%**
SDG&E	12-coastal	2,043	5.3%	1,886	5.4%
SDG&E	12-inland	930	6.0%	887	8.2%
SDG&E	**Total**	**2,973**	**4.2%**	**2,773**	**4.5%**
SMUD	13	2,158	8.2%	2,036	7.0%
SMUD	**Total**	**2,158**	**8.2%**	**2,036**	**7.0%**
LADWP	16	1,732	6.7%	565	7.2%
LADWP	17	807	4.8%	497	5.3%
LADWP	**Total**	**2,539**	**5.3%**	**1,062**	**5.7%**
Survey-wide	**Total**	**24,956**	**1.87%**	**22,933**	**1.85%**

Source: 2022 CEUS

CHAPTER 3: Survey Design and Implementation

Overview

This chapter describes the development of the survey instrument, development of the CEUS Tool (web-based data collection tool), surveyor training, implementation of the survey, customer recruitment, and pretesting. One of the initial tasks of the project was to develop the survey instrument (Appendix A), a detailed Data Collection Protocol document (Appendix E), and the overall process to implement the surveys.

The CEC's vision for the 2022 CEUS was to increase the sample size ten- fold from the previous CEUS, while maintaining focus on the essential data fields. The survey design was an interactive process that involved the ADM team and CEC staff. This survey used a web-based application (app) specifically designed to address the unique characteristics of this survey. The app is called the "CEUS Tool" and is a major part of this data collection effort. The CEUS Tool integrates the survey form and data submission with operational activities such as participant recruitment and travel-related coordination, data validation and quality control, and sample execution management.

This section presents the survey design and implementation process in the following order:

- Survey instrument design issues
- Introduction to the electronic data collection app known as the CEUS Tool
- Surveyor training
- Pretest implementation efforts
- Operations
- Tracking and Improvements
- Survey data validation
- Summary of the targeted and completed samples

Survey Instrument Design

The CEC provided a draft copy of the survey instrument in the Request for Proposal (RFP) as an example of the resolution considered for data collection.

Subsequently, ADM and CEC staff collaborated and drew upon experience in previous CEUS projects to expand and enhance the scope of the instrument. The team distributed a draft survey instrument to participating utilities and the TAC to get their feedback prior to the start of pretests. This process resulted in several additions to the survey instrument.

Some of the additions to the survey, relative to the RFP version, are listed below:

- Enhance data resolution related to the number of employees by recording both typical and peak-season employment in full-time, half-time, and quarter-time units
- Add a secondary measurement of building square footage total and unconditioned square footage total
- Estimate and record the percentage of interior and exterior LED lighting

- Record electric vehicle charging counts by charger type
- List all major renovations and additions since 1978, rather than within the last year
- Collect on-site generation annual full load hours and CHP thermal energy use
- Identify and document on-site battery energy storage
- Add a flowchart of questions help determine the survey area
- Document information sources for HVAC fuel types
- In addition to fuel types, record primary system types for heating and cooling systems
- In addition to fuel source, document the access to hot water as a continuous variable – a percentage – rather than with a binary variable
- Document specific miscellaneous end-uses such as Web or IT servers, air compressors, and motors
- Distinguish between minor and major exterior lighting
- Take an inventory of major commercial cooking equipment
- Break out refrigeration by use and condenser location
- Add a site-contact log

Previous CEUS efforts relied on paper-based data collection. Paper-based data collection has several advantages, including lower first-cost and minimal training requirements. The mode has several drawbacks as well, including time lag in conveying data from the site to the office, transcription errors, and a lack of standardization in certain data fields that should have homogeneous responses. To overcome these obstacles ADM proposed using a web-based survey tool, referred to as the CEUS Tool, specifically designed for CEUS. ADM also created an equivalent paper version of the survey form. The paper copy was primarily used to present the survey questions in reports and to solicit stakeholder feedback. It was also used as a backup by the field surveyors in the event of technical difficulties related to web-based surveying.

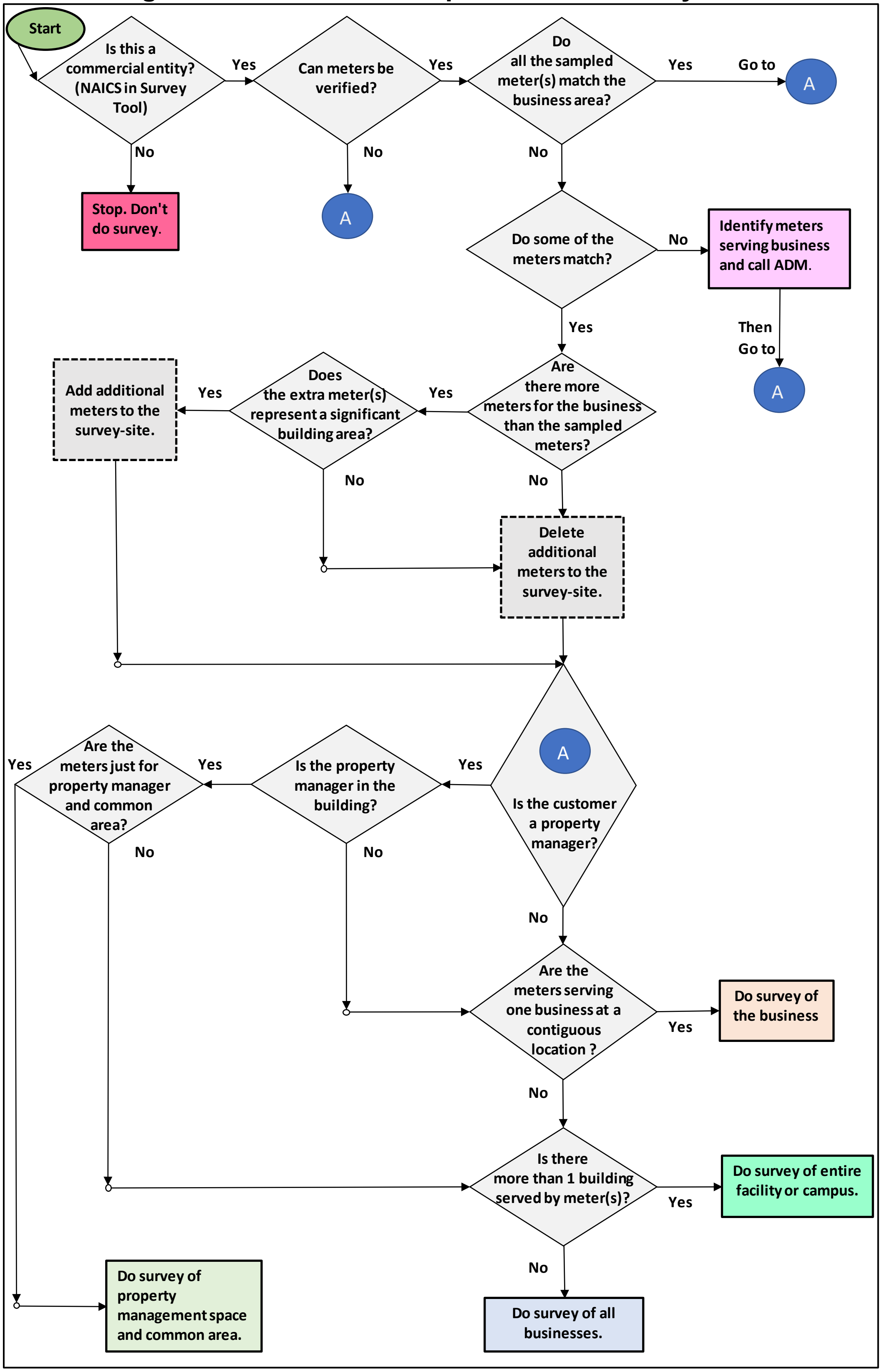
The project team used the term "survey-site" in reference to distinct sample points that are surveyed (the previous CEUS and some utility databases use the term "Premise"). A survey-site is defined as "*A contiguous location controlled by the same business entity with at least one utility meter*." For this study, a contiguous location is a building, or a set of buildings, owned or operated by a single entity on the same side of the street and adjacent sets of property (no buildings in between), not limited to one street address for the business. A survey-site may have one or more buildings, one or more electric utility meters, serving one or multiple business customers. A survey-site may house tenants that are unrelated businesses, such as a multi-tenant, high-rise office building with one master meter or multiple electric utility meters. Similarly, a survey-site may be a portion of a building such as one store in a strip mall, served by one or multiple electric utility meters.

To help determine the area of a survey-site, the survey instrument includes a flowchart to help surveyors identify the area to be surveyed for the survey-site. The prominent questions are:

- Is the utility customer a property manager or an owner-occupied business?
- If a property manager, do the meters only serve the common area or multiple businesses at a contiguous location?
- Do the meters serve part of a building, one building, multiple buildings, or a campus?

The flowchart of questions is presented in Figure 5. The first step is to identify the meter(s) and find the areas served by each meter. Electric meters are used to determine the survey area, and any gas meters that serve the same area are also included. The Data Collection Protocols (Appendix E) contains more details on the area determination including section 4.4.2 where various building configurations examples are provided.

Figure 5: Flowchart to Help Determine Survey Area



Source: 2022 CEUS

The following subsections provide some of the important survey questions and brief descriptions for each of the data block categories of the survey instrument.

Contact Information

The contact information block contains records such as business name, address, telephone number, site-contact information, when and by whom contact was made, and the disposition of the contacted customer, survey completion status along with any special notes. The notes could include directions that the project coordinator passed on to the surveyor regarding details of where to meet the site-contact.

Interview

The next block of information includes data collected through an interview with the site-contact. The data fields collected by the surveyor in the interview block include the following:

- NAICS code and a description of what makes this business unique
- Building-type (and percentage associated with up to three types)
- Physical type (i.e., single building and business, multi-tenant building, multiple buildings)
- Number of employees (If multiple tenants, a sample of employee counts.)
- Number of employees during the peak business season
- Percent of usable floorspace vacant
- Percent of employees that use office equipment on a regular basis
- Number of usable rooms (conditional for Lodging)
- Average occupancy (conditional for Lodging)
- Average number of meals served per day (conditional for Restaurants)
- Number of beds and average occupancy (conditional for Health Care)
- Average daily attendance (conditional for Education)
- Year built
- Year business started at present location
- Percent of interior and exterior lights that are LED
- Number of electric vehicle (EV) charging stations and type of station
- Major renovations, what, when, and percent of floor area
- Major additions, what, when, and floor area
- Number of holidays and was there a seasonality to operations
- Primary business hours by days of the week

One of the key aspects of the interview is to determine the economic activity of the business at the survey-site, and specifically to identify the NAICS code [11]. The CEUS Tool includes a three-level menu to facilitate navigation to the correct NAICS code for a business. Survey logic within

---

11 The Census Bureau maintains a comprehensive NAICS guide online.

the tool displays a pop-up menu to force additional consideration in cases where the selected NAICS code disagrees with initial NAICS codes provided by utilities.

In addition to determining the primary NAICS code and the corresponding Building-type (as defined for the CEC forecast), surveyors can separately enter up to three distinct Building-types that best fits the primary, secondary, and tertiary functions of the survey-site, each with a percentage that accounts for the overall weight by square footage. For example, a strip mall may be entered as 60% retail, 25% restaurant, and 15% office.

Another key interview question is the number of employees that work at the survey-site location. This was broken down into full-time, half-time, and quarter-time numbers of employees.

The interview questions ask for general information on renovations or additions that occurred since 1979. Several other data fields in the survey form, such as water heater age, saturation of LED lighting, and solar generation capacity can be used to cross-check and complement data related to additions and renovations.

Utility Meters

The utility meters data block section of the survey form contains entries for utility meter numbers.

- Electric service provider
- Natural gas service provider
- Meter numbers for all electric and all natural gas meters serving survey-site
- Electric and gas utility account numbers
- Status of verification of utility meter numbers
- Identification of meters for shared services meter with non-survey-site areas
    - Estimated amount of energy shared with neighboring non-survey areas

The electric utility meter number(s) are preloaded into the CEUS Tool based on service account information provided by the electric utilities. The gas meter numbers obtained from SDG&E and PG&E customers were also preloaded into the CEUS Tool.

One of the key goals of the survey is to estimate energy intensity per square foot of floorspace. Therefore, great emphasis was placed on the accuracy of the correspondence between measured floorspace, and the meters that serve the measured area. Despite the effort given to verification of meters, this was not always possible as some meters were either physically inaccessible, or site-contacts were not willing or able to provide access to meters. In most cases, the relationship between the surveyed area and the corresponding meters is uncomplicated and corresponds to the initial meter-to-area relationships provided by utilities. In some cases, additional meters found on site must be added, and associated with the survey-site, or meters that are not found must be removed (e.g., a meter changeout). The survey form allows one to associate or disassociate meters with survey-sites, although any such action automatically flags the site for a quality control review.

On-Site Generation and Storage

The On-Site Generation data block collects information about on-site energy generation, including type, capacity, full-load hours, the percentage sold back to the utility, and the presence of electric battery storage or thermal energy storage. Types of on-site generation include:

- Solar Power (On-Site Photovoltaic Generation)
- Wind Energy
- Combined Heat and Power
    - Gas Turbines
    - Micro Turbines
    - Back-Pressure Turbines
    - Internal Combustion Engines
    - Waste Heat Recovery
- Other Sources

Fuel cells comprised the predominant "other" type of on-site generation.

Other Energy / Service Accounts

The Other Energy Services data block collects information on non-utility sources of energy supplied to the survey-site, exclusive of on-site generation. Other sources of energy include:

- Bottled Gas, LPG, Propane
- Chilled water
- Steam
- Hot Water
- Biogas/Biofuel
- Leased Community Solar (solar power that is generated off-site)
- Other (sources not listed above)

Other sources of energy that were documented included on-site generation and thermal and electric battery energy storage. The survey form includes fields for quantities delivered to the site, and a freeform entry to define units and time intervals, such as bottles of propane delivered per month, or dollars spent on the fuel source per year.

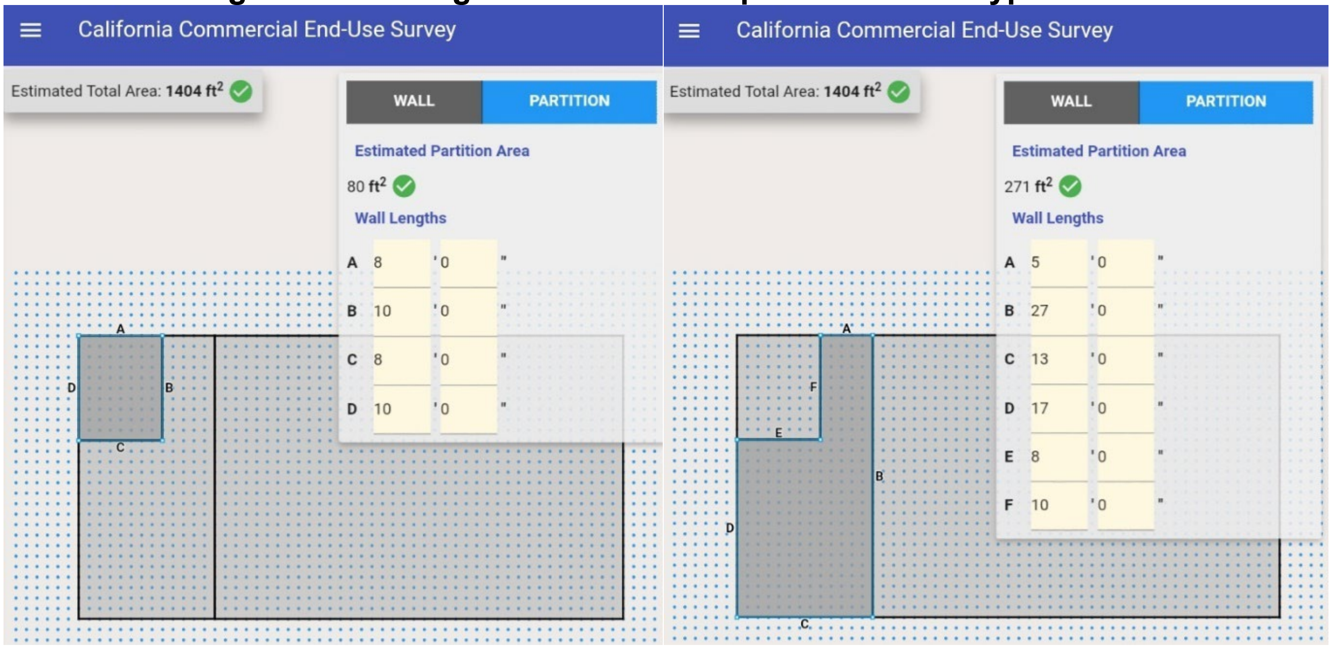
Partition Drawing

The drawing data block of the survey form is designed to facilitate the following data collection tasks:

- What is the total square footage of the survey-site?
- Identify areas or partitions that have different fuel sources for space conditioning.
- Identify areas that have mechanical ventilation.
- Identify areas that are refrigerated or frozen.

The drawing in the CEUS Tool expedites calculation of building square footage and partitioning the building into areas with different heating and cooling fuel types. These areas are called "end-use fuel partitions." An example of partitions with dimensions and calculated square footage is shown in Figure 6.

Figure 6: Building broken into multiple HVAC Fuel Type Partitions



Source: 2022 CEUS

The details of a building footprint are not critical in the CEUS data analysis. What is important is the number of distinct partitions and their respective floorspaces. Complex buildings or sites with multiple buildings were therefore simplified in the drawing. Rather than spending time replicating the layout of a campus, a picture of the campus map is inserted in the photos section. In those cases, the building is drawn as a simple box. The box would be divided into the number of virtual partitions (as opposed to physical partitions that mimic actual floor plans) needed to characterize the distinct HVAC configurations or various parts of the survey-site. The CEUS Tool automatically calculates partition square footages from the drawings, but surveyors may override these values if more accurate estimates of the partitioned areas are available from different sources such as floor plans or mechanical schedules.

Square Footage

The main questions in this section are:

- What is the total square footage of the survey-site?
- What is the unconditioned area of the survey-site?
- What are the square footages of the partitions with different HVAC fuels?
- What is the source of the square footage information?

The survey form allows a variety of area estimation approaches, listed in priority order below:

1. Floor plans
2. Property manager leasing records
3. On-site measurements
4. Satellite/aerial distance measurements
5. Interviews with site-contacts

For most approaches above, the form differentiates between interior and exterior measurements, and the CEUS Tool converts any exterior measurement to a corresponding interior one by accounting for wall thickness. Exterior wall thickness defaults to 12 inches in case a reliable measurement is not possible. The form requires two independent floorspace estimates, and also requires that the surveyor designates the superior method, based on the particular circumstances of the given measurement effort. The square footage data block also includes two Independent estimates of unconditioned floorspace (excluding parking garages), and an estimate of the parking garage area.

End-Use by Whole Survey-Site

Fuel saturation or penetration for each of the major end-use types is addressed in this data block. In this context, the term saturation refers to the fraction or percentage of the survey-site's floorspace that is served by a particular end-use, while the term penetration is a similar but binary construct and takes on the value 1 if the end-use is present at the survey-site, and 0 otherwise[12]. Brief descriptions are provided below, with the full survey questionnaire presented in Appendix B, and the associated data collection protocols in Appendix E.

HVAC

Although HVAC fuel saturations are regarded as essential data, the details of HVAC system types are not. The survey form records the primary HVAC system type for each facility. Survey-sites with multiple types of HVAC systems are limited to a selection of the primary system type as defined as the one conditioning the greatest amount of floorspace. Several of the data selections for the primary heating system type are by themselves, ambiguous. For example, "Package System / Heat Pump" may indicate a gas-heated packaged air conditioner and furnace, or a packaged heat pump. In such cases, the heating fuel serves to practically eliminate the ambiguity. For example, if a system is noted to be a "Split-System / Heat Pump" and the heating fuel is

12 For a more detailed discussion, please see the section titled End-Uses in CHAPTER 5: Analysis of Commercial Data - Key Concepts.

electric, then the unit is most likely a heat pump, since electric resistance furnaces are rare. Likewise, all no instances of "Boiler/Hydronic" heating were associated with electric boilers.

Domestic Water Heating (DWH)

The survey form includes several questions that capture the saturation of domestic water heating by fuel type, including solar thermal, purchased/shared hot water, and heat recovery.

Office & IT Equipment

Questions related to office equipment include:

- Is there any office equipment present?
- Are there any web / information technology (IT) server racks present?

To qualify, server racks must be in dedicated spaces larger than 100 square feet. Note that the interview data block includes a separate question regarding the number of employees that use office equipment on a regular basis.

Exterior Lighting

Qualifying exterior lights at the survey-site must be powered by the electric meter(s) associated with the survey-site. The questions include:

- Are there any exterior lights at the survey-site fed by the meter(s)?
- Are the exterior lights minor or major?

Exterior lighting is categorized as *major* if it includes 10 or more pole mounted fixtures, or more than 20,000 square feet of lighted space in a parking garage.

Cooking Equipment

The cooking equipment portion of the survey can be used to calculate cooking fuel saturations. Major commercial grade cooking equipment, such as fryers or steam cookers, are distinguished from *minor* cooking equipment, such as microwaves, toasters, and coffee makers often encountered in employee break rooms. Questions in this data block include:

- Is there any minor cooking equipment present?
- Is there any major cooking equipment present?
- What percent of cooking fuel is supplied by electricity, natural gas, and other fuels?

The survey form requires an inventory of all major cooking equipment by fuel type unless all such equipment is electric. Some non-Restaurant sites include commercial kitchens and food service equipment. In such cases, the total food preparation and service area are recorded into the survey form. The area is measured only for non-Restaurant survey-sites because the presence of major cooking equipment can skew the energy intensity of the site.

Refrigeration

Several survey questions help to characterize the refrigeration system(s) at the survey-site. Residential style refrigerators found in break rooms are differentiated from commercial refrigeration systems. The latter are categorized as remote compressor or self-contained, and also by type (walk-ins vs. reach-ins) and temperature (freezers vs. refrigerators).

If the survey-site has commercial refrigeration systems, but is not classified as a Restaurant, Food Store or Refrigerated Warehouse, then the amount of refrigerated floorspace is required by the survey form, as the data may help to reconcile unusually high energy usage for Building-types that seldom contain refrigeration equipment.

Air Compressors

The survey form includes a question to assess air compressor penetration. To qualify, the air compressors must have an air storage reservoir.

Electric Motors

The survey form includes a question to assess electric motor penetration. To qualify, the motors must be six inches in diameter or larger. Examples include motors in conveyor belts, elevators, and escalators.

Miscellaneous Electric Equipment

This section identifies any electric-powered equipment not addressed in the previous sections. General types of equipment that qualify include but are not limited to theatre systems, medical equipment, battery chargers, shop equipment, clothes washers and dryers, trash compactors, security alarms, and portable fans or air cleaners.

Miscellaneous Natural Gas Equipment

This section identifies any gas-powered equipment not addressed in the previous sections. General types of equipment that qualify include but are not limited to pool heaters, clothes dryers, dehydrators, cremation/incinerators, gas lanterns or fireplaces.

Photos and Notes

Photos and Notes are important tools during the QC process as well as for analysis of the data once the project is completed. They provide a general idea about the main activity at the site and can be used to obtain missing data or for verification of the existing survey data.

Photos

Photos are taken using the camera on the tablet. Photos can be tagged with titles and labeled with one of the nine categories listed below:

- Building Exterior
- Business Hours
- Meters
- Utility Bills
- Floor Plans
- Satellite View
- Business Activity
- Equipment
- Other

One key advantage of the CEUS Tool is that photos are automatically classified and coupled to the survey site and can thus be readily accessed during the quality control process and future analysis.

Notes

The surveyor uses this section to make general notes about the survey-site that are not captured in other note entries specific to a data block. All the notes entered throughout the survey sections are displayed in one place on the CEUS Tool to be conveniently reviewed by the surveyor or reviewer.

Submitting the Survey

As a surveyor makes entries, the data are stored locally on the tablet. Once the survey-site is complete, the data are uploaded and submitted to the servers at ADM headquarters. Data are transferred with ADM's private data plan with Verizon (rather than over public WIFI) to ADM's secure file server in Sacramento through HTTPS protocol.

Operations

The following sections describe operations of the project which include utility engagement, recruitment and recruitment methodology, sample quota enforcement, resource management, quality control and management.

Utility Engagement

Utility participation was critical to the survey's success. Utilities' CIS systems served as the foundation of the CEUS sample frame. Utility staff met with CEUS project staff to explain details of their CIS and billing data sets and to work out technical details associated with corresponding data requests. Utilities also supported day to day operations by maintaining their customer call centers informed of the CEUS effort. Most utilities also allowed ADM to use their official logos on customer recruitment materials, and several utilities helped to recruit high value customers for the survey.

Pre-Launch Packet, with Project Summary / Call Center Talking Points

Prior to starting customer contacts in each utility service territory, the project team provided utilities with a pre-launch informational packet to assist major account representatives and call center staff in case customers contact the utilities regarding the CEUS survey. The packet consisted of:

- A utility-specific copy of the customer recruitment letter
- A PowerPoint presentation that summarized the CEUS survey, including survey timeline, customer recruitment process, the approximate number of commercial customers that may be contacted for recruitment purposes, and contact information at ADM and the CEC.
- A brief presentation for call center staff to help identify incoming calls that may be associated with CEUS, and to answer potential questions related to participation.

Do-Not-Contact data field

Utilities provided do-not-contact (DNC) lists or do-not-contact data fields along with the CIS data. Customers designated as DNC accounted for less than one percent of all customers. No major chains or certainty sites were designated as DNC. The DNC list was incorporated into the sample frame which systematically excluded them from being contacted.

High Value Customer Recruitment

On several occasions, utility account representatives provided contact information and introductions to key customers that were targeted for surveying. Prior to contacting large customers or major national chains, ADM provided utilities with lists of these key customers, and asked if utility account representatives had any special requests associated with the customer recruitment process.

Customer Recruitment Methodology

ADM designated survey-sites in the sample frame into three exclusive categories of recruitment:

1. Assign
2. Schedule
3. Schedule or Canvass

Sites under the "Assign" category are deemed to be critical to the project's success. These sites typically are certainty sites or sites in sampling stratum 4 (the typical site in these categories will have annual electricity usage in the GWh range) or are controlled by entities such as large health management organizations or retailers that control and operate many hundreds of survey-sites. Recruitment of such sites is assigned to senior project staff.

Sites generally under the "Schedule" designation are eligible for recruitment by the CEUS call center. These sites can be contacted by telephone or email for recruitment purposes. Sites under the "Schedule or Canvass" designation are eligible for recruitment by telephone or email but are also eligible to be recruited through door-to-door canvassing by surveyors. The typical site in this category is a small business with a public-facing office or store front.

Sample Execution

The sampling stratification scheme included 1,305 distinct sample cells, each corresponding to a combination of Building-type, vintage, Forecast Zone, and energy usage range. The target sample size for each sample cell is referred to as the "quota" for that cell, and the term "quota" is used to refer to the sample quota for a given sample cell. One of the main tasks of the operations team was to achieve target sample sizes for each sample cell, without significant oversampling or under-sampling. This was a daunting task, since over half of the 1,305 cells had quotas of 10 or fewer sites, while the CEUS was yielding 50-60 surveys per business day at its peak.

To avoid overfilling quotas, the CEUS Tool kept track of completed surveys on a real-time basis and allowed project managers to close down quotas once a sample target was met, or nearly met. Sites in closed quotas were no longer eligible for recruitment through the call center, or through canvassing. In the following sections, the term "eligible site" refers to sites that are in open quotas and are eligible for recruitment through the given mode (e.g., "schedule" or "schedule or canvass").

Recruitment Considerations for Retail, Restaurant, and other Chains

In this discussion, the term *chain* refers to a large number of facilities that are under the ownership or control of a single entity. These may include chains of grocery stores, retail stores, restaurants, hospitals, and also facilities under the control of a school district or local government. Each sampling stratum has a target sample rate, which is simply the percentage of the population that is to be surveyed within the stratum. In an idealized random sample with a 100% response rate, each chain entity would be included in the survey, and the proportion of its facilities surveyed would be equal to the sample rate. In practice, however, the response rate is typically much lower than 100%. Moreover, if a chain refuses to participate, then none of the sites controlled by that chain can be recruited. In this condition, chains that do participate must be oversampled to compensate for non-participating chains. Failure to oversample sites within participating chains would lead to general under-sampling of chains or centrally managed organizations. The oversample rate for sites within participating chains is approximately equal to the inverse of the survey response rate for the given type of chain store.

Customer Recruitment by Telephone

The call center manager managed surveyor-to-caller assignments and released lists of eligible sites to each caller. In addition to convincing utility customers to participate in the voluntary survey, callers had several important tasks to accomplish during a recruitment attempt:

- Confirm the business name and address, and that the site receives electric service from the given utility company.
- Identify the primary business activity at the site and confirm that the survey-site is a commercial entity with at least 100 square feet of floorspace and is thus eligible to be surveyed.
- Reach a person that is authorized to allow the survey to be conducted.
- During the scheduling interview, identify a suitable site-contact at the facility. The site-contacts would be knowledgeable about facility operations and would be the main source of correspondence regarding the survey.
- Schedule a time for the survey and relay all relevant logistical information to the assigned surveyor.

Appendix D provides a telephone recruitment script used by the CEUS call center.

Customer Recruitment through Canvassing

Surveyors could canvass any site that was eligible for door-to-door recruitment, and approximately 40% of sites were recruited this way. Surveyor communications were guided by the telephone recruitment script described above, with modifications to suit direct in-person communication. Appendix C provides examples of utility-specific recruitment letters that were displayed during canvassing or mailed to customers that requested more information regarding participation. Most successful canvassing attempts resulted in immediate access to the facility, although surveyors also offered to schedule follow-up visits at times that were more convenient to customers.

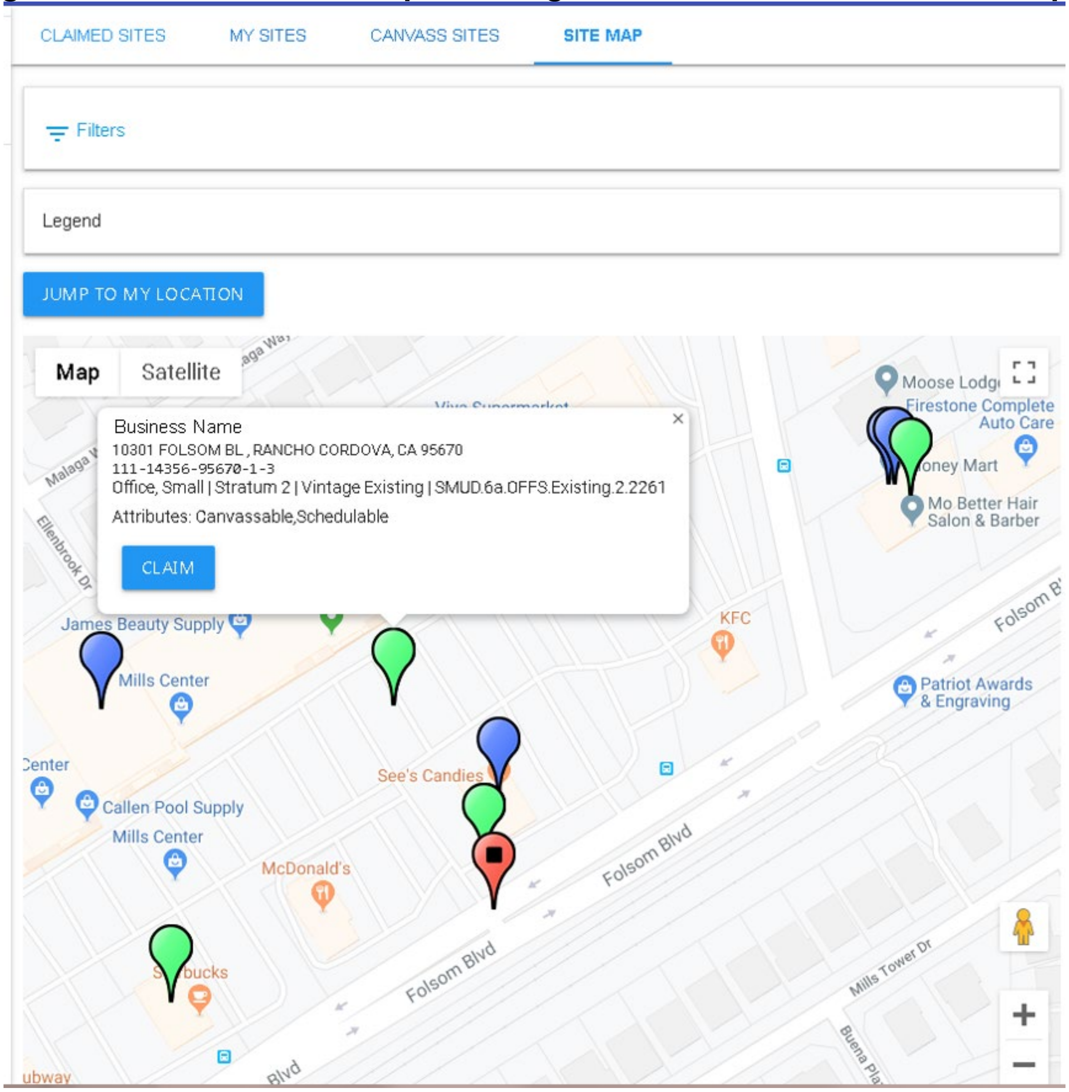
Survey-Site Data Collection Tool

ADM developed the CEUS Tool specifically for this data collection effort. It is a web-based app that can be accessed by tablets used by surveyors. It has a robust security structure with various levels of authorization that only allows specific pre-authorized devices to access the data in the database. The tablets are set up with data plans to have robust connectivity through a private network. Data can also be temporarily stored on tablets in case surveyors are in remote areas without reliable coverage. The tablets also have software that provides ADM's IT department the ability to ensure compliance with Personally Identifiable Information (PII) policy enforcement, deploy software applications the surveyors may need, revoke login privileges of any user at any time, and the ability to wipe the device if it was lost or stolen. The CEUS Tool itself automatically updates each time it is opened.

The tablet uses GPS sensing to determine the location, and an interactive map (Site Map) is displayed in the CEUS Tool to make it easy for the surveyors to find businesses near their location that are eligible for canvassing. Figure 7 shows a sample map with pins [13] for the survey-sites in the sample frame. Basic information about each sample frame point is loaded with the CEUS Tool and is displayed by tapping or clicking on a pin in the map. Importantly, only sites in open quotas are visible to surveyors. All sites from a particular sample cell disappear as soon as a quota is closed.

13 Blue pins show sites that are eligible for canvassing. Green pins show sites that are eligible for scheduling through the call center, but not through canvassing. Yellow pins (none shown above) are reserved for key sites in the "Assign" category. The black square on the selected site (red pin) indicates that the site is claimed by a surveyor, and thus is not editable until the surveyor releases the claim.

Figure 7: CEUS Tool Site Map Showing Pins for Businesses in the Sample



Source: 2022 CEUS

Integration with Sample Frame

The sample frame was developed primarily from utility CIS data. In addition, ADM purchased data from a source of commercial real estate data and merged the available real estate data with the data from the utilities. Matching facilities between the two datasets presented some challenges. Business names are not always identical; the utilities may have a customer with a meter that was one tenant in a building whereas the real estate database used buildings or properties as units. For example, a strip mall may be one building in the real estate database while the utility may have six business tenants in the mall all with their own electric meter and account with the utility company. After ADM produced a combined dataset, it was merged into the CEUS Tool database to pre-populate some of the data fields. The critical pre-populated fields were those needed to identify and contact the customer to schedule appointments and find the site-contact for conducting the survey. Following is a list of fields that were pre-populated when available:

- ADM generated survey-site ID
- Business name

- Business address
- Contact name
- Contact phone number(s)
- Contact email
- Electric utility provider
- Electric meter number(s)
- Electric account number(s)
- Annual MWh usage
- Gas meter number(s)
- Gas meter account number(s)
- Annual therms usage
- NAICS code from utility
- Building-type
- Latitude and Longitude
- Forecast Zone
- Year built
- Year moved in
- Percent vacancy
- Renovation year
- Stratum number
- Vintage

Integration with Operations

The CEUS Tool has several features that integrated with day-to-day operations. Perhaps the most important feature – quota enforcement – was described above. The tool also included quality control logic that prevented surveyors from turning in sites that were substantially incomplete or had conflicting or unphysical data entries. The CEUS Tool also auto populated surveyors' Outlook calendars with appointment information and notes, facilitated satellite-based area measurements, and integrated photos taken on site and geostamps with the CEUS database.

Training

All surveyors and telephone recruiters completed training prior to working on CEUS. Training occurred as the survey effort expanded into new utility areas and as additional staff were brought in to compensate for loss through attrition. The first surveyor training occurred in Sacramento during February 2018 and was attended by several CEC staff. As training expanded into new utility areas, utility staff were also invited to attend either in person or remotely by phone and over the internet.

ADM typically maintained about 30 trained surveyors in the field and approximately half as many trained telephone recruiters to support the field staff. As new staff were brought in and trained, they were then paired with experienced staff to get direct experience in the work being conducted.

Field Staff Training

Field staff training consisted of two days of formal in-class training, one day of field training with an instructor, and up to a week of shadowing a more experienced surveyor. Project staff provided surveyors copies of the survey form and data collection protocols in advance of training and encouraged staff to read the documents.

Classroom training started with a high-level project overview and then progressed into more detailed lessons. Lessons included an exposition and discussion of survey questions, methods that can be used to gather data and to identify equipment, procedures for communication with call center recruiters, and CEUS Tool operation. The class also covered how to submit completed surveys, how to easily tell what questions are missing to complete a survey, whether the quota for a site was still open or filled, and expectations on the number of sites to be completed per week after they have had a chance to gain experience.

Special emphasis was placed on the collection of six key pieces of data listed below.

- The definition of a Survey-Site
- Total floor area of building(s) for survey-site
- Fuel type and area for primary space heating & cooling
- Fuel type for water heating and cooking
- NAICS code determination
- Determination of annual and peak full-time-equivalent employment

Instructors covered NAICS code determination by describing the NAICS classification system, describing different approaches for getting the necessary information about the survey-site in order to determine the NAICS code, and providing copious examples.

Surveyors were also trained on safety policy and procedures, how to approach sites for canvassing, use of rolling tape measure and laser tape measure. The in-class training was followed by a day in the field with an instructor, followed by shadowing an experienced surveyor for up to one week.

ADM provided ongoing training to surveyors to keep them engaged and focused on data collection issues. Each Friday, the QC manager covered a concise list of salient topics discovered during the QC process.

Call Center Training

The CEUS project included several waves of hiring for the call center. With each hiring, ADM's call center manager conducted a one day in-class training. The training started with a general project overview, presenting concepts such as the CEC, the CEUS survey, Forecast Zones, Building-types, sampling and quotas, and energy end-uses. The call center manager also managed certain portions of the CEUS Tool, including appointment setting, logging of customer dispositions, and communication of appointment details with surveyors.

Recruiters learned how to identify and reach proper site contacts, to confirm business or NAICS type, and how to encourage customers to participate. The call center manager also provided examples of supporting documents (blueprints, utility bill, etc.) that recruiters should request to help with the data collection effort.

As a follow-up to in-class training, new recruiters were paired with more experienced staff and listened in on several scheduling calls to customers to experience a variety of responses and approaches to customer questions.

The Pretest

The Pretest was a limited scale implementation of the survey. In the project RFP, CEC staff proposed a pretest to debug and validate data collection methods and project operation on a small scale, prior to embarking on the greater effort. Specific goals for the pretest were:

- Validate and improve the tablet-based data collection form
- Uncover and correct any flaws related to data transfer and storage
- Establish and test field operational procedures
- Gather intelligence related to customer dispositions and response rates
- Test canvassing methods and gauge success rate
- Establish preliminary quality control system and feedback process

ADM conducted the Pretest in SMUD service territory. SMUD was ideal due to its proximity to both CEC and ADM headquarters. This proximity was beneficial in case significant information technology (IT) issues related to the tablet-based CEUS Tool would cause the effort to pause for prolonged periods.

The Pretest included three phases. The initial phase tested key features of the tablet-based CEUS Tool and related data transfer processes. Recognizing that data transfer issues may cause delays while on-site, participants in the first phase of the pretest were either recruited in advance by SMUD or consisted of commercial customers that were ADM's "neighbors," in the same business park and surrounds. The initial phase started in late February 2018 and concluded in early March.

The second phase of the pretest tested additional functionality of the CEUS Tool, such as integration with the sample frame and code updates to add data elements to the survey. The second phase also tested organizational aspects such as recruitment strategies, management of the canvassing effort, and quality control. The final phase of the Pretest was a "Soft Launch" in SMUD service territory. In this phase data collection continued and scaled to over 60 sites per week. This rate allowed testing of additional operational issues such as sample quota enforcement, and also allowed the project manager to gauge the accuracy of initial planning assumptions. The Pretest concluded after about 600 sites were surveyed.

Pretest Results

The pretest allowed the team to gain practical experience and to implement several improvements to the survey process. The main theme of these improvements was integration of data related to sampling, recruitment, on-site surveys, and quality control, and are described more in the following paragraphs. Although ADM's project proposal conceptualized many of these elements, implementation details were specified in large part with input from lessons learned in the pretest.

Several fields in the CEUS Tool had automatic feedback provided while data was being collected. Surveyors and QC analysts liked this feature and requested automated feedback on many additional fields, so CEUS programmers added such functionality to all fields.

Some sets of questions in the survey only apply to a small percentage of survey-sites. To streamline the process for the surveyors, an initial question was added to certain survey blocks, which enabled skipping the block of questions if they were not applicable to the site.

Canvassing proved to be highly effective during the pretest. The response rate for recruitment through canvassing was approximately 30%.

The overall response rate, defined as the total number of customers recruited divided by the total number of customers attempted, was 22% for SMUD (including all phases of the Pretest). The response rate for the early months for San Diego Gas and Electric (SDG&E) customers was 34%. This was an important confirmation of the response rate assumptions that were embedded into the sampling algorithm.

Tracking and Improvement Group

This section describes the protocols followed by the Tracking and Improvement Group (TIG), regarding the activities performed under recruitment and data collection processes. The TIG tracked the performance of recruitment and data collection staff on a regular basis and addressed the issues at hand to improve the processes as needed. Consistency and persistency have been the key to effectively implementing the tracking and improvement plan. To that end, TIG prepared and launched a comprehensive plan to monitor and take corrective steps to ensure quality product delivery in a timely manner.

The TIG established key performance indicators to gauge the performance of call center and field staff and to make necessary adjustments or improvements. Key performance indicators included:

- Number of surveys completed per surveyor, per week
- Number of successful canvassing attempts per surveyor, per week
- Total number of appointments set by scheduler per week
- Appointment completion rate by surveyor and caller
- Total survey backlog (number of sites that have been "checked out" but not yet submitted) by surveyor
- Automated QC scores by surveyor

The TIG also held weekly meetings to discuss and gauge the performance of field staff, recruiters, and QC analysts.

Surveyor feedback was another key factor in the tracking and improvement plan. The quality control (QC) team reviewed the survey data and provided detailed feedback to the surveyors. The QC manager actively followed up by telephone and email to ensure that surveyors understood the root causes of QC issues.

The TIG also directed the call center to place follow-up calls to recent survey participants to gauge surveyors' behavior during the onsite surveys. This process not only helped improve the behavior and performance of surveyors, but also provided confidence in the validity of the completed surveys.

Survey Data Validation

Survey data validation included manual reviews of site data as well as algorithmic QC checks that were run both within the CEUS Tool and on post-processed data. Algorithmic QC checks evolved throughout the project through a joint effort between CEC and ADM staff. QC processes are applied iteratively to all survey data. The iterative application ensured that appropriate remediation measures were taken if a correction to a data field to address a QC fault generate new faults in other algorithms that also depend on the affected data field. This is necessary because many of the QC algorithms were cross-cutting and tested the reasonableness and cohesion of interrelated data fields.

The first stage (Stage 1) occurs during data collection and within the CEUS Tool. The tool highlights fields with data gaps, inconsistencies, and values that are out of range. Surveyors have to address such issues before completion and submission of the data. Examples of how these are provided are presented in the next subsection.

At the second stage (Stage 2), data for all available survey-sites are analyzed and run through several automated validation checks. The second stage QC includes over 100 algorithmic checks that were jointly developed by CEC and ADM staff. The checks examine metrics such as energy intensity (kWh/ft^2, kBTU/ft^2), overall energy use, square footage, business hours, additions and renovations, and overall self-consistency of the data. Outliers are identified based on typical or reasonable ranges for each variable of interest (e.g., the number standard deviations from the mean for a particular metric). Survey-sites that fail the basic data integrity checks are flagged for third stage QC.

At the third stage (Stage 3), an ADM QC team member will review the data for sites that have been flagged for Stage 3 review, and make one of the following determinations:

- The data gaps or inconsistencies identified during Stage 2 review can be resolved by correcting simple issues, and no further data collection is needed.
- Remaining unresolved issues require a follow up telephone conversation with the site-contact.
- The survey-site has irrecoverable data losses which require a second visit or the selection of an alternate sample point.
- Outlier data are reviewed by QC staff and may be found to be naturally occurring; all data appear to be accurate and defensible. The QC staff log the record in a QC override log so that subsequent automated check runs (Stage 2) do not flag the issue as a follow-up item.

A random sample of surveys (with a sample rate of approximately 2%) are promoted to Stage 4 QC. At this stage, a senior team member checks the work done in Stage 3. In addition to these QC stages, all sites are reviewed for NAICS code accuracy. CEC staff reviewed detailed survey data throughout the survey effort. In the final few months of CEUS, the project team met weekly to discuss QC and related issues. Quality Control Procedures are described with greater detail in Appendix I.

CHAPTER 4: Matching Utility Billing Data to Survey-Sites

Overview

This section describes how utility billing data were matched to survey sites, annualized, and weather normalized. Utility billing data are requested and utilized twice in the process, which is summarized as follows:

1. Obtain CIS and billing data from participating utilities.
2. Cluster meters and accounts together into survey-sites[14].
    a. Cluster, by aggregation, monthly energy usages associated with meters and accounts.
3. Create sample frame and set sample quotas per stratum.
4. Merge gas bills from SoCalGas with LADWP and SCE data, gas bills from PG&E with SMUD data.
5. Identify chains, designate customer recruitment modes for each site.
6. Upload sample frames into the CEUS Tool and start customer recruitment.
7. Verify meters while on site; identify cases of incomplete or inaccurate clustering.
    a. Add or remove meters as needed to maintain correspondence between surveyed area and utility meters.
8. Develop weather-normalized hourly consumption data for each participant with available meter data.
    a. Use expansion weights to aggregate customer-level load profiles to Building-type, Forecast Zone, survey-wide, or statewide levels as needed.

Initial Assignment of Electric Consumption Data to Survey-Sites

The initial data provided by participating utilities included monthly gas and electricity usages for each line item in the CIS. Each line item generally corresponds to one meter, though in some cases a meter may represent most or all of a campus. The team's clustering algorithm identified each meter/account/premise combination that goes into a given cluster and aggregates the associated billing data to correspond with the clustered site. In cases where a full 12 months of data are not available for a site, the data were linearly extrapolated to a full year. This initial consumption data was used for stratum boundary assignments and sample point allocation.

---

14 The term *survey-site* is defined in the Survey Design subsection of CHAPTER 1: Introduction.

Meter Reconciliation

The clustering algorithm developed by the CEUS team is a set of simple rules that can be applied uniformly to hundreds of thousands of utility accounts. In certain cases, the algorithm may fail to cluster two meters or accounts that comprise the same survey site for one of the following reasons:

- The two contiguous buildings are more than ±20 apart in street number
- Two contiguous buildings can have different street names
- Customer names or street names that are intended to be the same can have considerable spelling variations, preventing the algorithm from recognizing the relationship

According to the definition of a survey-site, utility account changes related to tenant-turnover can technically change the boundaries of a survey-site. For example, a property manager may have wholly controlled a strip mall, with the property manager as the single electric customer for the strip mall. During the time between sampling and surveying, a new tenant, say, a restaurant, may have moved in and negotiated a direct, individually metered utility account with the electric utility company. In this situation, the original survey-site must be broken into two survey sites. One restaurant that represents the new tenant, and the remainder of the strip mall, which would still be controlled by the property management.

Cases like the above example are relatively rare, but still occur on a regular basis with such a large sample size. To assist surveyors in recognizing the potential needs for re-clustering, CEC staff and ADM jointly developed a flowchart to determine survey area (Figure 5 in CHAPTER 3: Survey Design and Implementation). The flowchart is an active part of the web-based survey instrument, and surveyor selections are recorded and used later in quality control algorithms that target meter-to-site correspondence.

Quality control analysts reviewed and confirmed or rejected surveyors' requests to combine or separate sites into new clusters. Project staff updated sample the frame to reflect any clustering modifications prior to calculating expansion weights. Over the course of the project over 600 surveyed sites were subsumed into other clusters. The quantities of surveyed sites listed in this report reflect the smaller number, after consolidation of these sites.

Assignment of Gas Consumption Data to Survey Sites

The team attempted to match gas usage data to the electric sample frames of SCE, SMUD, and LADWP. The data sets from different utility companies cannot be matched perfectly in a cost-effective manner given variations in the customer identification process, as well as in spellings of addresses. The team took two steps to address this difficulty. First, rather than matching all SCE and LADWP electric to SoCalGas customers, and all SMUD customers to PG&E customers, the workload was reduced to matching survey participants only. Second, rather than relying primarily on addresses and names, the team opted to perform locational matching using geolocations (latitude and longitude coordinates) provided by utilities. The most proximal matching meter was assigned as the corresponding gas meter, but only matches within 20 meters (about 60-feet) in distance were retained to minimize false matches. To assist in cases where matches were not possible, the team exported both gas and electric CIS data by zip code and sought manual matches by reviewing data in the same zip code as a given site.

CHAPTER 5: Analysis of Commercial Data – Key Concepts

Overview

This chapter provides an explanation of key methods and concepts that can be referred to when reviewing results, including:

- Expansion Weights
- Survey Data Analysis
- Definitions and Concepts
- Presentation of Results

Definitions and Concepts

One of the key study goals was to calculate end-use fuel saturations, commercial floorspace, gas and electricity usage at the Forecast Zone level by Building-type. The terms used to convey these results are reviewed below.

Expansion Weights

As described in CHAPTER 2: Sample Design, commercial sites were stratified by annual energy consumption, building vintage, Forecast Zone and Building-type. Sample quotas were then assigned through an optimization algorithm and are shown in Table 4 in the Source: 2022 CEUS

Sample Allocation subsection of that chapter. Sample points in the survey have different levels of representativeness when making assumptions regarding the overarching population of commercial buildings. For example, the typical sample point in the "Large Office – 4" stratum (which consists of very high-usage facilities of the Office Building-type) represented 25% of comparable buildings in its Forecast Zone. On the other hand, each surveyed small restaurant represents, on average, less than 3% of the restaurant market in its Forecast Zone. For each stratum of the study, ADM calculated an expansion weight that can be used to extrapolate from the sampled responses back to the total population. The expansion weight for a stratum was calculated as the total annual electricity usage of the stratum's population divided by the total annual electricity usage of the surveyed sites within that stratum. The expansion weights are provided in Appendix J.

Building-Type

The CEC's Commercial Forecast Model disaggregates the commercial sector into 12 subsectors called Building-types. Building-types are defined by grouping the commercial sector into subsets of relatively homogeneous NAICS classifications [15]. The NAICS to Building-type correspondence is provided in Appendix G. The 12 Building-types are:

- College

15 For more information on the North American Industrial Classification system, visit the US Census Bureau's excellent web site: North American Industry Classification System.

- Food Stores
- Health Care
- Lodging
- Miscellaneous
- Office, Large
- Office, Small
- Restaurant
- Retail
- School
- Warehouse, Refrigerated
- Warehouse, Unrefrigerated

Note that the two Office Building-types are distinguished by floorspace rather than NAICS. Offices larger than 30,000 ft^2 are categorized as *Office, Large*.

Forecast Zone

The CEC's Commercial Forecast Model disaggregates the state into 20 Forecast-zones (see Figure 3 in CHAPTER 2: Sample Design). Forecast Zones 1-6 correspond to PG&E electric service territory. Forecast Zones 7-11 correspond to SCE's service territory. Forecast Zone 12 corresponds to SDG&E, although this study subdivided SDG&E service territory into two zones: 12 Coastal (12c) and 12 Inland (12i). Zone 13 represents SMUD, and LADWP is represented with Forecast Zones 16 and 17.

Total Floor Stock

Total floor stock is the total floorspace as estimated by the survey, for a given level of granularity. Floor stock can range from the statewide level for the entire commercial sector, to the floorspace attributable to a given Building-type in a single Forecast-Zone. Floor stock is presented in units of 1,000 square feet (kft^2).

Annual Energy Intensity

Energy intensity was calculated at the Building-type level. Energy intensity for electric fuel is presented in units of kWh/ft^2. Energy intensity for natural gas or other non-electric fuels (the most common other fuel is propane) is presented in units of $kBtu/ft^2$.

Annual Energy Consumption

Annual energy consumption, like floor stock, can be presented at varying levels of granularity. Annual energy consumption for electric fuels is presented in units of GWh. Annual energy consumption for natural gas or other non-electric fuels is presented in units of 1,000,000 therms, or Mthm.

End-Uses

End-uses are equipment and appliances that are required for normal operation and business activity in buildings. The CEC's Commercial Model includes 10 distinct end-uses. Although this

CEUS is characterized as a high-volume-high-level survey, the survey form included subcategories for Cooking, Refrigeration, Exterior Lighting, and Miscellaneous end-uses.

- Heating
- Cooling
- Ventilation
- Water Heating
- Cooking
    - Commercial cooking space
    - Residential-grade cooking
- Refrigeration
    - Commercial-grade freezers
    - Commercial-grade refrigerators
    - Residential grade refrigerators
    - Refrigerated floorspace
    - Frozen floorspace
- Interior lighting
- Exterior lighting
    - Major Exterior Lighting
    - Minor Exterior Lighting
- Office equipment
    - IT Servers
- Miscellaneous
    - Equipment
    - Motors
    - Air compressors

End-Use Saturation and Penetration at the Survey-Site Level

Saturation is defined as the percent of a survey-site's total square footage in which an end-use was present. For example, if 20% of the floor-space of a warehouse is heated for comfort, the saturation of space heating is 20% for that warehouse. Penetration is a similar concept to saturation but has all-or-none resolution. For example, if electric battery chargers for forklifts are found in that warehouse, then the entire warehouse is said to be served with electric forklift chargers. Penetration is used when saturation is difficult to define. In this example, the difficulty would be to attribute a space or area boundary to the forklift chargers.

End-Use Saturation and Penetration at Aggregated Levels

At aggregate levels, both penetrations and saturations tend to assume continuous distributions, and convey the percentages of total floor stock that are served by the given end-use. For example, the floorspace associated with motors is either 0% or 100% for a given survey-site, but at the statewide level, 79% of the floor stock for large offices, and just 6% of the total floor stock for restaurants are associated with motors. Although the term penetration is essentially synonymous with saturation when describing aggregated results in this report, the authors may use the term as a reminder of differences in how floor-space shares were calculated for the end-use at the survey-site level.

Fuel Shares

In this report, a Fuel Share is defined as the percentage of the floor space with the given end-use that was fueled by either electricity, gas, or other fuel. The fuel shares are generally weighted by floorspace within a survey-site. For example, if 60% of a site is heated by natural gas, and 20% by electricity, and the remaining 20% is not heated, then the electric fuel share is 25%. Commercial cooking fuel shares are weighted by the food service area floor space within the survey-site, rather than the overall facility square footage. Water heating is weighed by the total square footage of the facility. Table 8 summarizes saturation, and floorspace methodology. Unless otherwise stated, the default weighting of penetrations or saturations among sites is conducted with the expansion weight associated with the site's sampling stratum.

Table 8: Summary of End-Use saturation and fuel share calculation methods

End-Use	Floorspace Assigned to a Given Site	Fuel Share Calculation Methodology
Heating	Space heated floorspace	Weighted by floorspace
Cooling	Space cooled floorspace	Weighted by floorspace
Ventilation	Ventilated floorspace	Weighted by floorspace
Water Heating	Entire site floorspace	Weighted by utilization within site (if there are multiple fuels), and by floorspace among sites
Interior Lighting	Entire site floorspace	N/A (all electric)
Exterior Lighting	Entire site floorspace	N/A (all electric)
Office Equipment	Entire site floorspace	N/A (all electric)
IT Servers	Dedicated server floorspace	N/A (all electric)
Residential-grade Cooking Equipment	Entire site floorspace	Weighted by site-contact interview within site
Residential-grade Refrigerators	Entire site floorspace	N/A (all electric)
Commercial Cooking Space	Combined food preparation and food service floorspace	Weighted by equipment capacity and utilization within site, and by food preparation and service floorspace among sites
Commercial-grade Refrigerators	Entire site floorspace	N/A (all electric)
Commercial-grade Freezers	Entire site floorspace	N/A (all electric)
Refrigerated Floor Space	Refrigerated Floor Space (excludes small walk-ins)	N/A (all electric)
Frozen Floor Space	Frozen Floorspace (excludes small walk-ins)	N/A (all electric)
Motors	Entire site floorspace	N/A (all electric)
Air Compressors	Entire site floorspace	N/A (all electric)
Miscellaneous Electric Equipment	Entire site floorspace	N/A (all electric)
Miscellaneous Gas Equipment	Entire site floorspace	N/A (all gas)

Source: 2022 CEUS Data Collection Protocols

CHAPTER 6: Results

Introduction

The following chapter provides a summary of the results of the CEUS aggregated statewide, as well as utility-specific results. The report includes gas usage information for LADWP and SCE customers that purchase gas from SCG.

Two types of results are presented:

- Building-type floorspace, electricity usage, and electric energy intensity.
- End-use market penetration, saturation, and fuel share by Building-type.

End-use level data are too copious to present in the main body of the report, and are instead provided in spreadsheet format in Appendix K.

Adjustment of Data to Reflect Post-COVID Norms

Much of the data collection for CEUS occurred prior to the COVID-19 pandemic. The sample frames and associated energy usage data were all obtained in 2018 and are informed with energy usage data from the period December 2015 to September 2018 [16], with 2018 regarded as the common "base year" for the survey. Remote data collection that occurred after March 2020 focused questions regarding occupancy and operation schedules to the pre-COVID period to maintain consistency with the pre-COVID billing data and with surveys conducted prior to March 2020.

The project team initially faced considerable uncertainty related to the duration and severity of the pandemic, but as of this writing there is mounting evidence that the pandemic has accelerated some preexisting trends, while some of the more acute economic impacts have abated. Examples of trends that have been accelerated include teleworking and digital food service. The "retail apocalypse," or the closing of many brick-and-mortar retail stores, was ongoing prior to the pandemic but increased significantly. Some COVID-related impacts, however, appear to be abating or approaching a new equilibrium. For example, many workers are returning to offices at least part-time. This in turn, increases demand for brick-and-mortar food service establishments, which were particularly hard-hit by the COVID-19 pandemic. The CEUS team felt that survey results would have greater utility if they reflected the post-COVID California economy rather than conditions that prevailed during the study design and sampling phase. To this end, the team developed a strategy and identified data sources to help "walk" the survey results from the base year of 2018 to the most recently completed year, 2022.

---

16 The CEUS team made data requests to different utility companies at different times, but each utility company provided approximately 24 months of data. The team annualized energy usage for each account by using all monthly billing observations that were available. While the participating utilities provided data at different times, each data request response was provided during calendar year 2018, and thus the CEUS sample frame is a "snapshot" of commercial utility data taken in year 2018. For this reason, we associate the calendar year 2018 with the CEUS sample frame.

One option was to request new billing data for calendar year 2022 for all survey participants to observe changes in usage. The main difficulty with this approach is that the project lacked the resources for the labor-intensive reconciliation process that would be needed for any site-by- site approach. One cannot simply update the annual energy usage for a site but leave other variables unchanged. For example, the facility could be occupied by a different entity in 2022, with a different NAICS code – it could map to another Building-type. Rather than to adjust the survey microdata, the CEUS team opted for adjustments at the Building-type and Forecast Zone levels, which are more tractable than compiling site-by-site changes. The CEC's Quarterly Fuel and Energy Report (QFER) served as the primary auxiliary data set for the adjustment. The QFER data includes annual electric sales by Forecast Zone, electric service provider, and NAICS code; and annual self-generation by Forecast Zone and Building-type. The QFER data can provide insights such as:

- Electric sales in the lodging industry (the Hotel Building-type) fell by 20% in Forecast zone 12, but just 3% in Forecast Zone 3 in 2020 relative to 2019.
- Self-generation grew by 74% in the commercial sector in Forecast Zone 1 between 2018 and 2022.
- Statewide, the Building-types that were most acutely affected by COVID were School, College, Lodging, and Restaurant
- On average, electric energy intensities in the commercial sector were 12% lower in 2022 than in 2018, while gas energy intensities are 6% lower.

The QFER sales data, when combined with self-generation data, can describe increases, or decreases in electricity consumption by Forecast Zone and Building-type. This information does not convey whether the difference is attributable to changes in floorspace, energy intensity, or both factors. For example, if energy usage for restaurants decreased by 10% between 2018 and 2021, it is not possible to know, with the QFER data, to what extent the floorspace associated with the restaurants has decreased, and to what extent the restaurants are operating at reduced capacity, or remain as vacant restaurants space, vacant general space, or are occupied by another business type. Several assumptions are needed to develop a methodology to approximate year-2022 energy usage patterns.

Floorspace Drift Across Building Types Should Be Small

The CEC has defined Building-types in such a way that repurposing one building type into another should be relatively uncommon. For example, converting a restaurant or grocery to an office, or vice versa, would involve a significant repurposing of the space and either the procurement or divestment of commercial food service equipment. Likewise, it seems unlikely for a gas station, auto repair shop, hospital, university, or motel to be repurposed into a different building type. Therefore, a key assumption is that changes in energy usage at the Building-type level are primarily due to differences in utilization (e.g., vacancy rates, hours of operation, and occupancy), rather than to increase or reduction of floorspace associated with the Building-type.

Overall, Commercial Floorspace Has Increased Modestly from 2018 to 2022

The CEUS team estimates that commercial floorspace has increased 4.4% from 2018 to 2022 (although growth in 2020 was hampered by the COVID pandemic)[17]. The team formed this estimate by casting the increased commercial floorspace estimates for the surveyed areas of PG&E, SCE, SDG&E, and SMUD, who participated in both the 2006 and 2022 CEUS surveys, as a function of normalized nonresidential construction starts (in 2005 $) in California in the period 2005 to 2021. The team then used the normalized nonresidential construction starts from 2018 to 2021 to estimate the floorspace added between 2018 and 2022. It is not known if the increased floorspace favored one Building-type over another, so the team applied the percentage increase uniformly for all Building-types. While it is reasonable to assume that commercial building occupancy rates have declined since 2018, the CEUS team did not estimate occupancy changes for commercial buildings. Changes in energy intensities between 2018 and 2022, however, may serve as indicators or proxies for occupancy changes.

Assume Gas Usage and Electric Usage Evolved Independently post-COVID

While the general economic shock of the COVID pandemic negatively impacted electricity and gas usage in the commercial sector, it is likely that gas and electricity usage had different recovery paths post-COVID. For example, ongoing electrification efforts could reduce gas energy usage relative to electricity usage. On the other hand, comparison of the 2006 CEUS and the 2022 CEUS data indicate an increase in gas energy usage over time. The CEUS team requested gas energy usage data by Building-type, Forecast Zone, and year from 2017 through 2022 from the CEC's QFER team. With this data, the team was able to develop separate scale factors for gas and electricity usage as described in the following section.

Methodology

The process used to scale energy usage to year-2022 usage is described below.

Step 1: Develop a series of *electric intensity scale factors* for each combination of Building-type and Forecast Zone. The value of the time scale factor is the ratio of 2022 total electricity usage (determined as the sum of sales and generation) to 2017[18] total electricity usage as reported by the electric service provider of interest for all NAICS that map to the given Building-type in the given Forecast Zone.

Step 2: Account for the fact that some of the changes in electricity usage are driven by floorspace growth. Divide the electric intensity scale factors by the estimated ratio of commercial floorspace in 2022 to 2018.

Step 3: Multiply each sample point's estimated electric energy usage by the corresponding scale factor.

---

17 ConstructConnect, "Insight Forecast: Construction Market Forecasts," 2023, [Construct Connect: Insight Forecast]

18 While the year 2018 is used to characterize floorspace, energy usage from calendar year 2017 from QFER is preferred over 2018 energy usage for this calculation, as it more closely aligns with information available for the majority of sites in the CEUS sample. The authors decided on this convention to account for the fact that, while floorspace measurement can take place on one given day, annual energy usage determination typically involves a long lookback window.

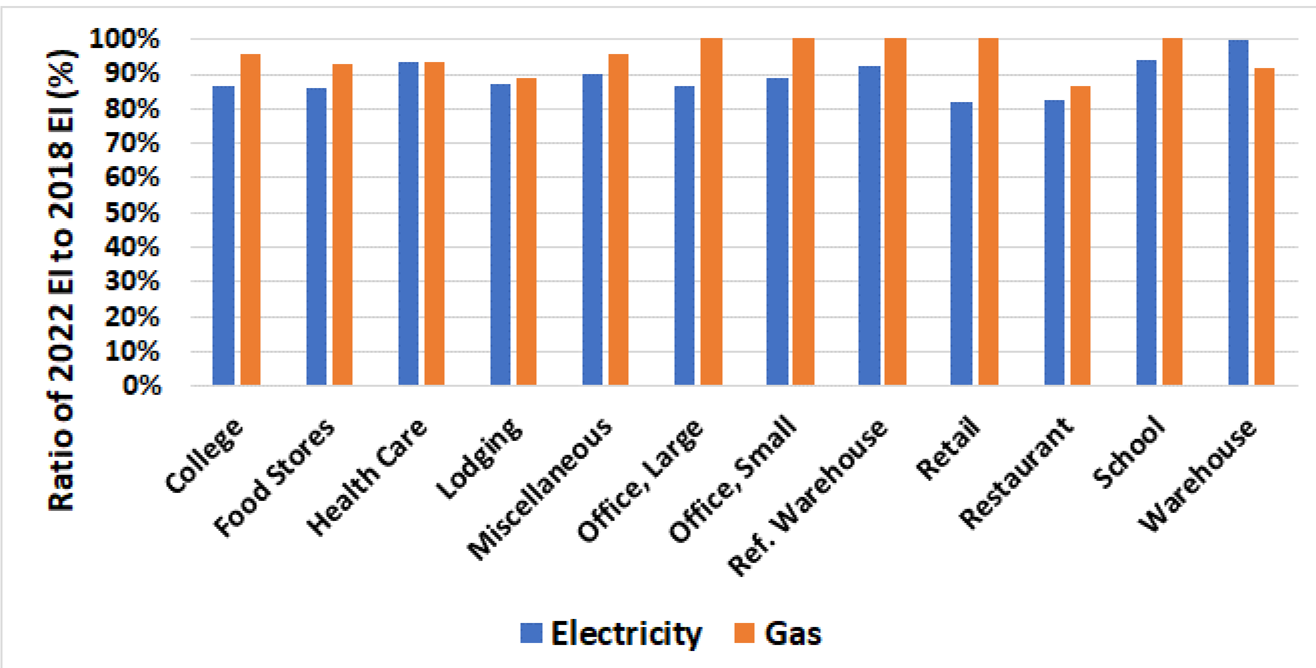
Step 4: Multiply each sample point's estimated gas energy usage by the corresponding scale factor.

Step 5: Since we assume growth in floorspace, this implies that the expansion weights need to increase. Multiply the expansion weights by the estimated ratio of commercial floorspace in 2022 to 2018.

Results

Using this process, the team created expansion weights, energy usages, and energy intensities that can be used to approximate California's post-COVID economy in 2022. The original energy usages, intensities, and weights are retained in the CEUS data set so users can select either scenario. Figure 8 below shows the statewide ratios of 2022 to 2018 electricity and gas EIs by Building-type. The full set of scale factors are shown in Appendix M.

Figure 8: Statewide ratios (2022:2018) of electricity and gas EIs by Building-type



Source: 2022 CEUS

Adjustment of Data to Reflect Non-Surveyed Commercial Customers

The CEUS sample frame consisted of the nonresidential customer lists that were mapped to the commercial sector through their NAICS codes for the five participating electric utilities [19]. The sample frame included the five participating electric utilities which account for most (approximately 75%) of electric sales in the state. However, there are three main sources of commercial electricity usage in the state that were not included from the sample frame:

[19] SCG also participated and provided gas data, but the sample frame and surveyed area are defined as the five electric service territories.

1. There are many smaller utilities within the surveyed Forecast Zones that did not participate in CEUS.
2. There are also some customers of participating utilities that do not have NAICS codes (referred to herein as "Unclassified NAICS codes") on file but are expected to be nonresidential. A portion of those is likely to be commercial customers.
3. Forecast Zones 0, 14, 15, 18, 19, and 20 were not included in the survey.

Methodology

The processes for constructing scale factors to account for nonparticipating electric providers, unclassified NAICS codes, and non-surveyed zones are described below. The first two sources of commercial electricity usage excluded from the sample are within the surveyed Forecast Zones. Therefore, the CEUS team leveraged the QFER data described on page 68 above to construct scale factors that account for their energy usage at the Forecast Zone and Building-type level. The team constructed a global scale factor to account for the third source listed above. These scale factors can be applied to the sample weights to construct new expansion weights which result in true statewide estimates of floorspace and energy usage.

Constructing scale factors to account for nonparticipating electric providers

Construct a scale factor for each zone and building type, with each one a fraction with the following specification [20]:

Numerator = The total electricity usage for the Building-type and Forecast Zone.

Denominator = The total electricity usage attributed to participating utilities for the Building-type and Forecast Zone.

Process for constructing scale factors to account for unclassified NAICS codes

Step 1: Distribute unclassified usage to Building-types in each zone according to their share of the overall nonresidential usage within that zone.

Step 2: Construct a scale factor for each zone and building type, with each one a fraction with the following specification:

Numerator = The total electricity usage for the Building-type and Forecast Zone inclusive of the portion of unclassified nonresidential usage attributed to that Building-type in Step 1.

Denominator = The total electricity usage for the Building-type and Forecast Zone not including the portion of unclassified nonresidential usage attributed to that Building-type in Step 1.

The resulting array of scale factors accounts for unclassified energy usage that should be attributed to that Forecast Zone and Building-type.

---

[20] The CEUS team constructed a scale factor of 1.0 for Colleges in Forecast Zone 4 since the largest university there was surveyed but received the majority of its electric service from nonparticipating electric service providers.

Constructing scale factors to account for Forecast Zones exclude from the survey

There is one more overall scale factor needed to represent statewide energy usage. This scale factor is the ratio of electricity usage for the entire state to the ratio of the electricity usage in the surveyed Forecast Zones. This overall scale factor is calculated from QFER data and has a value of 1.057.

A note regarding nonparticipating gas providers

Approximately ten percent of survey participants had natural gas service and equipment but could not be matched to billing data provided by participating gas utilities. Some of these customers were known to receive gas service from nonparticipating gas utilities (particularly Southwest Gas and Long Beach Gas), while others were not able to identify their gas providers. In some cases, customers identified participating utilities as gas providers, but all matching efforts failed to identify the associated account. While it is possible to modify gas energy usage sample weights with scale factors like the ones described above for nonparticipating electric providers, the CEUS team imputed gas energy usage on such sites by first constructing a NAICS-specific gas energy usage intensity (in units of kBTU per ft^2), and then multiplying the gas energy usage intensity by the site square footage. The data set was augmented by a data field which indicated that gas usage for such sites was imputed. Several universities received gas service from nonparticipating utilities. In most cases, the CEUS team was able to obtain gas usage data either directly from the university or indirectly from the Sustainability Tracking, Assessment & Rating System (STARS) database maintained by the Association for the Advancement of Sustainability in Higher Education (AASHE).

Results

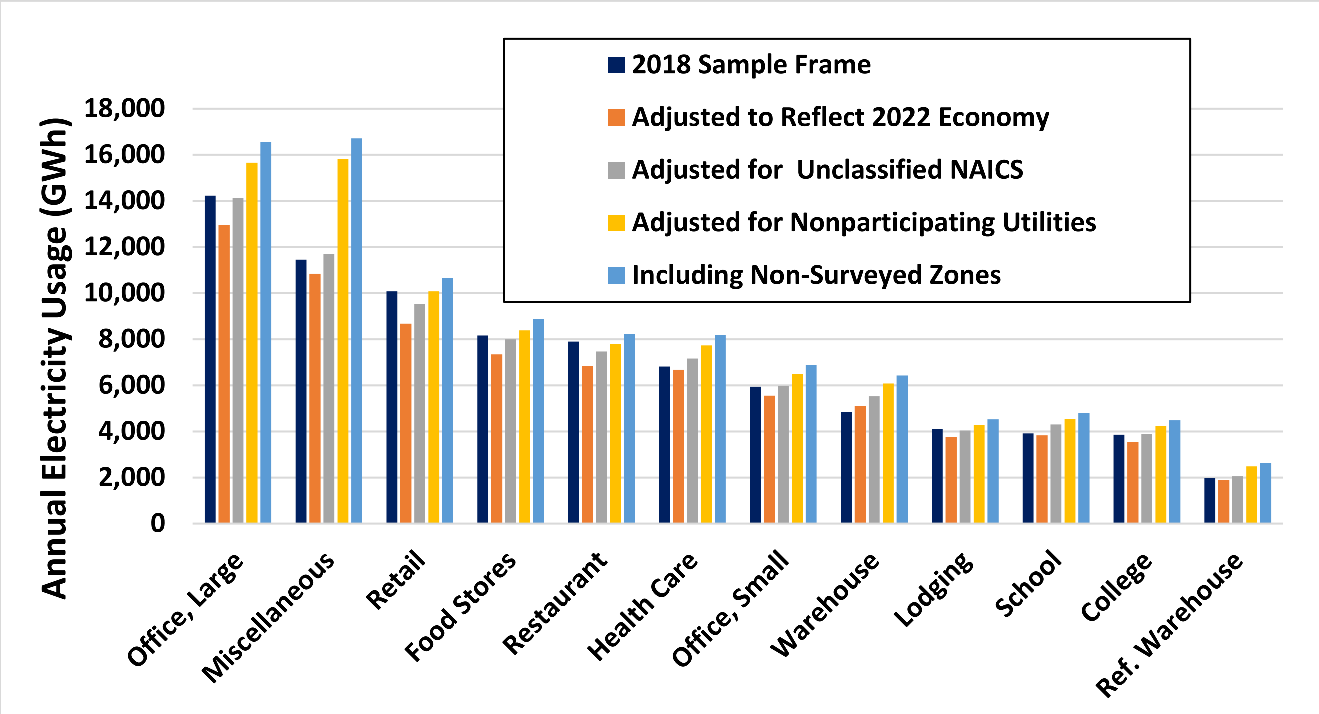
Figure 9 shows for each Building-type the total electric usage as estimated by the scale factors described above. The scale factors are essentially the ratios of the profiles shown, though in practice, there are three 192-element arrays of scale factors – one for each combination of Forecast Zone and Building-type – and an overall scale factor to account for Forecast Zones that were excluded from the survey.

The final CEUS data set includes all scale factors and describes them in the data dictionary. The full set of scale factors are shown in Appendix M. In the figure below, the first set of bars represents electricity usage as determined in our sample frame for commercial customers of the five participating electric providers, excluding any customers that had unknown NAICS codes, and thus were not part of the CEUS sample frame. The second set of bars represents the same set of customers, but in the year 2022 instead of the sample frame base year 2018. The third set of bars augments the second set by scaling to represent commercial customers with unclassified NAICS codes. The fourth set of bars augments the third set by scaling to represent nonparticipating utilities within the surveyed Forecast Zones[21]. The last set of bars include an overall scalar multiplier of 1.057 to represent electricity usage in Forecast Zones 0, 14, 15, 18, 19, and 20.

---

[21] The significantly increased energy usage for the Miscellaneous building type after this adjustment is driven by data centers in Forecast Zone 1 that purchase power from electric providers that did not participate in CEUS.

Figure 9: Electric Usage by Building Type After Each Adjustment



Source: 2022 CEUS

Definitions

The following sections present commercial building floorspace, energy usage, and energy intensities. The tables and values follow these conventions:

Projected Statewide: Statewide energy usage reflects the year 2022 and is inclusive of customers with unclassified NAICS codes, of non-participating utilities, and of all Forecast Zones. We use the term projected to indicate that the customer usage data from the 2018 sample frame has been scaled with ratios developed from QFER data to project usage patterns in year 2022.

Utility Service Territory: Utility-wide energy usage reflects the year 2022 and is inclusive of customers with unclassified NAICS codes but does not include usage from nonparticipating utilities within the service territories of the five participating electric utilities. Gas usages for electricity customers from the five participating electric utilities are reported whether the customer purchased gas from participating gas utilities or not.

Projected 2022 Statewide Floor Stock and Electricity usage

Table 9 provides a summary of the total floor stock, annual electric and gas intensities, and annual electric and gas consumption by commercial Building-type. Figure 10 provides a visualization of the percent of total annual electric usage by commercial Building-type. Figure 11 provides a visualization of the percent of total annual gas usage by commercial Building-type.

The projected statewide commercial floorspace was estimated to be 8.8 billion square-feet. Miscellaneous buildings make up most of the estimated commercial floorspace (19%), with large offices (15%) and warehouses (14%) being the second and third most common type of commercial floorspace. The total annual electric usage was estimated to be 98,909 GWh per year.

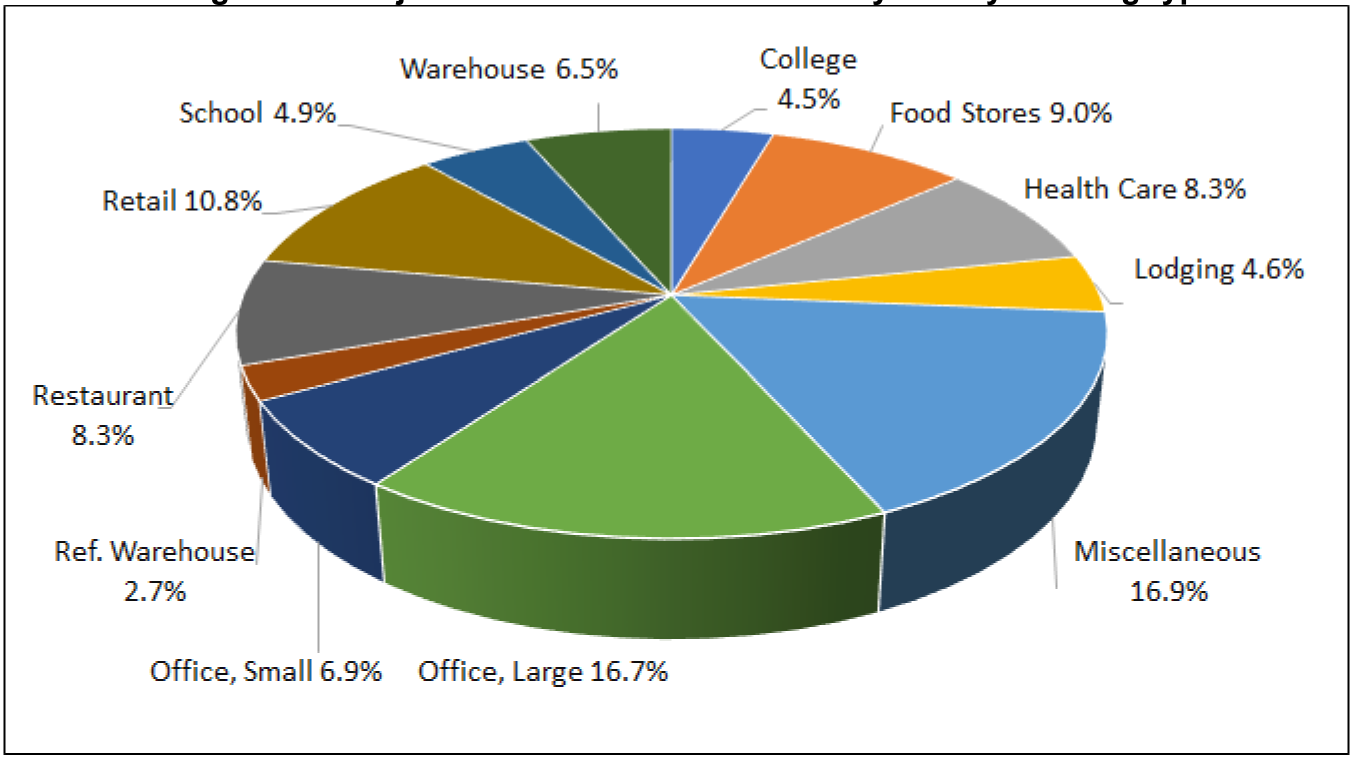
Miscellaneous commercial buildings are estimated to use the most electricity annually (17%). Large Offices (17%), and Retail (11%) use the second and third most electricity annually. The total annual natural gas usage was estimated to be 2,380 million therms (Mthm) per year. Miscellaneous commercial buildings are estimated to use the most natural gas annually (23%). Restaurants (19%), and Health Care (12%) use the second and third most natural gas annually.

Table 9: Overview of Projected 2022 Statewide Commercial Annual Energy Usage

Building-type	Floor Stock (kft^2)	Annual Electric Intensity (kWh/ft^2)	Annual Electric Usage (GWh)	Annual Gas Intensity ($kBTU/ft^2$)	Annual Gas Usage (Mthm)
College	384,440	11.6	4,476	56.2	202.5
Food Stores	241,676	36.7	8,864	57.4	138.8
Health Care	480,002	17.0	8,179	61.8	281.3
Lodging	471,706	9.6	4,516	33.9	159.2
Miscellaneous	1,704,294	9.8	16,714	32.7	551.2
Office, Large	1,321,787	12.5	16,558	18.0	236.9
Office, Small	771,141	8.9	6,871	18.4	142.0
Refrigerated Warehouse	145,619	18.0	2,622	3.6	5.2
Restaurant	223,831	36.8	8,229	206.7	462.7
Retail	1,126,373	9.5	10,650	7.1	78.3
School	686,285	7.0	4,801	10.5	72.1
Warehouse	1,252,308	5.1	6,428	4.1	49.6
All Commercial	**8,809,461**	**11.2**	**98,909**	**27.5**	**2,379.7**
All Office	**2,092,928**	**11.2**	**23,430**	**18.2**	**378.9**
All Warehouse	**1,397,927**	**6.5**	**9,050**	**4.0**	**54.7**

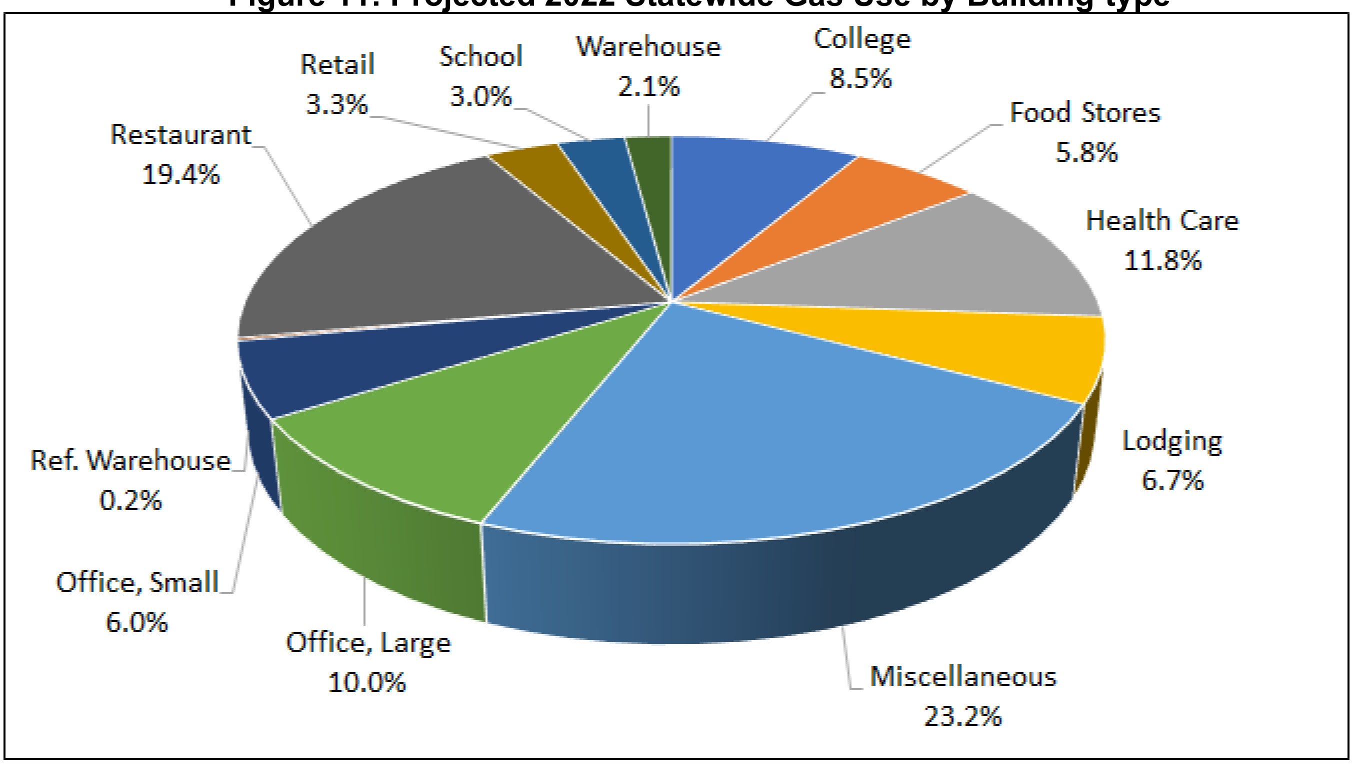
Source: 2022 CEUS

Figure 10: Projected 2022 Statewide Electricity Use by Building-type



Source: 2022 CEUS

Figure 11: Projected 2022 Statewide Gas Use by Building-type



Source: 2022 CEUS

PG&E Floor Stock and Electricity usage

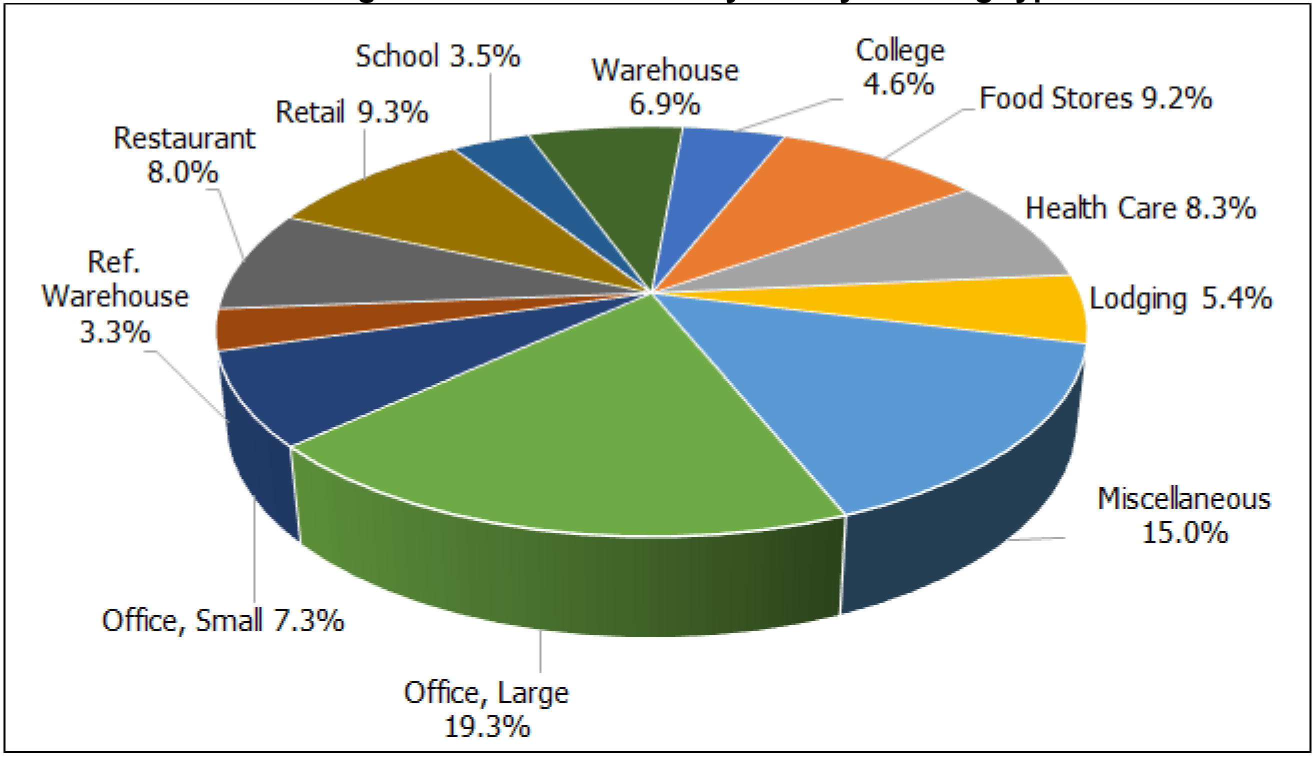
Table 10 provides a summary of the total floor stock, annual electric and gas intensities, and annual electric and gas consumption by Building-type. Figure 12 and Figure 13 provide visualizations of the percent of total annual electric and gas usage respectively by commercial Building-type.

Table 10: Overview of PG&E Annual Energy Usage

Building-type	Floor Stock (kft^2)	Annual Electric Intensity (kWh/ft^2)	Annual Electric Usage (GWh)	Annual Gas Intensity ($kBTU/ft^2$)	Annual Gas Usage (Mthm)
College	108,348	13.5	1,458	48.5	49.4
Food Stores	76,657	38.5	2,954	48.1	36.9
Health Care	158,800	16.7	2,655	47.8	73.3
Lodging	186,402	9.3	1,733	30.7	56.7
Miscellaneous	463,639	10.3	4,779	27.1	124.0
Office, Large	439,911	14.0	6,160	16.7	73.2
Office, Small	254,165	9.2	2,346	21.5	54.7
Refrigerated Warehouse	47,655	21.8	1,039	4.9	2.3
Restaurant	67,666	37.8	2,557	178.0	120.5
Retail	293,996	10.1	2,967	11.2	33.0
School	160,343	6.9	1,113	11.5	18.5
Warehouse	293,767	7.5	2,197	6.0	16.9
All Commercial	**2,551,349**	**12.5**	**31,959**	**26.2**	**659.2**
All Office	**694,076**	**12.3**	**8,506**	**18.5**	**127.9**
All Warehouse	**341,421**	**9.5**	**3,236**	**5.8**	**19.3**

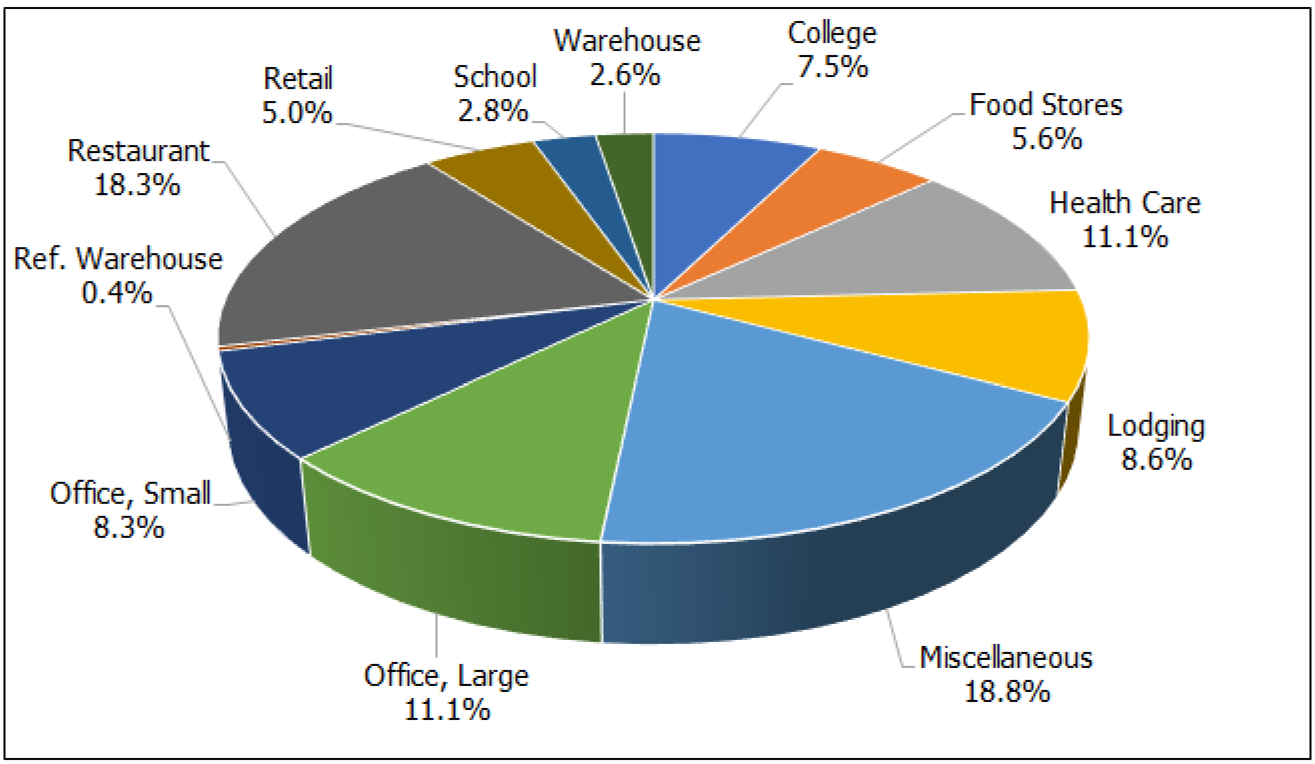
Source: 2022 CEUS

Figure 12: PG&E Electricity Use by Building-type



Source: 2022 CEUS

Figure 13: PG&E Gas Use by Building-type



Source: 2022 CEUS

SCE Floor Stock and Electricity usage

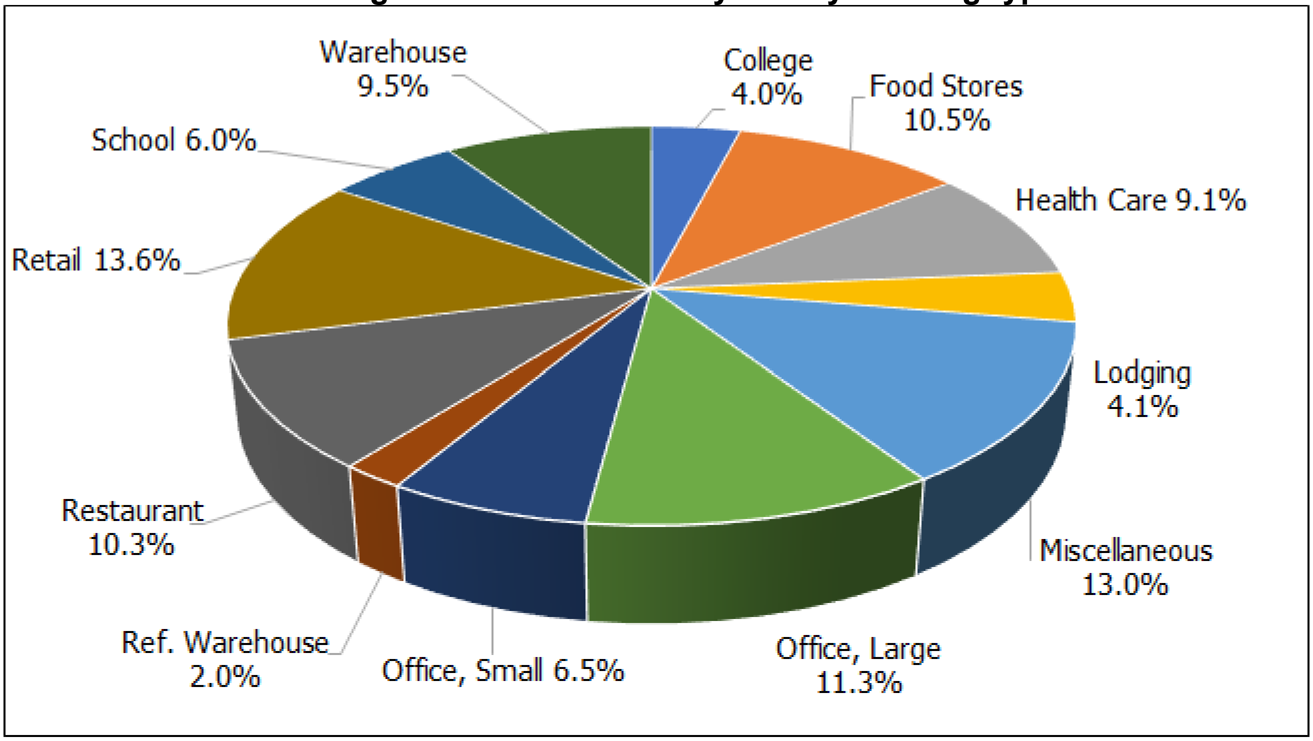
Table 11 provides a summary of the total floor stock, annual electric and gas intensities, and annual electric and gas consumption by commercial Building-type. Figure 14 and Figure 15 provide visualizations of the percent of total annual electric and gas usage respectively by commercial Building-type.

Table 11: Overview of SCE Annual Energy Usage

Building-type	Floor Stock (kft^2)	Annual Electric Intensity (kWh/ft^2)	Annual Electric Usage (GWh)	Annual Gas Intensity ($kBTU/ft^2$)	Annual Gas Usage (Mthm)
College	124,978	9.4	1,172	26.2	30.0
Food Stores	87,741	34.7	3,048	71.7	62.9
Health Care	149,992	17.5	2,623	83.5	122.0
Lodging	131,173	9.0	1,177	40.3	52.9
Miscellaneous	452,133	8.3	3,769	36.5	163.0
Office, Large	322,062	10.2	3,284	14.8	47.5
Office, Small	246,366	7.6	1,878	10.9	26.7
Refrigerated Warehouse	39,559	14.9	590	2.8	1.1
Restaurant	84,466	35.4	2,989	223.8	189.1
Retail	456,863	8.6	3,944	5.3	23.2
School	283,435	6.1	1,736	10.9	30.9
Warehouse	639,148	4.3	2,744	3.6	22.1
All Commercial	**3,017,918**	**9.6**	**28,955**	**26.2**	**771.5**
All Office	**568,428**	**9.1**	**5,162**	**13.1**	**74.2**
All Warehouse	**678,707**	**4.9**	**3,334**	**3.6**	**23.2**

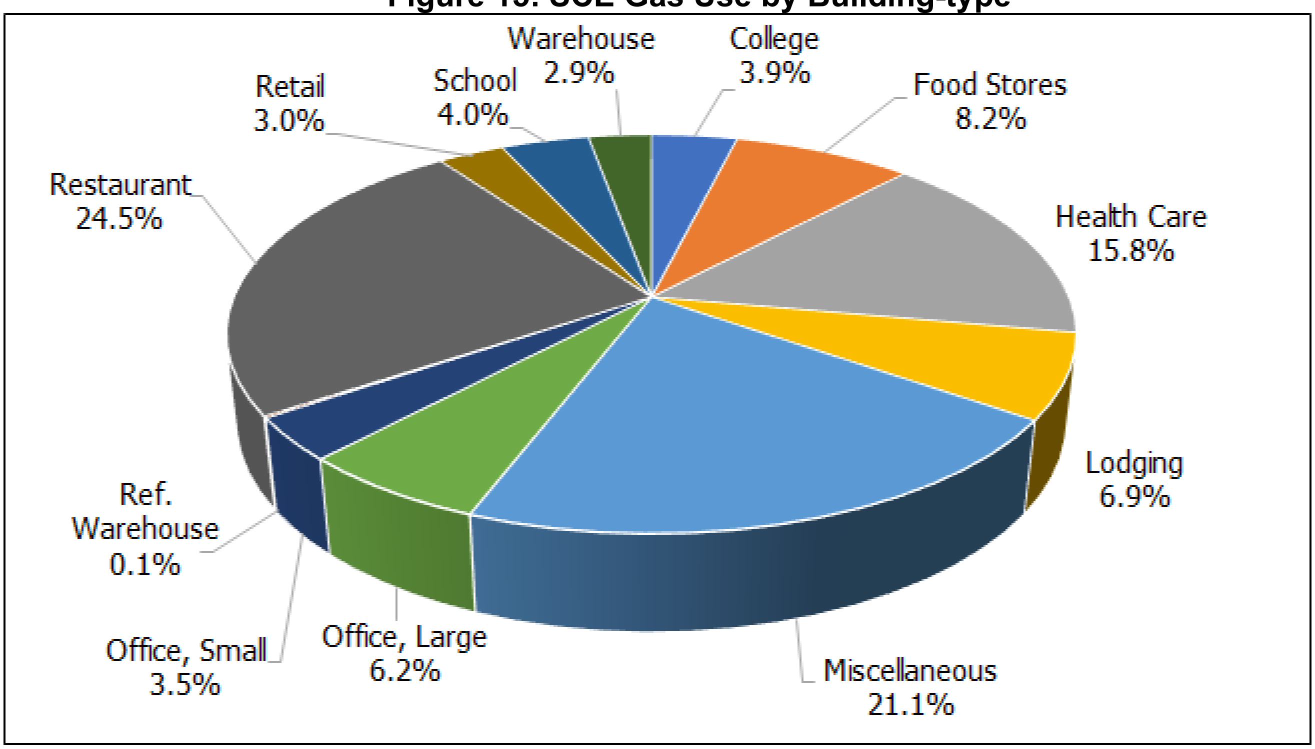
Source: 2022 CEUS

Figure 14: SCE Electricity Use by Building-type



Source: 2022 CEUS

Figure 15: SCE Gas Use by Building-type



Source: 2022 CEUS

SDG&E Floor Stock and Electricity usage

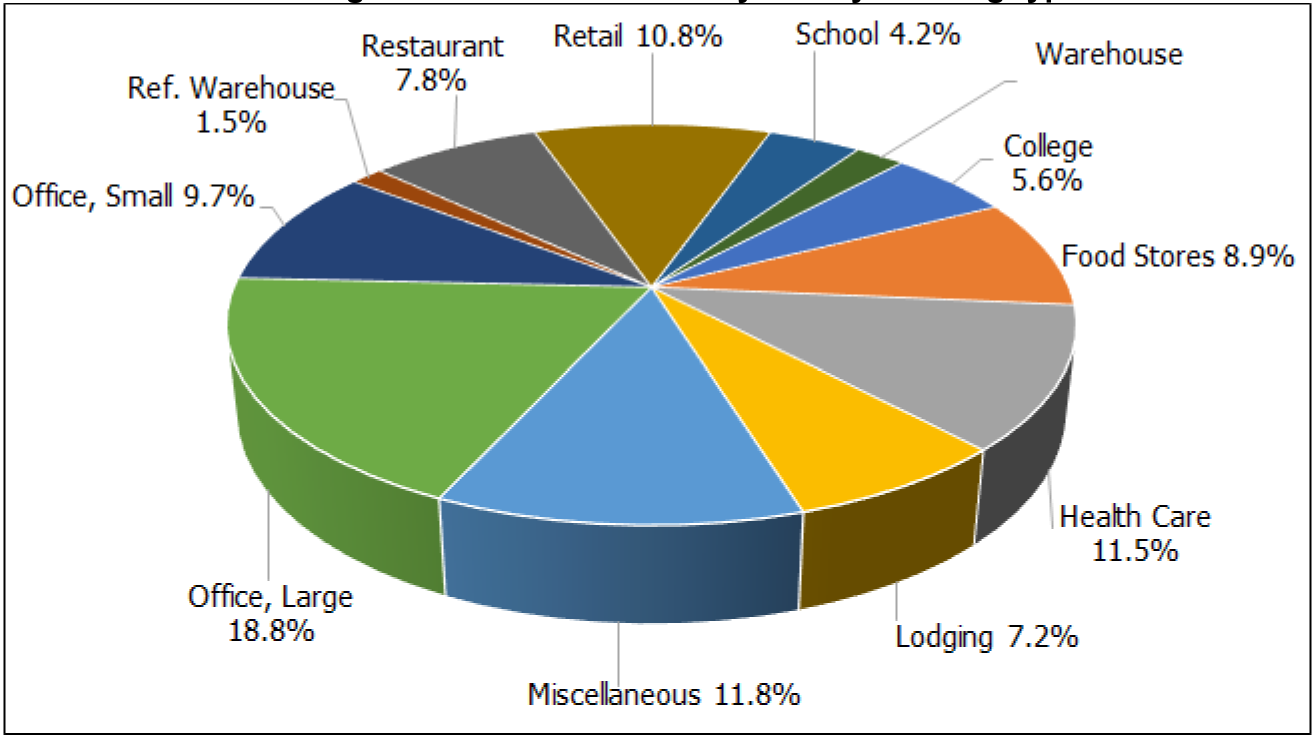
Table 12 provides a summary of the total floor stock, annual electric and gas intensities, and annual electric and gas consumption by commercial Building-type. Figure 16 and Figure 17 provide visualizations of the percent of total annual electric and gas usage respectively by commercial Building-type.

Table 12: Overview of SDG&E Energy Usage

Building-type	Floor Stock (kft^2)	Annual Electric Intensity (kWh/ft^2)	Annual Electric Usage (GWh)	Annual Gas Intensity ($kBTU/ft^2$)	Annual Gas Usage (Mthm)
College	47,531	11.4	542	54.8	23.6
Food Stores	21,648	39.4	854	60.3	13.0
Health Care	50,558	21.9	1,109	48.5	23.0
Lodging	59,444	11.7	695	30.6	18.2
Miscellaneous	168,390	6.7	1,134	39.3	65.3
Office, Large	122,135	14.8	1,812	32.4	39.0
Office, Small	87,567	10.6	929	23.2	20.3
Refrigerated Warehouse	4,323	32.8	142	7.1	0.3
Restaurant	18,270	41.0	749	228.3	41.7
Retail	101,055	10.3	1,036	3.4	3.2
School	55,964	7.3	408	7.0	3.9
Warehouse	34,741	6.3	220	3.5	1.2
All Commercial	**771,626**	**12.5**	**9,630**	**33.6**	**252.8**
All Office	**209,702**	**13.1**	**2,741**	**28.5**	**59.3**
All Warehouse	**39,064**	**9.3**	**362**	**3.9**	**1.5**

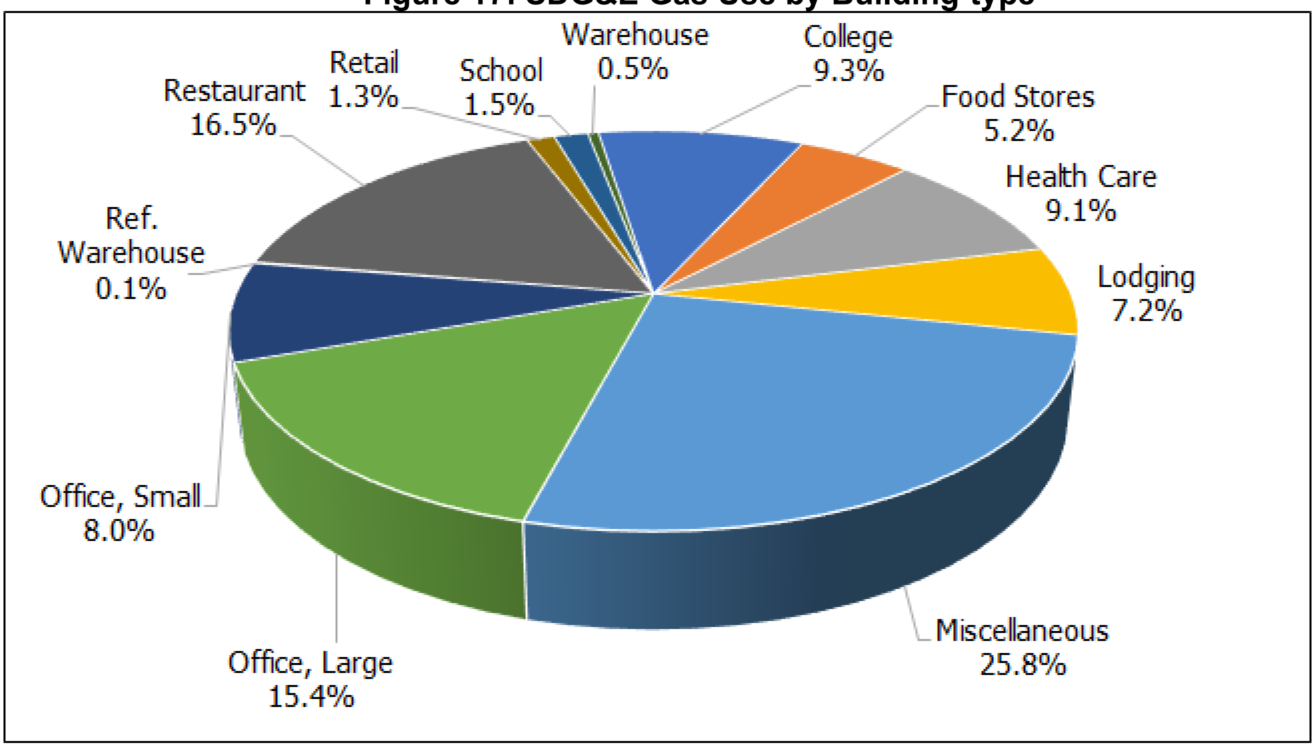
Source: 2022 CEUS

Figure 16: SDG&E Electricity Use by Building-type



Source: 2022 CEUS

Figure 17: SDG&E Gas Use by Building-type



Source: 2022 CEUS

LADWP Floor Stock and Electricity usage

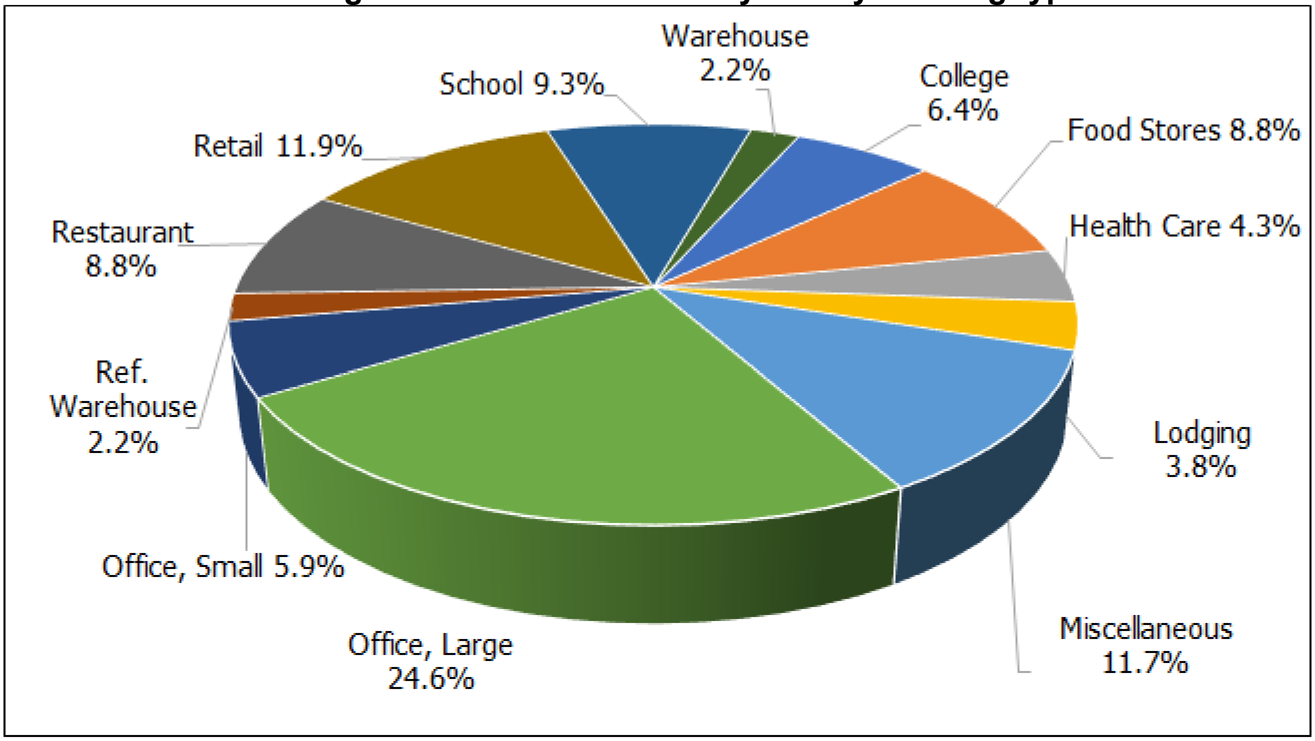
Table 13 provides a summary of the total floor stock, annual electric and gas intensities, and annual electric and gas consumption by commercial Building-type. Figure 18 and Figure 19 provide visualizations of the percent of total annual electric and gas usage respectively by commercial Building-type.

Table 13: Overview of LADWP Energy Usage

Building-type	Floor Stock (kft^2)	Annual Electric Intensity (kWh/ft^2)	Annual Electric Usage (GWh)	Annual Gas Intensity ($kBTU/ft^2$)	Annual Gas Usage (Mthm)
College	38,888	14.7	570	198.5	76.4
Food Stores	22,272	35.1	782	33.2	7.4
Health Care	40,043	9.6	385	66.6	20.4
Lodging	34,136	10.0	341	34.8	11.9
Miscellaneous	124,487	8.4	1,044	30.9	38.5
Office, Large	203,860	10.8	2,194	14.9	30.4
Office, Small	53,287	9.9	527	23.8	12.7
Refrigerated Warehouse	12,629	15.6	197	0.5	0.1
Restaurant	23,626	33.2	784	204.1	48.2
Retail	104,376	10.1	1,057	4.5	4.7
School	85,910	9.6	827	8.9	7.6
Warehouse	44,290	4.5	198	2.4	1.0
All Commercial	**787,804**	**11.3**	**8,907**	**33.4**	**259.3**
All Office	**257,147**	**10.6**	**2,721**	**16.8**	**43.1**
All Warehouse	**56,919**	**6.9**	**396**	**1.9**	**1.1**

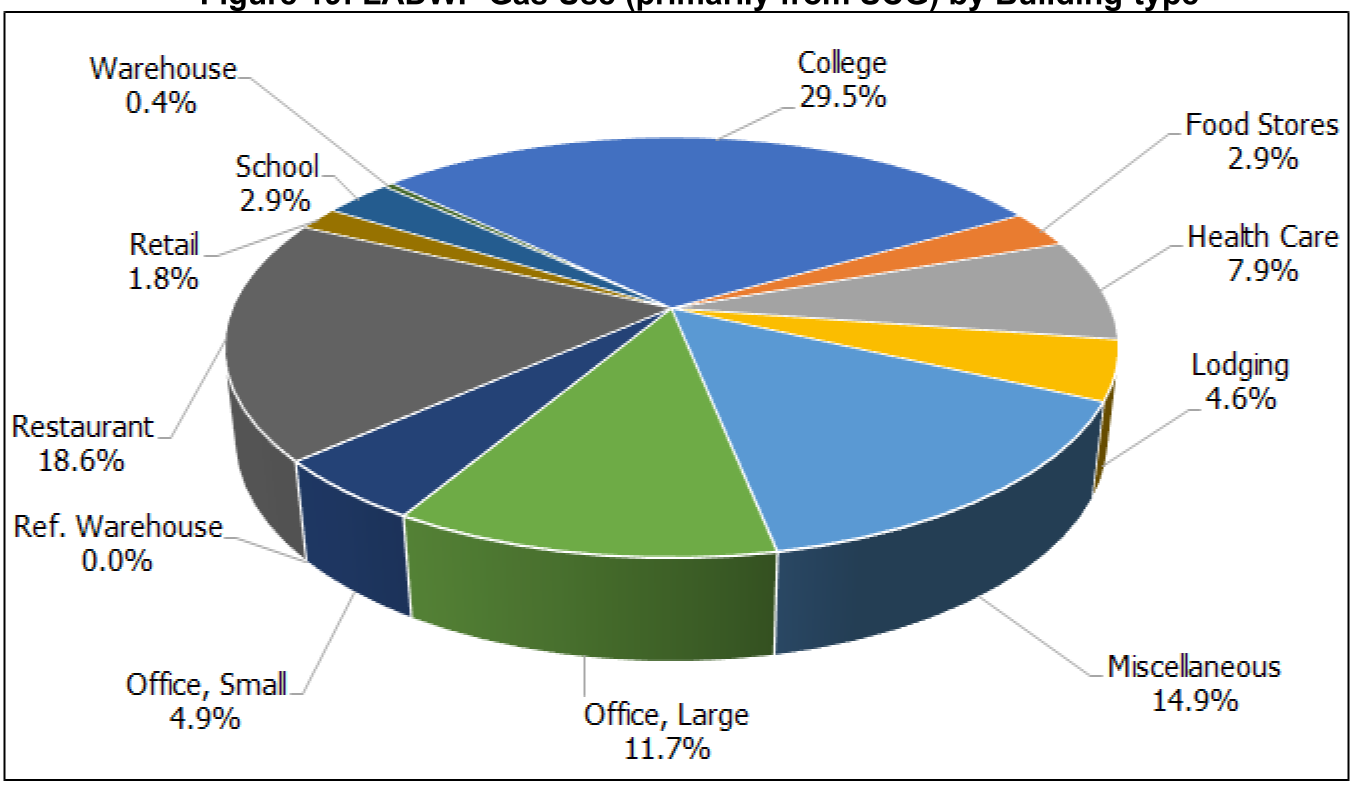
Source: 2022 CEUS

Figure 18: LADWP Electricity Use by Building-type



Source: 2022 CEUS

Figure 19: LADWP Gas Use (primarily from SCG) by Building-type



Source: 2022 CEUS

SMUD Floor Stock and Electricity usage

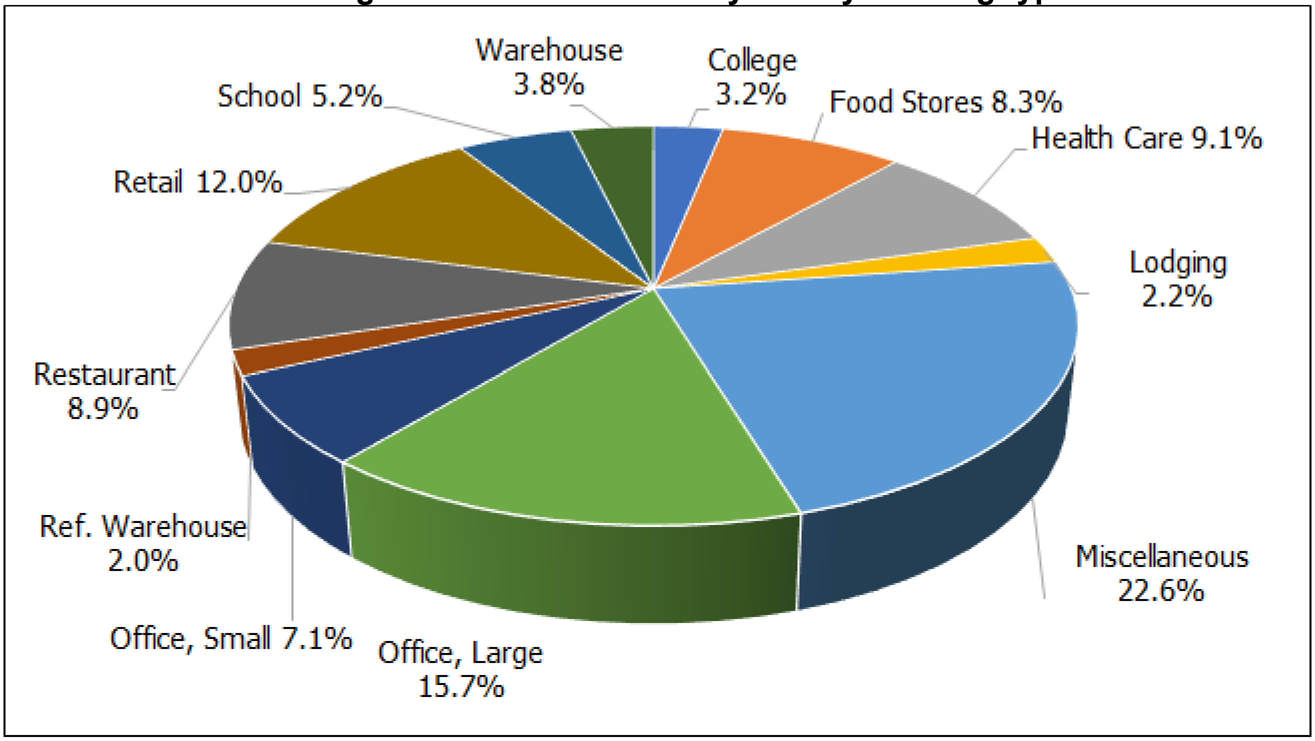
Table 14 provides a summary of the total floor stock, annual electric and gas intensities, and annual electric and gas consumption by commercial Building-type. Figure 20 and Figure 21 provide visualizations of the percent of total annual electric and gas usage respectively by commercial Building-type.

Table 14: Overview of SMUD Energy Usage

Building-type	Floor Stock (kft^2)	Annual Electric Intensity (kWh/ft^2)	Annual Electric Usage (GWh)	Annual Gas Intensity ($kBTU/ft^2$)	Annual Gas Usage (Mthm)
College	12,189	11.1	135	23.4	2.8
Food Stores	9,755	36.5	356	44.2	4.3
Health Care	20,901	18.5	386	29.3	6.1
Lodging	8,189	11.3	93	22.9	1.9
Miscellaneous	56,578	17.0	963	35.3	19.9
Office, Large	44,201	15.1	669	34.6	15.3
Office, Small	29,100	10.5	304	37.4	10.9
Refrigerated Warehouse	3,485	24.4	85	3.5	0.1
Restaurant	9,003	42.3	381	210.9	19.0
Retail	48,910	10.4	510	10.8	5.3
School	26,069	8.6	223	12.5	3.3
Warehouse	25,798	6.2	161	2.1	0.6
All Commercial	**294,179**	**14.5**	**4,266**	**30.4**	**89.5**
All Office	**73,302**	**13.3**	**974**	**35.7**	**26.1**
All Warehouse	**29,283**	**8.4**	**246**	**2.3**	**0.7**

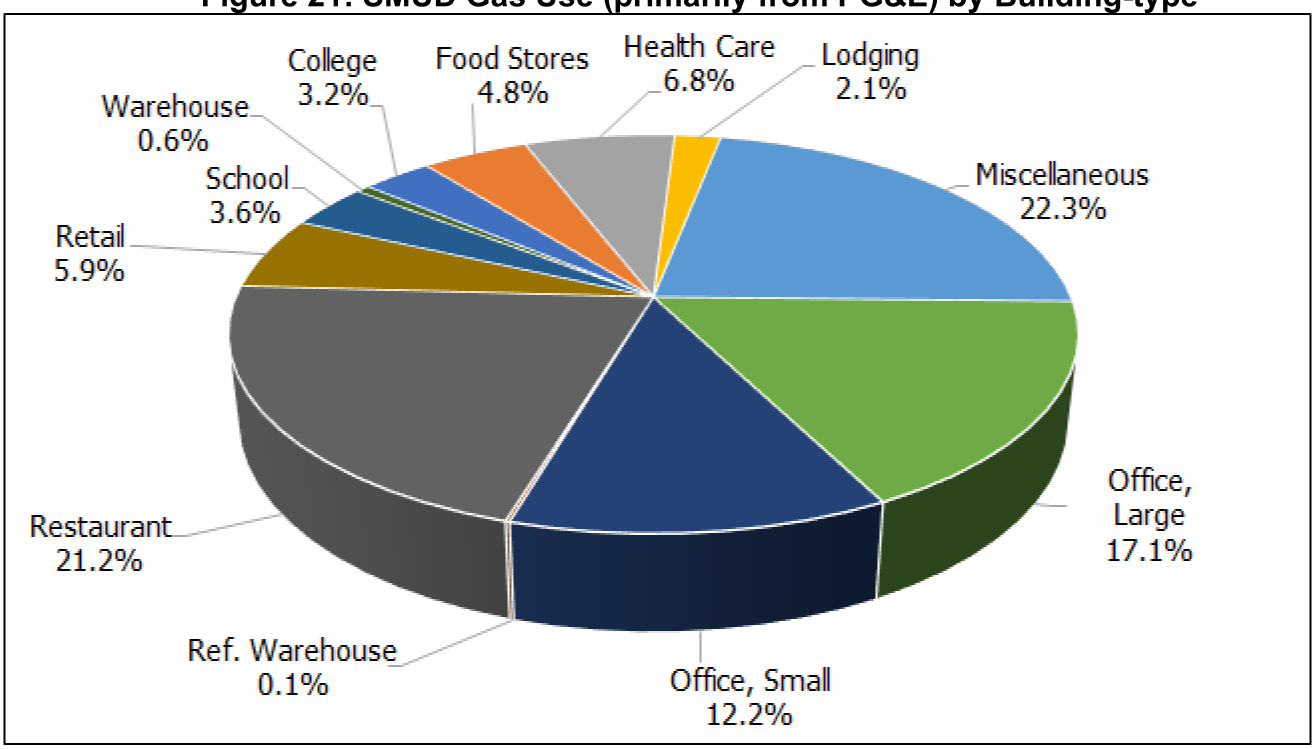
Source: 2022 CEUS

Figure 20: SMUD Electricity Use by Building-type



Source: 2022 CEUS

Figure 21: SMUD Gas Use (primarily from PG&E) by Building-type



Source: 2022 CEUS

Building-Type and End-Use Level Results

Appendix K provides as a spreadsheet, the preceding tables and graphs, as well as detailed tables at the Building-type and end-use level statewide and for each of the participating electric utilities. Appendix N provides survey-wide results that exclude the scale factors discussed earlier in the introduction to this section. Several reviewers from the CEC and participating utilities were interested in results related to electric vehicle charging, on-site generation, and building electrification. Appendix L relates relevant findings on these topics.

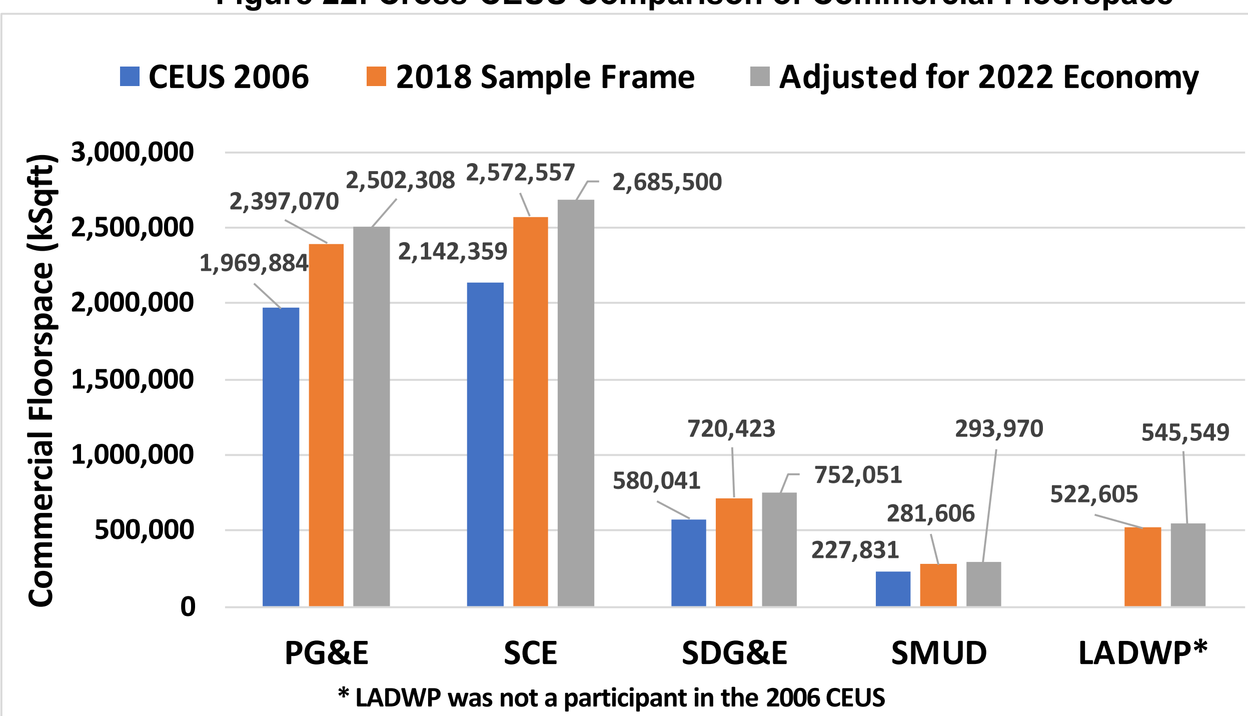
Chapter 7: Trends in Commercial Energy Usage

Although much time has elapsed since the previous CEUS survey, the CEUS team found that comparison of the two survey results was useful for quality control of the current effort and also evinced notable changes and consistencies in California's commercial sector. Some of the bar plots that follow include results from LADWP service territory from the current survey, but have blanks for LADWP for the previous CEUS, since LADWP did not participate in that survey. Results from the previous CEUS effort are denoted as "CEUS 2006", while results from the current CEUS are labeled as either "2018 Sample Frame" or "Adjusted to Reflect 2022" to correspond to the year represented by a given data series. The plots that follow compare service territories of electric utilities that participated in CEUS. Southern California Gas Company participated in both the 2006 and 2022 CEUS surveys and supplies most of the natural gas for SCE and LADWP electric service territories. Gas-related quantities in these service territories are largely derived from SCG data. Any overall comparisons in the following discussion pertain to the combined service territories of PG&E, SCE, SDG&E, and SMUD.

Commercial Floorspace

Figure 22 shows total estimated commercial floorspace, in units of kft^2, for the four electric utilities that participated in the previous CEUS, and LADWP. Commercial floorspace has grown in all service territories since the previous CEUS and has grown approximately 21%, from 2006 to 2018 and 4.4% from 2018 to 2022.

Figure 22: Cross-CEUS Comparison of Commercial Floorspace



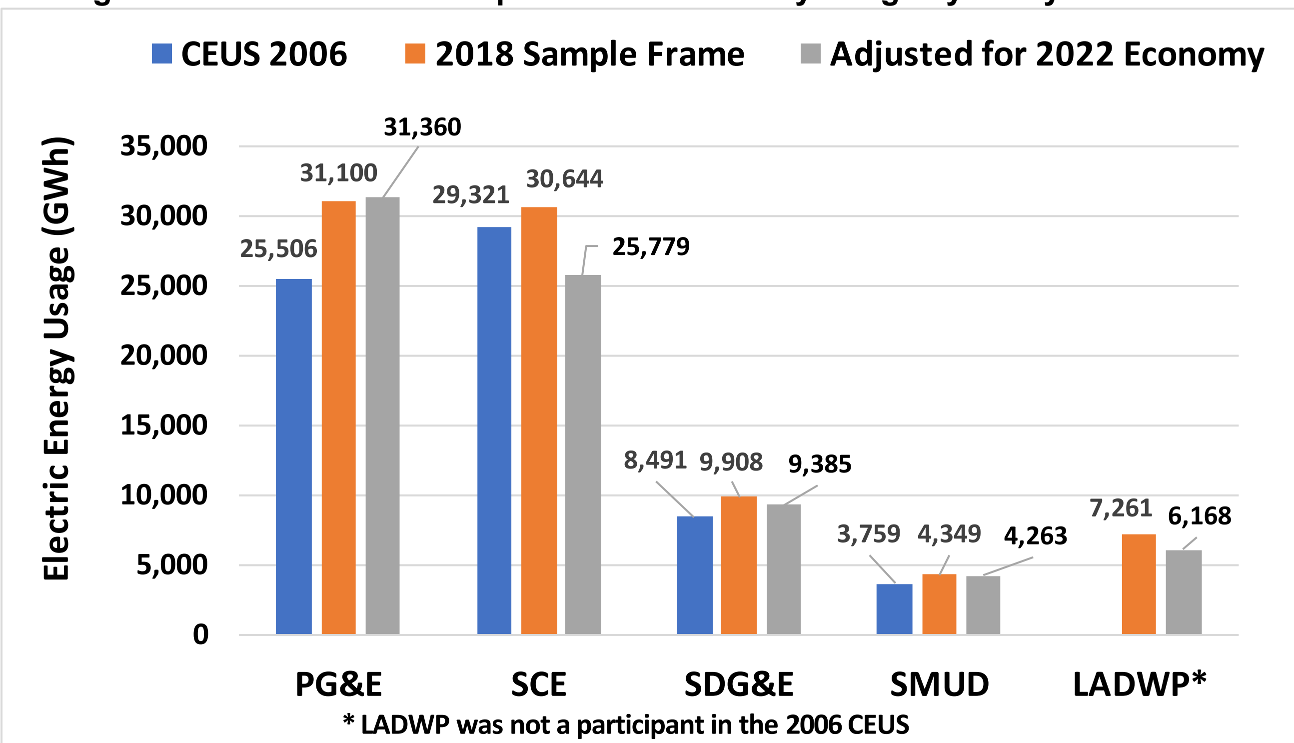
Source: 2022 CEUS and 2006 CEUS

Electricity Usage and Electric EI

Figure 23 and Figure 24 show total Electricity usage in GWh and average EI in kWh/ft^2 for electric utility companies surveyed in the 2006 and 2022 CEUS surveys, and LADWP. Overall electricity usage increased 13% between 2006 and 2018 but declined 7% between 2018 and 2022.

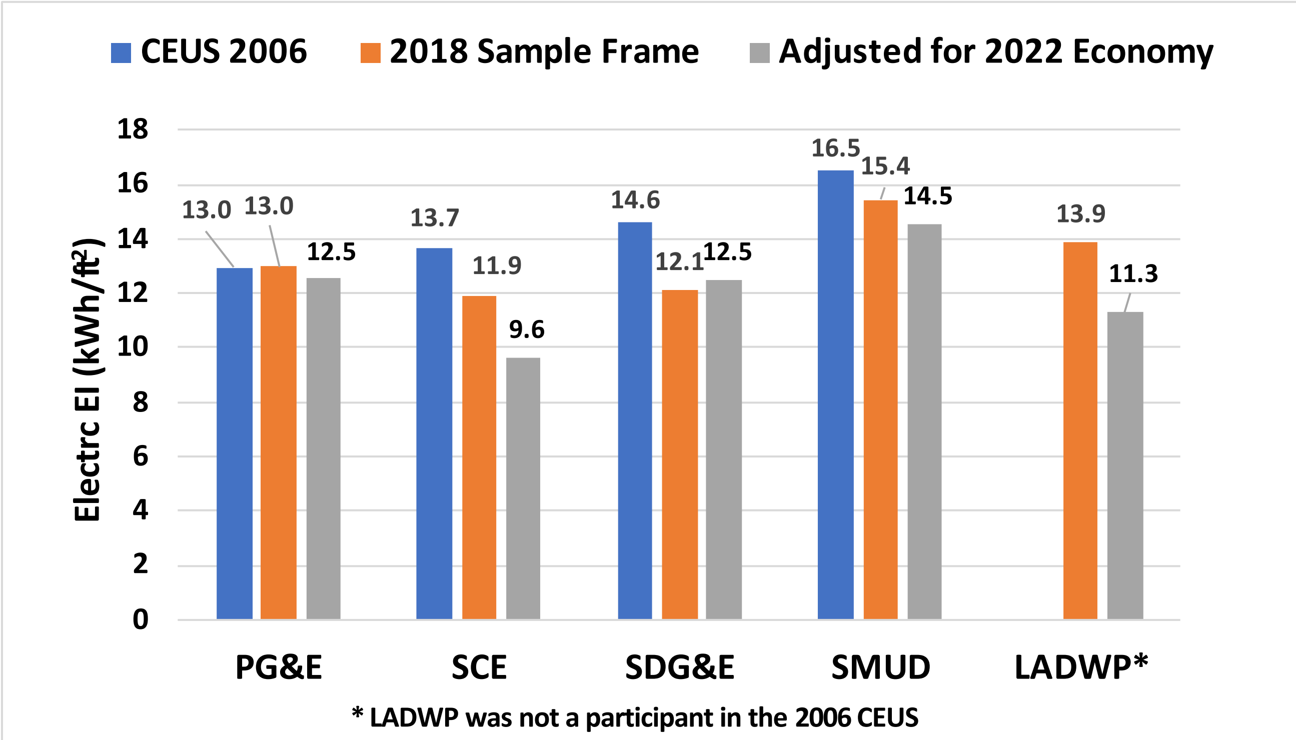
Electric EI trended downward 9% from 2006 to 2018), and a further 6% from 2018 to 2022. The only utility company that experienced increased electric EIs from 2006 to 2018 was PG&E. While the CEUS team did not research the causes for changes in EI to conclusion, the most likely causes for the increase in EI are localized increases in electricity-intensive business activities such as data centers and other computationally intensive activities.

Figure 23: Cross-CEUS Comparison of Electricity Usage by Utility Service Territory



Source: 2022 CEUS and 2006 CEUS

Figure 24: Cross-CEUS Comparison of Electric EI by Utility Service Territory

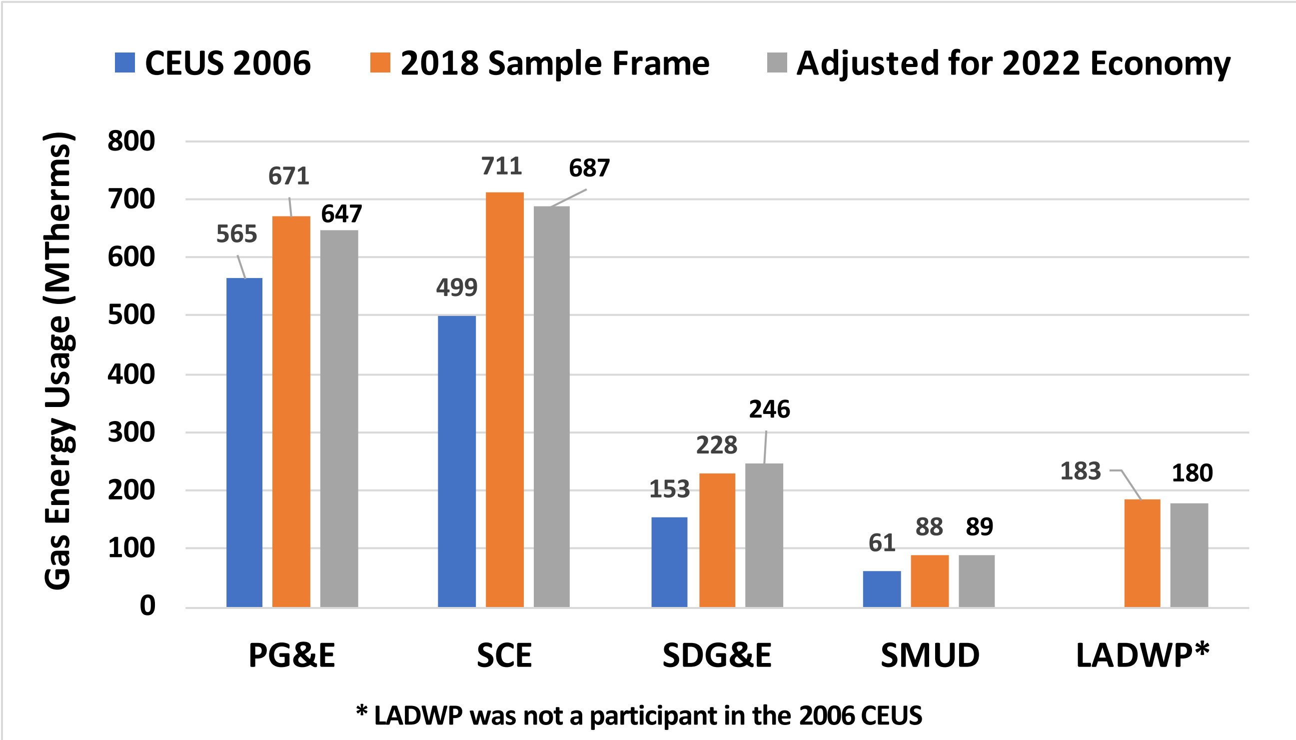


Source: 2022 CEUS and 2006 CEUS

Natural Gas Usage and Gas EI

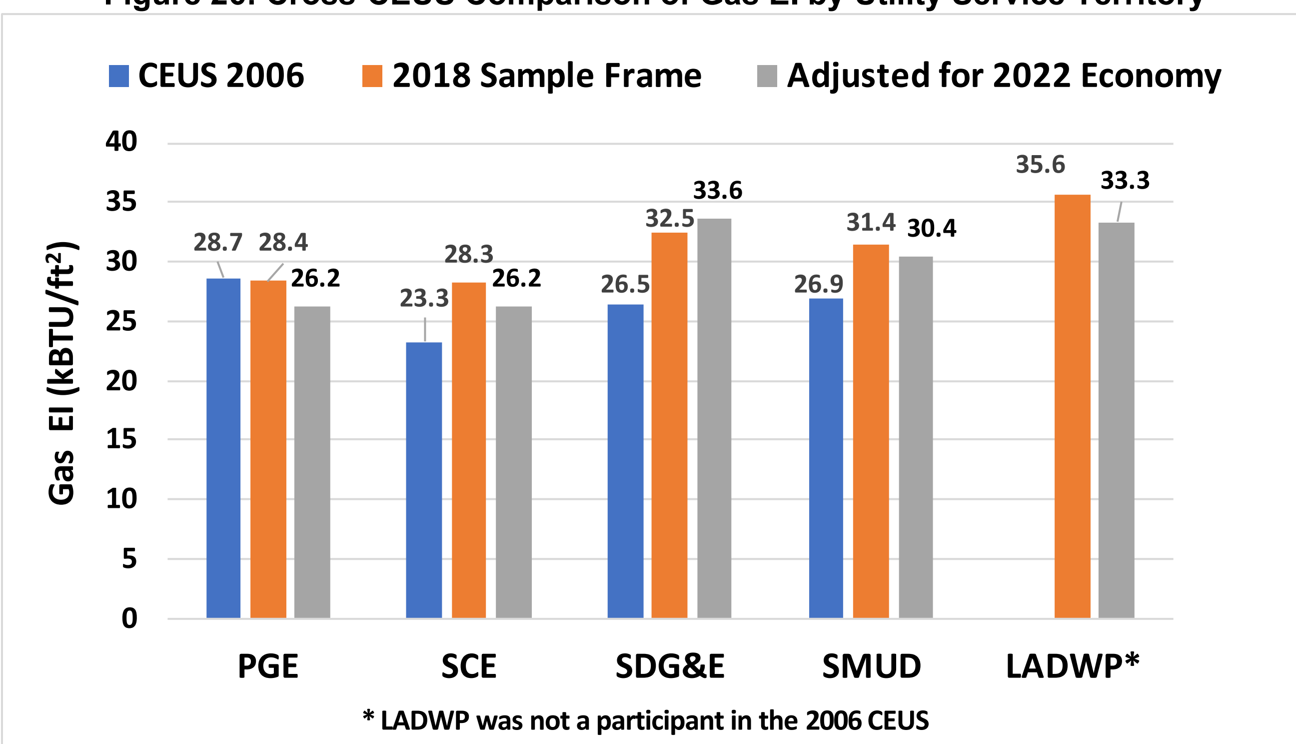
Figure 25 and Figure 26 show total Gas usage in Mthm and average EI in kBTU/ft^2 for electric utility company service territories surveyed in the 2006 and 2022 CEUS surveys, and LADWP. Gas usage increased 33% from 2006 to 2018. While the majority of this increase is attributable to increased floorspace, the current CEUS reports an 14.5% increase in Gas EIs in the same time period. As shown in Figure 26, EIs tended to increase more acutely in southern California. Between 2018 and 2022, gas usage fell 1.7 percent, driven by a 4.1% reduction in Gas EI.

Figure 25: Cross-CEUS Comparison of Gas Usage by Utility Service Territory



Source: 2022 CEUS and 2006 CEUS

Figure 26: Cross-CEUS Comparison of Gas EI by Utility Service Territory



Source: 2022 CEUS and 2006 CEUS

Possible Causes of Increased Gas Consumption between 2006 and 2018

This CEUS survey measured higher gas EIs and higher overall gas usage than the 2006 CEUS. While ten of twelve Building-types had increased gas usage, three Building-types accounted for over 50% of the overall increase in gas usage: Miscellaneous, Restaurant, and Colleges. The CEUS team did not make a detailed comparison of site-by-site data from the two surveys, but the team did identify several factors that could account for the increased gas usage as discussed below.

HVAC Interactive Effects

The increase in gas consumption is partially attributable to reduced electric EIs, since reduced electric EIs will increase space heating loads in winter. As a simple estimate, one kWh of reduced electric load in a gas-heated space will increase heating loads 4.3 kBTU during the heating season (estimated as 3.4 kBTU/kWh divided by an 80% assumed heating efficiency), or about 1.5 kBTU during the year assuming about a four-month heating season. According to this simplified estimate, HVAC interactive effects may account for approximately 35% of the increased gas EIs.

Gas-Fueled On-site Generation (CHP and Fuel Cells)

The CEUS team noted significant CHP and fuel cell capacity in certain regions and market sectors. For example, the retail sector in SCE's Forecast Zones 9,10, and 12 exhibited significant on-site generation with fuel cells. It is difficult to attribute an overall increase in gas usage to CHP and Fuel Cells, however, since the survey did not inquire if any generation capacity had been retired in years. Rather, the addition or retirement of CHP of Fuel Cells will cause localized differences in overall gas usage between the 2006 and 2022 CEUS surveys. The retail sector in SCE service territory, particularly in Forecast Zones 9, 10, and 12, also exhibited significant on-site generation with fuel cells.

Increase in Gas EIs related to Food Service

Relative to the previous CEUS, the gas EIs for restaurants and grocery stores have significantly increased. Most surveyed grocery stores offered cooked meals and had on-site bakeries. This may reflect a national trend of increased market share for food prepared away from home, rather than in homes [22]. However, other factors also relate to increased EIs at food stores as discussed in the next section.

Energy Efficiency Measures

While gas energy efficiency efforts reduce gas EIs, electric energy efficiency measures such as lighting upgrades tend to increase gas usage through HVAC interactive effects discussed above. It is important to acknowledge that there has been significant investment in natural gas energy efficiency in California. The factors discussed above increased gas EIs despite energy efficiency efforts.

---

22 United States Department of Agriculture, *America's Eating Habits: Food Away From Home*. 2018, A report summary from the Economic Research Service, America's Eating Habits: Food Away From Home.

NAICS Code to Building-Type Mapping

Migration of NAICS codes among Building-types could also be a contributing factor in differences seen between the results of the two surveys (Please see the NAICS Code Comparison section below). One of the main objectives of the current CEUS was to accurately characterize the economic activity of the surveyed sites. Consequently, as a result of a more stringent review of the data, some surveyed sites were assigned new codes that more accurately describe their business activity. Approximately 15% of surveyed sites migrated from one Building-type to another as a result of this NAICS review.

In addition, since the completion of the 2006 CEUS, the mapping of the NAICS codes to Building-types was reviewed and revised by the CEC staff. Certain NAICS codes that were originally mapped to buildings in the Commercial sector were either removed and assigned to buildings in other sectors, or they were mapped to a different Building-types within the Commercial sector. Appendix G provides the NAICS code to Building-type map used in this survey.

Potential Systematic Differences between Surveys

This and the previous CEUS surveys had different goals and designs. The previous CEUS opted for greater detail and accuracy of data collection at the site level required for building energy simulation. This CEUS opted for a greater sample size by reducing the scope of data collection to areas specified by the project objectives (see Executive Summary). The differences may account for some of the variation in results. For example, the larger sample size in this survey may have increased representation of sites that may have modest electric usage but significant gas usage, such as launders and dry cleaners, and the occasional gas station that served compressed natural gas.

Statistical precision can also account for some of the observed differences – particularly for smaller utility service territories and Building-types that account for lesser amounts of overall electric usage. While both CEUS surveys achieved good relative precisions, it is important to recognize that the stated relative precisions are calculated from electricity usage distributions, and do not apply equally to each data element collected in the survey. The relative precisions with respect to other attributes are necessarily larger than those reported for electricity usage. It is reasonable to expect a ±5% resolution when comparing gas usages or EIs as measured through the two surveys.

Price Elasticity

According to the Energy Information Agency[23] and the Bureau of Labor Statistics[24], natural gas prices for California commercial customers, in 2021 Dollars, averaged $9.65 per MBTU in the three-year period ending 2019 (the year when most data collection occurred for this CEUS). In contrast, prices averaged $13.07 in 2021 Dollars, during the three-year period ending 2005 (the end of data collection and analysis for the previous CEUS). This is a 26% reduction, in real terms, for natural gas prices. The EIA estimates the 3-year running price elasticity for natural gas in the

---

23 United States Energy Information Administration, California Price of Natural Gas Sold to Commercial Consumers - note this is a national estimate and is not specific to California.

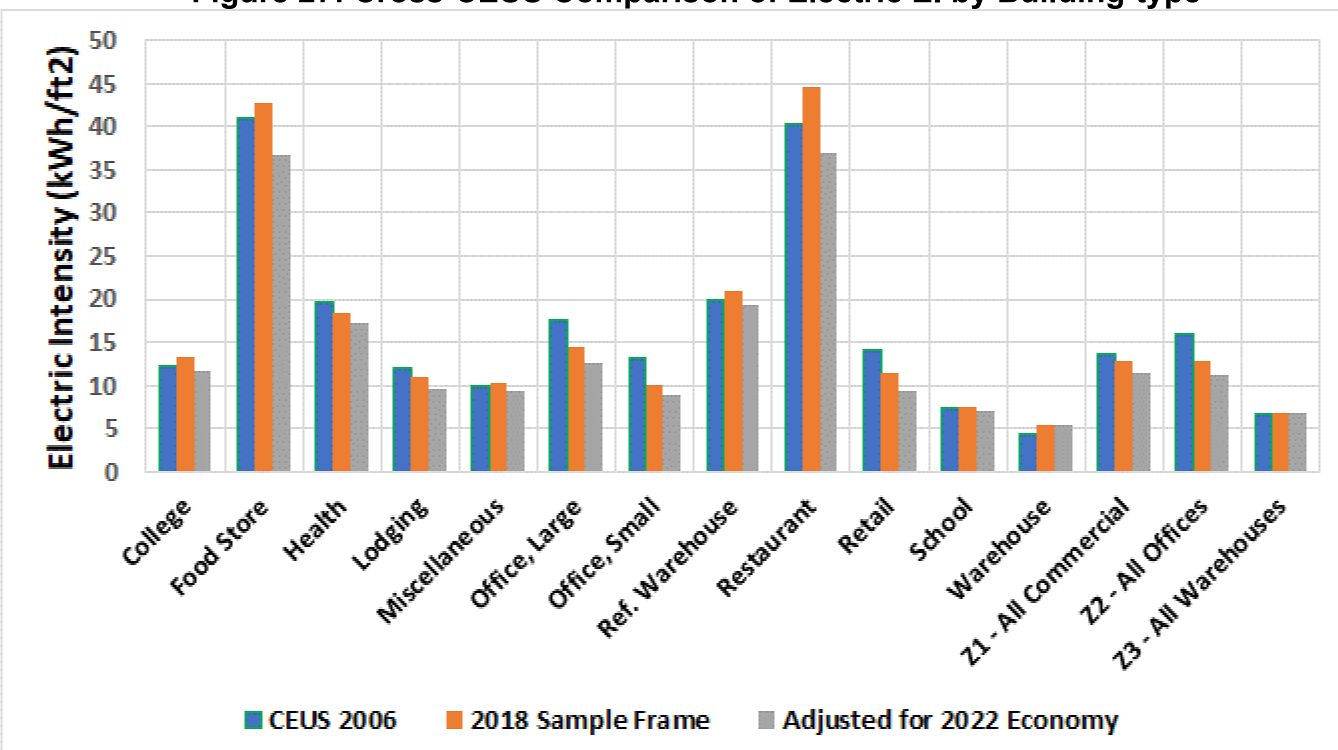
24 United States Bureau of Labor Statistics, CPI for All Urban Consumers (CPI-U)

commercial sector to be -0.25[25] (that is, for every 10% price decrease, one would expect a 2.5% increase in sales). Accordingly, price elasticity may explain a 6.6% increase in natural gas consumption, which is a significant portion of the 13% increase in gas EIs between the two surveys.

Energy Intensities by Building-type

Figure 27 and Figure 28 show electric and gas EIs respectively by Building-type, as gathered by the previous and current CEUS surveys. Two sets of results are shown for the current CEUS survey – EIs as calculated from pre-pandemic billing data, and adjusted EIs that reflect economic conditions that prevailed in 2022. While electric EIs as measured by the two surveys generally trended together, offices and retail establishments tended to have significantly reduced EIs in the more recent survey. Likewise, retail, food stores, colleges, and miscellaneous buildings had the highest increases in gas EIs. Both electric and gas EIs have diminished in 2022 (grey columns) relative to the base year of 2018 (orange columns).

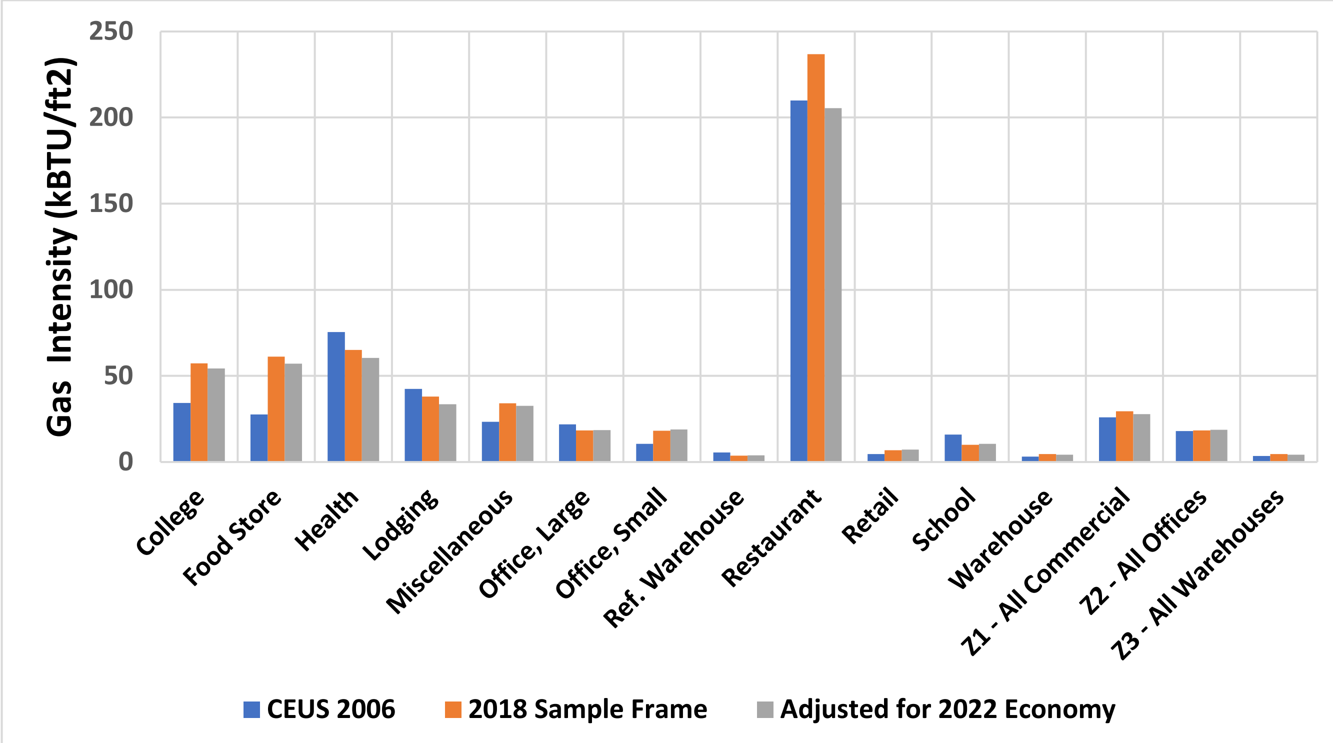
Figure 27: Cross-CEUS Comparison of Electric EI by Building-type



Source: 2022 CEUS and 2006 CEUS

25 United States Energy Information Administration, *Price Elasticity for Energy Use in Buildings in the United States.* 2021, U.S. Energy Information Administration: Price Elasticity for Energy Use in Buildings in the United States

Figure 28: Cross-CEUS Comparison of Gas EI by Building-type



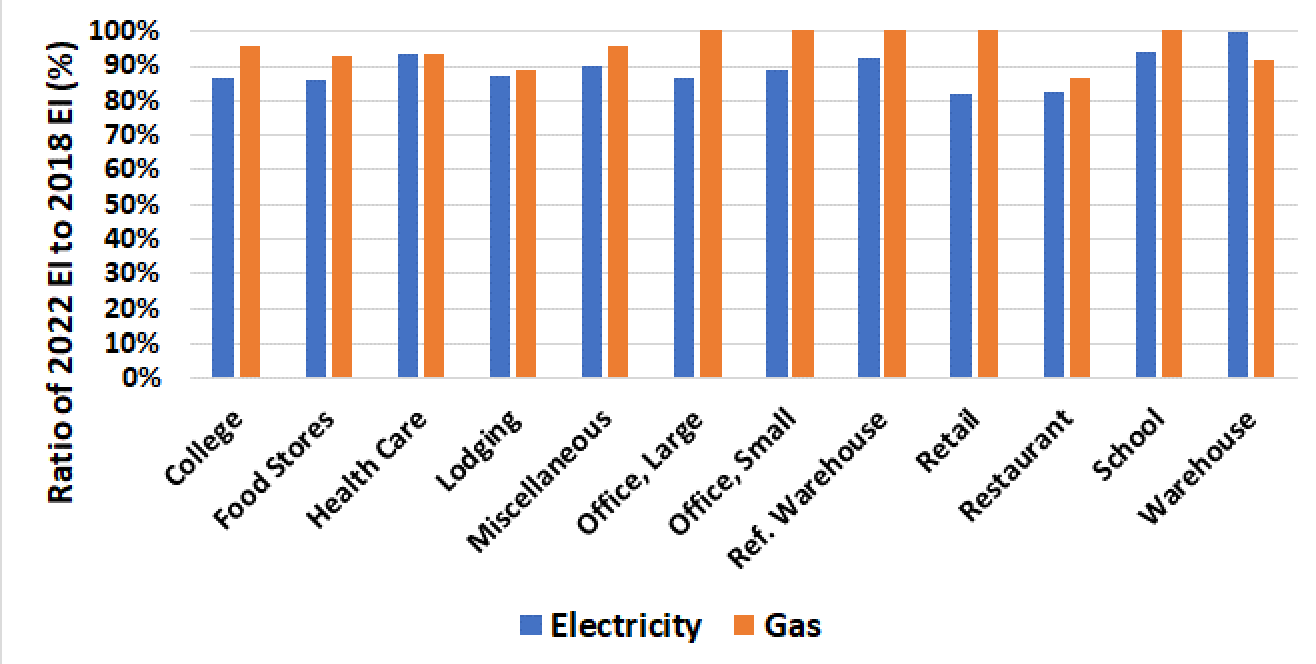
Source: 2022 CEUS and 2006 CEUS

Energy Consumption Changes Since 2018

Figure 29 below shows the average scale factors used to adjust year-2018 energy usages to year-2022 energy usages. Electric energy intensities for the Retail, Restaurant, Food Store, Lodging, and College building types are still 15% lower on average in 2022 than in 2018. On the other hand, electric EIs for the Health Care, School, and Warehouse building types are just five percent lower than in 2018.

One interesting finding is that, while gas usage has declined overall in the commercial sector statewide, it has increased for several Building-types, such as Offices, Retail, and Schools. Indeed, the largest decreases in gas usage appear to be correlated with high saturations of commercial food service, while the largest increases appear to be correlated with high saturations of gas space heating coupled with decreases in electric EI. One hypothesis is that reduced occupancy in the post-COVID era has resulted in reduced electric loads within heated space, which has increased heating loads. If so, there may be opportunities for energy savings through space heating optimization such as demand-control ventilation as well as simple thermostat adjustments and more effective spatial zoning (which may be an opportunity addressed during building electrification).

Figure 29: Statewide Ratios (2022:2018) of Electricity and Gas EIs by Building-type



Source: 2022 CEUS

Comparison of Saturations, Penetrations, and Fuel Shares

The CEUS Team compared end-use saturations, penetrations, and fuels shares between the 2022 and 2006 editions of the CEUS survey. The comparison served as a validation for this survey, and also helped to add context to overall fuel usage trends discussed in the preceding sections. The two CEUS surveys defined certain terms differently. For example, the heating fuel shares in this report are defined as the percentage of all heated floorspace that are heated with a particular fuel type, while in the 2006 CEUS the heating fuel share was defined as the percentage of all floorspace that are heated by a particular floor type. The CEUS Team put both the CEUS 2006 and CEUS 2022 data on equal footing by constructing similar characterizations for floorspace, end-uses, and fuel shares. In the following subsections, the terms saturation, penetration, and fuel shares are defined in the convention of the 2022 CEUS. Appendix P includes the figures in this subsection, and associated tables of values.

Definition of Saturation, Penetration, and Fuel Shares

Definitions of key terms used in the comparisons that follow are reviewed below for reference.

End-Use Saturation and Penetration at the Survey-Site Level

Saturation is defined as the percent of a survey-site's total square footage in which an end-use was present. For example, if 20% of the floor-space of a warehouse is heated for comfort, the saturation of space heating is 20% for that warehouse. Penetration is a similar concept to saturation but has all-or-none resolution. For example, if electric battery chargers for forklifts are found in that warehouse, then the entire warehouse is said to be served with electric forklift chargers. Penetration is used when saturation is difficult to define. In this example, the difficulty would be to attribute a space or area boundary to the forklift chargers.

End-Use Saturation and Penetration at Aggregated Levels

At aggregate levels, both penetrations and saturations tend to assume continuous distributions, and convey the percentages of total floor stock that are served by the given end- use. For example, the floorspace associated with motors is either 0% or 100% for a given survey-site, but at the statewide level, 79% of the floor stock for large offices, and just 6% of the total floor stock for restaurants are associated with motors. Although the term penetration is essentially synonymous with saturation when describing aggregated results in this report, the authors may use the term as a reminder of differences in how floor-space shares were calculated for the end-use at the survey-site level.

Fuel Shares

In this report, a Fuel Share is defined as the percentage of the floor space with the given end- use that was fueled by either electricity, gas, or other fuel. The fuel shares are generally weighted by floorspace within a survey-site. For example, if 60% of a site is heated by natural gas, and 20% by electricity, and the remaining 20% is not heated, then the electric fuel share is 25%. Commercial cooking fuel shares are weighted by the food service area floor space within the survey-site, rather than the overall facility square footage. Water heating is weighed by the total square footage of the facility.

Table 15 below shows floorspace saturations as determined from the 2006 CEUS and the 2022 CEUS for cooling, heating, refrigerated space, and unconditioned space.

Table 15: Cross-CEUS Comparison of Cooling, Heating, Refrigerated and Unconditioned Floorspace

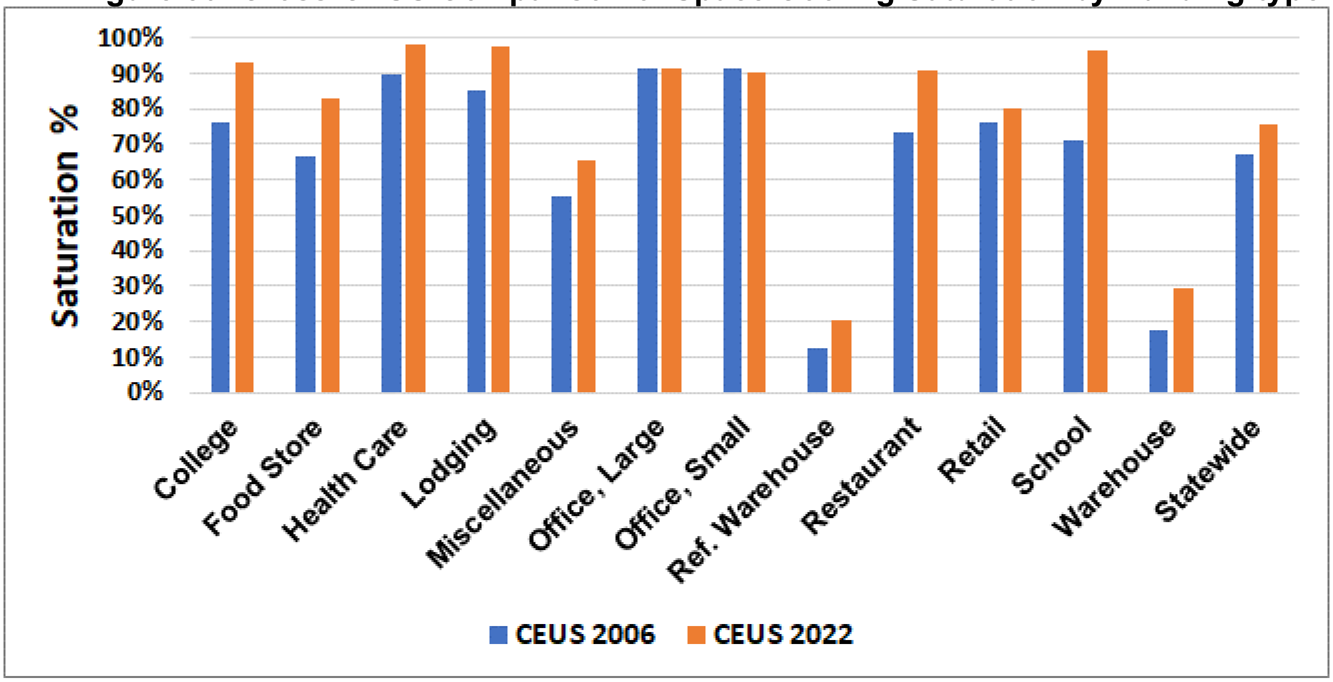
Building-Type	Cooled Floorspace Saturations		Heated Floorspace Saturations		Refrigerated Floorspace Saturations		Unconditioned Floorspace Saturations	
	CEUS 2006	CEUS 2022	CEUS 2006	CEUS 2022	CEUS 2006	CEUS 2022	CEUS 2006	CEUS 2022
College	75.9%	93.2%	89.5%	98.3%	0.0%	0.0%	8.6%	1.3%
Food Stores	66.6%	82.7%	61.7%	81.2%	7.0%	7.9%	17.9%	8.3%
Health Care	89.8%	97.8%	94.2%	98.7%	0.1%	0.0%	4.0%	0.9%
Lodging	85.1%	97.5%	90.7%	99.1%	0.1%	0.0%	4.6%	0.9%
Miscellaneous	55.1%	65.4%	63.7%	67.5%	0.4%	0.0%	29.0%	30.2%
Office, Large	91.2%	91.3%	87.5%	91.6%	0.1%	0.1%	4.5%	7.6%
Office, Small	91.5%	90.0%	88.8%	91.2%	0.0%	0.0%	7.0%	7.8%
Ref. Warehouse	12.4%	20.4%	10.6%	18.4%	46.3%	57.7%	38.9%	21.8%
Restaurant	73.1%	91.0%	73.9%	89.7%	2.7%	3.5%	17.1%	4.8%
Retail	76.0%	80.1%	69.5%	78.9%	0.3%	0.0%	17.6%	17.4%
School	71.2%	96.4%	90.9%	97.9%	0.1%	0.0%	4.4%	1.8%
Warehouse	17.8%	29.2%	26.7%	28.6%	0.5%	2.4%	67.6%	66.0%
Total Commercial	**67.1%**	**75.7%**	**71.1%**	**76.3%**	**1.4%**	**1.6%**	**20.7%**	**20.2%**

Source: 2022 CEUS and 2006 CEUS

Heated and Cooled Floorspace

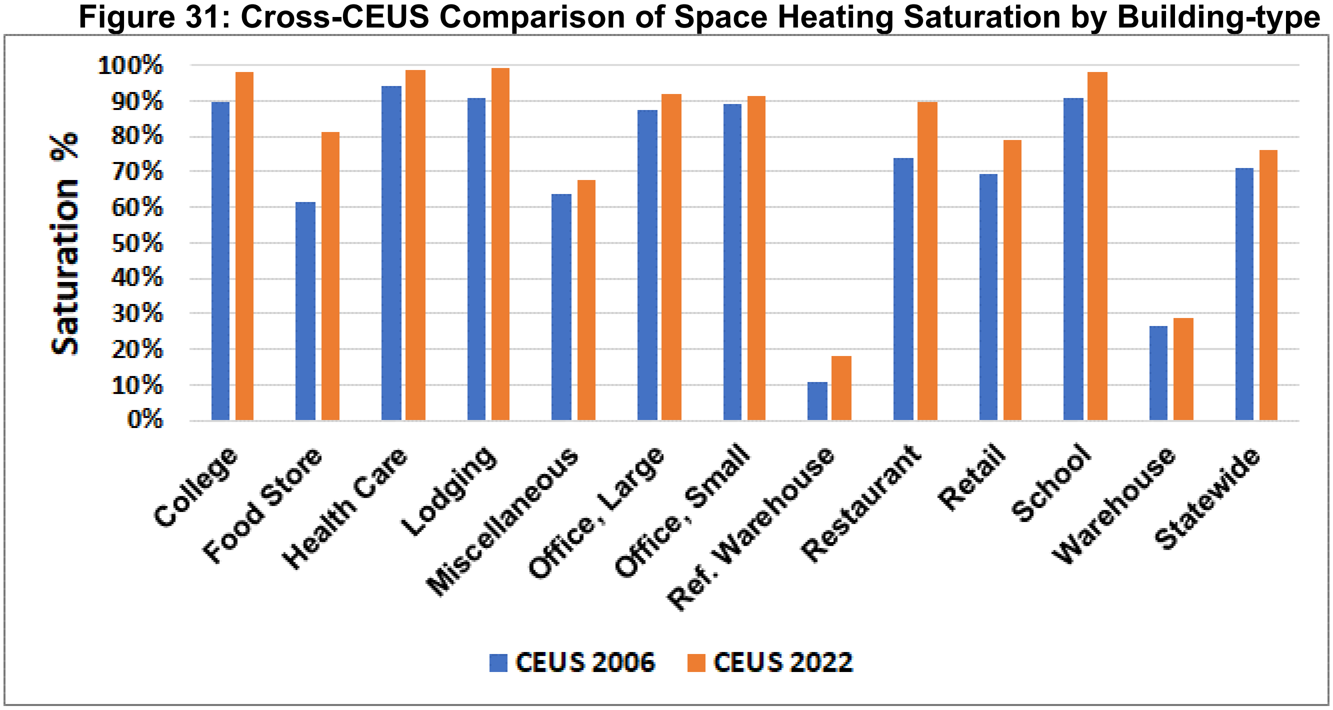
Figure 30 and Figure 31 show the percentages of floorspace that are cooled and heated for comfort respectively by Building-type and for the entire commercial sector, as measured in the 2006 and 2022 CEUS surveys.

Figure 30: Cross-CEUS Comparison of Space Cooling Saturation by Building-type



Source: 2022 CEUS and 2006 CEUS

Figure 31: Cross-CEUS Comparison of Space Heating Saturation by Building-type

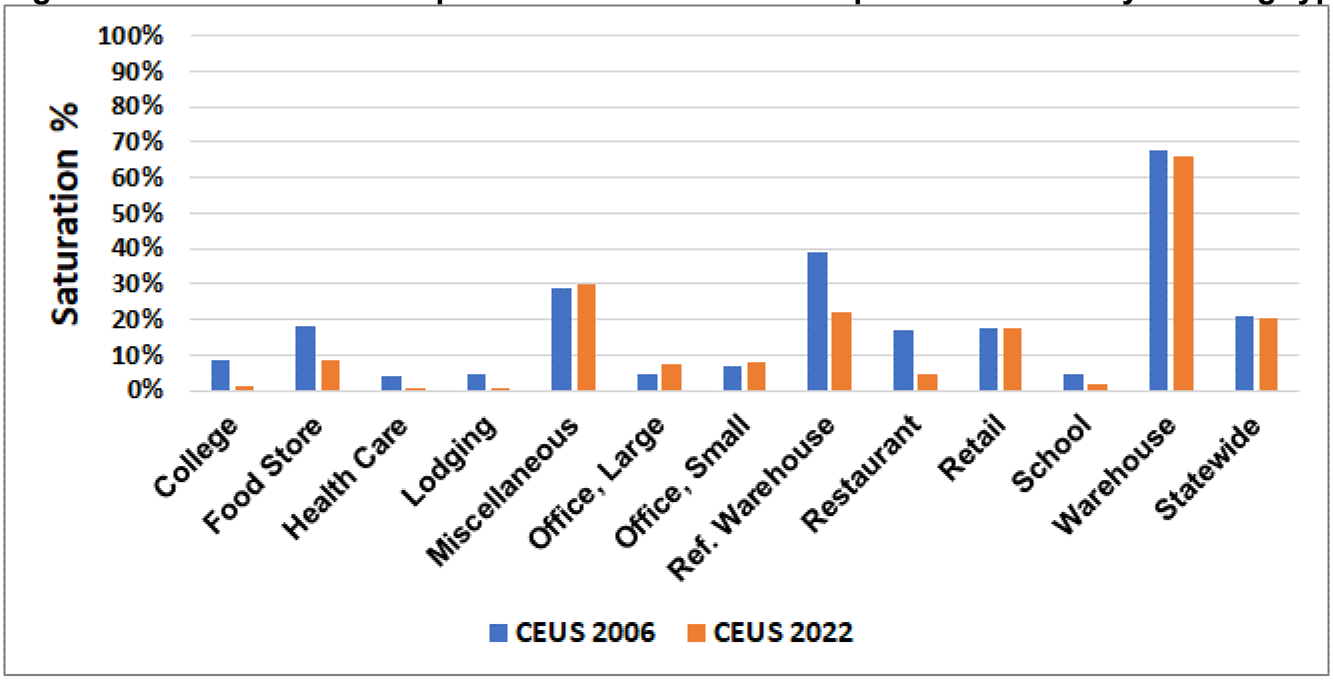


Source: 2022 CEUS and 2006 CEUS

Refrigerated and Unconditioned Floorspace

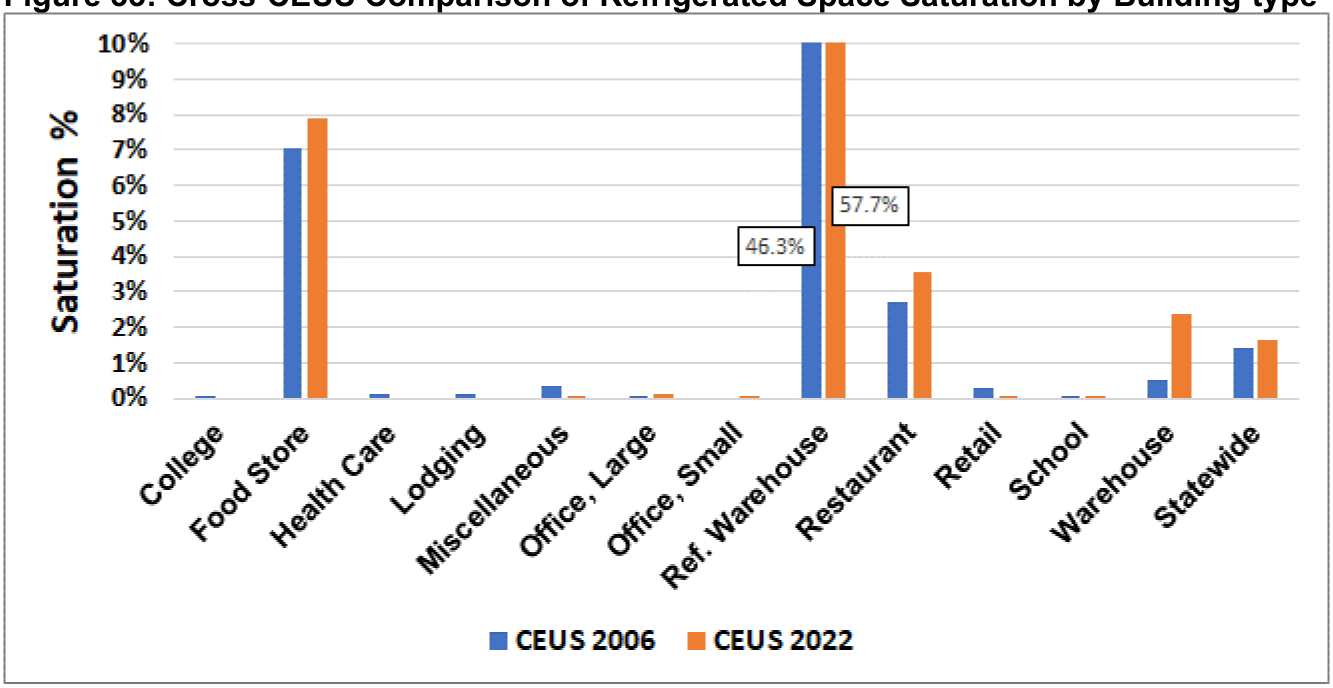
Figure 32 and Figure 33 show the percentages of floorspace that are refrigerated and unconditioned respectively by Building-type and for the entire commercial sector, as measured in the 2006 and 2022 CEUS surveys.

Figure 32: Cross-CEUS Comparison of Unconditioned Space Saturation by Building-type



Source: 2022 CEUS and 2006 CEUS

Figure 33: Cross-CEUS Comparison of Refrigerated Space Saturation by Building-type

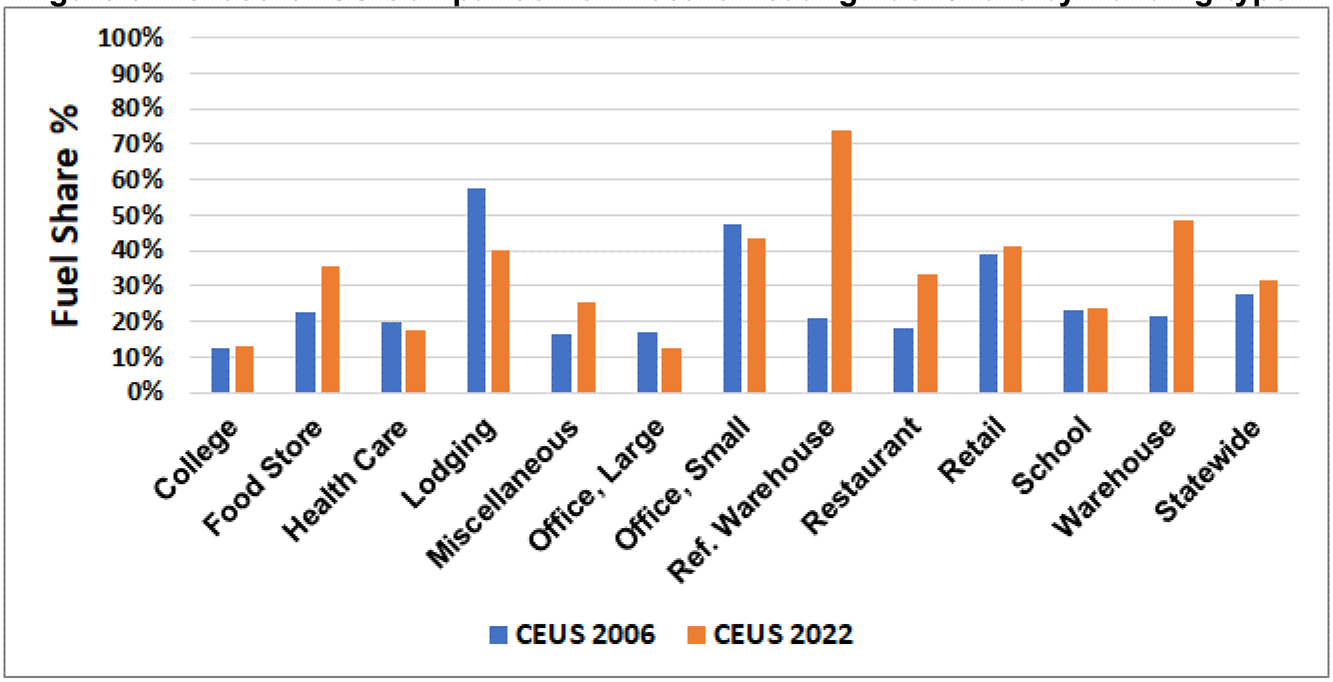


Source: 2022 CEUS and 2006 CEUS

Space Heating Fuel Shares

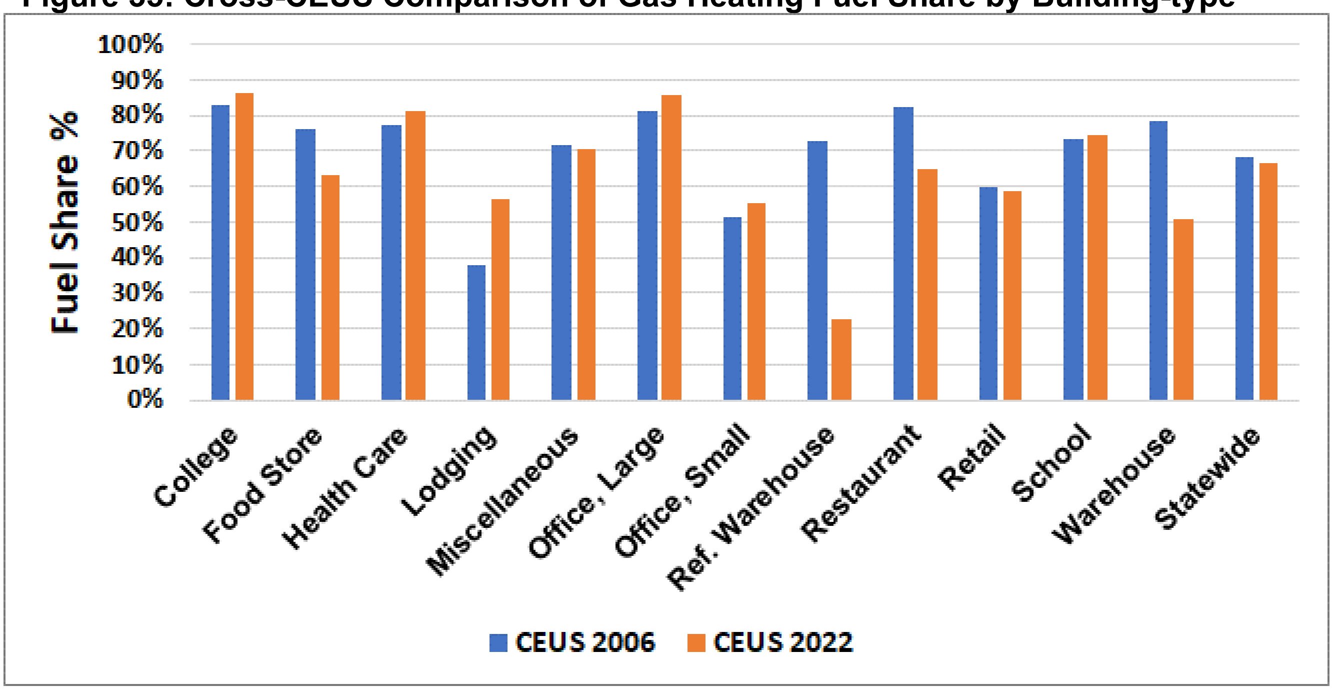
Figure 34, Figure 35, and Figure 36 show the space heating fuel shares for electricity, gas, and other fuels respectively by Building-type and for the entire commercial sector, as measured in the 2006 and 2022 CEUS.

Figure 34: Cross-CEUS Comparison of Electric Heating Fuel Share by Building-type



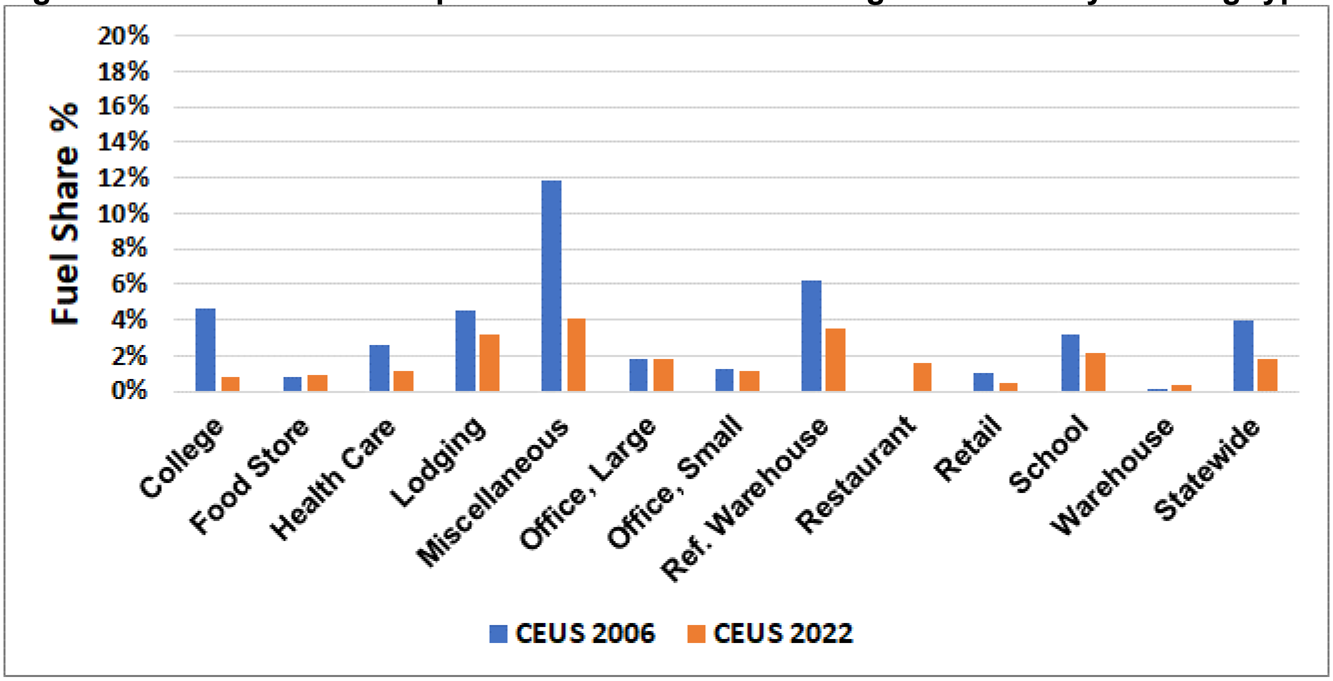
Source: 2022 CEUS and 2006 CEUS

Figure 35: Cross-CEUS Comparison of Gas Heating Fuel Share by Building-type



Source: 2022 CEUS and 2006 CEUS

Figure 36: Cross-CEUS Comparison of Other Fuel Heating Fuel Share by Building-type

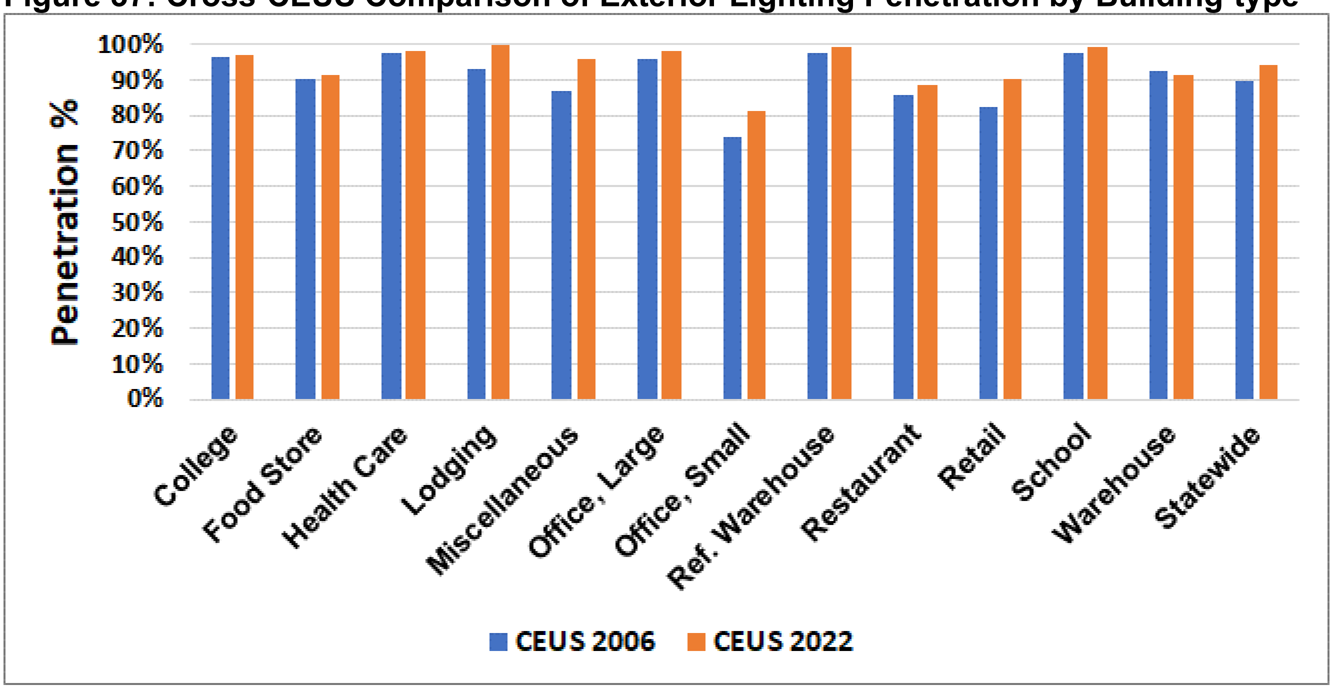


Source: 2022 CEUS and 2006 CEUS

Exterior Lighting Penetration

Figure 37 shows the exterior lighting penetration by Building-type and for the entire commercial sector, as measured in the 2006 and 2022 CEUS surveys.

Figure 37: Cross-CEUS Comparison of Exterior Lighting Penetration by Building-type

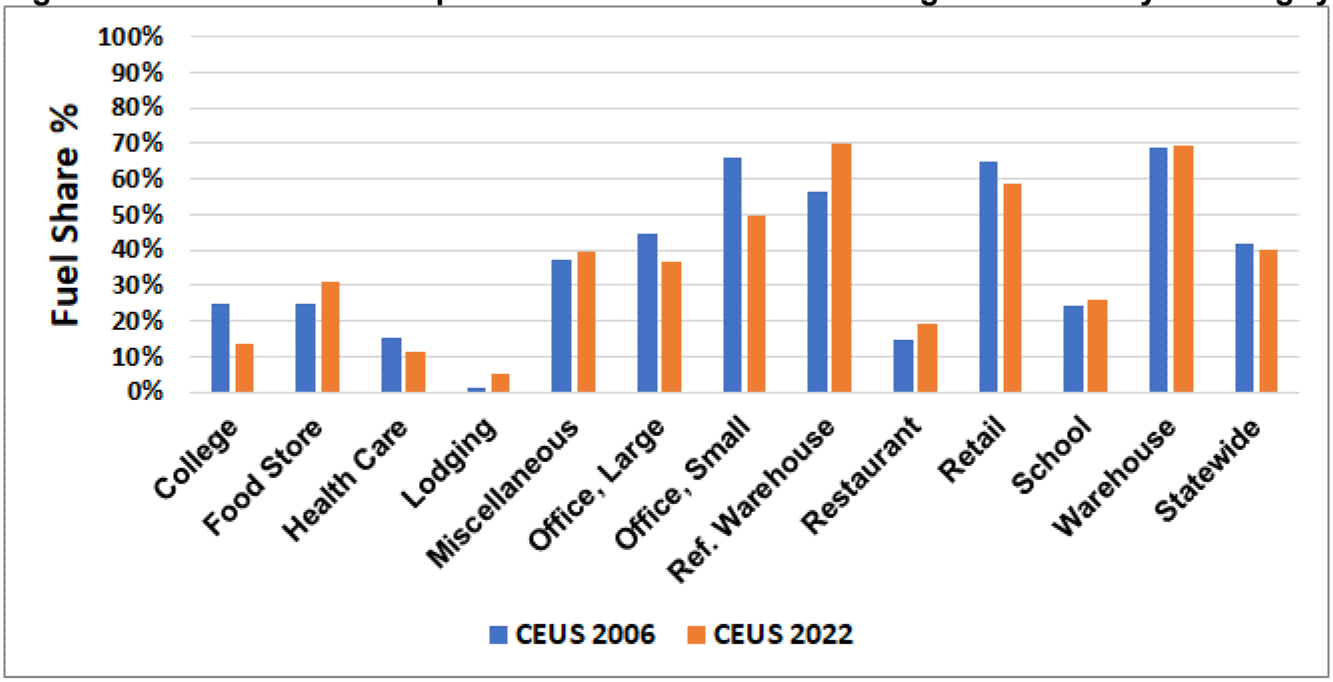


Source: 2022 CEUS and 2006 CEUS

Water Heating Fuel Shares

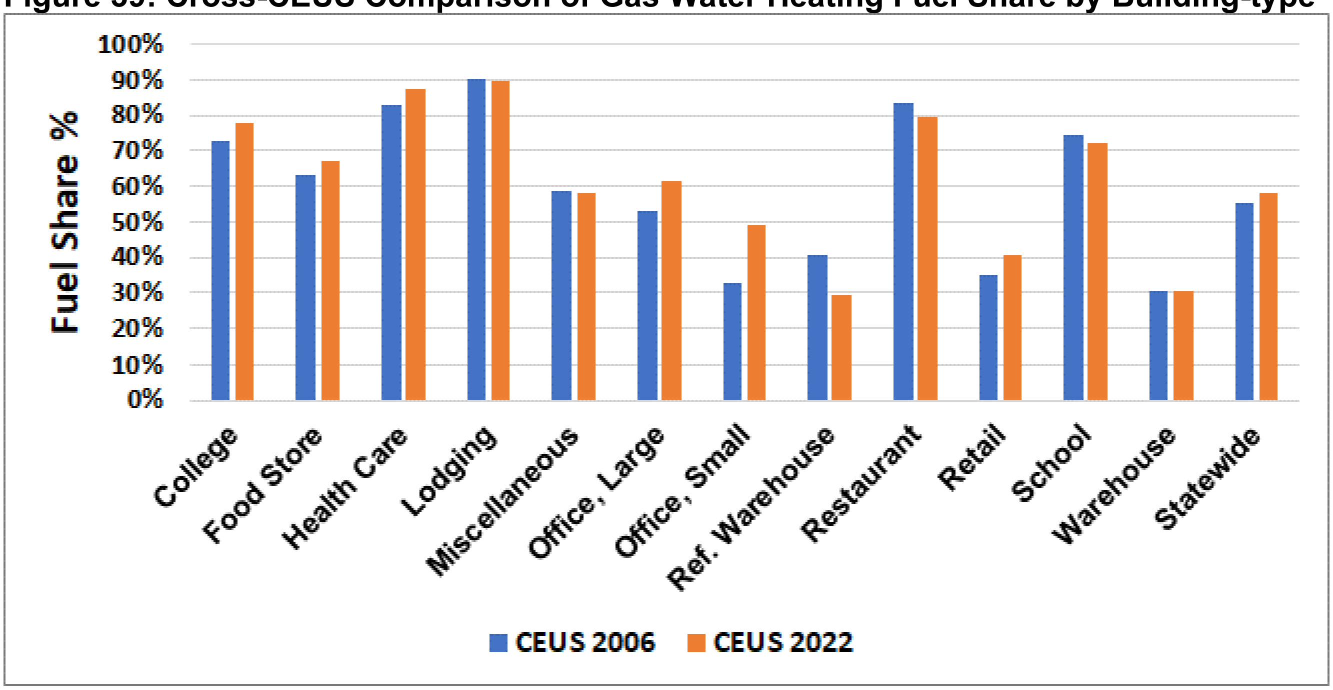
Figure 38 and Figure 39 show the water heating fuel shares for electricity and gas respectively by Building-type and for the entire commercial sector, as measured in the 2006 and 2022 CEUS surveys.

Figure 38: Cross-CEUS Comparison of Electric Water Heating Fuel Share by Building-type



Source: 2022 CEUS and 2006 CEUS

Figure 39: Cross-CEUS Comparison of Gas Water Heating Fuel Share by Building-type

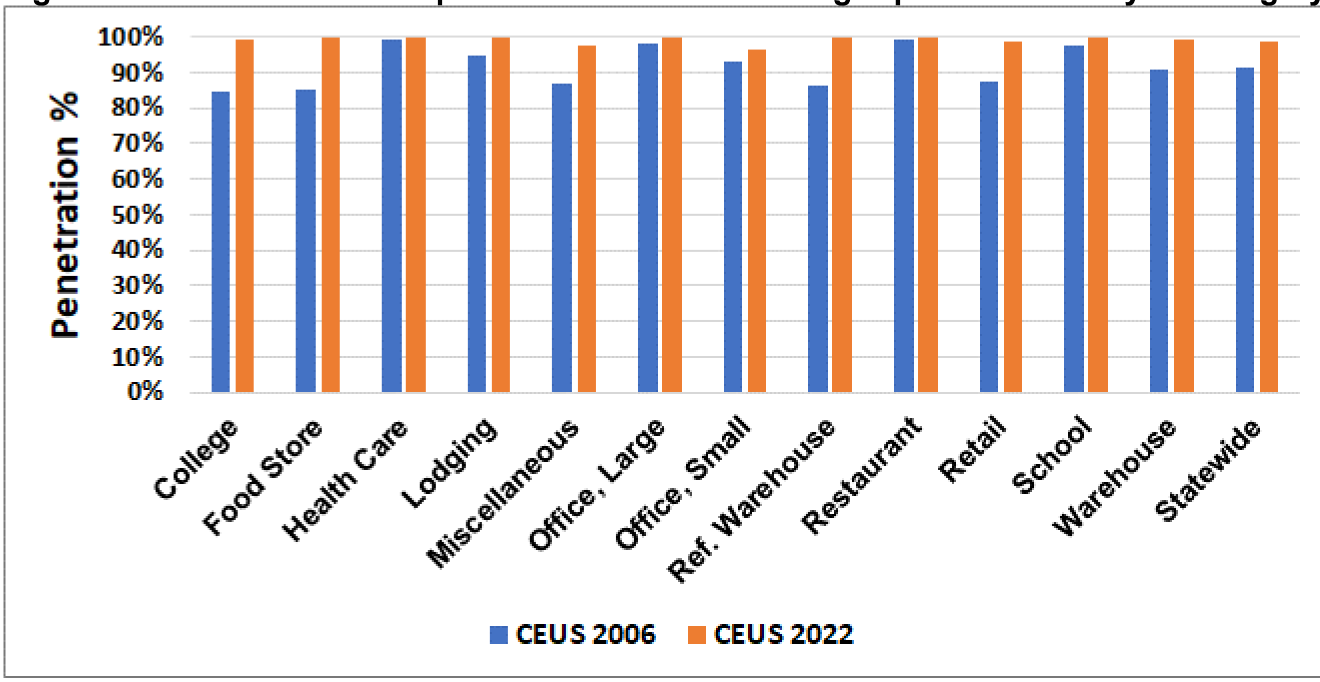


Source: 2022 CEUS and 2006 CEUS

Cooking Equipment Penetration

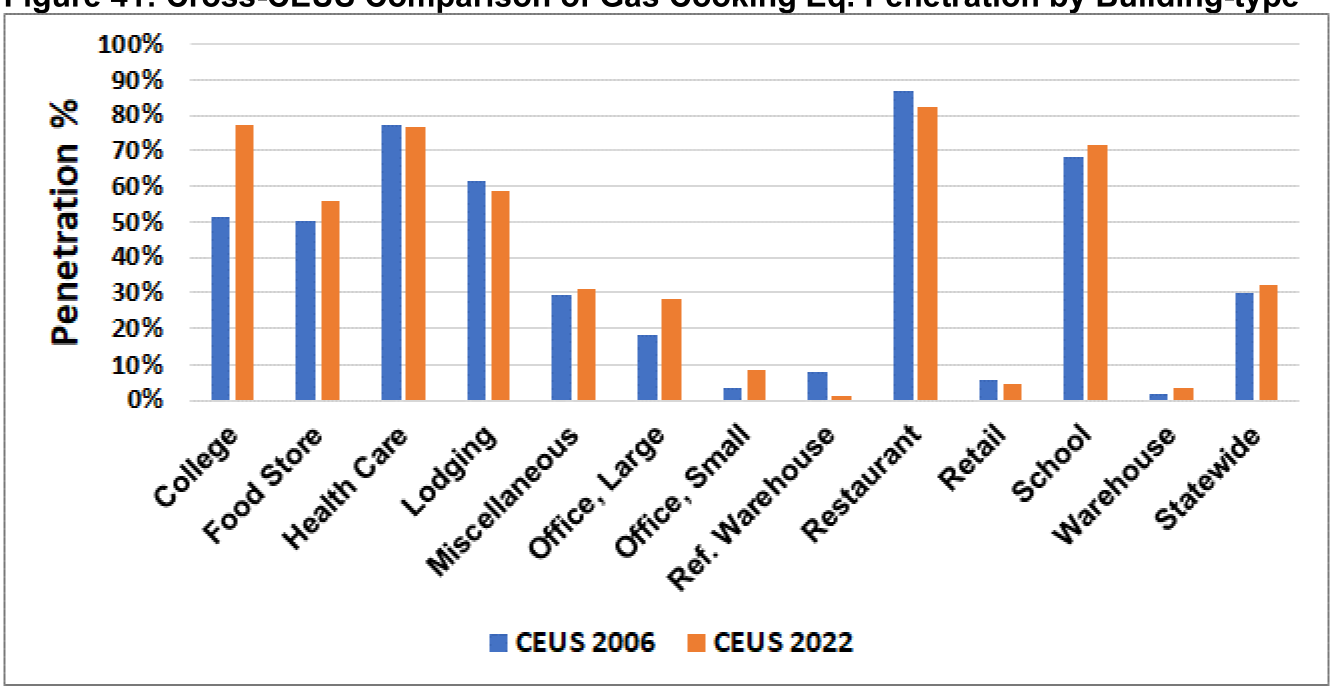
Figure 40 and Figure 41 show the electric and gas cooking equipment penetrations respectively by Building-type and for the entire commercial sector, as measured in the 2006 and 2022 CEUS surveys.

Figure 40: Cross-CEUS Comparison of Electric Cooking Eq. Penetration by Building -type



Source: 2022 CEUS and 2006 CEUS

Figure 41: Cross-CEUS Comparison of Gas Cooking Eq. Penetration by Building-type

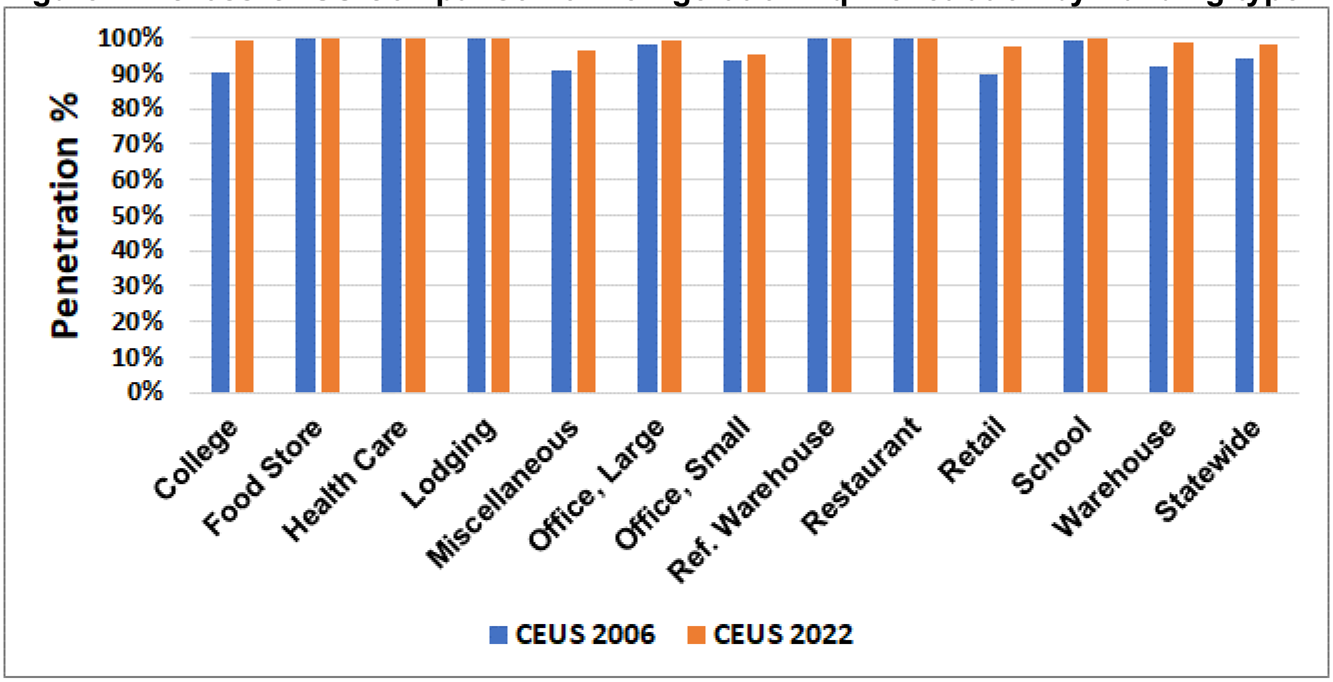


Source: 2022 CEUS and 2006 CEUS

Refrigeration and Office Equipment Penetration

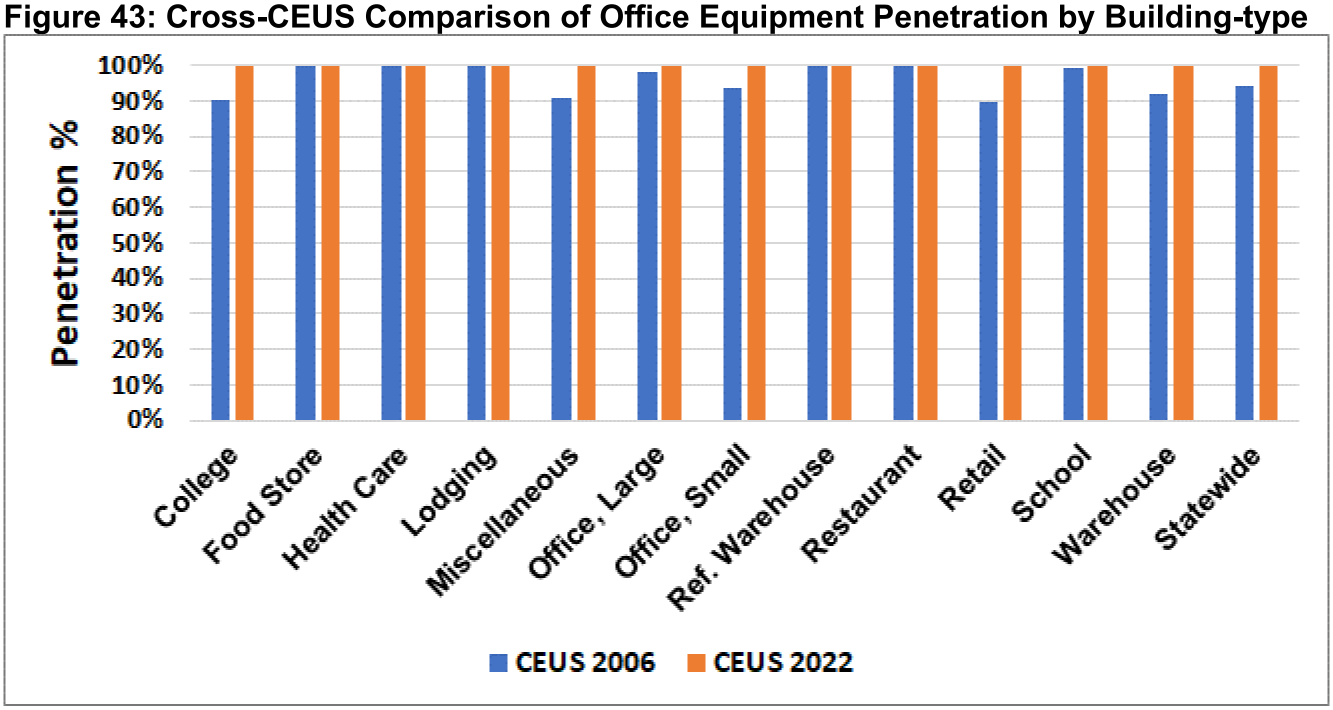
Figure 42 and Figure 43 show the refrigeration and office equipment penetrations respectively by Building-type and for the entire commercial sector, as measured in the 2006 and 2022 CEUS surveys.

Figure 42: Cross-CEUS Comparison of Refrigeration Eq. Penetration by Building-type



Source: 2022 CEUS and 2006 CEUS

Figure 43: Cross-CEUS Comparison of Office Equipment Penetration by Building-type

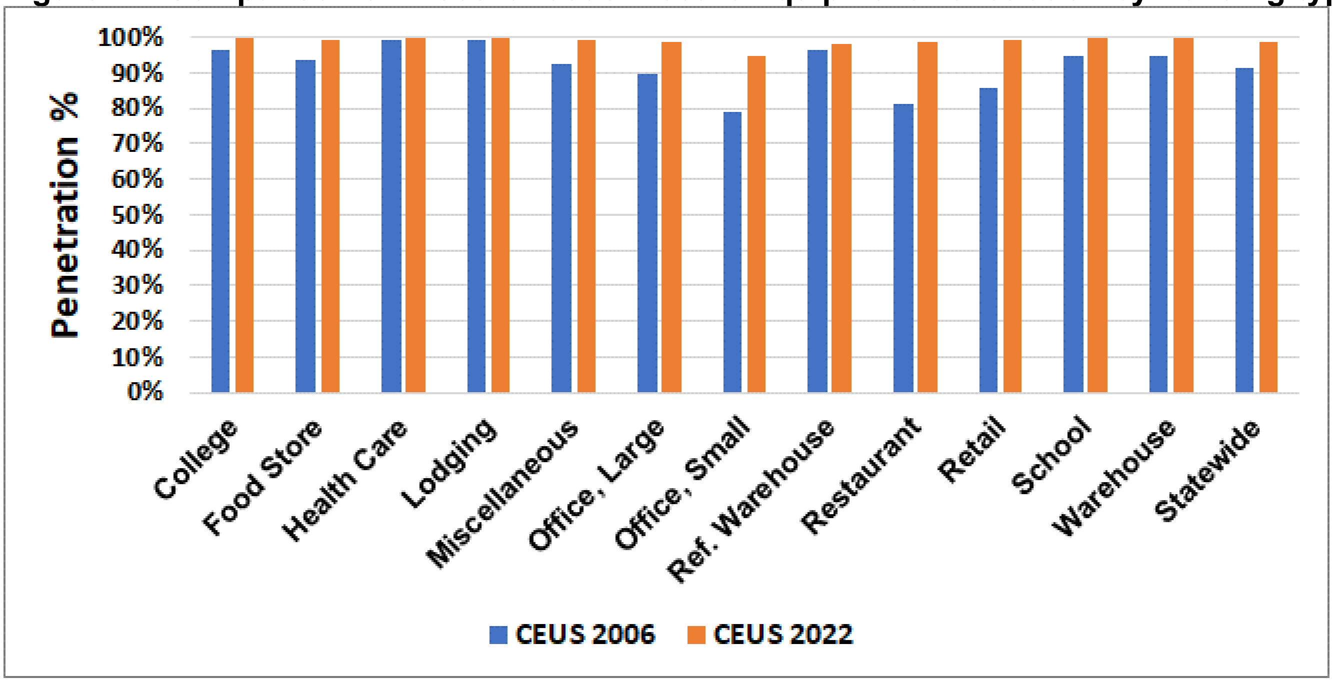


Source: 2022 CEUS and 2006 CEUS

Miscellaneous Equipment Penetration

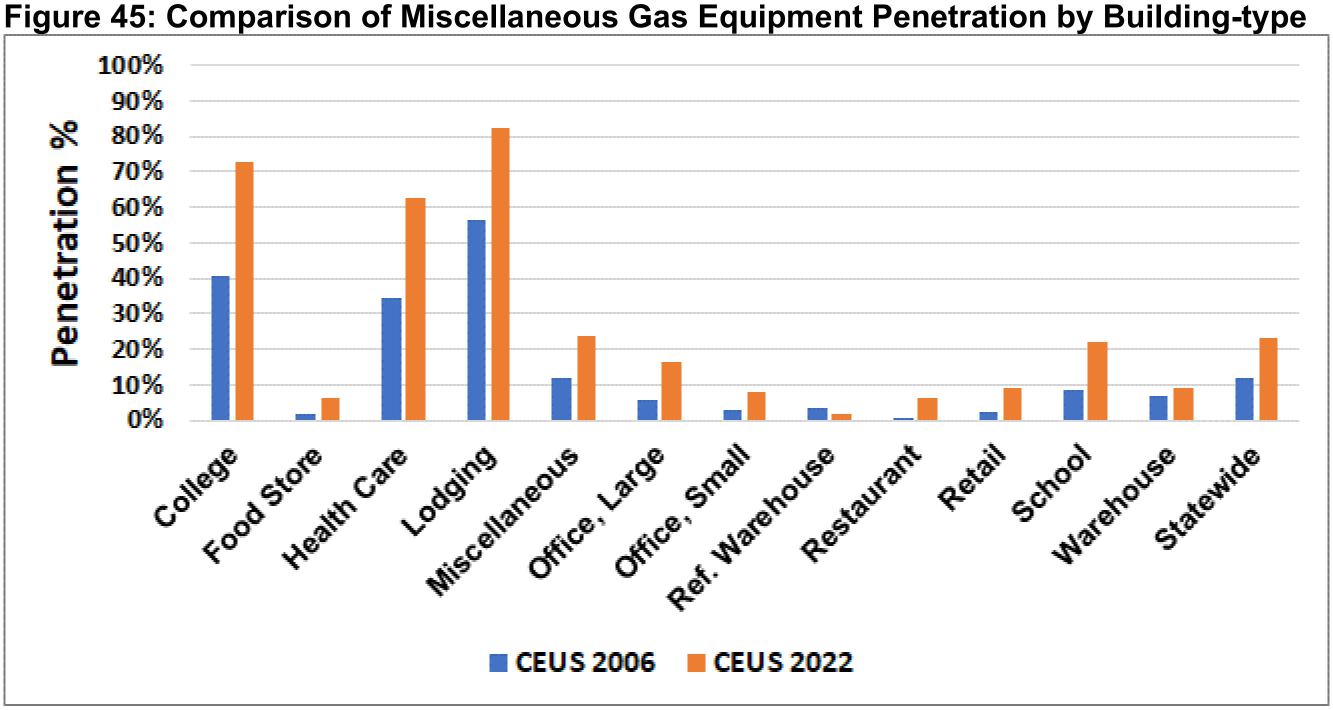
Figure 44 and Figure 45 show the miscellaneous electric and gas equipment penetrations respectively by Building-type and for the entire commercial sector, as measured in the 2006 and 2022 CEUS surveys.

Figure 44: Comparison of Miscellaneous Electric Equipment Penetration by Building-type



Source: 2022 CEUS and 2006 CEUS

Figure 45: Comparison of Miscellaneous Gas Equipment Penetration by Building-type



Source: 2022 CEUS and 2006 CEUS

Chapter 8: NAICS Code Comparison

The North American Industry Classification System, or NAICS, is the standard used by federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. The six-digit NAICS codes are designed such that the left-most two digits describe broad economic sectors, and the additional digits to the right represent finer distinctions between business activities. For example, the first two digits can distinguish sectors such as utilities (22), accommodation and food services (71), or health care and social assistance (62). Within the health care and social assistance group, the third digit serves to distinguish subsectors such as hospitals (622), nursing and residential care facilities (623), or social assistance (624). The distinctions are rather subtle at the five or six-digit precisions, for example 623311 represents continuing care retirement communities, while 623312 represents assisted living facilities for the elderly.

This section offers a summary and discussion of variances between NAICS codes as listed in utility CIS data, and as found in the CEUS survey. There are legitimate reasons for differences between the two sets of NAICS codes. NAICS codes are highly specific, yet many buildings may support multiple business activities. For example, many sampled sites carried out company management, design, some manufacturing, storage, distribution, and sales all under one roof. In addition, to a certain degree, NAICS code selection could be subjective – depending on which aspect of the business is thought to be more prominent. Even CEUS team members that had exhaustive training and site-specific photos and interview notes, agreed on NAICS code assignments approximately 90% of the time. The goal of the following discussion is to help utility companies understand the extent and types of variances in NAICS codes, and potentially to improve accuracy of NAICS codes on file for customers. There was considerable variation in NAICS code accuracy among utilities. For example, agreement with as-found NAICS codes from this survey, at the 3-digit level of resolution, ranged from 61% to 84% among the five participating utilities. It is also hoped that the discussion may help future researchers to interpret utility CIS data, to develop algorithms or analyses to update NAICS codes based on contextual data (e.g., is the building in a retail district or warehouse district?), and to inform potential updates of NAICS to Building-type correspondence maps. One option may be to periodically survey customers regarding their NAICS codes, or to include the NAICS field in customer forms such as rebate applications or interconnection agreements. It may also be possible to initiate a NAICS update as customers log on to utility web sites.

Utility CIS data typically include NAICS codes for each account or premise. The CEUS team relied on these NAICS codes to stratify utility customers into the twelve Building-types in the Commercial Forecast Model. NAICS codes are then determined for surveyed sites through various forms of data collection including customer interviews, observations of business activities, and cross-referencing other data (for example, NAICS codes listed on publicly- available government documents such as databases on the Small Business Administration website). For the purpose of this discussion, NAICS codes in the utility CIS data are referred to as initial NAICS codes, and NAICS codes determined through the survey are referred to as final NAICS codes. Ideally, the correspondence between initial and final NAICS codes would be perfect. Necessary methodological differences, however, lead to variances between the initial and final NAICS codes.

The main methodological difference is that, in the CEUS survey, the final NAICS may be determined by the business activity of a tenant that does not directly pay utility bills. For example, a retail space may be rented by a camera and photography supply store (NAICS 443130 mapping to the Retail Building-type), but the property manager may hold the utility account and would therefore be listed as a commercial property lesser (NAICS 531120, mapping to the Office Building-type) in the utility CIS data. In this example, the most likely outcome is that the initial NAICS is 531120, while the final NAICS is 443120. There can be other reasons for variances between initial and final NAICS codes. For example, a customer may change business activities in a given site, but the initial code assigned to the account would likely remain unchanged in CIS data.

Initial and Final Building-Type Correspondence

The mapping of NAICS codes to Building-types often requires 4-digit resolution. A full listing is provided in Appendix G of this report. Despite the relatively high resolution required to map NAICS codes to Building-types, the CEUS team found 85% agreement between initial and final Building-types. This indicates that the NAICS to Building-type mapping is constructed in a logical way that is robust with respect to NAICS differences in the last two to three digits. Figure 30 shows the correlation matrix between initial and final Building-types. In this figure, small and large offices are combined into a single Office Building-type since the distinction between them is not based on NAICS codes, but rather on floorspace. Likewise, the CEUS survey used criteria such as the amount of refrigerated floorspace to distinguish refrigerated warehouses from warehouses, so both of those Building-types are represented as warehouses in the figure. Inspection of Figure 30 reveals that a significant portion of discrepancies are not random, and further study of the data may yield algorithms that can improve correspondence between initial and final NAICS codes. For example, while 82% of sites with the initial Health Care Building-type also had Health Care as the final Building-type, some 15% mapped to offices. Below, we discuss the four Building-types determined in utility CIS data that have the lowest correspondence dates to CEUS-determined Building-Types.

Warehouses: The Warehouse Building-type includes NAICS codes that generally describe wholesale trade. Buildings with initial NAICS codes mapping to the Warehouse Building-type often hosted multiple business activities which presented a challenge to NAICS code final assignment. The CEUS team also found that discernment between wholesale and retail trade is often difficult, as many wholesalers also conduct retail sales from the same facility. For this reason, the largest off-diagonal element for the Warehouse Building-type corresponds to the Retail Building-type. Likewise, the largest off-diagonal element for the Retail Building-type corresponded to the Warehouse Building-type.

Offices: The main source of discrepancy for the Office Building-type is that the utility accounts often belong to commercial property managers, which typically have NAICS code 531120. Whenever possible, the CEUS survey assigns the NAICS code of the dominant tenant (or tenant type, for example if a building is leased primarily to various dentists) within a leased building. Also, certain NAICS codes were remapped from Offices to other building-types or sectors and vice versa. For example, agricultural related codes (115111-16) that were mapped to Offices were dropped and moved to Agricultural sector.

Health Care: A significant portion of buildings that had Health Care NAICS codes within the utility CIS data were mapped to other Building-types by the CEUS team consisted of initial code 621000 mapping to final code 621111. Not all NAICS codes within utility CIS have six-digit precision, but like the example above contained only the first three or four digits, then zeroes. This may be due to conversion of codes from initial Standard Industrial Classification (SIC) which preceded NAICS and had lower, 4-digit resolution.

Colleges: The main source of discrepancy for College building types was that certain off-campus buildings with specific functions, such as storage or administration, were assigned the NAICS code of the larger entity that owns the building, such as a university or fine-arts school.

The highest levels of correspondence between initial and final Building-types were for Lodging (96%), Restaurants (96%), and Food Stores (93%). Overall, the Building-types as determined through utility CIS data showed good correspondence to those determined through the final NAICS codes.

Figure 46: Correlation Between Initial and Final Building-types

Building Types		Final NAICS Codes									
		College	Food Stores	Health Care	Lodging	Miscellaneous	Office	Restaurant	Retail	School	Warehouse
Initial NAICS Codes	College	83%	0%	1%	0%	6%	5%	0%	1%	3%	1%
	Food Stores	0%	93%	0%	0%	0%	0%	3%	2%	0%	1%
	Health Care	0%	0%	82%	0%	1%	15%	0%	2%	0%	0%
	Lodging	0%	0%	0%	96%	1%	2%	0%	0%	0%	0%
	Miscellaneous	1%	8%	0%	0%	83%	3%	1%	2%	1%	1%
	Office	1%	2%	3%	1%	6%	77%	3%	5%	0%	3%
	Restaurant	0%	2%	0%	0%	1%	0%	96%	0%	0%	1%
	Retail	0%	1%	0%	0%	2%	2%	1%	90%	0%	3%
	School	2%	0%	0%	0%	2%	4%	0%	0%	90%	0%
	Warehouse	0%	2%	0%	0%	6%	6%	1%	14%	0%	70%

Source: 2022 CEUS

NAICS Correspondence by NAICS Resolution

NAICS codes are structured such that they are meaningful at the two-digit level (e.g., first two digits 23 is construction, 61 is educational services, etc.), with each additional digit indicating a more specific aspect of business activity. As shown in Table 16, the agreement in NAICS assignments between utility CIS data and CEUS improves as the resolution decreases. The level of agreement between initial and final NAICS codes is 64% at the 6-digit level, 68% at the 5-digit level, 71% at the 4-digit level, 78% at the 3-digit level, and 85% at the 2-digit level. Appendix O lists all utility and as-found NAICS codes and tabulates site-level NAICS agreements into the results presented herein.

Table 16: Utility and CEUS NAICS code agreement at various resolutions

Utility	6-Digit Agreement	5-Digit Agreement	4-Digit Agreement	3-Digit Agreement	2-Digit Agreement	Building Type Agreement
PG&E	63%	66%	69%	79%	87%	86%
SCE	72%	76%	79%	84%	87%	88%
SDG&E	53%	55%	58%	66%	79%	80%
LADWP	48%	52%	55%	61%	79%	82%
SMUD	59%	63%	67%	72%	76%	80%
Total	**64%**	**68%**	**71%**	**78%**	**85%**	**85%**

Source: 2022 CEUS

CHAPTER 9: Recommendations

Recommendations

Recommendations include lessons learned from carrying out the 2022 CEUS, and ideas for future research or novel data collection modes.

Lessons Learned

The ADM team is thankful for the opportunity to contribute to the 2022 CEUS. Given that the previous CEUS occurred 15 years ago, certain aspects related to customer contact, data collection, and technology have changed. Despite ADM's involvement in each CEUS to date, the unprecedented scale of this survey, coupled with heavy reliance on previously unavailable software and hardware solutions to run the survey, meant that this effort was in many ways a first experience for the team. The scale and pace of the survey presented unique challenges to operations and organizational management.

Project Timing

The EPIC-funded portion of the 2022 CEUS formally started with a kick-off meeting in October 2016 and ended in March of 2020. However, the CEUS project could not start in earnest until January 2018. The primary reason is that funding for the non-EPIC portion of the CEUS project was not approved and available to the project until July of 2017 – exactly one year after EPIC funding became available. Given the scale of this project, CEC staff prudently awaited to confirm both the availability of non-EPIC funding (approximately 39% of total project budget) and the participation of key utilities, prior to expending considerable project resources. Moreover, data collection related to gas data could not have been authorized prior to the availability of the requisite non-EPIC funds for the project and collecting electric and gas data on different timelines would be inefficient and would necessitate marked reductions in sample size. Formal invitations to two of three IOUs were not sent until November of 2017.

EPIC funding expired in June 2020, which forced much of the data collection to conclude in March of 2020. The short duration between January 2018 and March 2020 was a major challenge to the project team. ADM and CEC management spent considerable effort in modifying plans, staging deliverables, and otherwise mitigating the impacts of the short timeline between authorization of non-EPIC funding, and expiration of EPIC funding. The team completed over 15,000 on-site surveys in 2019 to ensure maximum utilization of EPIC funding prior to their expiration. Staff that would have been assigned to collect data in LADWP service territory focused on EPIC-funded data collection in SCE instead. While the team managed to complete the EPIC-funded portion of the study prior to the funding expiration, the delay in on-site data collection in LADWP service territory proved problematic as the COVID-19 pandemic caused statewide shutdowns exactly as the team launched the LADWP survey effort.

Our primary recommendation related to project timing is to attempt to synchronize funding sources and to gain early participation commitments from utilities to allow the project to proceed at or near the designed data collection rate. A secondary recommendation is to extend the duration of funding sources for large and long-term projects such as CEUS to accommodate potential delays and unforeseen events.

Data Acquisition

At its peak rate, the field effort yielded over 1,700 surveys per month distributed throughout 13 distinct geographical zones. The CEUS team had initially planned for maximum rates of approximately 1,000 surveys per month but increased the data collection rate to conclude EPIC-funded activities before the expiration of EPIC funds. Many of the design elements developed by the CEUS team in the work plan proved essential to maintaining order during such a frenzied effort. Perhaps the most important design element was the practice of establishing quotas for each sample-cell and allowing simultaneous recruitment through direct in-person contact (referred to herein as *canvassing*) as well as telephonic recruitment and scheduling for each cell. This is made possible by data acquisition management infrastructure within the CEUS Tool that provides the ability to:

- Assign specific sets of sites to call center representatives
- *Check out* sites for recruitment, and check them back in after a survey or after a definitive disposition from the site-contact
- Manage progress toward quotas by automatically checking completed sites against target sample sizes for over 1,300 distinct quotas.
    - The operations manager can close down any sample cells that are nearing the quota by downloading, editing, and uploading a simple spreadsheet file
    - When a sample cell is closed, all associated sites are automatically purged from the pool of sites that are available for recruitment
- Conduct staged, automated data completeness, standardization, and validation checks to minimize the manual QC burden.
- Assist the surveyor by relating all notes taken by the call center related to appointments, providing driving directions to survey-sites, and providing key details about the site in advance, including a tool that facilitates satellite-based building footprint measurements.

Although the automation described above proved indispensable to the effort, the sheer pace of data collection meant that project staff were inundated with day-to-day operational and management tasks such as fielding questions from surveyors, conducting quality control reviews of recently submitted sites, and continuous training and maintenance of the survey and call center teams. Although data collection activities can be scaled up by hiring more field and call center staff, the increased throughput ultimately taxed the management team's ability to keep up with the rapidly accumulating data. Fortunately, the automated quality control and sample management capabilities of the CEUS Tool augmented the management and analysis team's ability to control the project even as data collection rates surpassed 400 on-site surveys per week. A positive consequence of conducting simultaneous field work in more areas than planned was that it forced additional local hiring of field staff, which dramatically reduced travel expenses. One key takeaway was that during 2018 and 2019, the labor markets even in remote parts of California provided competent surveyors with local familiarity and a curiosity to learn about the CEUS project.

Reconciling Meters

Meter reconciliation is necessary to ensure that the actual surveyed area corresponds to (1) the survey-site defined by our sampling algorithm and (2) energy usage amounts reported by utilities.

This is especially true because the project team actively clustered meters into survey-sites, rather than relying on the native premise designations within the utility CIS data.

In many cases, there is a simple one-to-one correspondence between a meter and the survey - site since the vast majority of sites have just one or two meters. However, sites such as strip malls and large office buildings can involve multiple meters and rentable spaces, which can change in the time between the initial clustering and sampling, and the on-site survey. Due to the large sample size, the meter reconciliation effort was prolonged and labor intensive. While the team developed strategies to minimize the survey burden on the participants, one notable drawback was that not all participants had the required time, trust, or commitment to disclose utility bills or to allow surveyors to view and record utility meter numbers. The lack of reliable meter information for all sites increased the labor associated with meter reconciliation.

It was also a challenge to match gas meters with survey-sites that have different gas and electric providers. The CEUS team developed successful strategies for matching gas meters and associated energy usage to survey-sites that previously had only electric usage information available (primarily sites in SMUD, LADWP, and SCE service territory), and for validating those matches. These involved fuzzy matching of text and numeric fields between different utility databases and statistical modeling to discern genuine matches, as well as manual review of sites that had anomalous energy usage intensities (kWh/ft^2 and kBTU/ft^2) relative to facilities with the same NAICS code.

Survey Site Definition

Utility companies tend to perform their own clustering of areas or buildings into premises or service addresses. Our recommendation is for CEC staff to explore usage of the "native" clustering within utility company databases as the sampling units for the next CEUS survey. If utility companies have based their premise definitions on clearly delimited electric or gas services, this recommendation may alleviate labor associated with clustering prior to sampling, and with meter reconciliation after data collection.

Commercial Real Estate Data

One of the project goals was to assess the feasibility of using commercial real estate data to benefit the CEUS design or as a means of collecting commercial end-user characteristics. The CEUS team found that the primary benefit of commercial real estate data was to enhance the sample frame with building construction dates, thereby enabling the survey to oversample newly built facilities. Apart from construction dates, the data enabled several useful cross-checks on site floorspace, the site physical type (e.g., whether the site comprises an entire building or a part of a building), and the site's vacancy. The main drawbacks to the commercial real estate data were coverage gaps for public-sector buildings or building types that are infrequently offered on the real estate market (e.g., hospitals, universities, schools, government buildings) and cost: in addition to the cost of the data itself, there was a significant labor cost associated with matching over 600,000 unique sample points derived from utility CIS data to a comparably-sized list of properties based on street address or geographical coordinates. In retrospect, an alternate approach to focusing on newly-created accounts (or premise numbers or meters), along with a mid-survey data request for such new accounts would have been more effective to oversample new construction.

Recommendations for Additional Research

Californians will experience significant energy-related changes over the next decade. Legislative mandates are causing increased investment in energy efficiency, transportation electrification, building electrification, and behind-the-meter generation and storage. The research activities listed below may help to increase forecasting ability during this period of exciting changes to California's energy infrastructure.

Develop a Parametric Modeling Framework Informed by CEUS Data

CEC staff need tools to gauge potential impacts associated with technology and market changes and to facilitate codes and standards studies. Over time, codes and standards enhancement studies will involve complex control and optimization studies that may benefit from building energy modeling. For example, imagine a potential code change related to fenestration: smart blinds that automatically adjust to optimize energy usage, comfort, and natural lighting.

Survey data alone is not sufficient to predict or forecast the energy and demand impacts of codes and standards changes or other significant market or technological developments. Building energy simulation models can serve this purpose. A comprehensive set of building simulation models could serve as a basis for detailed scenario analysis related to technological changes.

The set of Building-types defined for the forecast should be more granular than the 12 Building-types in the Commercial Model, in case the forecast effort disaggregates certain Building-types in the future. To ensure proper diversification of loads on the grid, there should be many instances of any given Building-type, with different operation schedules, technology / equipment types and fuel shares, and construction characteristics.

A parametric EnergyPlus modeling framework with a user interface shall allow batch parametric specification of model attributes such as window shading schedules, ventilation control schemes, "smart" thermostats, as well as more basic, but impactful changes such as gas to electric space heating, water heating, laundry, and cooking retrofits. Some potential parametric fields include:

- Heating/cooling system type
- Heating/cooling coefficient of performance
- Part-load curves for heating and cooling equipment
- Outside air fractions
- Temperature set points
- Economizer operation profiles
- Fan and pump controls: VFD vs. dampers or const/volume
- Window U-value and SHGC
- R-values for walls and ceiling
- Lighting power density
- Lighting controls (daylighting, occupancy sensors)
- Occupancy schedules
- Demand control ventilation tied to occupancy schedules

With this modeling framework, CEC researchers can run thousands of individual models and aggregate results into meaningful measure-level impacts both at the individual customer level (for example, medium, low-bound, and high-bound per-customer savings from a given measure or code enhancement), as well as localized or aggregated grid-level impacts for any hour of a typical year.

Track Emerging Technologies

This CEUS survey collected information related to behind-the-meter generation, storage, and electric vehicle charging. Battery storage and electric vehicle charging are nascent but rapidly growing fields, and a concern is that data collected prior to 2020 would not be representative of California five or ten years from now. The authors recognize that CEC staff are engaged in multiple efforts that focus on electric vehicle charging infrastructure, electrification, and distributed generation. Since many of these technologies are closely related, and relevant to forecasting and other demand side management efforts, the recommendation is to continue to collect data, and to maintain data in a unified and readily accessible format.

Develop a Forever Cohort

Just as the Case-Schiller Index[26] tracks sales prices for the same homes over time, researchers can track a list of key survey variables for the same buildings over time. As an example, a subset of the 2022 CEUS participants could be recruited into a cohort that can be asked to complete a "light" version of the CEUS form online on an annual basis for years to come. This may eventually replace the current survey process. The project team notes three experiences that motivate this recommendation:

- Participants that had entered facility information in EnergyStar Portfolio Manager often agreed to share the data with the CEUS team.
- Property managers, corporate entities, school districts, and health care organizations maintain digital inventories of floor stock, equipment types, utility account information, and many other important data that correspond to the CEUS survey instrument.
- While Assembly Bill 802 requires annual benchmarking for commercial buildings larger than 50,000 square feet, data from smaller buildings would need to be provided on a voluntary basis. Drawing on the experience of hiring and training new field staff for the survey, the team is confident that most businesses have at least one employee that would be able to complete a somewhat reduced version of the CEUS survey instrument with a minimal amount of training. If possible, this data acquisition mode could largely supplant far costlier on-site data collection.

Remote surveys have proven to be feasible in this study, but the team observed that passive online surveys had more data gaps and data quality issues than surveys that were conducted remotely by project staff. Remote data collection would still require a staffing commitment, albeit a much smaller one than the CEUS. Another benefit from this approach is that participants in this cohort could be recruited for other purposes, such as end-use metering, more detailed data collection, or focus group studies.

---

26 The Case Schiller Index is a repeat-sales house price index maintained by the Standard & Poor credit rating agency.

CEUS APPENDICES

Please see Appendices A-P (on California Commercial End-Use Survey) listed below.

Appendix A: CEUS Survey Instrument

Appendix B: Annotated CEUS Survey Instrument

Appendix C: Recruitment Letters

Appendix D: Recruitment Script

Appendix E: Data Collection Protocols

Appendix F: CEUS Database Dictionary

Appendix G: NAICS to Building-type Map

Appendix H: Detailed Sample Tables

Appendix I: Quality Control

Appendix J: Expansion Weights (Spreadsheet)

Appendix K: Results at Building-type and End-Use Levels (Spreadsheet)

Appendix L: BTM Generation and Electrification

Appendix M: Scale Factors

Appendix N: Unscaled Results at Building-type and End-Use Levels (Spreadsheet)

Appendix O: Comparison of as-found to utility-assigned NAICS codes (Spreadsheet)

Appendix P: Comparison of Saturations, Penetrations, and Fuel Shares (Spreadsheet)

REFERENCES

Baroiant, Sasha, Barnes, John, Chapman, Daniel, Keates, Steven, Phung Jeffrey, (ADM), 2019. *California Investor-Owned Utility Electricity Load Shapes.* CEC-500-2019-046. Available at California Investor-Owned Utility Electricity Load Shapes

ConstructConnect, *Insight Forecast: Construction Market Forecasts*, 2023. Insight Forecast Make Informed Decisions on Pricing, Business Growth Strategies, & Market Potential

Dalenius, T. and Hodges, J. L. (1959), Minimum Variance Stratification, *Journal of the American Statistical Association*, 54, 88-101.

Gunning, P., and Horgan, J.M. (2004). A new algorithm for the construction of stratum boundaries in skewed populations. *Survey Methodology*, *30*(2), 159-166.

Hidiroglou, M. A., and Srinath, K. P. (1993) Problems associated with designing subannual business surveys, *Journal of Business and Economic Statistics*, 11,397-405.

Itron, Inc., (2002). [CEUS] Final Sample Design. Submitted to California Energy Commission March 6, 2002.

Itron, Inc., (2006). California Commercial End-Use Survey. California Energy Commission Publication Number: CEC-400-2006-005.

Lavallee, P. and Hidiroglou, M.A. (1988). On the stratification of skewed populations. Survey Methodology, 14, 33-43.

Rivest, Louis-Paul and Baillargeon, Sophie (2017). Stratification: Univariate Stratification of Survey Populations. *R package version 2.2-6*. Stratification: Univariate Stratification of Survey Populations

R Core Team (2018). R: A language and environment for statistical computing. *R Foundation for Statistical Computing, Vienna, Austria*. The R Project for Statistical Computing

RStudio Team (2016). RStudio: Integrated Development for *R. RStudio, Inc., Boston, MA*. RStudio.

Saksena, Michelle et al, *America's Eating Habits: Food Away From Home*, 2018. America's Eating Habits: Food Away From Home

United States Energy Information Administration, *Price Elasticity for Energy Use in Buildings in the United States,* 2021, Price Elasticity for Energy Use in Buildings in the United States: Introduction.

LIST OF ACRONYMS AND RELATED DEFINITIONS

Acronyms and Abbreviations

Acronym	Definition
AAEE	Additional Achievable Energy Efficiency
AC	Alternating current
ADM	ADM Associates, Inc.
App	web-based application
AWS	Airport weather station
BTU	British Thermal Unit
CAISO	California Independent System Operator
Canvassing	In-person recruitment of survey participants
CDD	Cooling degree day
CDH	Cooling degree hour
CEC	California Energy Commission
CEUS	California Commercial End-Use Survey
CEUS Tool	Web-based application designed and used for this CEUS
CHP	Combined heat and power
CIS	Customer information system
COP	Coefficient of performance
CPUC	California Public Utilities Commission
CSI	California Solar Initiative
DAV	Davenergy Solutions, Inc.
DC	Direct current
DEER	Database of Energy Efficiency Resources
DWH	Domestic Water Heating
DOE	Department of Energy
DNC	Do not contact (designation used during customer recruitment)
EER	Energy efficiency ratio
EI	Energy Intensities
CEC/Energy Commission	California Energy Commission
EPRI	Electric Power Research Institute
EV	Electric vehicles
EM&V	Evaluation Measurement and Verification
GB	Gigabyte
GWh	Gigawatt hour
HDD	Heating degree day

Acronym	Definition
HDH	Heating degree hour
HVAC	Heating, ventilation, air conditioning
IEPR	Integrated Energy Policy Report
IOU	Investor-owned utilities
ISO	(Electric Power Grid) Independent System Operator
IT	Information technology
KPI	Key Performance Indicator
kWh	Kilowatt hour
kBTU	Kilo BTUs
LADWP	Los Angeles Department of Water and Power
LED	Light emitting diode
NAICS	North American Industry Classification System
NCNC	Northern California Non-California ISO
NERC	North American Electric Reliability Corporation
NREL	National Renewable Energy Laboratory
NRMSE	Normalized root mean squared error
MWh	Megawatt hour
Mthm	Megatherm (10^6 therms)
PC	Personal computer
PDT	Pacific Daylight Time
PG&E	Pacific Gas & Electric Company
PII	Personally Identifiable Information
POC	Point of Contact
POU	Publicly owned utilities
PST	Pacific Standard Time
PV	Photovoltaic

Acronym	**Definition**
QC	Quality Control
RFP	Request for Proposal
SAM	System Advisor Model
SCE	Southern California Edison
SCG	Southern California Gas Company
SDG&E	San Diego Gas & Electric
SEER	Seasonal energy efficiency ratio
SoCalGas	Southern California Gas Company
Survey-site	The sampling unit for this survey. A survey-site is a contiguous location controlled by the same business entity with at least one utility meter.
TAC	Technical Advisory Committee
TCU	Transportation, communications, and utilities
Therm	1 Therm = 100,000 BTUs
TIG	Tracking and Improvement Group
TMY	Typical meteorological year
TOU	Time of use
VSD	Variable speed drive
Wh	Watt hour