FINAL REPORT

Equitable Electrification of Existing Buildings: A Pathway to Decarbonization

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Disclaimer

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Abstract

This study assesses the progress towards, barriers to, and equity implications of residential and commercial building electrification. For residential buildings, statewide electrification program data, building permits, and utility energy usage data were combined with renter surveys and multi-family property owner interviews. For commercial buildings, a prioritization framework, consisting of metrics on emissions, technical feasibility and social impacts, was developed to produce a prioritization ranking at a statewide scale, customizable by metric weighting and directionality. Lodging subsector was selected for a more in-depth feasibility assessment, featuring vendor and operator interviews, site visits, and statewide market analysis. Despite over $550 million in electrification incentives (2021-2023), only approximately 7% of the 600 thousand additional households who have adopted residential electric space heating can be attributed to incentive programs, with most occurring through "natural adoption." Current programs support piecemeal, end-use-specific measures rather than comprehensive retrofits, failing to address panel capacity constraints, coordination costs, and whole-building planning needs. Multifamily buildings face particularly acute challenges, with only one-third considered "electrification-ready" and declining electric heating adoption in 2-4 unit buildings between 2017 and 2022. The commercial sector demonstrates even lower uptake despite comparable budgets, with incentives failing to cover marginal electrification costs in most subsectors. Between 2006 and 2022, electricity's share of commercial energy consumption declined from 37% to 31%, suggesting market decisions are shifting away from electrification. The feasibility assessment of the lodging sector found that properties are largely under consolidated ownership, and operators often lack the time and resources to participate in traditional programs. Achieving California's decarbonization goals will require substantially higher funding, comprehensive retrofit support, subsector-specific strategies, and addressing structural barriers beyond equipment rebates.

Executive Summary

Background

California’s building sector accounts for approximately 25% of statewide greenhouse gas emissions, when accounting for fossil fuels consumed onsite, electricity demand, and refrigerants used in air conditioning systems and refrigerators. 12 percent of total statewide GHG emissions are emitted onsite in residential and nonresidential buildings, with natural gas combustion producing significant quantities of air pollutants such as nitrogen oxides (NOx) and carbon dioxide that contribute to poor ambient and indoor air quality and climate change. Electrification is a viable strategy for achieving significant and immediate reductions in greenhouse gas and criteria pollutant emissions from the building sector. This research addresses critical knowledge gaps regarding the status of electrification progress in commercial and residential buildings statewide, data gaps preventing accurate cost and impact estimates, populations under-served by existing policies, and the values and barriers affecting electrification decisions, providing the California Air Resources Board (CARB) with evidence-based findings to align policies and programs with the state's decarbonization and air quality goals.

Objectives and Methods

This study had three primary objectives that addressed six core research questions: first, to examine California's building electrification trends and spatial patterns across geographic and demographic dimensions to characterize progress, gaps, and under-served populations; second, to quantify electric service panel capacity constraints and understand stakeholder decision-making through primary data collection; and third, to develop a commercial building prioritization framework evaluating equity implications and feasibility to guide state investments.
The study combined quantitative analysis with qualitative research to provide improved characterization of buildings and populations impacted by electrification policies.

For residential buildings, researchers developed a novel bottom-up methodology estimating electrical service panel capacities statewide using parcel-level building attributes, historical National Electrical Code requirements, and empirically-derived probability functions from manually-assembled building permit databases for several large municipalities, analyzing how panel upgrade likelihood correlates with building age and CalEnviroScreen percentile scores.

The team analyzed incentive program data from the California Energy Data and Reporting System (CEDARS) and TECH Clean California, synthesized electrification cost estimates from existing literature, and compared them with empirical project cost data from over 20,000 TECH program participants. Adoption trends were examined using the Energy Consumption Database (2006-2022), American Community Survey (2013-2022), Residential Appliance Saturation Survey (2009, 2019), and other datasets. Primary data collection included a survey of 807 renters in disadvantaged communities

conducted by FM3 Research and 15 in-depth interviews with multi-family property owners managing over 10,000 units statewide.

For commercial buildings, researchers developed a prioritization framework with seven metrics including emissions impacts, residential exposure risk, sensitive population exposure, worker vulnerability, grid outage risk, and technology readiness. To develop emission estimates, utility account-level consumption data (2015-2021) from investor-owned utilities were matched to California Commercial End Use Survey subsectors using NAICS code crosswalks, CO_2 emissions were calculated using the emission factors from the U.S. Environmental Protection Agency (EPA), NOx emissions were estimated using the NOx emission factors from the San Joaquin Valley Air Pollution Control District methodology along with the control factors from CARB. An interactive web-based tool for this prioritization framework was created allowing users to adjust metric weights and directionality. The lodging subsector was selected for detailed feasibility assessment. Through analysis of CoStar property data for over 7,000 California hotels and stratified random sampling, 100 properties statewide were identified for outreach, of which 50 were in disadvantaged communities. Outreach included phone interview and site visits, which were conducted in August-September 2025. Data collection for existing sources occurred between March 2023 and February 2024.

Results

Residential Building Sector

California's residential building stock demonstrates modest electrification readiness, with approximately half of single-family homes having sufficient electrical panel capacity (≥200 Amps) to support immediate space and water heating electrification, but only one-third of multi-family properties meeting this threshold. Disadvantaged communities (DAC) face disproportionate challenges, with single-family homes having undersized panels at four times the rate of non-DAC properties (8% for DAC compared to 2% for non-DAC). Despite 231 active residential rebate programs and more than $550 million in combined CEDARS and TECH funding allocated between 2021-2023, incentive-driven adoption remains limited. Between 2019 and 2023, 540,079 households adopted electric space heating[1], yet only 42,810 electric space heating recorded claims in CEDARS and TECH. This indicates that fewer than 8% of electric space heating installations are likely attributable to an incentive. Total installed costs from TECH program data reveal significant gaps between available incentives and actual project expenses: median costs for single-family ducted heat pump installations without panel upgrades reached nearly $20,000, while incentives typically cover only a fraction of total costs. Consumer attitude research demonstrates that cost sensitivity fundamentally shapes adoption decisions, with renters' willingness to electrify declining precipitously even at modest monthly cost increases, while potential savings prove less motivating—reflecting loss aversion and uncertainty about long-term benefits. Multifamily property

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[1] Difference between American Community Survey (ACS) 1-Year Estimate 2023 and ACS 1-Year Estimate 2019: Table DP04 Occupied housing unit using electricity as primary house heating fuel

owners uniformly emphasized that electrification projects must achieve cost-neutrality for owners, not just tenants, with nearly all stating they would not proceed without incentives, yet many finding even subsidized projects economically infeasible due to inadequate funding for electrical infrastructure upgrades.

Commercial Building Sector

The commercial building sector whilst having a lot of resources available, they are under-subscribed. While 120 active commercial rebates are available with budgets exceeding residential allocations, program participation has collapsed—from 2,428 claims in 2019 to 299 in 2023, representing only 2% of residential claim volumes despite comparable funding. Between 2006 and 2022, electricity's share of total commercial energy consumption declined from 37% to 31% as gas use increased, with particularly concerning trends in subsectors offering the greatest decarbonization potential: electric space heating share declined in lodging and office buildings where heating demands are substantial, while electric water heating share fell in colleges, healthcare facilities, and offices. Cost analysis reveals severe incentive inadequacy across most subsectors, with the average incentive values varying considerably by end-use: cooking equipment incentives range from $1,130 to $17,500 per project, while whole building incentives average $10,000 per facility. Whole building incentives apply to projects that involve converting all gas appliances and equipment to electric systems. Water heating rebates, critical for many commercial subsectors, average between $1,550 and $1,812 per unit. Meanwhile, restaurants face electrification costs of $60,835-$123,855 per facility against maximum cooking equipment incentives of $17,500, while office buildings require $158,078 in upgrades that available incentives cannot meaningfully offset.

The prioritization framework analysis showed that offices, restaurants, and health care facilities emerged as top contributors to total CO_2 and NO_x emissions, while colleges had the highest emissions per facility. Restaurants dominated indoor NO_x emissions and ranked highest for worker vulnerability due to low wages and large workforces. Miscellaneous (e.g., movie theaters and gymnasiums) and office subsectors pose the greatest residential exposure risk, and miscellaneous facilities also rank highest for sensitive population impacts. Technology readiness varied, with lodging and offices scoring high, while process-heavy subsectors faced greater challenges.

To identify a subsector offering maximum returns to learning, the team adjusted the tool's weights and directionalities to emphasize difficulty factors: older building vintages, larger building sizes, greater end-use diversity, and higher gas consumption intensity (average annual therms per premise). All difficulty-related criteria received a weight factor of 10, while emissions and social impact metrics retained their original weights and directions. The team prioritized technology-ready subsectors to focus the feasibility assessment on electrification processes rather than equipment market readiness. Under this modified framework, lodging emerged as the highest-priority subsector and was selected for a comprehensive feasibility assessment. A preliminary literature review indicated a scarcity of examples of fully electrified lodging buildings, in contrast to other commercial buildings such as restaurants, university buildings, and hospitals, which have implemented all-electric systems. The feasibility assessment encountered systematic engagement barriers: despite 180+ call attempts and 15 site visit attempts, no substantive interviews were completed, revealing that traditional program outreach models fundamentally misunderstand commercial property operations where owners are rarely on-site, managers lack bandwidth, and contractors have abandoned certain market segments as economically unviable due to chronic underinvestment.

Conclusions

Achieving California's 2045 net-zero goals will require a paradigm shift from the current piecemeal, equipment-focused approach to comprehensive building system strategies. This includes: (1) electrification incentives scaled to actual project costs rather than equipment purchase prices; (2) whole-building retrofit programs that address electrical infrastructure, deferred maintenance, and multiple end-uses simultaneously; (3) delivery mechanisms designed around trusted intermediaries—contractors, industry associations, and turnkey service providers—rather than expecting direct engagement from time-constrained property owners; (4) rate structures and financing tools that eliminate the operational cost penalty of electrification; and (5) workforce development and contractor training programs sufficient to build market capacity. The multi-family sector, where only one-third of buildings have electrification-ready electrical panels and split-incentive problems prevent investment despite tenant benefits, requires special attention through regulatory reforms that align owner and tenant interests. Most fundamentally, the state must confront the reality that current program participation rates and natural adoption trends, if unchanged, will fall orders of magnitude short of decarbonization targets, necessitating either mandatory standards with comprehensive support systems or acceptance that building electrification timelines will extend well beyond mid-century goals.

Equitable Electrification of Existing Buildings: A Pathway to Decarbonization Final Report

1 - Introduction

This study assesses the equity implications, costs, and knowledge gaps associated with the electrification of existing buildings within the state of California. The scope of study is limited to residential and small commercial properties, with a dedicated focus on the experiences of priority populations as part of this transition. The results of this study are intended to aid policymakers' ability to evaluate existing programs and plan for the development of new mechanisms of State support for equitable building decarbonization.

This was a multi-year project that employed a set of hybrid research methods including meta-analysis of existing published literature and datasets, as well as the development and execution of novel primary research methods to fill important data gaps. The scope of the project included several research questions relating to the status of electrification progress within the state. These included documenting patterns in the adoption of electric end-use technologies throughout the state as well as characterizing participation in existing fuel-substitution incentive programs. In this process, UCLA identified several important gaps in the sources of data available for monitoring the progress of electrification statewide. Finally, the Research Team conducted novel primary research bottom-up methodology estimating electrical service panel capacities statewide to address several important data gaps related to the readiness of the residential building stock to support the adoption of electrical appliances in different end-use sectors.

1.1 - Residential Buildings

California has approximately 14.76 million total residential housing units. These can be broken down by type as shown in *Table 1*, below.

Table 1. Percentage of California's total housing units by type

Housing Type	Percentage of Total Housing Units
Single-family Detached	56.4%
Single-family Attached (Townhomes, etc.)	7.6%
Multifamily (2-4 units)	8.4%
Multifamily (5 or more units)	23.0%
Mobile & Manufactured Homes	4.4%

Other (Boats, RVs, Vans, etc.)	0.2%

Single-family (SF) detached homes make up the majority of California's residential building stock, accounting for more than half of the state's total housing units. The prevalence of these residential buildings is a defining feature of California's suburban and urban communities and has important implications for the dynamics of the state's electrification process. Attached single-family homes, such as townhouses and duplexes, make up a smaller but still significant portion of the building stock (7.6%). Multifamily (MF) housing, which includes apartments and condominiums in buildings of various sizes, comprises 31.4% of the state's housing stock, the bulk of which are buildings with 5 or more units. Mobile & Manufactured (MM) homes represent a smaller but important component of the housing market in California (4.4%). Given the state's history of complex challenges related to both housing affordability and availability, the research team recognizes that both MF and MM housing constitute an important component of available affordable housing and that these types of properties are also disproportionately inhabited by priority population households. To that end, and to the extent by which data were available, considerations related to these sectors were prioritized in the development of the project's methods and analyses.

1.2 - Small Commercial Buildings

For the purposes of this study's scope, small commercial buildings were defined and segmented based on the definitions developed within the 2006 California Commercial End Use Survey (CEUS). The CEUS categorizes commercial buildings in California into twelve distinct categories: small office, large office, restaurant, retail, food/liquor, refrigerated warehouse, unrefrigerated warehouse, school, college, health care, hotel, and miscellaneous. *Table 2* below illustrates the breakdown of total commercial floor area within the state by these subsectoral designations.

Table 2. Percentage of California's total commercial building floor area by subsector.

Commercial Subsectors	Percentage of Total Commercial Floor Area
Colleges	4.4%
Food Stores	2.7%
Healthcare	5.4%
Lodging	5.4%
Miscellaneous	19.3%
Office, Large	15.0%
Office, Small	8.8%
Refrigerated Warehouse	1.7%
Restaurant	2.5%
Retail	12.8%
School	7.8%
Warehouse	14.2%

While the different subsectoral designations used in the CEUS generally reflect recognizable building types, it is important to recognize that there can be a significant amount of diversity in the sizes, vintages, and composition of installed end-use energy equipment among the individual facilities which may be classified as belonging to each of these subsectors. The existence of a “Miscellaneous” category is an obvious example of this, as it encompasses a huge diversity of commercial property types and associated end-use energy activities that do not strictly conform to the other, much more common building types. However, this same observation can also be applied to other sub-sectors, such as Colleges, which can encompass a wide range of facility types that might otherwise be individually categorized as offices, restaurants, lodging, or retail facilities were they to be considered in isolation.

From the perspective of the electrification of existing small commercial buildings, what ultimately matters most is the number, type, size, and usage intensity of the different installed gas end-use equipment that must be substituted with zero-emissions alternatives. Unfortunately, this type of information is not readily accessible in any existing dataset, at least in any comprehensive and detailed way. Through this analysis, the project team has therefore endeavored to synthesize different sources of information, ranging from end-use consumption surveys to detailed customer electricity and natural gas meter data, to plausibly infer as much as possible about the composition of this existing installed gas end-use equipment within different sub-sectors. Moreover, the work has additionally leveraged a wide range of other contextual data ranging from employment to pollution exposure, to grid outage vulnerability, to better anticipate the full spectrum of likely barriers that will be encountered when pursuing fuel-substitution measures within different sub-sectors primarily via electrification.

2 – Methods

2.1 - Residential Building Sector Materials and Methods

The evaluation of residential building electrification was conducted in two phases. First, an array of data reflecting different measures of electrification progress were compiled and analyzed in-depth. This included a literature review of previously published studies within peer reviewed academic journals as well as reports and other trade literature sources. This literature review encompassed published works documenting empirical costs, incentive programs, and trends in end-use adoption across single-family and multi-family housing.

The second phase of the residential building electrification analysis explored additional dimensions of electrification. These included challenges associated with the potential need for property owners to upgrade electric service panels in California's housing stock to support electrification, renter awareness of electrification options and benefits, and the experiences of multi-family property owners who have pursued electric service panel upgrades. These additional data were collected and analyzed to complement existing sources.

Data collection for this project (excluding opinion research) was conducted between March 2023 and February 2024. Datasets, studies, and analyses produced after this period are not reflected in the materials, methods, or findings presented here.

2.1.1 - Existing Data

Electrification Program Availability

A comprehensive source of data for tracking all available and active incentives for residential electrification in California does not currently exist. As a result, data on rebates were collected, cross-referenced, and verified for accuracy and timeliness. Two primary sources of information were used for this process: the Building Decarbonization Coalition (BDC) and North Carolina's Database of State Incentives for Renewables & Efficiency (DSIRE). The BDC data source accessed was a snapshot of the backend database that underpins the Switch is On web tool.[2] This data set included the program administrator (PA), program areas served, incentive price, incentive type, eligible building types, equipment type, applicant eligibility, electrification requirements, and whether the program is layerable. Available offerings were cross-referenced and supplemented with DSIRE, which offers an overview of financial incentives and policy measures supporting renewable energy and energy efficiency in the United States. Prices and active status were validated in cases where incentives were listed in both databases. Outdated incentives were omitted.

Incentives not specific to electrification or fuel-switching programs were excluded. These exclusions included incentives for whole house fans, technical assistance, smart thermostats, insulation and ductwork, home batteries, electric backup power units, air

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[2] Switch Is On, Building Decarbonization Coalition, “About” (webpage), available at https://switchison.org/about/.

sealing, and comprehensive energy upgrades (which may include attic insulation, duct sealing, smart thermostat, and whole home energy assessment). Incentives were also excluded if they were exclusively free loaner programs or programs with highly limited availability. Rebates for electric service panel upgrades were included for consideration, as they constitute a focus area of primary data collection in this study. This investment is largely considered essential to enabling whole-house electrification and transportation electrification.[3] Ultimately, 231 active residential rebate programs were identified across California, serving either the entire state or specific regions.

Program Uptake

Residential participation in California Public Utilities Commission (CPUC)-approved, ratepayer-funded energy efficiency (EE) programs is reported to the California Energy Data and Reporting System (CEDARS) by program administrators from investor-owned utilities (IOUs), regional energy networks (RENs), and select community choice aggregators (CCAs). CEDARS is a database overseen by the CPUC that consists of both publicly and privately accessible data attributes. The program administrators who report to CEDARS include Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas & Electric (SDG&E), Southern California Gas Company (SoCal Gas), select CCAs (Marin Clean Energy, Redwood Clean Energy Authority, San Jose Clean Energy), and RENs (Bay Area Regional Energy Network [BayREN], Inland REN, Southern California Regional Energy Network [SoCalREN]). CEDARS provides publicly accessible data on program budgets and implementation claims, which document when an energy efficiency measure has been delivered to a participant. Publicly available CEDARS reporting data span from 2016 to the fourth quarter (Q4) of 2023, the most up-to-date quarter of claim data at the time of analysis.

The second program uptake dataset utilized was the Technology and Equipment for Clean Heating, known as TECH Clean California or simply TECH. In September 2018, Senate Bill 1477 directed the CPUC to develop and supervise the administration of the TECH program. TECH is a statewide initiative providing incentives to distributors and contractors to sell and install electrification measures in existing residential homes.[4] A key component of the TECH program was to collect, clean, and publicly publish data on claims reported by participating contractors. Anonymous working datasets for single-family and multi-family projects from the launch of statewide incentives in December 2021 to the present are published and updated on an ongoing basis on the project’s website. These publicly accessible data are anonymized with some key identifying attributes aggregated to protect the privacy of program participants' identities.

While CEDARS focuses primarily on EE measures, claim data from 2020 onwards also include a fuel-substitution field. To address the absence of that attribute in claim data from 2019 and earlier, a filtering process was developed. Using the 2020-2022 data, common keyword search terms applicable to the measure description for claims

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[3] Jeffrey Daigle, Bryan Jungers, Building Decarbonization Coalition, *Enhancing the Customer Experience of Upgrading an Electric Service Panel*, p. 1, available at https://buildingdecarb.org/wp-content/uploads/BDC-Panel-Upgrade-Report.pdf.

[4] SB 1477: Low-emissions buildings and sources of heat energy. Reg. Sess. (CA. 2018).Available at: https://legiscan.com/CA/text/SB1477/id/1809546

classified as being of fuel-substitution type were identified. Those terms included "mini-split," "dxhp," "heat pump," and similar. The 2016-2019 data were filtered on the basis of this dictionary of keyword search terms and further examined for the frequency of terms used to describe measures that may signal fuel-substitution, such as "cook," "pkg_hp," "oven," "fryer," "food_service," and "electric_clothes_dryer". This data subsetting process helped ensure that all potential fuel-substitution claims were investigated. Any claims that included language signaling that the claim was not related to an actual fuel-substitution measure, but rather straightforward replacement and upgrades of existing gas equipment will more efficient replacements, when not present in combination with the keyword "electric", were filtered out. To confirm that changes in claim language or keywords across the years were accounted for, the filtering process was repeated for each year of data from 2016 to 2019. It is important to note that the count of claims provided in the CEDARS database refers to each observation in the dataset. It is not a measure of the number of housing units or the number of equipment units.

CEDARS claims were then sorted into the following categories: packaged terminal heat pumps, mini-split heat pumps, heat pump clothes driers, electric single ovens, electric combination ovens, electric friers, induction cooktops, electric steam cookers, electric holding cabinets (full size), electric holding cabinets (half size), water source heat pumps, and heat pump water heaters.

The process of filtering and cleaning claims with the TECH Clean California data set was simpler. The installation start and end date fields were transformed into a new "year" field. Product type categories were then reorganized into a measure category field to align with the same set of categories assigned to the processed CEDARS claims. Given their level of detail, TECH-specific product type categories were used in analyses involving only TECH specific claims: ducted multi-split, ductless mini-split, ductless split unitary equipment, ducted split unitary equipment, and small duct high velocity. The data were then split into single-family and multi-family working datasets.

For analysis of total residential claims across the TECH and CEDARS data sets, it was imperative to avoid any possible double-counting of claims. Based on clarification from Amy Reardon, a Senior Regulatory Analyst at the CPUC who oversees the administration of CEDARS, it was determined that CEDARS only captures TECH program claims submitted through secondary incentive program administrators. Secondary incentives are layered incentives associated with a single equipment installation. For example, BayREN may offer an incentive for a heat pump water heater, and TECH may offer an additional incentive for the same installation. In some cases, customers can layer these incentives to receive a higher total rebate. In TECH’s database, these layered claims are recorded by identifying the additional incentive provider as the “secondary incentive program administrator.” In total, 1,361 TECH claims are likely represented in the CEDARS dataset, as indicated by matching secondary incentive providers listed in the TECH data and corresponding claims in CEDARS. These program administrators (PAs) are PG&E, BayREN, and Tri-County

REN. In the combined analysis, these overlap counts were excluded by omitting them from the TECH dataset.

Through a non-disclosure agreement with the CPUC's Energy Division, an attempt was made to geocode the raw, unredacted CEDARS claim data accessible to UCLA to provide insights on geographic and demographic dimensions. It was found that only 6,662 of 16,692 electrification program claims over the period from 2016 to 2020 could be confidently connected to point addresses. Of that collection, only 3,135 unique addresses were found. Given the insufficient number of unique addresses across the state, these geolocations were unlikely to consistently reflect the end-point locations where claim measures were implemented. Instead, it is likely that these shared addresses were used across upstream and midstream program claims. As a result, these geolocations were not used in the analysis.

Budget Analysis

Sixty-seven unique PAs were identified based on the electrification program compilation. Inconsistent methods for documenting and reporting PA budgets made it impossible to compare data among the different PA types (IOU, publicly owned utility [POU], CCA, REN, municipality). Among these, IOUs and POUs had the most consistent internal reporting standards. As a result, IOU and POU budgets were examined independently and in the context of their energy efficiency program data.

The CEDARS database includes budget filing data for program administrators who have filed energy efficiency claims spanning 2017 to 2023. CEDARS budget filings detail the different measures and approved budgets within each program identification number (ID). For example, one program ID may include both electrification and non-electrification related measures. To isolate the approved budgets allocated exclusively to electrification measures, a similar filtering method as was used with processing the CEDARS and TECH raw program claims data was employed. However, the summary and record-level data only provide explicit budget amounts for each PA's annual approved budget. Information on their respective direct implementation expenditures and total expenditures remains unclear. The CEDARS budget data dictionary did not provide clarity on expenditure and budget amounts. Energy efficiency budget filing spreadsheets for each PA were downloaded from the CEDARS document section, covering the years 2017 through 2022. Depending on the PA, spreadsheets containing budget and expenditure data were listed as T-3 Exp's, T-4 Program Data, or T-4 Expenses. Administrative and direct implementation expenditures by individual program IDs for each PA were manually extracted into a unified spreadsheet. The individual program expenditures were then compared with the approved budget amounts included in the CEDARS budget filings. The most granular level of expenditure was at the program ID level. Thus, expenditures for specific electrification measures could not be determined.

For POUs, energy efficiency total utility costs from 2020 to 2023 were manually extracted from the California Municipal Utilities Association (CMUA), which publishes California POU Energy Efficiency Reports. Data between 2016 and 2019 were downloaded from the California Energy Commission's (CEC) Energy Efficiency in California's Public Power Sector interactive dashboard, which features data that have already been extracted from POU reports. These two sources only provide data on total utility costs, which are understood to be expenditures relative to the entire approved EE budget. The actual approved budgets, meanwhile, were not identified. It is hypothesized that it may be available in each POU's budget reports, as reported through their own internal websites. However, extracting each individual budget report across several years for each POU without a centralized source would be extremely cumbersome and time-consuming. Therefore, visibility into POU budget data were limited to only the energy efficiency expenditures.

For the budget data that were successfully acquired, interpretation was difficult because some PAs do not clearly indicate how much funding is dedicated specifically to electrification and electrification projects. For instance, SCE’s energy incentive budget includes lighting and energy efficiency programs that may not include the electrification of gas appliances. Similarly, the energy efficiency budgets of POUs reported by the CMUA have a category labeled "electrification." However, that encompasses both transportation and building electrification, complicating the task of isolating the costs specific to building electrification measures. Therefore, the actual expenses for building electrification by POUs are likely lower than what is indicated under the "electrification" category.

Electrification Adoption and Trends

To represent the historical progress of building electrification within California as accurately and in as much detail as possible, two databases and six survey reports were compiled, spanning 32 years from 1990 to 2022. This included the CEC's Energy Consumption Database (1990-2022), CEC's Building Decarbonization Assessment (2021), American Community Survey (ACS) (5-year estimates for 2013-2017 and 2018-2022, 1-year estimates for 2016-2022), Residential Energy Consumption Survey (RECS) (2009, 2015, 2020), American Housing Survey (AHS) (2015-2021), and CEC Residential Appliance Saturation Survey (RASS) (2009, 2019). A more detailed explanation of the selection of these datasets and survey reports can be found in Appendix Table A2.

The CEC Energy Consumption Database was the sole source of data for trends in aggregated residential building energy consumption by geography over time. Natural gas and electricity consumption were provided separately at county and by entity between 1990 and 2022. The database provides gas consumption in millions of therms and electricity consumption in gigawatt-hours (GWh) or millions of kilowatt-hours (kWh). To compare rates of consumption between fuel types over time, both units were converted to a common unit of million British thermal units (MMBtu). Units in GWh were multiplied by a factor of 3,412.14163312, while units in millions of therms were multiplied by a factor of 100,000. The electricity conversion factor operates under the assumption that electricity is a primary energy source and is 100% efficient in its conversion to MMBtu units.

Given the interest in analyzing patterns across electricity and gas consumption over this full 32 year period, all counties with incomplete data, whether across years or fuel type, were excluded. Residential natural gas consumption was not provided for Lake, Mariposa, and Sierra counties while residential consumption data for Lassen County are only available from 2013 onward. In total, 119 observations were removed.

Trends in fuel share (electricity consumption relative to the sum of electricity and natural gas consumption over time) were analyzed by entity at the county level. This analysis was not feasible statewide due to (1) the geographic overlap and complexity of utility territories and thus (2) the possibility that more than one energy entity may service customers within the same building. This complexity is highlighted by the number of unique electric-only and gas-only utilities between 1990 and 2022: 58 electric and 11 gas utilities. Pacific Gas and Electric Company and San Diego Gas and Electric Company are exceptions to this and provide both electricity and gas, allowing for analysis of the relationship between electricity and natural gas consumption over time in their territories.

The four surveys utilized to examine electrification adoption and trends are provided in *Table 3* below with additional information about the relevant survey variables and periods.

Table 3. Surveys for Residential Analysis

Survey Title and Sponsor	Survey Design	Variable(s) of Interest	Geographic Granularity
US Census Bureau American Community Survey (ACS)	5-year estimates (2013-2017), (2018-2022) by census tract	Primary home heating fuel	Census tract level
US Census Bureau American Housing Survey (AHS)	Longitudinal housing unit survey data for 2015, 2017, 2019, and 2021, returning to the same households every other year	Primary home heating fuel, water heating fuel, heating appliance, clothes drying fuel, solar panels	State level
California Energy Commission Residential Appliance Saturation Survey (RASS)	2009 and 2019, households in areas served by the large investor-owned utilities	Electricity and gas-fueled appliance saturation	IOU region
Residential Energy Consumption Survey (RECS)	2009, 2015 and 2020 through household voluntary survey	Space Heating, Water Heating	Climate Region, Census Region, State,

Publication standards and disclosure concerns in the AHS have resulted in data gaps across variables and for certain years. While demographic data, housing tenure type, and income levels are included in the dataset, these specifics were not consistently available for housing units based upon their primary fuel consumption characteristics for each year surveyed.

To deepen the understanding of electrification trends across various end-use categories, comparisons were made between AHS values and the CEC RASS (2009, 2019). However, disparities in sample sizes and methodologies between the AHS and RASS may impact the reliability of comparisons and trend analysis.

Home heating fuel data from the ACS are provided at the census tract level, with estimates available every five years. 1-year ACS estimates were additionally available at the state level. This home heating fuel type variable was analyzed alongside other ACS data points such as demographics, median income, housing characteristics (including building vintages), residential building types, and home values.

Electrification Costs

This part of the analysis seeks to identify specific cost barriers that would need to be addressed to support comprehensive end-use electrification. It involves an examination of retail price ranges for electrically powered gas-substitute equipment, installation costs, and additional integration costs such as the need for customer-owned building electrical infrastructure upgrades, labor, permitting, and inspections. Cost estimate studies that employ various methodologies and are specific to different geographic areas were synthesized and evaluated. While the costs for many commercially available electric appliances are becoming increasingly cost-competitive with gas-fueled appliances, the full substitution costs associated with electrification must be fully examined to identify the gap between existing policy-supported electrification and the state's long-term goals.

Appliance costs were examined using three primary sources, as shown in *Table 27 Section 3.1*: the US Energy Information Administration (EIA), which reports on the costs of gas and electric appliances from studies by Guidehouse and Leidos; Opinion Dynamics' Heat Pump Market Study, which covers some, but not all, gas and electric appliance categories (appliance types not included are marked as "Not Reported"); and electric appliance estimates from Redwood Energy's A Pocket Guide to All Electric Retrofits of Single-family Homes, which were used to supplement the other electric appliance cost sources. Redwood Energy does not report gas appliance costs, as a result, gas appliance costs are listed as "Not Reported" for Redwood Energy.

To best estimate the cost of electrification in different building types and sectors, studies led by state and federal agencies, nonprofit organizations, and academic institutions over the last decade have employed various methodologies. These include studies consisting of small independent convenience samples, stratified random samples, qualitative studies, and predictive modeling. Most studies reviewed for this memorandum evaluated capital costs, labor costs, and energy savings over the equipment's life cycle. The focus of those methods is on cost-effectiveness and benefit-to-cost ratio metrics. While this memo utilizes some of those metrics as a springboard for the analysis, the primary focus here is on up-to-date upfront installed costs. These are defined as costs that include equipment, labor, additional installation materials, and, if applicable, additional electrical infrastructure upgrades, such as the need to upgrade in-wall electrical wiring or even main electrical service panels. A summary of reviewed electrification cost studies and reports can be found in *Table A1 of Appendix A*. Operations and maintenance costs are outside the scope of this analysis.

In alignment with the existing literature, residential building types were differentiated as single-family and multi-family, with low-rise multi-family buildings considered as a multi-family subcategory. Low-rise multi-family buildings are defined as two-story apartment buildings with six to eight units.[5] Gas-fueled appliances with electric counterparts were the focus of the analysis, based on the 2019 RASS.[6] *Table 4* below highlights gas appliances and their electric substitutes from RASS.

Table 4. Residential Gas-fueled Appliances and Electric Substitutes[7]

End Use	*Gas-Fueled Appliance*	*Electric Appliance*
Space Heating and Cooling	Natural gas furnace (heating only)	Electric furnace (heating only)
	Natural gas boiler (heating only)	Electric baseboard heater (heating only)
		Central AC (cooling only)
		Room AC (cooling only)
		Evaporative cooler (cooling only)
		Packaged terminal heat pump (heating and cooling)
		Ductless mini-split heat pump (heating and cooling)
		Ducted split heat pump (heating and cooling)
Water Heating	Gas storage water heater	Electric storage water heater
	Tankless/demand-type gas water heater	Tankless/demand-type electric water heater
		Heat pump water heater
Cooking	Natural gas stove	Electric induction stove
		Electric resistance stove
	Gas oven	Electric oven
Clothes Dryer	Gas clothes dryer	Electric dryer
Pool Heater	Gas pool heater	Heat pump pool heater

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[5] "Building Energy Efficiency Standards." California Energy Commission. Accessed 10/1/23. https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards.

[6] DNV GL Energy Insights USA, Inc., "2019 California Residential Appliance Saturation Study. California Energy Commission" (2022), available at: https://www.energy.ca.gov/publications/2021/2019-california-residential-appliance-saturation-study-rass.

[7] DNV GL Energy Insights USA, Inc., "2019 California Residential Appliance Saturation Study. California Energy Commission" (2022), available at: https://www.energy.ca.gov/publications/2021/2019-california-residential-appliance-saturation-study-rass.

The cost estimates from existing literature, largely based upon modeling studies reported from existing literature, were subsequently compared with empirical data from TECH's program claims. Special consideration was required when assessing the costs of multi-family electrification projects reported per dwelling unit versus those reported for entire properties. In observations where the field "total project cost per residences served" was blank (256 instances out of 2,762 observations), the "project cost per unit installed" was used to estimate the total project cost per dwelling unit. It was assumed that each individual equipment unit installed served an individual dwelling unit. The TECH data also include true or false fields for "panel upgrade," "electrified stoves," and "solar photovoltaic (PV)." Though TECH did not offer incentives for any of those products at the time the data were accessed, the fields are included to signal whether those products were installed by the contractor. It is unclear whether those costs, panel upgrades, electrified stoves or solar PV, are included in the TECH project cost estimates or whether they may reflect the condition of the property prior to participation in the program. Thus, TECH project cost observations were filtered as reflected in *Table 5* and subsequently by single-family and multi-family status as shown in *Table 6*.

Table 5. TECH Project Costs Incremental Filtering Steps

Steps	Observations
1. Raw dataset	25,059
2. Filtering panel upgrades, electrified stoves, and solar PV	23,361
3. Filtered project costs less than 1	23,361
4. Filtered project costs that were NA	23,084

Table 6. Single-family and Multifamily TECH Project Costs Incremental Filtering Steps

Single-family Steps	Observations	Multifamily Steps	Observations
1. Filtered by single-family	20,375	1. Filtered by multi-family	2,709
2. Filtered single-family homes with more than 7 bedrooms	20,326	2. Filtered if product type is NA	2,709
3. Filtered if product type is NA	18,916	3. Remove project unit costs that are outliers	2,709

2.1.2 - Primary Data Collection

Electrification Readiness of the Residential Building Stock

A key set of issues associated with the readiness of existing buildings to support gas fuel-substitution via the installation of new electrical appliances relate to the rated capacity and number of available breaker slots in buildings' main electrical service panels. The electrical service panel is the point of interconnection between a customer premise and their serving utility's electrical distribution infrastructure. They are part of a building's energy infrastructure and are owned by the customer. The primary concern relative to electrification initiatives is that a significant number of buildings may have existing service panels which are not able to accommodate the installation of major new electrical loads. Existing buildings with insufficient panel capacities can necessitate costly panel upsizing projects or other, potentially complex, panel optimization strategies to electrify different end-uses.

As reported in the peer reviewed journal article derived from this work (Fournier et al. 2025), a novel methodology was developed for estimating the size of existing electric service panels in residential buildings throughout California.[8] The method operates from the bottom-up and is fundamentally based upon parcel-level building attributes. A detailed review of this methodology is detailed in Appendix G. This approach was intentionally designed to complement previously published work derived from program participation data and survey-based studies on installed electrical panel service capacities. In this way, the intent was to provide a means of triangulation using estimates derived from fundamentally different approaches.

As a general overview, the first step in this methodology was to establish an initial set of estimates for the as-built capacity of the electrical service panels at each single-family and multi-family property throughout the state. These estimates were based on a set of reported assumptions about the most common sizes of service panels installed in properties of different square footage ranges, built in different historical periods, derived from historical evolution in required panel sizing guidelines specified in the National Electrical Code (NEC).

Following from this initial step, the likelihood that a previous panel upgrade may have occurred at each property since the time of its initial construction was assessed using a set of empirical probability density functions derived from a database of statewide panel upgrade building permits assembled as part of the research. This database was manually assembled from different publicly available sources of historical building permit application data published for several large municipalities throughout the state. These likelihoods were conditional upon the property's age and the CalEnviroScreen 4.0 (CES) composite percentile score of the census tract in which it is located. For a small minority of properties, the existing panel size is assigned on the basis of direct observations from the permit upgrade record. However, for the majority of properties, for which no permit data is available, a Boolean upgrade flag is assigned by sampling from the appropriate probability density function.

In cases where a previous upgrade was assessed as having likely occurred, a corresponding estimate of the existing service panel size is then derived by incrementing from the as-built panel size according to a range of commonly used panel sizes. The procedure by which these upgrade likelihoods were calculated, and associated destination panel sizes selected, with accompanying result figures and statistics, are reported discussed in detail within Appendix G.

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[8] Fournier, Eric D., et al. "Quantifying the electric service panel capacities of California's residential buildings." *Energy Policy* 192 (2024): 114238. https://doi.org/10.1016/j.enpol.2024.114238

Opinion Research

To augment the previous quantitative research and help fill important data gaps, a partnership was formed with a specialist opinion research firm called FM3, also known as Fairbank, Maslin, Maullin, Metz & Associates. The goal of the partnership was to conduct a statewide survey of residential renters in high-priority communities and collect information about the existing penetration of various electrical appliances. While the survey paid special attention to the multi-family housing context, it also included renters in single-family buildings. The survey additionally gauged renters in disadvantaged community households' attitudes toward different categories of home electrification measures.

The result of this effort was an FM3-designed survey with 23 multi-part questions. The surveys were conducted over telephone or online in English, Spanish, Chinese, and Vietnamese, lasting, on average, 15 minutes per interview. Because the original set of sample addresses was insufficient to reach the survey response target, two additional address sample datasets were purchased. The need for additional time and supplemental contact datasets can probably be explained by the fact that renter populations are more likely to move than other populations, thus making it particularly difficult to match addresses to contact information. FM3 researchers also found that response rates to survey outreach efforts administered by text, email, and postcard were very low. Most of the successful surveys were carried out by phone. Additionally, a disproportionate share of respondents came from the Los Angeles County area, seemingly a result of initial email invitations listing UCLA as the research sponsor. Based upon this experience, the original invitation language was subsequently revised by removing the reference to UCLA, resulting in a more geographically balanced group of respondents.

Overall, FM3 conducted 807 interviews as part of the study. The responses were then weighted by the expected proportions of ages, genders, ethnicities, and geographies among the targeted population. The final survey sample was equally split between households in single-family buildings and multi-family buildings, was comprised of more than 60% of respondents identifying as Hispanic/Latino, one-third of respondents who reported living in Los Angeles County, one-third of respondents who reported living in the Central Valley, two-thirds of respondents with annual household incomes of $75,000 or less, and most respondents living in households with three or fewer people. Comparing the respondent demographic characteristics to ACS 2024 5-year estimates, only ~35% of households live in multifamily homes, nearly ~40% are Hispanic/Latino, 25% of households live in Los Angeles County, 18% live in the Central Valley, median household income is $96,334 and the majority of households are 3 people or less. FM3's interviews oversampled LA and Central Valley, which may also account for some of the other deviations, both regions have above-average Hispanic/Latino populations and below-average household incomes relative to the California statewide average. Table B3 in Appendix B includes the descriptive statistics of the demographics of survey respondents.

Following the survey of renters in high-priority communities, new questions emerged around the experiences and motivations of multi-family property owners in pursuing electrification projects. Between September 10, 2024, and January 24, 2025, FM3 additionally conducted a series of in-depth one-on-one interviews with 15 property owners representing management over more than 10,000 units statewide. The sample included five private small-building owners, one private low-income housing developer, eight nonprofit affordable housing providers, and one county housing authority. Participants were based in regions across California, including Sacramento and Placer counties, the San Francisco Bay Area, Fresno County, the Central and San Joaquin valleys, the Central Coast, and the Los Angeles metropolitan area. Interviews were conducted via telephone, ranging from 20 minutes to over an hour, with an average duration of approximately 30 minutes. Participants received compensation through personal incentives, organizational donations, or donations to causes of their choice.

Affordable housing providers interviewed for this study maintain portfolios that include both existing and newly constructed properties. As this study aims to understand the transition from gas to electric appliances, the discussions and subsequent findings in this report will primarily focus on these providers' experiences with their existing building stock.

2.2 Commercial Building Sector Materials and Methods

2.2.1 - Existing Data

Electrification Program Data

The approach to analyzing commercial building incentives differed slightly from that which was used for the residential building sector. This is partly because the Switch Is On Incentive search tool is designed for residential customers. Consequently, the commercial analysis relied primarily on DSIRE. The active status of each commercial incentive was then confirmed on the relevant PA website. Ultimately, 113 active rebate-only commercial rebates were identified.

Program Uptake

CEDARS is the only public source of claim data for commercial building incentives. The same methodology used in the residential building claim analysis was used for the data cleaning, categorization, and identification of electrification claims in the commercial analysis. Additionally, CEDARS included over 30 unique commercial building type descriptions. To adequately match them to the rest of the analysis, those descriptions were re-categorized using the California Commercial End Use Survey (CEUS) building type subsector designations: health, retail, restaurants, large office, small office, school, college, lodging, warehouse, refrigerated warehouse, and miscellaneous. However, this process yielded some potential for misclassification given that the definitions of several CEDARS building categories do not have clear alignment with CEUS subsector building types. This issue was especially true for CEDARS' "miscellaneous" building type category. Not only does the miscellaneous category have by far the highest number of electrification claims compared to any other building type, but it also has the most ambiguous alignment with the CEUS subsectoral definitions. Thus, it is hypothesized that the "miscellaneous" category in CEDARS may refer to commercial buildings in general and not a specific set of commercial building types. Overall, the evaluation of commercial incentive uptake by building type is limited and may not reflect the actual commercial buildings utilizing the incentives.

Budget Analysis

The budget analysis for the commercial building sector followed the same budget data collection and analysis methodologies as were used for the residential portion of this work. Data were subsetted when listed in the CMUA and CEDARS by nonresidential or commercial building types and programs. Please consult the corresponding documentation for the residential budget analysis for future details on these methods.

Account-level gas and electric data

Subsector classification

Account-level electricity and gas consumption data were sourced from IOUs and provided to the UCLA research team under a data sharing agreement with the CPUC’s Energy Division. These data have been shared under a non-disclosure agreement (NDA) which requires that research project applications receive Institutional Review

Board (IRB) compliance or exemption, researchers adhere to strict cybersecurity guidelines, and all CPUC-mandated privacy preserving aggregation procedures be followed prior to public release of any consumption related information or derivative analyses. The account-level gas consumption data used for this analysis come from PG&E, SDG&E, and SoCal Gas. The account-level electricity data come from PG&E, SDG&E, and SCE. The most recent available consumption data (2021) were used for all calculations.

Each nonresidential customer in the utility consumption dataset includes a North American Industry Classification System (NAICS) code. A NAICS code is a three to six-digit code with a hierarchical structure in which each successive digit represents a higher level of categorical specificity. Federal statistical agencies have used NAICS codes to classify business establishments since 1997, and they are updated every five years. The 2006 CEUS subsectors are defined by Standard Industrial Classification (SIC) codes. The SIC code is a four-digit system developed in the 1930s to classify business establishments based on their primary economic activity. It was the primary classification standard used by federal statistical agencies. Though SIC codes are still used in some regulatory and private-sector contexts, they were largely replaced by the NAICS system in 1997. The SIC codes from the 2006 CEUS were matched to a complete list of NAICS codes. NAICS codes associated with each utility account varied in detail, ranging between three to six digits. In a small number of cases, the SIC to NAICS crosswalk matched a single NAICS code to multiple SIC codes, and thus multiple CEUS subsectors. Any instances of duplicates were reviewed and manually assigned to a single CEUS subsector. Valid NAICS codes were then matched to the utility accounts via NAICS code. Matches were attempted in descending order from most specific (6 digits) to least specific (3 digits). Matching utility account NAICS codes to CEUS subsectors was only partially successful. Of the 2,312 unique utility NAICS codes, 100 (4.3%) could not be matched, representing 148,164 utility accounts (5.7%) out of 2,580,793 total. These figures reflect all nonresidential utility accounts and are not specific to small commercial buildings.

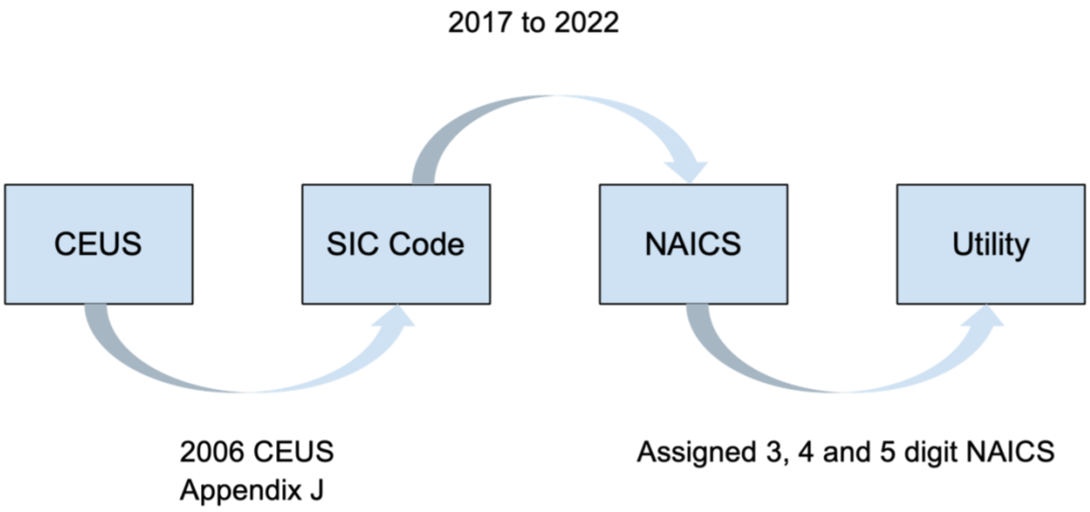

Figure 1. Process for Matching CEUS Subsectors to the Account-Level Natural Gas Consumption Data

Subsector classification validation

The mapping of NAICS codes was validated and refined using the updated 2022 California Commercial End Use Survey (CEUS), published on February 28, 2024. In the 2022 CEUS, survey respondents reported their own NAICS codes, which were then cross-referenced with utility-assigned NAICS codes to identify discrepancies. The initially assigned CEUS subsectors (as illustrated in *Figure 1* above) were compared to the 2022 NAICS to SIC code crosswalk. The comparison introduced updated building type categorizations for 184 out of the 1,334 (13.79%) NAICS codes used in this analysis. For each of these codes, the building type assignment was manually reviewed based on (1) the NAICS title description and (2) the building type designations under both the original 2006 CEUS methodology and the updated 2022 CEUS methodology. As a result, 124 of the 184 NAICS codes were reassigned to new CEUS subsectors consistent with the 2022 CEUS framework, while 60 codes retained their original classification based on the NAICS title description. Finally, because utility customer data do not include building square footage, it was not possible to distinguish between small and large office buildings. Therefore, the “small office” and “large office” subsectors were combined into a single “office” category for this analysis.

Matching electricity and gas utility accounts

In regions without dual-fuel utility providers, the process of matching customers between gas and electric utilities is difficult given a lack of shared identifiers between these different utilities. Though addresses are provided by all utilities, the address fields cannot always be matched precisely across utilities due to slight differences in address string formatting. *Figure 2*[9] below highlights the significant overlap between SCE and SoCal Gas customers (left) and the diversity of climate zones (CZs) in the Southern California region (right). The complex overlap of utility service territories and the number of differentiable CZs in the area make it increasingly difficult to identify SoCal Gas

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[9] Adapted from: US EIA, Southern California Daily Energy Report, 2021; California Energy Commission, 2020

customers who are also SCE customers when aggregated at this level. Ultimately, the 2006 CEUS gas consumption breakdowns by end-use category that were specific to SCE customers were also applied to SoCal Gas customers. That procedure was followed under the assumption that the SCE customer analysis, rather than statewide data, would result in greater accuracy when applied to these SoCal Gas customers.

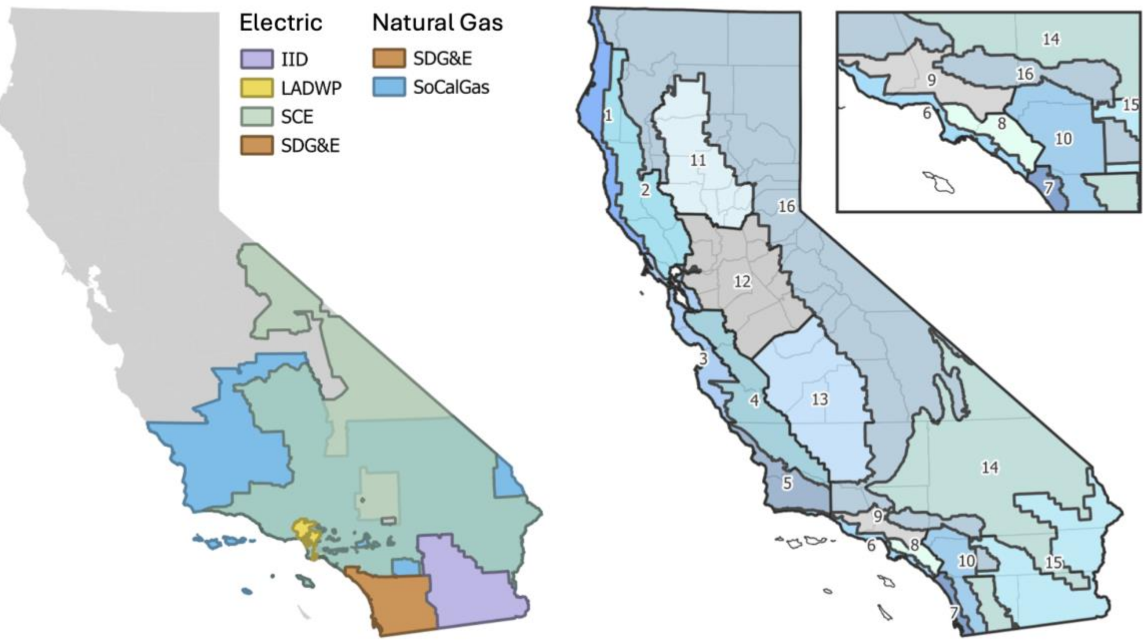

Figure 2.Southern California Utilities (left) and Climate Zones (right)

Electrification Adoption and Trends

Commercial buildings were examined both as nonresidential accounts and within small CEUS subsectors identified by the 2006 CEUS: offices, restaurants, retail, food stores, refrigerated warehouses, unrefrigerated warehouses, schools, colleges, health, lodging, and miscellaneous. Consumption data were sourced from the CEC's Energy Consumption Database (1990-2022), segmented by entity type but not distinguished by commercial building type.

Additionally, utility account level electricity and gas consumption data from SCE, SoCal Gas, PG&E, and SDG&E from 2015 to 2021 were utilized. Utility accounts were classified according to CEUS small commercial sub-sectors using their associated NAICS designations, necessitating a multistep reconciliation process. The 2006 CEUS provides a SIC Code to the CEUS building type mapping table, which was crosswalked with NAICS codes. Duplicates and inconsistencies among NAICS and SIC codes were resolved manually to assign the prevalent SIC code to the appropriate CEUS category (see *Figure 1*, introduced previously, which describes this process). The newly released 2022 CEUS introduced an updated methodology for reconciling NAICS codes and

CEUS building types. This methodology incorporated utility data from additional providers such as the Los Angeles Department of Water and Power (LADWP) and Sacramento Municipal Utility District (SMUD). This revealed variations in how utilities classify building types by NAICS code, impacting the accuracy of the assigned CEUS building types by NAICS codes. The combined datasets from CEC Energy Consumption Data Management System and the utility accounts provided comprehensive temporal, geographical, and sectoral insights into commercial building energy consumption across California. Analysis of electrification adoption trends first required the rigorous cleaning and manipulation of utility account data. These data must be geocoded to the parcel level to facilitate reaggregation and analysis at the level of climate zones and counties. Handling of partial customer account addresses or those provided with obvious typographic errors were addressed through a multi-part procedure that involved the use of programmatic address standardization facilities available as extensions to the PostGRES database as well as the use of an online geocoding service that provided quantitative match accuracy scores. In cases where account addresses were unable to be confidently geocoded to the parcel level, they were instead analyzed at the utility level. Additionally, any net-metered solar accounts that reported energy outputs to the grid were adjusted to zero. This was done to avoid the inclusion of energy usage reported as negative values. While that solution was the most suitable for this analysis, it is important to note that the actual grid electricity demand of those accounts may not be zero.

Electricity and gas consumption values were converted to a common unit of million British thermal units (MMBtu) for consistency across datasets.

Throughout the analysis, outlier detection techniques were employed to exclude anomalous data points, ensuring data integrity and reliability. Additionally, the analysis strictly adhered to privacy guidelines per the CPUC which specify rules for the protection of the privacy of customer information via data aggregation and anonymization procedures.

Electrification Costs

Where possible, the analysis focused on small commercial buildings as defined by the 2006 CEUS, however some cost estimates did not precisely match the CEUS small commercial prototypes. Ultimately, the majority of commercial building electrification cost estimates, acquired through the California Energy Codes and Standards Cost-Effectiveness Reports, employed the US Department of Energy's (DOEs) set of minimum efficiency standards for equipment, appliances, and building prototypes..[10] *Table 7* highlights the floor area and number of floors of the reference commercial building prototypes used by the DOE.

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[10] "Prototype Building Models | Building Energy Codes Program." available at: https://www.energycodes.gov/prototype-building-models.

Table 7. U.S. Department of Energy Commercial Buildings Reference Prototypes[11]

	Floor Area	Number of Floors
Large Office	498,588	12
Medium Office	53,628	3
Small Office	5,500	1
Warehouse	52,045	1
Stand-alone Retail	24,962	1
Strip Mall	22,500	1
Primary School	73,960	1
Secondary School	210,887	2
Supermarket	45,000	1
Quick Service Restaurant	2,500	1
Full-Service Restaurant	5,500	1
Hospital	241,351	5
Outpatient Health Care	40,946	3
Small Hotel	43,200	4
Large Hotel	122,120	6
Mid-Rise Apartment	33,740	4

For small commercial buildings, the primary source of appliance cost data—aggregated across all commercial subsectors—was the 2022 U.S. Energy Information Administration (EIA) Updated Buildings Sector Appliance and Equipment Costs and Efficiencies report. These data were supplemented with cost information from the California Energy Codes and Standards Nonresidential Retrofit Reach Code Cost-Effectiveness Study.[12]

To contextualize the cost and equipment data sources discussed above, the following table (*Table 8*) summarizes the primary gas-fueled appliances used in commercial buildings and their corresponding electric alternatives. Commercial buildings have high variability in appliance configurations, especially for HVAC and water heating. Note that the end-uses and associated gas-fueled and electric appliances below are not exhaustive. Rather, they are the most relevant based on the literature review. Excluded gas-fueled equipment are primarily those related to processing, such as kilns, Bunsen burners, and sterilizers.

Table 8. Commercial Gas-Fueled and Electric Appliances

End Use	Gas-fueled Appliance	Electric Appliance

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[11] Ibid.

[12] Goyal & Farahmand, TRC Companies, “2022 Code: Nonresidential Alterations Cost-effectiveness Study,” supra.

HVAC		
Space Heating and Cooling	Packaged unit single zone (heating only)	The rooftop heat pump (heating and cooling)
		Variable refrigerant flow (VRF) system (heating and cooling)
	Split single-zone system (heating only)	Ducted split system heat pump (heating and cooling)
		Ductless heat pump (heating and cooling)
	Gas boiler (heating only)	Variable refrigerant flow (VRF) system (heating and cooling)
		Air conditioning unit (cooling only)
Non-HVAC		
Water Heating	Gas storage water heater	Electric storage water heater
	Tankless/demand-type gas water heater	Tankless/demand-type electric water heater
		Heat pump water heater
Cooking	Natural gas stove	Electric induction stove
		Electric resistance stove
	Griddle	Induction griddle
	Combination oven and gas rack oven	Electric oven
	Convection oven	
	Fryers	Electric fryers
Air Compressor	Gas air compressor	Electric air compressor
Clothes Dryer	Gas clothes dryer	Heat pump clothes dryer

Information on the saturation of appliances across the commercial sector is even more sparsely available than it is for residential buildings and primarily concerns space heating trends. For small commercial buildings, packaged rooftop systems are the most typical end-use appliance type utilized for space heating.[13] According to Redwood Energy's Pocket Guide to All Electric Commercial Retrofits, packaged rooftop systems comprise about 59% of heating systems used in California, with split systems at approximately 13%, unit heaters at 8%, and packaged terminal units at 7%.[14] Multi-zone commercial HVAC equipment was excluded from this study because these systems are used by approximately 1% of all buildings.[15]

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[13] Mohammad Hassan Fathollahzadeh and Anish Tilak, Rocky Mountain Institute (RMI), The Economics of Electrifying Buildings: Medium-Size Commercial Retrofits" (2022), available at: https://rmi.org/insight/economics-of-electrifying-buildings-midsize-commercial-retrofits/.

[14] Redwood Energy, "Redwood Energy's Pocket Guide to All-Electric Single-family Retrofits" (2022), available at: https://assets-global.website-files.com/62b110a14473cb7777a50d28/6396be1051f34460e7dd5f26_A%20Pocket%20Guide%20to%20All%20Electric%20Retrofits%20of%20Single%20Family%20Homes.pdf.

[15] Ibid.

2.2.2 - Prioritization Framework Development and Metrics

Spatial, quasi-spatial, and non-spatial data layers information were assembled and analyzed to prioritize a single CEUS subsector for further detailed study regarding its potential barriers and opportunities to electrification. These CEUS subsectors, as defined by both the 2006 and 2022 CEUS, include colleges, food stores, health care buildings, lodging, offices, refrigerated and unrefrigerated warehouses, restaurants, retail stores, schools, and a miscellaneous category that spans commercial facilities from movie theaters to gymnasiums. The novel prioritization framework which was developed consists of quantitative metrics associated with factors such as pollution impacts, worker and nearby resident vulnerability, electrification technical feasibility, and electric service reliability. These metrics and their respective units are listed in *Table 9*. Measurements for each metric were calculated at the statewide value to reflect the impacts of electrifying each CEUS subsector at scale.

When considering potential data sources, building permit data from the Construction Industry Research Board (CIRB) were examined, which include descriptions and costs of work. However, these data are somewhat limited as they (1) are not explicitly categorized by NAICS code, and (2) would require extensive manual identification to extract relevant findings. Given these constraints, proxy variables were incorporated, such as building size and vintage, which are correlated with end-use technology characteristics.

Table 9. Prioritization Framework Metrics

Metric Category	Metric	Units
Emissions	CO_2 Emissions	Tons of CO_2
	Ambient NOx Emissions	Tons of NOx
	Indoor NOx Emissions	Tons of NOx
Social Impact	Emissions Exposure Risk for Residential Populations	Persons
	Exposure of Sensitive Populations	Unitless
	Worker Vulnerability	Unitless
Difficulty	Electric Grid Outage Vulnerability Risk	Total Annual PSPS Outage Hours
	Technology Readiness	Unitless
	End Use Diversity (Variance)	Unitless
	Median Building Vintage	Year
	Median Building Size	Square feet
	Average Therms per Premise	Therms

CO_2 Emissions Estimates

To calculate carbon dioxide (CO_2) emissions, account-level gas data were assigned to the CEUS subsectors as illustrated in *Figure 1*. CO_2 emissions were then calculated by applying the national CO_2 emissions factor from the U.S. EPA AP-42 to natural gas consumption in therms for each CEUS subsector. The emissions factor was converted to pounds per therm (approximately 11.56 pounds per therm) in order to arrive at pounds (and tons) of CO_2.

Table 10. CO_2 Emissions Estimates Data Sources

Estimates Calculation Input	*Source*
Account-level natural gas consumption	Pacific Gas & Electric, San Diego Gas & Electric, and SoCal Gas via CPUC Energy Division data sharing agreement
CO_2 emissions factor	National EPA AP-42 Section 1.4[16]

The average CO_2 emissions for facilities within each CEUS subsector was then calculated by dividing the total CEUS subsector CO_2 emissions by the count of premises provided in the account-level natural gas consumption data.

Ambient NOx

Figure 3 below provides an overview of the methodology for the ambient NO_x emissions estimates. The ambient NO_x emissions estimates built upon the steps completed for the CO_2 emissions estimates (Steps 1 and 2). The same methodology was used to assign account-level gas consumption data to the commercial subsectors, facilitating the assignment of consumption breakdowns by end use data from the 2006 CEUS (Step 3). The ambient NOx emissions estimates were calculated under the assumption that all indoor emissions from gas appliances eventually travel outdoors, which is a health protective and conservative assessment.

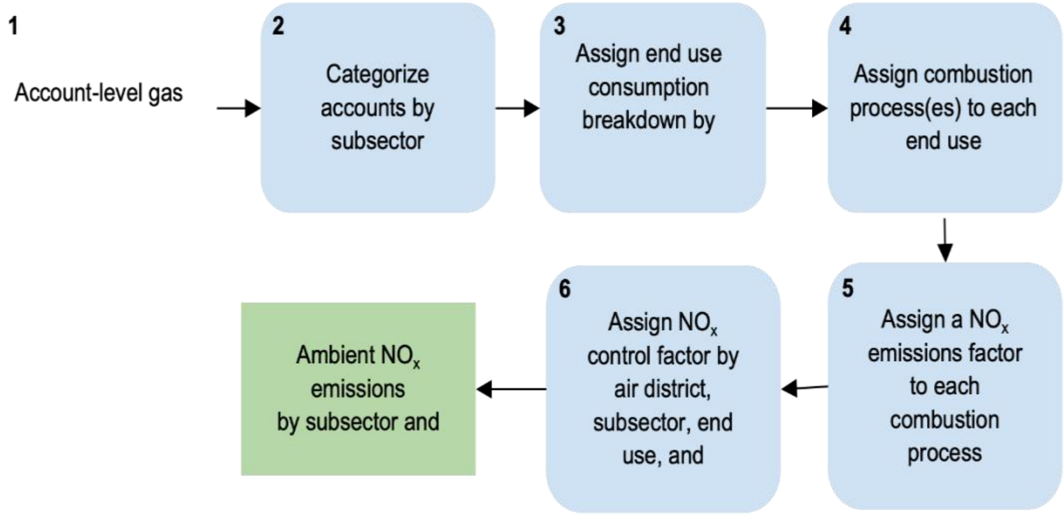

Figure 3. Process for Calculating Ambient NOx Emissions Estimates

Table 11 details the data sources derived for each step in *Figure 3*.

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[16] U. S. Environmental Protection Agency (1998). *Emission Factor Documentation for AP-42 Section 1.4—Natural Gas Combustion*. https://www.epa.gov/sites/default/files/2020-09/documents/1.4_natural_gas_combustion.pdf

Table 11. Data Sources for Ambient NOx Emissions Estimates

Estimates Calculation Input (Process Step)	Source
Account-level natural gas consumption (Step 1 in Figure 3)	Pacific Gas & Electric, San Diego Gas & Electric, and SoCal Gas via CPUC Energy Division data sharing agreement
Gas end-use breakdowns (Step 3 in Figure 3)	2006 California Energy Commission (CEC) California Commercial End Use Survey (CEUS) (Tables 8-4, 9-4, 10-4, 11-4)
End-use to combustion process (Step 4 in Figure 3)	San Joaquin Valley Air Pollution Control District 2009 Area Source Emissions Inventory Methodology, 060 - Commercial Natural Gas Combustion
NO_x emissions factors (Step 5 in Figure 3)	National estimate EPA AP-42 Section 3.1, Table 3.1-1 (Uncontrolled Natural Gas-Fired Turbine); national estimate EPA AP-42 Section 3.2, Table 3.2-2 (Uncontrolled 4-Stroke Lean-Burn Engines <90% Load); national estimate EPA AP-42 Section 1.4, Table 1.4-1 (Uncontrolled Small Boilers)
Control factors (Step 6 in Figure 3)	CARB California Emissions Projection Analysis Model (CEPAM)

To estimate ambient NOx emissions, the analysis referenced the San Joaquin Valley Air Pollution Control District (APCD) 2008 Area Source Emissions Inventory Methodology.[17] This methodology was used to align end-use categories with corresponding combustion processes and national estimate EPA AP-42 NOx emission factors. All AP-42 emission factors were converted to pounds of NOx per therm of natural gas. The conversion used the EIA 2021 annual average heat content of natural gas deliveries, reported as 1,039 British thermal units (Btu) per cubic foot. *Table 12* below summarizes the assigned end-use categories, combustion processes, and corresponding emission factors based on the San Joaquin Valley APCD methodology.

Table 12. End Use Category Combustion Processes and Emissions Factors, San Joaquin Valley APCD (2008), EPA AP-42

End Use Category	Combustion Process	NOx Emissions Factor (lbs/Therm)
Space heating	Small boiler	0.0096
Water heating	Small boiler	0.0096
Cooling	Turbine	0.032
Cooking	Approximated as small boiler	0.0096
Process heat/machinery	60% small boiler	0.0096
	20% turbine	0.032
	20% engine	0.0847

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[17] San Joaquin Valley Air Pollution Control District (APCD) (2008). *2008 Area Source Emissions Inventory Methodology*. https://ww2.valleyair.org/media/uzuhm5hh/other_industrial-processes_2008.pdf

Misc.	50% turbine	0.032
	50% engine	0.0847

The conversion methodology described here establishes estimates for uncontrolled NOx emissions. It does not consider possible emissions reductions as dictated by control levels and achieved by control technologies. Control levels are established by either air districts or CARB for each emissions inventory code (EIC).

To incorporate control effects, this analysis used data from CARB's California Emissions Projection Analysis Model (CEPAM) web tool. CEPAM generates emissions estimates for point and area sources using two key inputs: growth factors (which reflect emissions increases driven by economic and demographic trends) and control factors (which reflect emissions reductions resulting from regulatory controls). For each air district, annual NOx emissions projections were downloaded for two CEPAM scenarios:

1. "Grown only," which accounts for growth without controls (i.e., emissions increases driven by economic and demographic trends and excluding any emission reductions resulting from regulatory controls), and
2. "Grown and controlled," which includes both growth and regulatory control effects (i.e., emissions increases driven by economic and demographic trends and any emission reductions resulting from regulatory controls).

CEPAM starts with a base year (2017 in the current model version), and forecasts emissions for point and area sources using the growth and control data available at the time of the development of the model version. The control levels used to develop the emission estimates were extracted from the CEPAM web tool. Annual emissions projections for both grown and grown and controlled oxides of nitrogen were downloaded for each air district from CEPAM. The control levels were then calculated by dividing the grown and controlled projections by the grown projections for emissions from commercial natural gas fuel combustion *(Table 13*). The growth factors in CEPAM were not needed for the estimates in this report given the use of up-to-date natural gas consumption data.

Based on the CEPAM data, nineteen control factors were found to be less than 1 as of 2021, across six air districts: Sacramento Metropolitan Air Quality Management District (AQMD), San Diego APCD, San Joaquin Valley APCD, Santa Barbara County APCD, South Coast AQMD, and Ventura County APCD. Gas consumption data were assigned to air districts using census tract numeric identifiers (GEOIDs).

The identified control factors were then matched to end uses, combustion processes, and CEUS subsectors using the Source Category Code (EICSOU) and referencing air district rules and the 2006 CEUS Appendix J, which matches non-HVAC equipment to end uses. The space and water heating end uses matched clearly with the Source Category Codes. The control factors associated with Source Category Code 005-Boiler were applied to all small boiler combustion processes except for cooking as the combustion process is only "approximated as" a small boiler.[18] The control factors associated with Source Category Code 045-I.C. TURBINE ENGINES were applied to all turbine combustion processes. The control factor associated with Source Category Code 995-OTHER was applied across the Miscellaneous end use. The Miscellaneous end use in the 2006 CEUS includes medical/health process heating equipment, such as an autoclave. Therefore, the control factor associated with Source Category Code 010-PROCESS HEATERS was applied to the Miscellaneous end use for the health CEUS subsector and the process end use combustion processes. The control factor associated with Source Category Code 012-OVEN HEATERS (FORCE DRYING SURFACE COATINGS) was applied to end use combustion processes except for small boilers, as there was already a control factor specific to boilers applied for the air district. The control factor for Source Category Code 070-IN-PROCESS FUEL was excluded because it is reserved for industrial processes and out of scope for the commercial focus of this project. One control factor was applied to each combustion process.

Table 13. Control factors for end-uses and combustion processes in different regions[19]

End Use and Combustion Process	Sacramento Metropolitan AQMD	San Diego County APCD	San Joaquin Valley APCD	Santa Barbara County APCD	South Coast AQMD	Ventura County APCD
Heating: Small Boiler	1	1	0.899	0.948	0.97	1
Cooling: Turbine	1	1	1	1	1	1
Water Heating: Small Boiler	0.78	1	1	0.842	0.969	0.829
Cooking: Approx. Small Boiler	1	1	1	1	1	1
Misc: Turbine	1	1	1	0.984	0.1	1
Misc: Engine	1	1	1	0.984	0.1	1
Proc.: Small Boiler	1	0.999	0.924	0.975	1	0.979
Proc.: Turbine	1	1	0.924	1	1	1
Proc: Engine	1	1	0.924	1	0.95	1

Data from the CEUS were additionally used to examine the breakdown of natural gas usage by end use and CEUS subsector (as illustrated in Step 3 of *Table 11*). The diversity of gas consumption across these various end-use categories was deemed potentially important as a constraint to electrification implementation due to the need to address multiple end-use technology types simultaneously. To calculate these

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[18] San Joaquin Valley Air Pollution Control District. 2008. "2006 Area Source Emissions Inventory Methodology 060 - Commercial Natural Gas Combustion." https://ww2.valleyair.org/media/enlnlmiq/commercialngcombustion2006.pdf.

[19] The control levels were then calculated by dividing the grown and controlled projections by the grown projections for emissions from commercial natural gas fuel combustion.

distributions, the 2006 CEUS was used (Table 14), as this breakdown was not available in the more recent 2022 edition.

Table 14. 2006 Commercial End Use Survey Natural Gas Consumption Breakdown

	Heating	Cooling	Water Heating	Cooking	Miscellaneous	Processing
Warehouse	0.871	0	0.106	0.006	0.012	0.006
Refrigerated Warehouse	0.145	0	0.145	0.218	0	0.49
Retail	0.6523	0	0.169	0.111	0.058	0.009
Food Store	0.345	0	0.277	0.375	0	0.003
Office	0.792	0.020	0.129	0.011	0.004	0.046
Miscellaneous	0.302	0.016	0.400	0.044	0.042	0.196
School	0.626	0.008	0.294	0.066	0.001	0.004
College	0.580	0.101	0.246	0.048	0.026	0.000
Health	0.433	0.020	0.415	0.044	0.019	0.067
Lodging	0.172	0.002	0.682	0.104	0.034	0.006
Restaurant	0.037	0.000	0.232	0.730	0.000	0.002

Indoor NOx

Figure 4 below provides an overview of the methodology for deriving the indoor NOx emissions estimates. To further estimate the contributions to indoor air emissions from gas appliances, an additional step utilizing the variable ranges of ventilation capture efficiency rates reported in the literature was taken to quantify the portion of NOx emissions that stay indoors (Step 7 in *Table 15* and *Figure 4*).

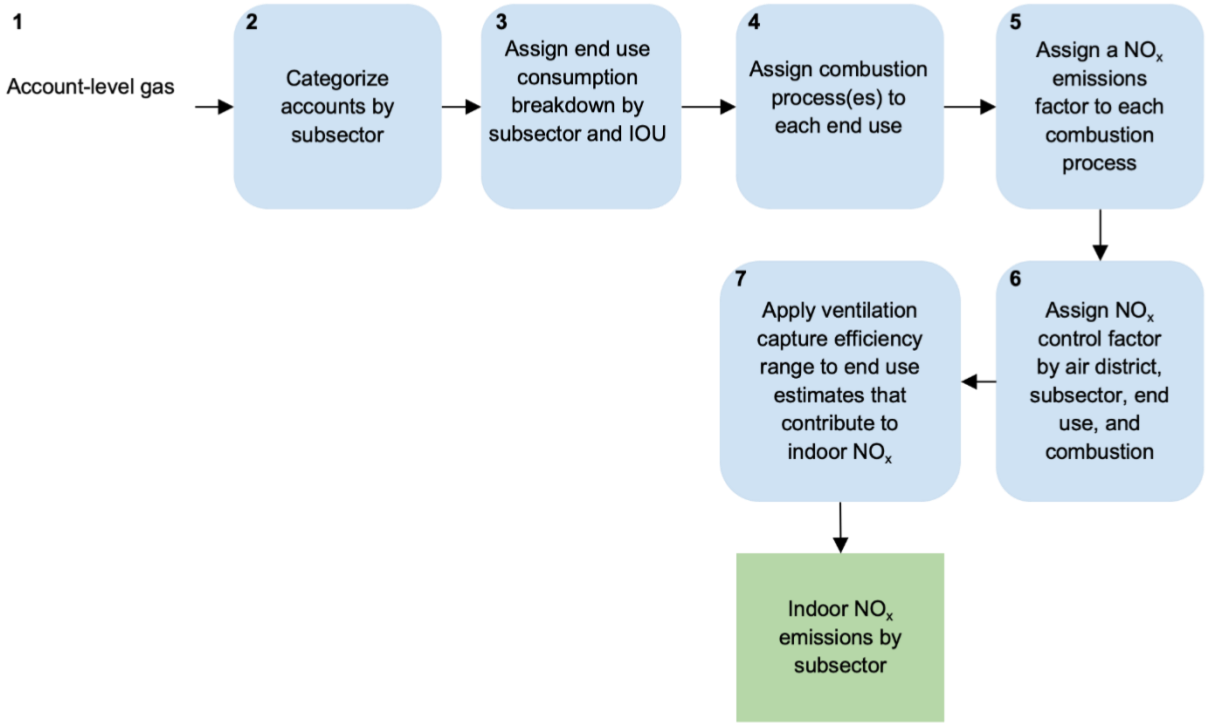

Figure 4. Process for Calculating Indoor NOx Emissions Estimates

Table 15. Data Sources for Inputs in the Emissions Estimates Calculations

Estimates Calculation Input (Process Step)	Source
Account-level natural gas consumption (Step 1)	Pacific Gas & Electric, San Diego Gas & Electric, and SoCal Gas via CPUC Energy Division data sharing agreement
Account categorization (Step 2)	2006 California Energy Commission (CEC) California Commercial End Use Survey (CEUS)
Gas end-use breakdowns (Step 3)	2006 California Energy Commission (CEC) California Commercial End Use Survey (CEUS) (Tables 8-4, 9-4, 10-4, 11-4)
CO_2 emissions factor (Step 3a)	National estimate EPA AP-42 Section 1.4
End-use to combustion process (Step 4)	San Joaquin Valley Air Pollution Control District 2009 Area Source Emissions Inventory Methodology, 060 - Commercial Natural Gas Combustion
NO_x emissions factors (Step 5)	National estimate EPA AP-42 Section 3.1, Table 3.1-1 (Uncontrolled Natural Gas-Fired Turbine); national estimate EPA AP-42 Section 3.2, Table 3.2-2 (Uncontrolled 4-Stroke Lean-Burn Engines <90% Load); national estimate EPA AP-42 Section 1.4, Table 1.4-1 (Uncontrolled Small Boilers)
Control factors (Step 6)	CARB California Emissions Projection Analysis Model (CEPAM)

Ventilation capture efficiency rate (Step 7)	Experimental studies on commercial kitchen exhaust hood capture efficiency (see Table 15)

Indoor NOx emissions associated with commercial facilities by subsector were calculated assuming that cooking is the only end-use that is not fully vented to the outdoors. The California Mechanical Code and the California Health and Safety Code require that all cooking equipment in food facilities be vented. However, the effectiveness of the ventilation technology in capturing harmful pollutants is highly variable. Capture efficiency is a key performance indicator of ventilation systems and is influenced by disturbing airflows, hood geometric features and locations, burner position, and exhaust airflow rates (Han et al. 2019). Both operational conditions and individual equipment characteristics introduce variability in capture efficiency. *Table 16* below summarizes field and laboratory tests on capture efficiency of kitchen exhausts in commercial buildings. The factors that affect capture efficiency make it difficult to apply these ranges based on the geographic distribution of regulations and equipment types. Therefore, the range of indoor NOx emissions was estimated by applying an average minimum and average maximum capture efficiency from the experimental studies listed below (57.6% min - 98.4% max).

Table 16. Summary of experimental studies on commercial kitchen exhaust hood capture efficiencies (Han et al. 2019)

Reference	Air exhaust conditions	Environmental conditions	Capture efficiency, (%)
Kosonen and Mustakallio (2003)	Ventilated ceiling system, the exhaust airflow rates were 0.4–1.09 m^3/s.	Ventilated ceiling with capture jet.	42.9–91.3
Kosonen (2007)	Ventilated ceiling system, the exhaust airflow rates were 0.58–1.2 m^3/s.	Ventilated ceiling and thermal displacement ventilation.	17.3–98.9
Takano (2009)	A variable-sized hood with 5 conditions of exhaust flow rate.	Air was supplied naturally and exhausted by the hood and ceiling fan.	25–100
Kotani et al. (2009)	Canopy-type exhaust hood with a baffle plate, the exhaust airflow rates were 0.075, 0.1125 and 0.15 m^3/s.	No supply air.	49–100
Huang et al. (2010)	Wall-mounted range hood with exhaust airflow rates 0.175, 0.2, and 0.25 m3/s, jet-isolated hood with jet velocity 3 and 4 m/s.	Draft level was < 0.03 m/s.	99.4–99.9
Chen (2015)	An inclined air-curtain range hood, the exhaust airflow rates were 0.168, 0.182, and 0.21 m^3/s.	No other supply air, draft velocity was < 0.05 m/s.	71–100
Iwamatsu and Urabe (2015)	Airflow rate of the hood were 0.136 and 0.16 m^3/s.	Displacement ventilation, and ventilated ceiling for exhausting air.	91–99

Fujimura et al. (2017)	Canopy hood, 11 exhaust airflow rates were selected from 0.15 to 1.27 m^3/s.	Air was supplied from the louver.	65–98

Emissions Exposure Risk for Residential Populations

Commercial facilities are defined as being within DACs if they are located within census tracts whose CalEnviroScreen-4.0 (CES-4.0) composite index scores are greater than or equal to the 75th percentile, statewide. This assignment was performed by executing a spatial join between each parcel’s centroid coordinate and the polygon boundaries for the CES-4.0 census tracts.

The methodology that was developed to quantify exposure to commercial subsector facility emissions is based upon the identification of residential properties located within a defined proximity buffer to commercial facilities. A buffer size of 200 meters around facility sites was selected based on a literature review of previously published public health/emissions fate-transport studies focused on the movement of neighborhood-scale plumes of PM and other gas co-pollutants emitted from small commercial facility point sources.[20] Feedback on this choice of buffer distance was also solicited from CARB staff at various junctions throughout the project’s evolution.

The first step in the process involved selecting all of the facilities throughout the state associated with each commercial subsector. Here, it is worth noting that, within this context, a unique “facility” corresponds to a unique customer premise identification number within the utility customer account database. These premise designations, and thus their corresponding counts, do not necessarily correspond to entire buildings (such as is the case with Offices, for example) but rather, discrete locations where customer utility services are rendered and billed. According to this approach, the total number of facilities identified within each subsector is listed in *Table 17* below.

Table 17. Total number of facilities identified within each designated CEUS subsector.

CEUS Subsector	*Total Facility Count*
College	9,936
Food Store	18,644
Health Care	19,785
Lodging	10,432
Miscellaneous	82,665
Office	193,297
Refrigerated Warehouse	2,359

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[20] Robinson, Ellis Shipley, Peishi Gu, Qing Ye, Hugh Z. Li, Rishabh Urvesh Shah, Joshua Schulz Apte, Allen L. Robinson, and Albert A. Presto. "Restaurant impacts on outdoor air quality: elevated organic aerosol mass from restaurant cooking with neighborhood-scale plume extents." *Environmental science & technology* 52, no. 16 (2018): 9285-9294.

Restaurant	92,247
Retail	95,292
School	17,562
Unrefrigerated Warehouse	23,638

The next step in the process was to associate the centroid locations for these commercial facilities with their corresponding set of parcel boundary polygons via a spatial join against a statewide parcel database. Once this was done, a 200-meter buffer zone was generated around each distinct parcel polygon identified. In instances where multiple facilities were found to be collocated on the same parcel, their usage was aggregated to that parcel level to avoid double counting of emissions exposures. All of these individual facility-level parcel buffers were then spatially unioned into a single, large multi-part polygon, corresponding to all of the parcels associated with all of the facilities within each commercial subsector. Each of these aggregated polygons were then spatially joined to the centroids for all of the residential parcels in the state, yielding aggregated counts for the total numbers of residential parcels, and the corresponding total numbers of dwelling units, in proximity to each commercial subsector's facilities. These total dwelling unit counts were then multiplied by values for the average occupancy rate and average household size obtained from the Census American Community Survey, for the census tracts in which each parcel was located. The final calculation provided an estimate of the total residential population in proximity to each commercial subsector category summed according to Equation 1. *Figure 5* and *Figure 6* provide snapshot illustrations of two examples of residential parcel centroids located within 200 meters of commercial facilities.

Equation 1.

$$P_a = \sum_{i=0}^{p} \sum_{j=0}^{f} U_{i,j,a} H_i O_i$$

Where:

P_a = The estimated total population living within all residential parcels located in proximity to all identified facilities within each CEUS subsector (a).

$U_{i,j,a}$ = The total number of dwelling units for each residential parcel $(i \in p)$ located in proximity to each identified facility $(j \ni f)$ within each CEUS subsector (a).

H_i= The average household size (persons per dwelling unit) for each parcel $(i \in p)$, derived from census tract level data

O_i= The average occupancy rate (percentage of occupied dwelling units) for each parcel $(i \in p)$, derived from census tract level data

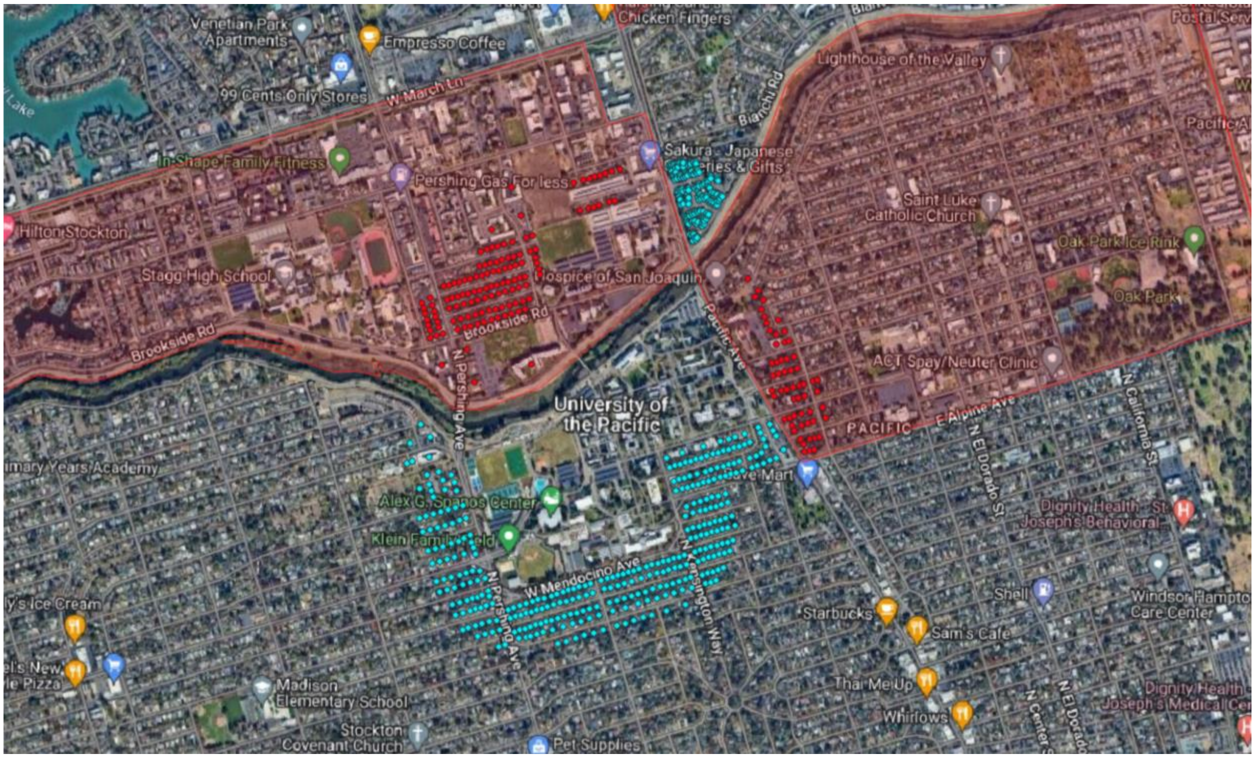

Figure 5. Sample illustration of residential parcel centroids located within 200 meters of the University of the Pacific (CEUS Subsector = College) colored by DAC status (DAC = red, non-DAC = blue)

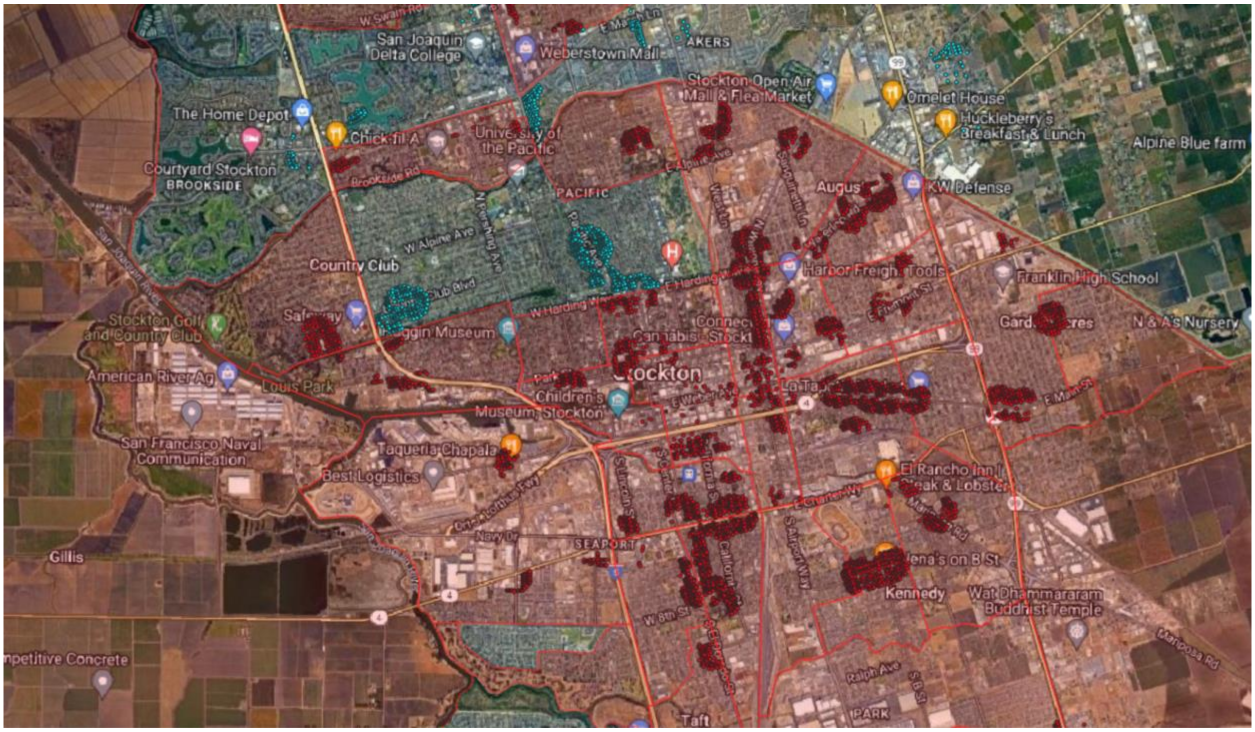

Figure 6. Sample illustration of residential parcels within 200 meters of Restaurant facilities in the Stockton area (CEUS Subsector = Restaurant) colored by DAC status (DAC = red, non-DAC = blue)

Exposure of Sensitive Populations

Calculation of the exposure of sensitive populations metric relied on the ambient NO_x emission estimates, as calculated in *Table 14*, in addition to the use of data from the Public Health Alliance of Southern California Healthy Places Index (HPI). The Healthy Places Index combines 25 community characteristics, including access to healthcare, housing, education, and more, into a single indexed HPI score. Higher HPI scores represent healthier communities. The Research Team elected to use the HPI instead of the CalEnviroScreen tool because the HPI included more specific community and population characteristics including race, housing, health risk behaviors, and more comprehensive measurements of health outcomes and community characteristics. These additional metrics better reflected the aim of measuring sensitive populations.

The total ambient NO_x emissions from commercial buildings for each census tract were calculated by summing the subsector-level estimates. For each subsector and within each census tract, the subsector's contributions to total commercial NO_x emissions were then calculated as a percentage (e.g., as a concrete example, the restaurant subsector makes up 40% of the total ambient NO_x emissions from commercial buildings in Census Tract 229.01). This value was then divided by the census tract's Healthy Places Index percentile. The quotient represents the relationship between community health and subsector emissions impacts: smaller values signal the subsector has lesser impacts in healthier communities; larger values indicate the subsector has greater impact in less healthy communities. The values for each subsector at each census tract were summed across the state, providing a statewide measure of the correlation between subsector emissions and community health.

Worker Vulnerability

The worker vulnerability metric is meant to explore the multiple ways in which the replacement of fossil-fuel end uses across various commercial subsectors may impact workers. For instance, businesses are likely to face higher operational and capital costs, potentially leading to employee layoffs as they seek to offset these expenses. However, eliminating fossil-fuel end uses could also reduce workers' exposure to harmful air pollution. To assess both of these impacts in a single metric, monthly wages are used as a proxy for vulnerability. Lower wages have been linked to limited access to healthcare and groceries as well as increased exposure to air pollution.[21] Additionally, low-wage workers are more likely to be employed in higher-risk occupations, putting them at greater risk of occupational hazards and climate-related health issues.[22,23]

The analysis for the worker vulnerability metric originally used two datasets. The first is the Quarterly Census of Employment and Wages (QCEW), which provides a quarterly count of employment and wages based on tax reports submitted to California's Economic Development Department by employers subject to the state's unemployment insurance (UI) law. The second is the Occupational Employment and Wage Statistics (OEWS), an annual survey that produces employment and wage estimates for approximately 830 occupational classifications. Worker vulnerability was assessed by weighting wages according to the total number of employees by NAICS code (QCEW dataset) and by occupational wages and employment within CEUS subsectors (OEWS dataset). The QCEW dataset calculates average annual wages per employee by dividing total annual wages by the average annual employment in a given industry. However, this can be misleading, as each industry may encompass a wide range of occupations, which could hide differences between high- and low-paying roles and skew the averages. In contrast, the OEWS data allowed the research team to look directly at low-wage occupations. Given the focus on low-wage workers and low-wage occupations, the research team chose to proceed only with the OEWS data.

Industry wage estimates from the OEWS and distinguished by NAICS are available between the 2-digit and 3-digit industry classification levels, at most 4-digit levels, and for a subset of 5- and 6-digit levels. The dataset was downloaded from the U.S. Bureau of Labor Statistics for the most recent available year, 2023. The survey defines wages as "straight-time, gross pay, exclusive of premium pay," which includes tips, production bonuses, commissions, incentive, and hazard pay and excludes back pay, holiday and year-end bonuses, meal and lodging, overtime, stock, and discounts.

Using the same crosswalk employed in *Figure 1*, NAICS codes within the OEWS dataset were matched by their corresponding commercial subsectors defined in CEUS. There were 3,325 unmatched entries out of the total 38,972 observations. The

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[21] Jbaily, A., Zhou, X., Liu, J. et al. 2022. Air pollution exposure disparities across US population and income groups. Nature 601, 228–233. https://doi.org/10.1038/s41586-021-04190-y

[22] Schulte PA, Chun H. 2009. Climate change and occupational safety and health: establishing a preliminary framework. *J Occup Environ Hyg*. 6(9):542–554. doi: 10.1080/15459620903066008

[23] Ndugga, Nambi, Pillai,Drishti et al. 2023 Climate-Related Health Risks Among Workers: Who is at Increased Risk? Kaiser Family Foundation. Accessed at: https://www.kff.org/racial-equity-and-health-policy/issue-brief/climate-related-health-risks-among-workers-who-is-at-increased-risk/#

unmatched entries were identified as “OEWS Designation.” Some of the unmatched entries were altered versions of standard NAICS codes. These altered codes included extra letters and numbers to represent grouping of multiple 4-digit NAICS codes. For example, the code NAICS 4240A1 was used to combine industries represented by NAICS codes 4244 and 4248, as indicated by its OEWS designation. Additionally, there were unmatched entries labeled with codes like 9991, 9992, and 9993—special NAICS categories used exclusively for the OEWS survey that do not correspond to any official NAICS industry. These categories include occupations in government establishments (excluding schools and hospitals). All 4-digit NAICS unmatched entries were manually assigned to corresponding CEUS sectors and CEUS subsectors, informed by the NAICS to Building-type Map in Appendix G of the 2022 CEUS.

Once NAICS codes and CEUS subsectors were completely aligned, the OEWS dataset was filtered to only include data for California, the ‘major’ occupation group, 4-digit NAICS, and the ‘Commercial’ CEUS sector. The ‘commercial’ sector level was selected because it included almost all CEUS subsectors. *Figure 7* illustrates the range in average monthly wages across all occupations within each CEUS subsector. Wages by occupation have a far wider interquartile range and different medians, illustrating a variation in concentration of wages by one occupation versus another occupation, as opposed to a concentration of wages by NAICS.

Table 18. Employment and Unique Occupations per CEUS Subsector, OEWS

CEUS Subsector	*Unique NAICS Codes*	*Unique Major Occupations*	*Total Employment*
College	81	22	563,240
Food Store	20	14	378,270
Health Care	190	22	1,348,760
Lodging	35	18	232,530
Miscellaneous	300	22	1,100,010
Office	544	22	6,252,410
Refrigerated Warehouse	41	20	179,430
Restaurant	34	14	1,458,920
Retail	201	19	1,124,660
School	46	21	1,026,410
Unrefrigerated Warehouse	120	18	858,940

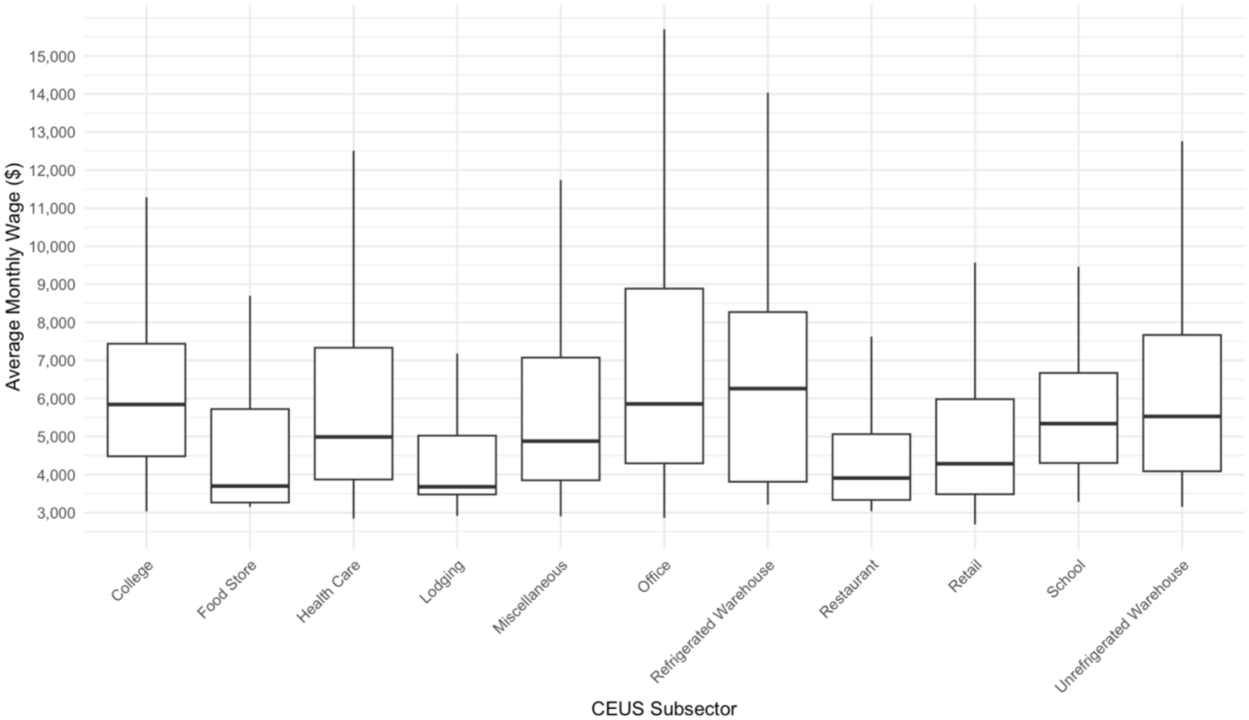

Figure 7. OEWS California Average Monthly Wages by occupation grouped by CEUS Subsector

The average, median, lower quartile, and upper quartile monthly wages were weighted using a two-stage method. First, wages were weighted by the distribution of occupations within each NAICS code in each CEUS subsector. Then, they were weighted by the total number of employees within each NAICS code in those subsectors. This methodology ensures that more prevalent occupations and NAICS codes within each subsector are accurately represented in the analysis.

To assess the impact of commercial subsector scale on worker vulnerability, both wages and total employment by CEUS subsector were normalized and scored on a scale from 0 to 1. Wages were scored so that the lowest wages received a score of 1 and the highest wages received a score of 0. Similarly, subsectors with the highest employment were given a score of 1, while those with lower employment received a score of 0. Wage and employment scores were summed by the CEUS subsector, with the highest score representing the highest scaled vulnerability.

Electric Grid Outage Vulnerability Risk

Replacing existing fossil fuel appliances and equipment across various commercial subsectors could potentially increase those facilities' vulnerability to grid outages and thus lead to operational downtime or temporary facility closures. This issue has previously been raised as a potential concern for the implementation of fuel-substitution measures in different commercial subsectors, particularly as the state's utilities have increasingly been forced to implement mandatory Public Safety Power Shutoffs (PSPS) to protect against wildfire risks within particular regions. To assess how outage vulnerability in electrical grid infrastructure might affect different commercial subsectors, an analysis for the spatial correlation between historical PSPS outages on individual distribution circuits and the number of commercial facilities in their proximity was analyzed.

A composite dataset containing the geographic locations of all three-phase distribution circuit centerlines located across the State's major electrical IOU service territories (SCE, SDG&E, PG&E) was assembled, using data downloaded from each IOU's individual Distributed Energy Resource Planning External Portals (DR-PEPs). These individual IOU datasets were merged into a unified data resource containing records for 7,759 individual distribution circuits, as visualized in *Figure 8* below.

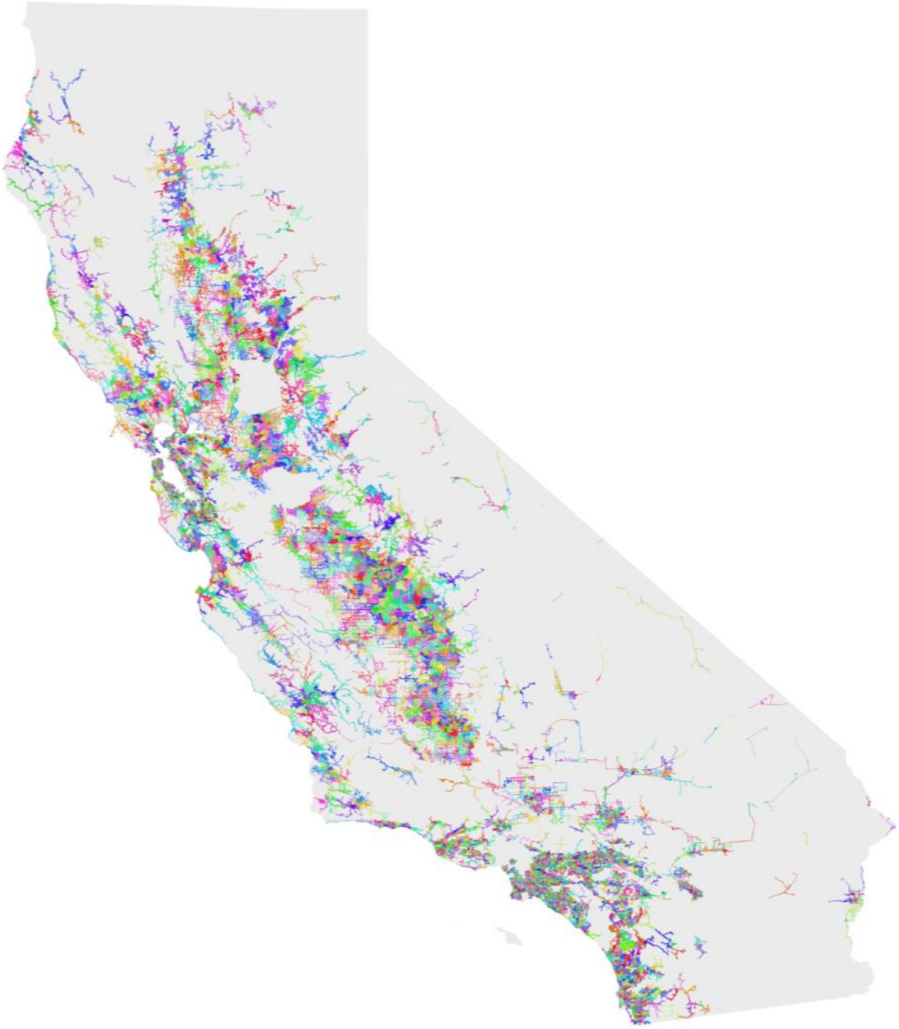

Figure 8. Illustration of the geographic coverage area for the assembled dataset of 7,759 three phase distribution circuit centerlines, individually obtained from IOU hosted DR-PEP sites (Note: each named circuit has been assigned a unique color within this figure)t.

A dataset containing information about the frequency and duration of historical grid outages at the distribution circuit level was obtained from the CPUC. These data are reported by the state's investor-owned electric utilities pursuant to Resolution ESRB-8, Ordering Paragraph 1 of California Public Utilities Commission Decision (D.) 19-05-042 (Phase 1), and Ordering Paragraph 1 of Decision (D.) 20-05-051 (Phase 2).[24]

The raw outage reporting dataset contained information for 5,471 historical outages on 2,458 unique circuit segments. These outage data were aggregated up to the full circuit level to facilitate joins against geospatial data for the location of circuit centerlines previously discussed. The final processed dataset provided information for the cumulative frequency (total events) and duration (total hours) of PSPS outages occurring along 1,410 distinct distribution circuits over the ten-year period from 2013 to 2023.

The approach to the quantification of grid outage exposure risk for different commercial subsectors involved an analysis of the cumulative duration of historical PSPS grid outage events occurring on specific distribution circuits relative to the number and type of commercial facilities identified in their proximity. The first step in this process involved assigning each identified commercial facility to its nearest neighboring distribution circuit. This was accomplished through the application of a minimum distance based, geospatial proximity assignment rule. This approach yielded the data structure illustrated in *Table 19*, which was keyed upon each unique facility ID. It is worth noting that at this stage in the process, these data were complete for all of the facilities identified in the historical account-level consumption data assembled for the state's three major IOU electricity providers. Individual facilities were further flagged according to the DAC/non-DAC status of the census tracts in which they were located using a spatial join executed between the tract geographies and each facility's centroid coordinate.

Table 19. Examples of intermediate results produced by assigning CEUS subsector facilities to their nearest distribution circuits.

Facility ID	*CEUS Subsector*	*Circuit Name*	*Circuit Proximity (m)*	*Facility Centroid Coordinate*
xyV8oPYB	Lodging	BAKERSFIELD	22.6211528	POINT (93293.56839, -291891.18256)
e1N2S3i8	Food Store	BAKERSFIELD	27.5268755	POINT (93272.98989, -292283.00699)
A6yiGeEZ	Lodging	BAKERSFIELD	3.91919001	POINT (93235.88011, -291925.29675)
SML5REgz	Health Care	BAKERSFIELD	81.2138923	POINT (93175.16514, -290980.54117)
maBqqQjV	Miscellaneous	BAKERSFIELD	6.02487098	POINT (93220.30946, -290868.38583)

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[24] https://www.cpuc.ca.gov/consumer-support/psps/utility-company-psps-reports-post-event-and-post-season

YEQg4NnJ	School	BAKERSFIELD	98.9132189	POINT (93399.95807, -290836.37144)
NAyDYk9S	Food Store	COLUMBUS	29.2649227	POINT (93557.40516, -291079.64785)
7LbSPLX4	Restaurant	COLUMBUS	24.9978298	POINT (93636.45924, -291026.62398)
bpa413oV	Restaurant	COLUMBUS	7.03140385	POINT (93648.54966, -291071.14527)
YSUZnjhj	Retail	COLUMBUS	48.1185341	POINT (93662.01188, -290990.87863)

The facility level data represented in *Table 19* were then joined to the PSPS shutoff data obtained from the CPUC using the Circuit Name field as a common join key. This join was only partially successful, however, in terms of the number of facilities that were able to be linked. This was due to inconsistencies in the way that distribution circuit names were represented between the two data sets, as well as the fact that many individual distribution circuits were not subjected to PSPS shutoffs at any time over the ten-year data coverage period. Thus, these circuits should legitimately not appear within the PSPS outage dataset. As a result of the partial success of this join, the data used for the calculation of outage vulnerability scores is considered to be a sample and not complete for all commercial facilities in the state. With that said, this sample was sufficiently large enough to be considered representative for the purposes of this analysis.

Equation 2.

$$S_{a,d} = \sum_{j=0}^{f} O_{j,a,d}$$

Where:
$S_{a,d}$ = The outage vulnerability score for each CEUS subsector (a) by disadvantaged community status (d)
$O_{f,a,d}$ = The duration of PSPS outage hours (O) experienced by each CEUS facility ($j \ni f$) by CEUS subsector (a) and DAC status (d).

Technology Readiness

Facilities within different commercial subsectors consume varying amounts of gas to deliver different categories of end-use services. For each category, the set of technologies available to replace existing gas appliances and equipment vary in their stages of engineering development and commercial readiness. This current state of technological readiness and commercial viability for substitute electric appliances and equipment is a key factor in determining which commercial subsectors should be prioritized for future electrification. In addition, there are also concerns about the challenges associated with integrating these new technologies into existing buildings. To quantify these concerns, several metrics were developed to capture different aspects of the feasibility of electrification for each commercial subsector. The first metric is technological readiness component as described below, and the other metrics, including end use diversity, median building vintage, median building size and average therms per premise, are further described in the following sections.

The technological readiness of substitute electric appliances and equipment for different gas end-use categories relates to the availability of substitute electric appliances and equipment that could replace existing appliances and equipment. Values for this metric are generated by assigning a composite technological readiness level (TRL) score. TRL score is based upon the technological readiness and commercial viability of substitute electric appliances and equipment for each gas end-use category within each subsector. The scores were then weighted according to the fractional contribution of different gas end-uses to the total volume of gas consumption within different subsectors. Subsectors where most gas consumption comes from end-uses lacking viable electrical alternatives—or where such alternatives are still technically or commercially immature—would be assigned lower scores.

Key data sources for deriving TRL scores include technical reports and documentation for emerging new electrical end-use technologies developed by the Department of Energy and other trade/industry sources, as well as the gas consumption breakdown data from the CEC's 2006 CEUS, and statewide parcel-level building attribute information obtained from CoreLogic. This approach builds upon the scheme documented in the DOE's Technology Readiness Assessment Guide, which defines a formal scale of different technological readiness levels (TRLs) ranging from 1-9 (low-high) that is based upon the achievement of key engineering feasibility and implementation milestones.[25] Table 20 shown below, reproduced from this guide, provides some useful context for how these different TRLs are defined. Generally, the types of electrical end-use technologies that would be considered as replacements for existing gas appliance and equipment within commercial facilities are going to be at the higher range of these TRLs (7-9), though there are likely a few exceptions related to miscellaneous process uses that are still in the early phases of engineering development/pilot validation studies.

While the TRL classifications presented in *Table C1* in *Appendix C* provide a useful foundation for the development of this type of electrification readiness index, they do not readily account for situations where technologies have been successfully validated and deployed in real-world environments (i.e. TRL 9) but are not necessarily cost-competitive with incumbent alternatives. To address this omission, the research team introduced a TRL 10, which reflected a situation where an existing electric substitute technology for an existing gas end-use is not only commercially available, but also has the lowest levelized cost of implementation. Thus, absent other concerns, logical

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[25] U.S. Department of Energy. Technology Readiness Assessment Guide. DOE G 413.3-4. 10-12-09. https://www.directives.doe.gov/directives-documents/400-series/0413.3-EGuide-04/@@images/file

replacement for existing gas appliances and equipment should be considered upon its end of life if an electric alternative meets TRL 10.

Table 20. TRL based electrification feasibility score assignments by gas end-use and CEUS subsector

CEUS Subsector	*Air Heating*	*Air Cooling*	*Water Heating*	*Cooking*	*Process*	*Miscellaneous*
College	8	8	8	9	6	5
Food Store	8	8	9	9	7	4
Health Care	8	8	8	9	5	4
Lodging	10	10	9	9	5	5
Miscellaneous	8	8	8	8	5	4
Office	10	10	9	10	7	5
Restaurant	10	8	9	10	6	5
Retail	10	10	9	9	6	5
School	10	10	9	9	7	5
Unrefrigerated Warehouse	10	10	9	9	7	5

End Use Diversity

Values for this metric were computed in terms of the variance in the breakdown of gas usage by gas end-use within each commercial subsector as shown in Table 21. Subsections with more evenly distributed gas usage across a wider range of categories would be considered more difficult to electrify, due to the need to replace multiple existing types of gas appliance and equipment and thus be assigned lower scores relative to this metric.

Table 21. 2006 Commercial End Use Survey Natural Gas Consumption Breakdown

	Heating	Cooling	Water Heating	Cooking	Miscellaneous	Processing
Warehouse	0.871	0	0.106	0.006	0.012	0.006
Refrigerated Warehouse	0.145	0	0.145	0.218	0	0.49
Retail	0.6523	0	0.169	0.111	0.058	0.009
Food Store	0.345	0	0.277	0.375	0	0.003
Office	0.792	0.020	0.129	0.011	0.004	0.046
Miscellaneous	0.302	0.016	0.400	0.044	0.042	0.196
School	0.626	0.008	0.294	0.066	0.001	0.004
College	0.580	0.101	0.246	0.048	0.026	0.000
Health	0.433	0.020	0.415	0.044	0.019	0.067
Lodging	0.172	0.002	0.682	0.104	0.034	0.006
Restaurant	0.037	0.000	0.232	0.730	0.000	0.002

Median Building Size and Median Building Vintage

Data on median building size and median building vintage were derived from statewide parcel level building attribute information obtained from CoreLogic. These related metrics attempt to address important scaling relationships between electrification costs—specifically, the upfront cost of capital equipment and the expenses tied to upgrading building energy systems and utility electrical service — and building sizes and vintages. These cost relationships have been observed particularly in the electrification of older and larger existing buildings. For Median Building Size, the Research Team computed the median size (in terms of square footage) of the buildings associated with the utility premises identified within each commercial subsector. For Median Building Vintage, the median construction vintage years were similarly computed for the set of buildings. As such, larger and older buildings are both assigned lower scores relative to each of these metrics within the framework in its default setting.

Average Therms per Premise

This metric utilized utility account level electricity and gas consumption data from SCE, SoCal Gas, PG&E, and SDG&E from 2015 to 2021. The average consumption per premise by CEUS subsector was computed for each census tract. In instances where the number of distributions of usage among premises did not meet CPUC mandated data aggregation guidelines, results were suppressed to maintain customer confidentiality.

Other Variables Explored But Not Included In Prioritization Framework

During the development of the prioritization framework and its underlying variables (*Table 9* above), the research team received periodic feedback from CARB staff and members of the Technical Advisory Committee. All feedback was fully considered and evaluated, and decisions regarding whether to incorporate suggested updates are documented below.

Worker Vulnerability

Stakeholders recommended incorporating additional variables to measure worker vulnerability, such as small business ownership, race, sex, and unionization within a sector. The research team explored several data sources to include these variables in the worker vulnerability score. For small business ownership, datasets from the Department of General Services were examined, but this measure was ultimately excluded due to the lack of data available by NAICS or SIC code. This limitation made it difficult to align with the existing prioritization framework and commercial subsector categories based on the Commercial End Use Survey.

Additionally, data on immigration status, race, sex, and union presence within sectors were considered. While such data exists at higher sector levels, demographic information at the 5- or 6-digit NAICS level is extremely limited, preventing its inclusion in the framework.

Indoor Air Emissions

Stakeholders expressed interest in incorporating particulate matter (PM) data into the indoor air emissions metrics. CARB staff noted that while PM emissions are a strong indicator of combustion, there is limited data on emission factors. In contrast, NOx emissions are better documented and studied. Furthermore, PM can originate from multiple sources, making it a less precise measure for combustion-related emissions.

Given these factors, the research team decided not to include PM data in the analysis of indoor air pollution exposure.

Grid Outage Vulnerability

Stakeholders raised concerns about the use of historical PSPS data to assess grid vulnerability, questioning its predictive value given ongoing utility investments in wildfire mitigation and grid reliability. They suggested renaming the category to reflect historical outage trends rather than implying future risk. Additionally, they noted that certain subsectors, such as warehouses, may experience indirect impacts from outages—such as disruptions to trucking operations—that are not directly captured by PSPS data.

The current criteria measure average annual outage hours per facility by commercial subsector based on historical PSPS data. However, this approach does not account for potential future changes in outage frequency or duration, including those influenced by climate change. Recognizing this limitation, the research team documented and qualified these factors when discussing grid outage vulnerability.

The team also considered including grid capacity constraints as a variable, particularly in the context of electrification-driven demand growth. However, grid capacity is dynamic and generally expands in response to load growth. Rising demand from electrification is anticipated to influence distribution system capacity planning, leading to targeted infrastructure investments to increase capacity where required. Moreover, future grid capacity constraints are likely to be meaningfully impacted by rates of adoption of load modifying distributed energy resources (solar, storage, EV charging, etc.). Given the dynamic nature of this situation, it remains uncertain whether current grid constraints should be viewed as a long-term barrier to electrification. Therefore, grid capacity constraints were not included in this analysis.

Previous modeling studies have investigated the potential need for future grid investments to support more widespread adoption of different electrification measures. However, to date, the majority of these have principally focused on the impacts of transportation electrification and distributed energy resources. A notable example is Kevala's multi-part Electrification Impacts Study, which has been funded by the CPUC as part of their High DER proceeding. [26] In their Part 1 report, the Kevala team discussed several challenges related to accurately modeling both future building electrification uptake and the grid capacity investments would be implicated as a result. Generally, however, the seasonality of heating loads (which peak in winter) is not coincident with California's electrical system's current summer peak. Thus, it is likely that significant electrification of existing gas-powered heating end-uses can be supported before capacity constraints become a pervasive issue (with localized exceptions).

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[26] Kevala Inc., Electrification Impacts Study Part 1: Bottom-Up Load Forecasting and System-Level Electrification Impacts Cost Estimates, prepared for the CPUC in support of Proceeding R.21-06-017 (Order Instituting Rulemaking to Modernize the Electric Grid for a High Distributed Energy Resources Future), May 9, 2023, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M508/K423/508423247.PDF.

Technical Difficulty

A member of the Technical Advisory Committee inquired whether the weighting approach accounts for technological differences in buildings, such as the use of high-temperature steam systems that are not currently compatible with heat pumps. Additionally, stakeholders noted that buildings with mechanical equipment located in basements tend to be more difficult to electrify.

To explore potential data sources, the research team examined building permit data from the Construction Industry Research Board (CIRB), which includes descriptions and costs of work. However, these data are somewhat limited, are not explicitly categorized by NAICS code, and would require extensive manual identification to extract relevant findings. Given these constraints, the research team opted to incorporate proxy variables—such as building size and vintage—which are correlated with end-use technology characteristics.

2.2.3 - Priority Subsector Feasibility Assessment

A priority subsector was selected utilizing the prioritization framework and an assessment of which subsector offered maximum returns to learning. The priority subsector feasibility assessment featured sequential dimensions of analysis to inform sampling methodology and overall outreach efforts conducted by subcontracting firm, The Energy Coalition (TEC). This analysis was conducted using data from CoStar, a commercial real estate and hospitality database, and equity indicators from CalEnviroScreen 4.0. CoStar provided property-level information on building class, vintage, room count, renovation status, operation type (independent vs. chain-managed), and listed amenities. To assess energy-related impacts, hotel amenities were flagged for potential gas end uses (e.g., pools, spas, restaurants, bars, meeting/event spaces, kitchens), and hotels were categorized by their diversity of gas end use (basic, normal, high). CoStar contained a list of amenities for each property and the unique values across the dataset included: fully-equipped kitchen, outdoor pool, room service, hot tub, restaurant, on-site bar, meeting event space, wedding venue, pool, spa, on-site casino, and waterpark. The Energy Coalition created a gas end-use diversity flag for hotels based on the presence of amenities that typically require additional gas consumption. The classification criteria were as follows:

- Basic: No listed amenities beyond the standard room heating, which is common to most hotels in California;
- Normal: At least one listed amenities;
- High: At least one listed amenities that likely use additional space, water, and cooking heating (kitchens, pools, laundry, etc.)

Analysis showed that 65% of hotels have amenities associated with a higher diversity of gas end uses. Equity considerations were added by overlaying hotel data with CalEnviroScreen to identify properties located within the top 25 percentile of DACs.

Sampling Methodology

To develop a representative and policy-relevant sample of lodging facilities in California, TEC implemented a stratified random sampling method, designed to ensure geographic, operational, and socioeconomic diversity while prioritizing highly diverse gas-use buildings relevant to decarbonization research. Figure 9 below shows the sample sizes for each step of this method. This method produced two parallel samples:

- A statewide cohort of 100 hotels
- A subset of 50 hotels located in Disadvantaged Communities (DACs)

Stage 1: Stratification by Hotel Attributes and Climate Zone

The foundation of the sampling design was geographic stratification by California Climate Zone (CZ), recognizing that energy use intensity and retrofit potential vary significantly across the state's sixteen distinct zones. TEC divided the dataset into distinct strata based on combinations of key hotel characteristics known to influence energy use and policy relevance. Within each climate zone, hotels were further classified into multi-attribute strata based on:

- Room Count: Binned into four quantiles (e.g., Bin 1: 6–58 rooms, Bin 2: 59–102 rooms, etc.), derived from the actual data distribution using pandas.qcut().
- Hotel Class: Grouped as reported ("Economy," "Midscale," "Upper Midscale," "Upscale," "Upper Upscale," "Luxury") with missing values labeled as "Unknown."
- Chain Affiliation: Flagged as "Yes" if a parent company was listed; "No" otherwise.
- Disadvantaged Community (DAC) Status: Based on the presence of CalEnviroScreen or equivalent indicators.
- Pool Amenity: Binary flag indicating whether the hotel included a pool.
- California Climate Zone: One of 16 zones relevant to building energy standards.

Each stratum represents a unique combination of these variables (e.g., Medium-sized, Non-chain, DAC hotel with pool in Climate Zone 5).

Stage 2: Proportional Target Assignment

After defining strata, the function allocate_by_combination() computed proportional sample targets within each climate zone. The statewide target sample (100 hotels) was distributed in proportion to each stratum's share of the population — first by climate zone weight, and then by hotel characteristics within that zone.
For example:

- A climate zone with 15% of all hotels would receive roughly 15 of the 100 sample slots.
- Within that zone, those 15 slots were divided among strata (e.g., by class, DAC status, or pool presence) according to each group's relative frequency.

This two-level proportional approach ensured that the final sample was geographically balanced while preserving intra-zone diversity. A parallel sampling frame was created for DAC-only hotels (target N = 50), using the same climate-zone-based allocation logic but restricted to DAC tracts.

Stage 3: Random Selection Within Strata (Highly Diverse Gas Use Only)

Once the proportional targets were set, each stratum's hotel list was filtered to include only properties classified as having high gas-use diversity:

- Hotels within each stratum were filtered to include only those flagged as highly diverse gas use (via the Gas.Use column).
- If the number of eligible highly diverse-use hotels in a stratum met or exceeded the target, a random sample was drawn using a fixed random seed for reproducibility.
- If the number of eligible hotels was less than the target, all available highly diverse gas use hotels in the stratum were included, and the shortfall was left unfilled (i.e., no substitution with low-use hotels)

Using the function final_sample_from_high_gas(), a random sample of hotels was drawn within each stratum — bounded by its assigned climate-zone target.
This step guaranteed that:

- Each climate zone contributed at least some hotels to the final statewide sample;
- Randomness operated within, not across, climate zones — maintaining the stratified structure;

If a stratum contained fewer eligible hotels than its target, all qualifying records were included and the unfilled remainder was left blank rather than reallocated, preventing artificial overrepresentation of any climate zone.

Table 22. Illustrative table of sampling methodology

Stratum (CZ + Features)	*Target*	*Eligible Hotels*	*Final Sample*
CZ 3, Large, A, Yes, Yes	2	5	Randomly pick 2
CZ 7, Small, B, No, No	1	1	Take 1
CZ 10, Medium, C, Yes, No	3	2	Take 2 (limited by available data)

This approach preserves the statistical rigor of stratified sampling while ensuring all selected buildings are relevant to gas-focused decarbonization research.

Output Format

The process generates comprehensive Excel workbooks with the following five tabs:

1. Matrix – All strata with population counts, percentages, and sample targets
2. Matching Hotels – All hotels eligible within each stratum
3. Highly Diverse Gas Use Hotels – Subset of matching hotels filtered to highly diverse gas use
4. Final Sample – Randomly selected sample of hotels based on proportional targets
5. Pivot Matrix – Summary tables showing how each dimension contributes to sample composition across climate zone

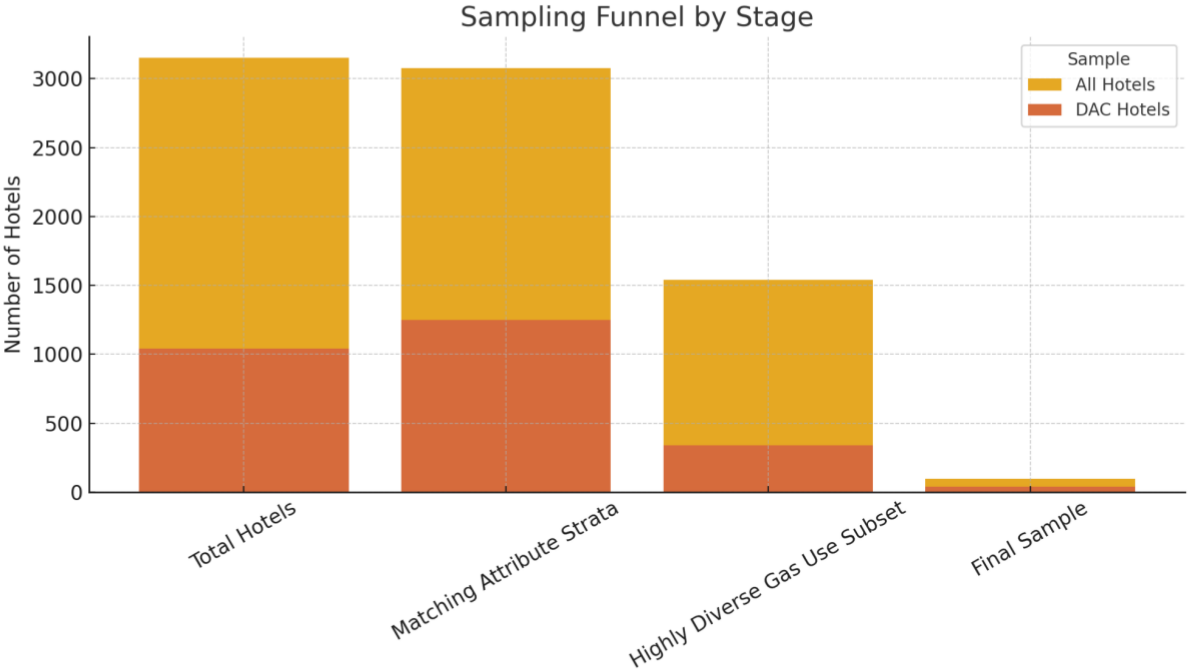

Figure 9. Sampling method - funneling of sites and criteria

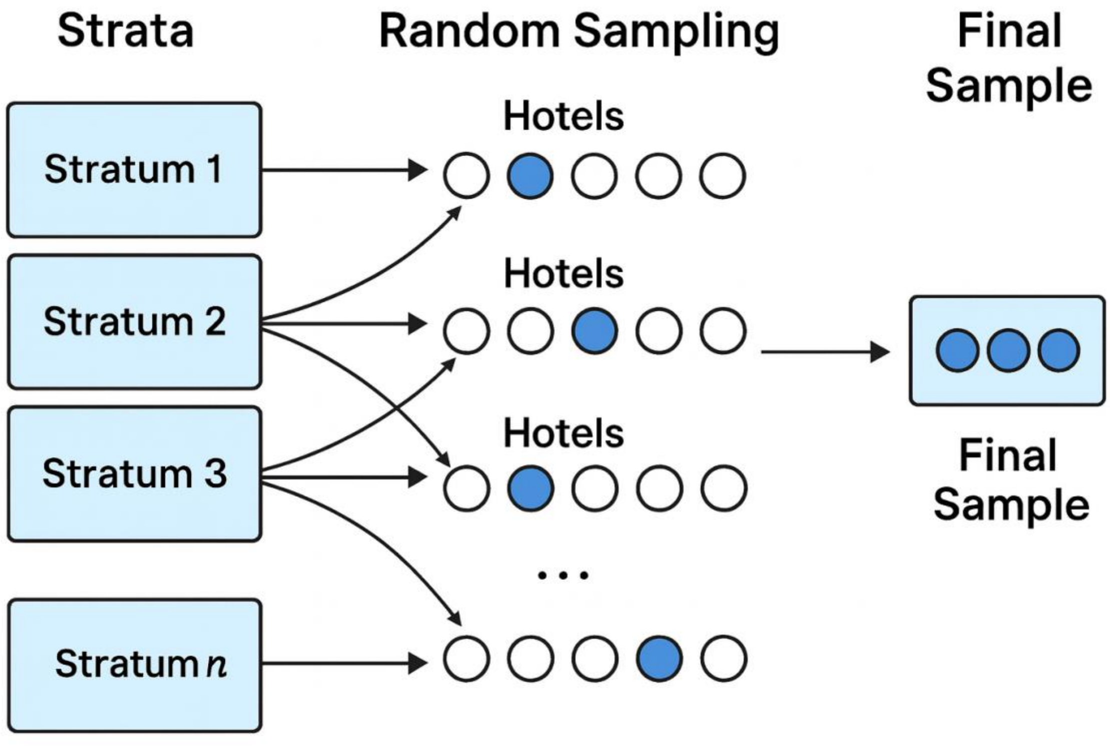

Figure 10. Random sampling and final sample illustrative workflow

Figure 10 above illustrates the three-stage stratified random sampling process used to construct a representative and policy-relevant sample of hotels for decarbonization analysis.

Survey Instruments

The email template, virtual interview survey questions and site visit interview questions are found in Appendix E. The questions were co-developed by UCLA and TEC.

3 - Results

3.1 - Residential Building Results

This section presents findings from analyses exploring the readiness of California's residential building sector for electrification, as well as the barriers, impacts, and opportunities that are likely to shape this transition. These analyses address the following key questions: How prepared are California's homes to electrify their existing gas end-use equipment? What programs, especially in disadvantaged communities, are helping to advance this shift? How much progress has the state made toward its electrification goals? And how do decision makers and consumers view electrification?

In addressing those key questions, the following results highlight major barriers facing the residential sector, the role of incentives and costs in influencing feasibility, and the current reach and effectiveness of incentive programs in reducing cost burdens and supporting the transition to zero-emission appliances.

3.1.1 - Electrification Readiness of Residential Building Stock

Electrical Service Panel Capacities

The capacity of a home's electrical service panel plays a critical role in determining its ability to support the electrification of existing gas appliances and equipment. Homes with very limited panel capacity are unlikely to accommodate electric air and water heating without either substantial panel optimization or an upgrade to a higher-capacity panel. Panel optimization refers to a set of strategies that can be applied in various configurations to address panel capacity or space constraints of differing severity. Panel upsizing involves replacing the existing panel with one of greater capacity to meet increased electrical demand.

The panel size quantification analysis revealed that only a small percentage (approximately 3%) of single-family properties in California are likely to have extremely small capacity electrical service panels (less than 100 Amps). A somewhat larger proportion of multi-family properties (approximately 10%) have panels in the smallest capacity range (less than 60 Amps). When considered together, these findings indicate that only a small minority of the state's residential building stock would necessarily require panel upsizing projects to comply with a zero-emission space and water heating appliance standard.

At least half of the state's single-family residential buildings have sufficient electrical service panel amperage capacity (≥ 200 Amps) to support the immediate electrification of both space and water heating equipment with minimal need for additional building energy system upgrades or interventions beyond the potential installation of new or larger (240V) plug receptacles. By contrast, only about ⅓ of multi-family structures can be considered similarly electrification-ready based upon panel size distribution estimates for their individual dwelling units. Estimates in the multi-family sector, however, have considerably more uncertainty. In multi-family buildings, there is the possibility of installing centralized end-use equipment that could be interconnected to a building’s common “house-loads” service panel rather than the sub-panels associated with each individual dwelling unit.

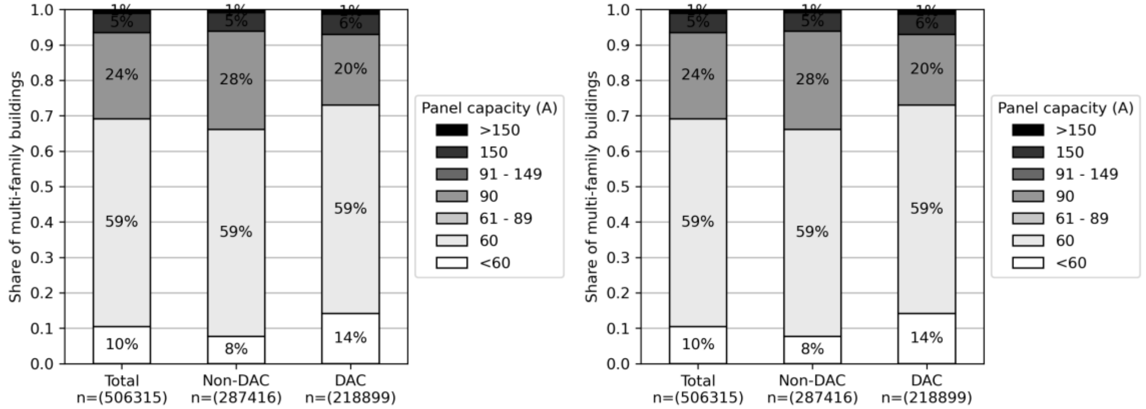

Figure 11. Estimated panel size ratings for California single-family (left) and multi-family (right) properties, both in total and disaggregated by DAC status.

Figure 11 presents the estimated size distribution of electrical service panels in single-family and multi-family contexts and further differentiates between the panel size distributions within disadvantaged communities (DACs) and non-DACs, as defined by the CalEnviroScreen 4.0 percentile scores of the census tracts in which each property is located. This analysis reveals key findings related to important equity concerns associated with the implementation of potential zero-emission residential air and water heating appliance standards.

Single-family homes within California’s DACs have panels in the smallest size category (<100 Amps) at about four times the frequency of homes outside of DACs. It is unlikely that homes with such small panels will be able to electrify their air and water heating appliances without either significant panel optimization effort or upsizing their existing panel hardware. The difference in this proportion of buildings with the panels in the smallest size category decreases to 2x within the multi-family sector.

The spatial trends in panel size estimates can be attributed primarily to differential rates of new housing construction, income levels, rental property ownership patterns, and the pace of retrofit upgrades to electrical panel hardware within different communities. Generally, disadvantaged communities in the state are characterized by a greater abundance of rental properties that are of older construction vintage, smaller in size, and less likely to have received permitted upgrades to their electrical systems. This pattern aligns with deferred property maintenance commonly observed within low-income communities where financial resources are not available to undertake anything beyond essential work or, in the case of rental properties, where structural barriers to such work exist. This issue is known as the renter-owner split-incentive problem: property owners who pay for electrification upgrades often do not directly benefit from reduced utility bills when tenants pay for their own utilities. This misalignment of costs and benefits fundamentally shapes decision-making on both sides of the rental relationship.

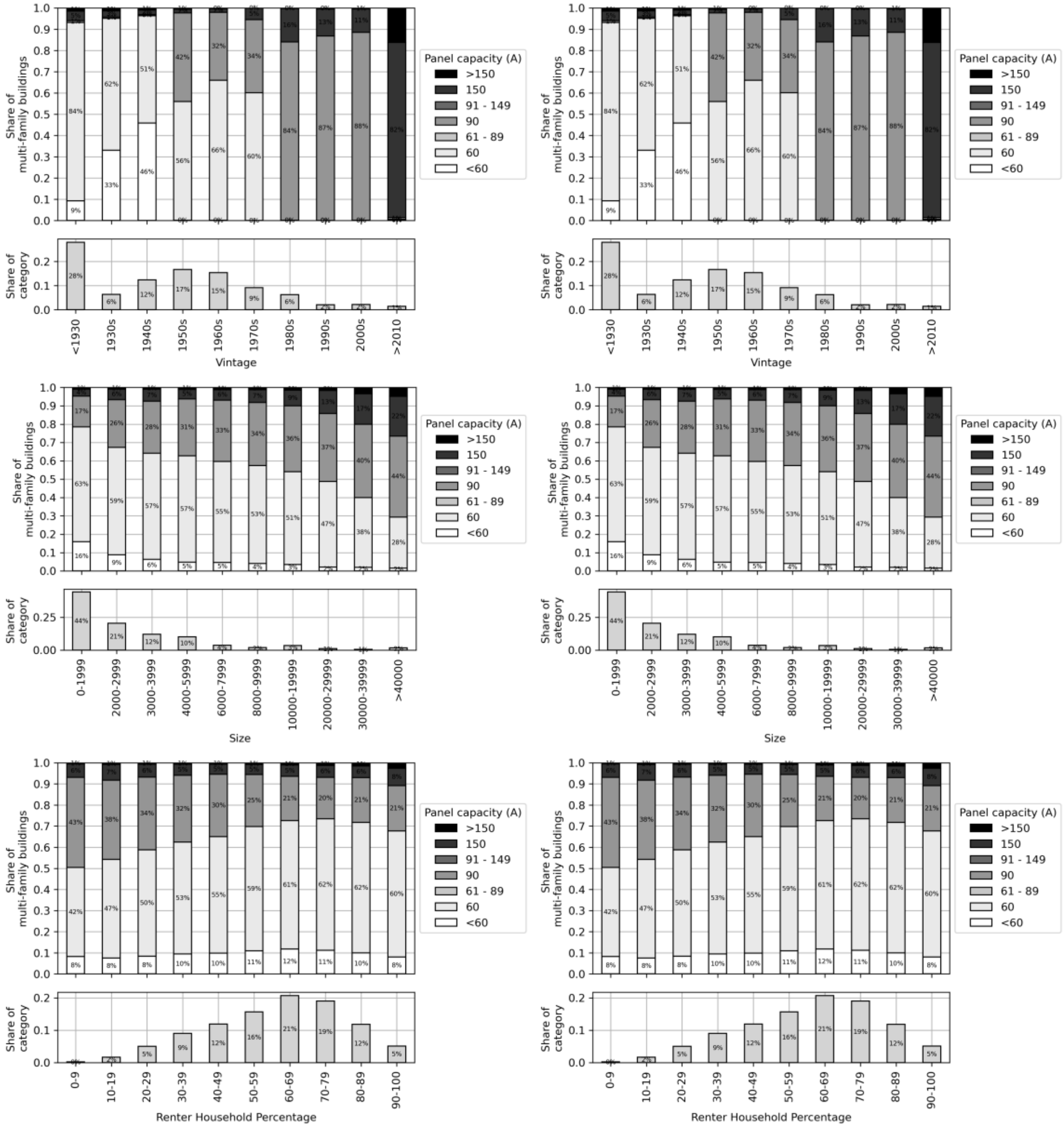

Figure 12. Estimated panel size ratings for California single-family (left) and multi-family (right) properties, disaggregated by building construction vintage year range values (top), building size (ft2) range values (middle), and the percentage of renter households living within the census tract where each property is located.

Figure 12 plots the estimated distribution of existing installed electrical service panel capacities (Amps) among California's single-family and multi-family residential buildings disaggregated by construction vintage year, building square footage, and the percentage of renter households in the census tract where the property is located. These plots illustrate some of the previously discussed trends relating to structural differences between single-family and multi-family properties, in terms of the historical rates of retrofits to building electrical infrastructure and the implications that this has for future electrification efforts.

Other Installation Related Concerns

Air-source heat pump technologies are generally regarded as the optimal solution for zero-emissions space and water heating applications within residential contexts due to their high coefficients of performance (COP) and relatively low peak power consumption, as compared to electrical resistance-based heating technologies. Despite their significant advantages, these technologies present distinct physical installation and operational challenges that warrant careful consideration. A more detailed analysis of the costs associated with these configurations and solutions is presented in *Section 3.1.3*.

Heat Pump Water Heater Installation Constraints

Many heat pump water heaters utilize small packaged condenser units designed to operate at peak efficiency within indoor environments where ambient temperatures remain relatively stable (approximately 68 ± 5°F). Additionally, this equipment typically must be installed in large indoor spaces with unobstructed access to air volumes of at least 700 ft^3.[27] Operating these units outdoors, where ambient temperature ranges are significantly wider, or indoors, in confined or poorly ventilated spaces, can substantially impact their COP. In extreme cases, efficiency degradation may necessitate reliance on backup resistance heating systems, thereby negating much of the energy efficiency advantage these technologies offer.

This consideration is particularly relevant in California, where gas water heaters are commonly installed in small, thin-walled enclosures external to the main structure. It is not well understood precisely how common this type of installation is in terms of the percentage of the existing housing stock, and whether or not appropriate alternative indoor locations might be available for a new heat pump substitute.

Heat Pump Installation Physical Space Constraints

In contrast to water heating applications, most air-source heat pump HVAC units feature robust condenser units specifically engineered to operate in outdoor environments with wider ambient temperature variations. However, a critical mismatch exists between these design requirements and existing infrastructure: the majority of installed gas-fueled heating appliances are located indoors as wall-mounted units, in attic crawl spaces, or within dedicated utility closets and garages. Many of these locations are likely to be unsuitable for the drop-in replacement of an air-source heat pump system. Thus, alternative options for the siting of these equipment must be identified before the existing hardware can be replaced. This can be extremely challenging in some space-constrained environments, which tend to be more common in denser urban areas. These issues can also lead to convoluted solutions where the only suitable location for an outdoor condenser unit is, for example, far away from the location where diffuser hardware must be located to integrate with existing ductwork.

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[27] Larson, B & Larson, S. “The Amazing Shrinking Room: HPWHs in Small Spaces.” Northwest Energy Efficiency Alliance (NEEA). 2024. Date Accessed: December 8, 2024. https://neea.org/product-council-documents/confined-space-analysis-the-amazing-shrinking-room

Electrical Panel Space Considerations

Air-source heat pump systems present additional challenges related to electrical service panel configurations. Although heat pump equipment exhibits lower peak power draws than traditional resistance heating appliances, most air-source heat pump water heaters and HVAC systems still require dedicated 240V circuits rated between 30-60 Amps, with some applications requiring up to 100 Amps. These 240V loads occupy substantial space within electrical service panel enclosures because their associated circuit breakers must maintain two points of contact with the internal bus-bar through a dual-pole configuration. These requirements can create situations where a panel's main breaker possesses sufficient rated capacity to support a new 240V load, yet the number of available breaker slots or their configuration relative to existing breakers physically prevents installation of the required dual-pole breaker. In such cases, installation of a dedicated sub-panel may provide a cost-effective alternative to complete panel replacement and upsizing. A sub-panel effectively expands available breaker slot capacity while maintaining the existing overall service capacity rating, offering a lower-cost solution than wholesale panel replacement. [28] Similarly, there are also now alternative solutions for integrating new distributed energy resources (solar, batteries, EV chargers, etc.), called meter collars that can be used to bypass the main service panel if there are a limited number of breaker slots available.

3.1.2 - Electrification Program and Access

Different legislative and policy directives established energy efficiency and electrification programs, whose implementation is tracked separately. This section first discusses energy efficiency programs, which are more longstanding than relatively recent electrification incentives programs. Efforts to incentivize residential fuel-substitution via electrification are currently fragmented across various incentive programs which lack comprehensive data tracking and coordination. Energy efficiency (EE) programs that were established prior to the emergence of electrification as a policy objective offer incentives like rebates, loaner programs, and tax credits to customers to incentivize energy savings through building weatherization and more energy efficient gas and electric appliances. Support for the implementation of EE measures within residential buildings is available from local and regional, state, and federal programs, through implementation mechanisms that operate across the supply chain, with the vast majority of EE incentive programs designed and implemented by IOUs, regulated by the CPUC, and operated using ratepayer funds. However, since 2021, an increasing share of incentive programs—particularly those supporting electrification—has been provided by CCAs and RENs. *Figure 13* below outlines the various stages at which EE incentive programs are offered.

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[28] SPUR. Policy Brief: Solving the Panel Puzzle. May 2024. https://www.spur.org/sites/default/files/2024-05/SPUR_Solving_the_Panel_Puzzle.pdf. Accessed: 1/15/2026.

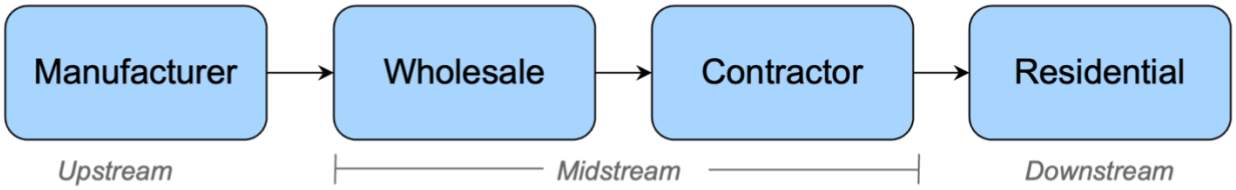

Figure 13. Points of Intervention Along the Supply Chain for Residential Incentive Programs

EE programs are implemented by various types of PAs.[29] These PAs include utilities, state and local government agencies, nonprofits, and other types of organizations, such as community choice aggregators (CCAs) and regional energy networks (RENs). Public funding for EE programs includes taxpayer funds, utility ratepayer funds, cap-and-trade allowances, and grants from air districts and water agencies. However, the vast majority of EE incentive programs are designed and implemented by investor-owned utilities (IOUs) and funded by ratepayers *(Figure 14)*.

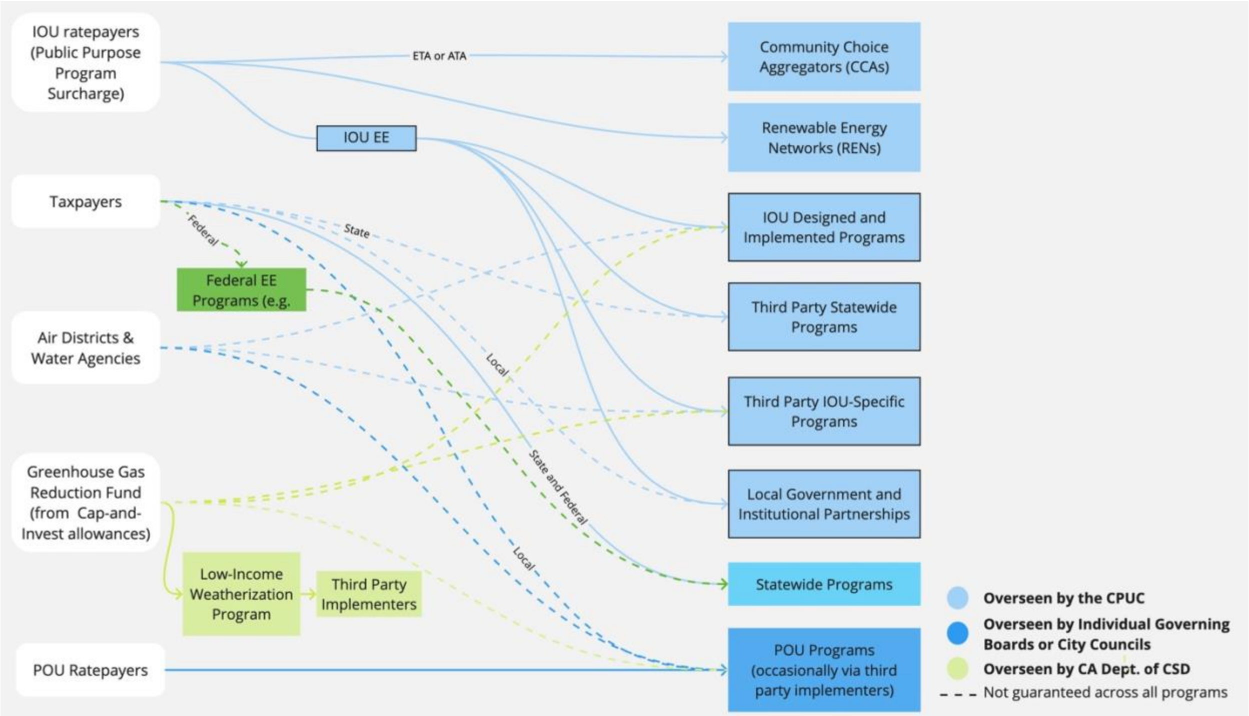

Figure 14. Overview of EE Program Funding Sources, Program Administrators, and Oversight

These programs are driven by state and CPUC policy that requires California's utilities to first meet their energy needs through demand-side reductions enabled by cost-

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[29] Program administrators are the entities accountable for program performance, as defined in the US Department of Energy Office of Energy Efficiency & Renewable Energy Residential Program Guide Glossary.

effective energy efficiency measures as opposed to supply-side capacity expansion of renewable and conventional generation resources.[30]

Electrification budgets within these legacy EE incentive programs, though growing, still make up a very small proportion of investor-owned utilities' total EE budgets. In 2022, the total approved budget for investor-owned utilities ratepayer-funded EE programs was $842,763,533 with $422,304,234 in total expenditures. During this same period, the total approved budget for EE programs that fund electrification was $46,276,967. That is about 5.5% of the total approved budget for EE program measures at large (*Figure 15)*. In 2023, electrification accounted for just 8.5% of total EE budgets—the highest level to date, but still only a fraction of the hundreds of millions invested annually. Meanwhile, gas appliance efficiency upgrades are still available within the residential energy efficiency portfolio.

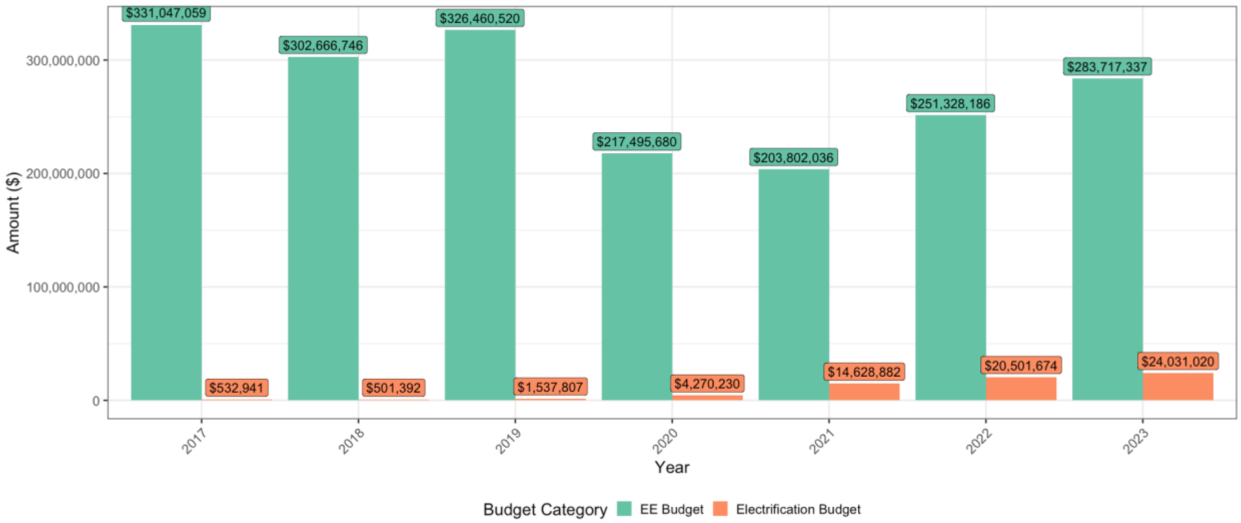

Figure 15. Total Residential Energy Efficiency and Electrification Budgets, CEDARS

In recent years, efforts to incentivize building electrification have been expanded beyond California's legacy EE programs, as in Figure 16. The TECH Clean California initiative—a statewide program that provides incentives to contractors for the installation of heat pump–based technologies—was initially funded with natural gas investor-owned utility ratepayer dollars under the direction of the CPUC. Beginning in fiscal year 2022-2023, however, the state legislature directed taxpayer funding to the program.[31] TECH has since emerged as the main electrification incentive initiative, with new electrification incentive funding being allocated and administered through the program. Funding earmarked by the Inflation Reduction Act (IRA), an estimated $582 million in Federal Home Efficiency Rebates (HOMES) and Home Electrification and Appliance Rebates

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[30] California Public Utilities Commission, Energy Efficiency Policy Manual (April 2020), p. 9, available at https://www.cpuc.ca.gov/-/media/cpuc-website/files/legacyfiles/e/6442465683-eepolicymanualrevised-march-20-2020-b.pdf

[31] TECH Clean California, "TECH Clean California receives $145 million to expand decarbonization efforts" (press release), available at https://techcleanca.com/about/news/september-27-2022/.

(HEEHRA), have been channeled through TECH Clean California. HEEHRA Phase I rebates, a total of $80 million, were made available November 2024. As of January, 2026, $152 million in rebates that were allocated to HEEHRA Phase II have yet to be made available. In July 2024, $25 million in funding from the State's Budget General Fund and Greenhouse Gas Reduction Fund was allocated to TECH Clean California. Overall, this signals a massive expansion of taxpayer-funding for electrification programs, which were previously primarily supported by ratepayers, and an effort to centralize electrification incentives.

While budget data for CEDARS is limited to 2023, comparing the first three years of both CEDARS and TECH reveals that TECH's cumulative budget is over four times as large as the cumulative electrification budgets in CEDARS from 2021 to 2023 ($59,161,576).

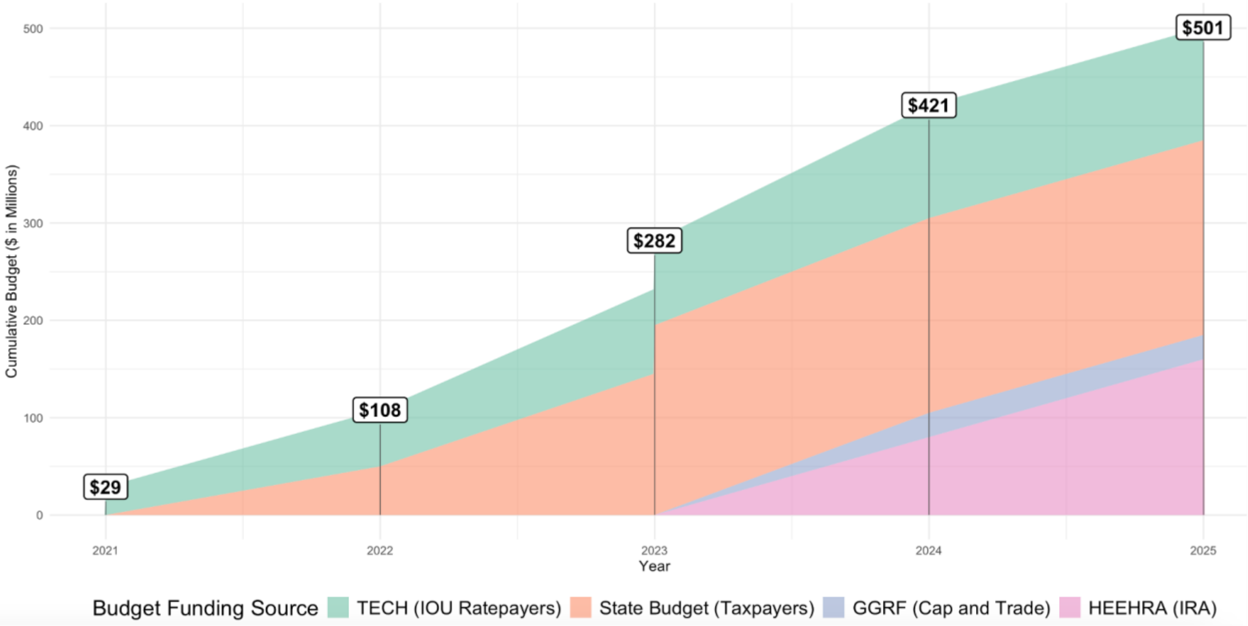

Figure 16. Cumulative TECH Budget and Funding Sources

Since 2023, TECH Clean California's cumulative budget has nearly doubled. The passage of the Inflation Reduction Act (IRA) and the introduction of HEEHRA rebates for multi-family properties serving income-qualified Californians have expanded available incentives beyond heat pump space heating and cooling and heat pump water heating. HEEHRA was temporarily paused in February 2025, as a result of President Trump's January 20, 2025, Executive Order[32], then resumed one month later in March.[33] Rebates offered include electric cooking equipment, heat pump clothes dryers, as well as electrical panel and wiring upgrades. The maximum rebate per low- to

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[32] Unleashing American Energy, Executive Order 14148, January 20, 2025, White House, § 7, https://www.whitehouse.gov/presidential-actions/2025/01/unleashing-american-energy/.

[33] Inflation Reduction Act Residential Energy Rebate Programs. California Energy Commission. Available at: https://www.energy.ca.gov/programs-and-topics/programs/inflation-reduction-act-residential-energy-rebate-programs

moderate-income multi-family household is $14,000.[34] Although this represents a promising step toward equitable electrification, if most low-income multi-family households require the maximum incentive amount, the total budget would support only about 2,857 multi-family households—a stark contrast to the nearly 1.5 million low-income households living in multi-family rental housing across California.

Lastly, the Equitable Building Decarbonization (EBD) Program is a statewide initiative established by Assembly Bill 209 (2022) and administered by the California Energy Commission. One of the program's largest components is the Statewide Direct Install Program, which is funded through a combination of state funds (including California Climate Investments and General Fund appropriations) and federal U.S. Department of Energy HOMES program funding, totaling approximately $565–570 million. The Direct Install Program is designed to provide no-cost electrification and energy efficiency upgrades, such as heat pumps, efficient appliances, and building envelope improvements, to low-income households in designated priority communities. While program guidelines were adopted in 2023 and regional administrators were selected in late 2024, full-scale home retrofit deployment is expected to begin in late 2025 and continue into 2026, and public information on early implementation progress remains limited as of now.[35]

Building electrification incentives are designed to accelerate the transition away from fossil fuel–based end uses by offsetting the higher upfront costs associated with fuel switching and encouraging adoption of carbon-free appliances. While these incentives are delivered through a range of mechanisms—including rebates, financing options, and loan or on-bill programs—the following analysis focuses specifically on a comparative assessment of electrification rebates in order to evaluate how current electrification budgets translate into scale, availability, incentive magnitude, and end-use coverage across single-family and multifamily buildings.

Table 23 and *Table 24* below detail the distribution of rebates available by end-use and the average minimum and average maximum incentive prices for single-family and multi-family buildings, respectively. *Appendix A Table A1 includes a list of programs summarized in this table.* When a program does not offer a range in incentive amounts, only the average rebate amount is listed. Many PAs offer incentives denominated in different units, for example: per ton of air-conditioning load (in BTU), per equipment unit, per dwelling unit, and per kWh. Thus, the average minimum and maximum ranges are listed using the unit defined by the PA.

Among all measures, electric service panel upgrades, which are critical enablers of building electrification though not fuel-switching measures on their own, offer the highest average rebate amounts. They are, however, among the least frequently available incentives. Additionally, multi-family incentives remain limited, with only 43

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[34] California Housing Partnership Housing Needs. Available at: https://chpc.net/housingneeds/.

[35] California Energy Commission, *Equitable Building Decarbonization Program: Statewide Direct Install Program*, adopted program guidelines October 2023; funding and implementation details updated 2024, https://www.energy.ca.gov/programs-and-topics/programs/equitable-building-decarbonization-program/ebd-statewide-direct.

total offerings compared to 165 single-family rebates. Nonetheless, multi-family incentives exhibit a more balanced distribution across end uses, rather than being heavily concentrated in space heating, cooling, and water heating as seen in single-family programs. This suggests that programs serving multi-family buildings, though limited, may be designed to support more comprehensive electrification.

Table 23. Single-family Residential Rebates by Functional Category and Average Minimum and Maximum Value

	Cooking	*Clothes Drying*	*Space Heating/Cooling*	*Water Heating*	*Whole Building*	*Electric Service Panel*
Active Rebates	18	15	82	46	1	13
Average Incentive Price	$336 - $377 per unit	$197 - $208 per unit	$349-$352 per ton $1,308 - $1,410 per unit	$1,122 - $1,313 per unit	$4,250 per unit	$1,885 per unit

Table 24. Multifamily Residential Rebates by Functional Category and Average Minimum and Maximum Value

	Cooking	*Clothes Drying*	*Space Heating/Cooling*	*Water Heating*	*Whole Building*	*Pool Heating*	*Electric Service Panel*
Active Rebates	3	3	12	15	3	2	7
Average Incentive Price	$658 - $783 per unit	$292 - $333 per unit	$1,594 - $1,938 per unit $975 - $1,800 per common area	$5,000 per project $1,221 - $1,724 per unit	$5,133 per unit	$1,875 - $2,250 per pool	Per dwelling unit $1,820 - $1,920 Per project $6,250 - $7,500

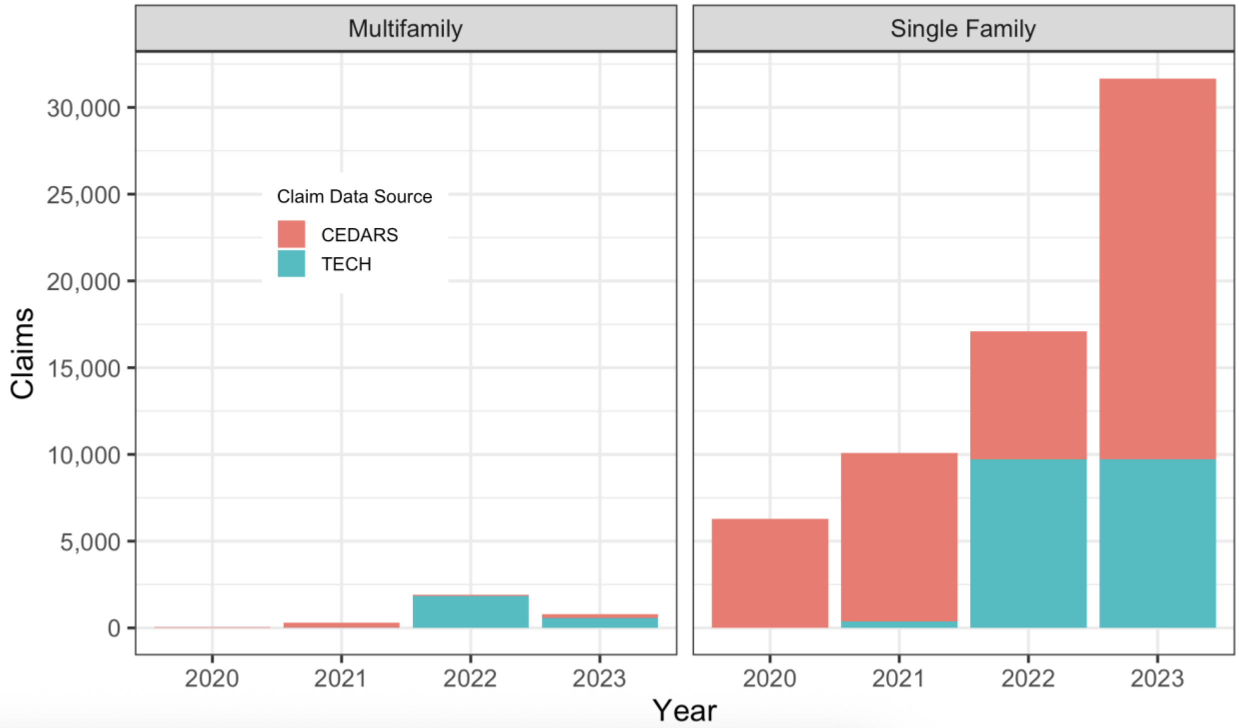

Figure 17. Total Claims for CEDARS and TECH Clean California Residential Claims - No Secondary Incentive Funder Overlap

Incentives are predominantly available and accessed by households in single-family buildings as shown in Figure 17. More detailed information by end use can be found in Tables 25 and 26. Multifamily buildings have fewer incentives available and remain underutilized. Only 1.5% of the total number of installed equipment units in the residential claims reported in CEDARS are for multi-family buildings. In contrast, nearly 12% of the total installed equipment units reported for the TECH program are for multi-family buildings. For multi-family claims, TECH also includes the number of spaces served by each equipment unit. Assuming each single-family claim accounts for one household, summing each single-family claim with the number of spaces served for multi-family claims, approximately 19.32% of total households served by TECH were in the multi-family sector. This is in contrast to nearly 30% of households in California living in multifamily buildings.

Table 25. Single-family Claims by End Use (CEDARS and TECH)

	2020	*2021*	*2022*	*2023*
Space Heating	6022	9196	14803	24004
Water Heating	283	687	1935	6695
Cooking	0	122	264	767
Clothes Drying	0	71	80	182

Pool Heating	0	0	0	0

Table 26. Multifamily Claims by End Use (CEDARS AND TECH)

	2020	2021	2022	2023
Space Heating	35	250	1153	247
Water Heating	4	34	740	523
Cooking	0	0	0	0
Clothes Drying	0	0	0	0
Pool Heating	0	0	0	1

Despite a near doubling of its cumulative budget, the annual number of the TECH program's residential claims largely remained the same between 2022 and 2023. Meanwhile, while still minimal among multi-family buildings, single-family CEDARS claims skyrocketed between 2022 and 2023 (*Figure 18*).

Given that the delivery type of CEDARS' claims dramatically shifted to almost exclusively 'upstream' delivery after 2021, the subsequent rise in CEDARS reported claims is unsurprising (*Figure 17*). One would expect higher uptake given that upstream and midstream programs are less cumbersome to customers. Almost all of the increase in CEDARS reported claims can be attributed to these upstream measures. However, while the number of equipment units and fuel substitution claims have increased, it is unknown how much these incentives related savings are passed onto the consumer, as opposed to being retained by the contractor.

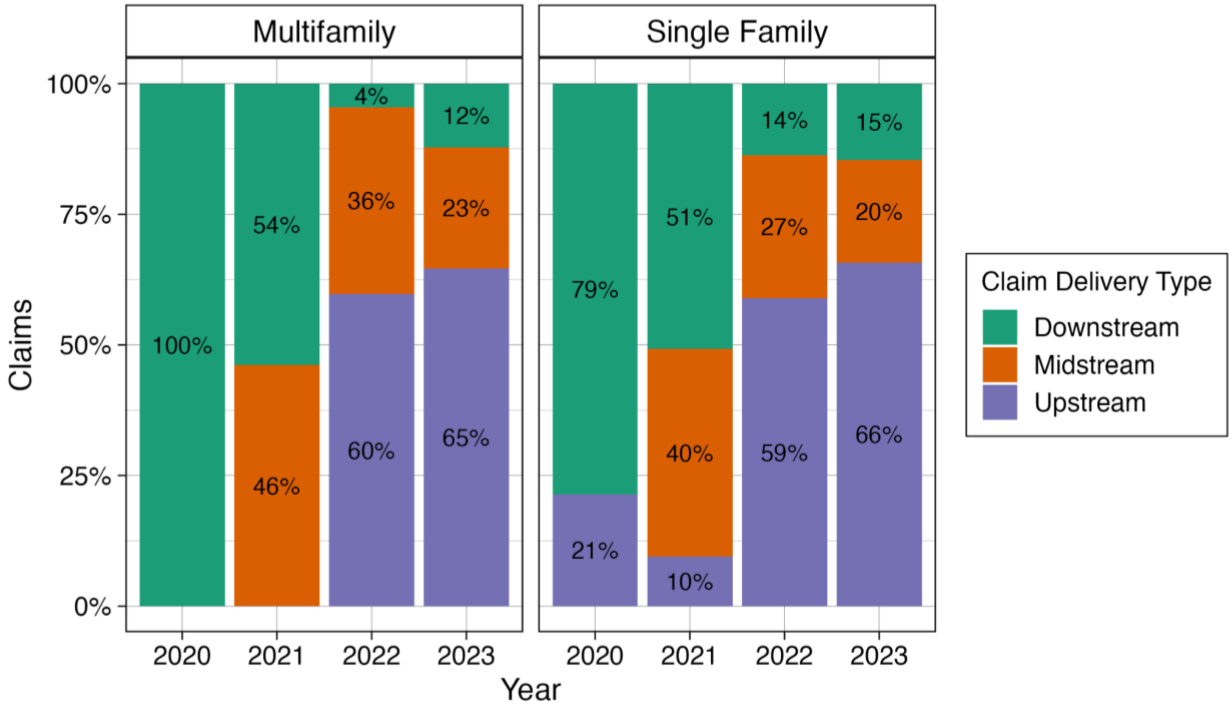

Figure 18. Claims by Delivery Type (CEDARS and TECH)

Tracking which households and customers specifically benefit from state-funded incentive programs is essential for assessing progress toward California's equity and decarbonization goals. According to the TECH Clean California's Equity Budget and Spending Report, last updated on January 17th of 2024, 46% of incentives paid have been in equity communities. Only recently have CEDARS administrators added a new field in their public data which identifies DAC and low-income claims recipients. However, a preliminary review of flagged data from 2023 and 2024 (available up to Q3 at the time of this updated analysis in December 2024), suggests extremely low rates of claims among DAC and low-income customers. In 2023, 1.8% of all energy efficiency claims were either flagged as DAC or low-income or both. Of all electrification claims, only 0.5% were flagged as DAC or low-income or both. For data available for 2024, 11.8% of claims were flagged as DAC or low-income or both, while only 0.08% of electrification claims were flagged in either or both of those categories. This rate, however, may be attributed to the methodology of how claims are flagged, and the lack of geographic precision associated with upstream program claim reporting within CEDARS.

Incentive Uptake in Opinion Research

Findings from opinion research conducted by FM3 with multi-family property owners indicate that financial incentives play a decisive role in enabling electrification projects. Nearly all respondents who completed electrification projects in existing buildings reported that they would not have pursued these projects without access to financial incentives. In many cases, incentives served as a tipping point—covering the cost of upgrades already planned, such as the replacement of aging equipment, and making the decision to electrify economically viable.

Despite their importance, incentive programs face several barriers that continue to limit their uptake. Property owners cited a lack of awareness and understanding of available programs, rapid depletion of incentive funds, and complex or time-intensive application processes as major deterrents. Some participants also noted that incentives are typically offered as reimbursements rather than upfront payments, which can make participation infeasible for owners without sufficient cash flows or access to capital.

Small scale property owners, in particular, identified additional challenges. Some expressed concern that program requirements—such as using contractors from approved lists—can increase project costs and reduce the net value of incentives. One multi-family building owner, for example, noted that although the TECH program incentive would have provided approximately $6,000 in support, using a TECH-approved contractor would have cost $30,000 more than a nonparticipating contractor, according to FM3 reported interview. These findings suggest that while incentives are crucial to driving electrification in the multi-family sector, program design and delivery mechanisms significantly affect accessibility and participation.

3.1.3 - Electrification Costs

This component of the analysis examines the costs and barriers associated with residential building electrification in California. The study synthesizes findings from existing literature, empirical data from TECH Clean California, a survey of 434 renters in disadvantaged communities, and interviews with 15 multi-family property owners. Key findings indicate that while electric appliance costs are approaching parity with gas alternatives, significant ancillary costs—particularly electrical infrastructure upgrades—create substantial barriers to adoption, especially for renters and low-income households.

Appliance Costs

Electric appliances are increasingly available as substitutes for the four major residential gas end-uses, and their cost competitiveness is rising. The upfront costs of electric appliances, excluding labor, ancillary materials, ducting modifications, and potential electrical infrastructure upgrades, are approaching parity with gas appliances and, in some cases, are even more affordable. Appliance costs were examined using three primary sources, as shown in *Table 27*: (1) the U.S. Energy Information Administration (EIA), which reports on the costs of gas and electric appliances from studies by Guidehouse and Leidos, (2) Opinion Dynamics' Heat Pump Market Study, which covers some, but not all, gas and electric appliance costs (appliance types not included are marked as "Not Reported"), and electric appliance estimates from (3) Redwood Energy's A Pocket Guide to All Electric Retrofits of Single-family Homes, which were used to supplement the other electric appliance cost sources. As a result, gas appliance costs from the other two studies are listed as "Not Reported" for Redwood Energy.

Space Heating and Cooling

Ductless mini-split air-source heat pumps cost roughly half as much as mixed-fuel HVAC systems that combine a gas furnace with electric air conditioning. Available data indicate that ductless mini-split units range from $790 to $1,900, compared to $4,050 to $4,425 for combined gas furnace and central air systems. However, this apparent cost advantage can be misleading. Because ductless mini-splits are typically installed in each major room, a single home may require several units, which can quickly reduce or eliminate the upfront cost savings.

Standard air-source heat pumps show greater cost variability. Redwood Energy estimates these systems at $2,000 to $3,200, representing potential savings of up to $2,000 compared to purchasing separate gas furnaces and air conditioning units. However, EIA and Opinion Dynamics report higher ranges ($3,387 to $6,740), which exceed combined mixed-fuel system costs by over $2,000 in some cases. Notably, CARB staff, in their modeling for the Cap-and-Trade Program Standardized Regulatory Impact Assessment (SRIA), assume that when space heating equipment is replaced, the existing air conditioning unit retains 50% of its remaining useful life. This implies that anticipated savings from combined system purchases may not apply universally.

Water Heating

Heat pump water heaters (HPWH) have a wider range of equipment costs than their equivalent gas counterparts. These variations depend significantly on the size of the tank, with prices generally increasing with tank size. Proper sizing cannot be disregarded, and generally, it is recommended that HPWH tanks should be sized up from gas powered units that were previously in-place due to the longer recharge cycles associated with the technology. In the US EIA's reported data, cost ranges for both gas-fired storage water heaters and HPWH reflect this expected difference in unit capacity sizing (to achieve feature parity). The US EIA captures two classes of water heaters: smaller- and larger-sized. The cost-difference for smaller-sized water heaters is reported to be $210 more for heat pump water heaters, while the electric counterparts of larger-sized water heaters are roughly $450 more expensive.

Other End Uses

In terms of electric appliances for clothes drying and cooking, there are compelling electrical fueled options that can be cheaper than gas-fueled options with similar features and performance specifications. Electric cooktops can use either resistance heating elements, with comparable costs to gas-fueled ranges, or more advanced induction heating elements, which are generally more expensive than gas alternatives at this time. Heat pump clothes dryers, though more energy-efficient and gentler on fabrics, cost approximately twice as much as gas dryers, contributing to limited market demand and retail availability.

Table 27. Equipment Unit Costs for Single-family Homes

End Use	*Appliance Type*	*Appliance Cost (2022)*

		US EIA[36]	*Opinion Dynamics*[37]	*Redwood Energy*[38]
HVAC	Natural Gas Furnace	$1,200	$1,575	Not Reported
	Gas-fired Boilers	$2,890	Not Reported	Not Reported
	Central Air Conditioners	$2,850[39]	Not Reported	Not Applicable
	Air Source Heat Pump	$3,970 - $6,740	$3,387	$2,000 - $3,200
	Portable Air Source Heat Pumps	Not Reported	Not Reported	$575 - $670
	Ductless Mini-split Air-source Heat Pumps	$1,580	Not Reported	$790 - $1,900[40]
Water Heating	Gas Tankless	Not Reported	$1,484	Not Reported
	Gas-fired Storage Water Heaters	$420 - $990	Not Reported	Not Reported
	Heat Pump Water Heater	$630 - $1,440	$700 - $3,250	$1,200 - $2,600
Clothes Dryer	Gas Clothes Dryer	$670	Not Reported	Not Reported
	Heat Pump Clothes Dryer	$980	Not Reported	$1,000 - $1,900
	Electric Resistance Dryer	$580	Not Reported	$400 - $700
Cooking	Gas Range	$770	Not Reported	Not Reported
	Induction Range	$630[41]	Not Reported	$1,000 - $7,499
	Electric Resistance Range	$630	Not Reported	$650

Rows in grey are gas-fueled appliances or used as part of a dual-fuel system.

Installation and Integration Costs

The cumulative total installed cost of an electrification project can comprise several different elements, some of which may not be necessary in all contexts. The items included in *Table 28* reflect some of the most common ancillary costs associated with

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[36] US Energy Information Administration (EIA), “Updated Buildings Sector Appliance and Equipment Costs and Efficiencies” (2023), p. 6, available at https://www.eia.gov/analysis/studies/buildings/equipcosts/pdf/full.pdf.

[37] Opinion Dynamics, CPUC, “California Heat Pump Residential Market Characterization and Baseline Study," supra.

[38] Redwood Energy, "Redwood Energy's Pocket Guide to All-Electric Single-family Retrofits" (2022), supra.

[39] Estimated for South (Hot-Dry and Hot-Humid) climate region in EIA.

[40] Price range given for ductless mini-split air source heat pumps of smaller capacity (under 24 kBTu/h) to match capacity reflected in EIA estimate.

[41] This is likely an underestimation of induction range equipment costs given the US EIA methodology. The US EIA cost estimates were based on DOE rulemaking data for the most representative product class: electric smooth cooking tops. This category includes both cooking tops with electric resistance heating elements and those with induction heating elements. Induction cooking tops, being a higher-end option, are expected to have higher retail equipment costs as well as increased installation costs due to the need for specialized technology.

new electrical appliance installation and integration. These costs, over and above the upfront appliance purchase price, are typically captured in, but not explicitly itemized by, available studies on the total installed costs of electrification projects.

Table 28. Common ancillary expenses associated with zero-emission air and water heating appliance installation projects within the existing residential building sector.

Issue	*Solution*[42]	*Cost Range*[43]	*Likelihood*
Insufficient interior space for equipment installation (Heat-pump Hot Water Heater specific)	Relocate the water heater in a new indoor location in the main structure	Difficult to express in monetary terms	Moderate
	Build new weatherized enclosure external to the main structure and run insulated water service lines back into the main structure	$5,000 - $20,000+ (Highly variable - depends significantly on the site context)	Low
Insufficient exterior space for equipment installation (Heat-pump HVAC specific)	Affix condenser unit to wall mounted bracket	$300 - $500	Moderate
	Affix condenser unit to roof mounted platform	$500 - $800	Moderate
Insufficient duct size to provide adequate airflow (Ducted Heat-pump HVAC specific)	Ductwork modification or replacement	$900 - $6,000 (Depends on extent of modification and if it includes insulation upgrades or complete replacement)[44,45]	Moderate
No available electrical outlet	Install new 120V wall outlet	$250 - $500	Very High
	Install new 240V wall outlet	$500 - $1,200 (Depends on breaker amperage/wire gauge ratings)	Very High
	Hard-wire appliance to a dedicated breaker on the main panel	$300 - $800 (Depends on breaker amperage/wire gauge ratings)	Very High
Insufficient panel breaker slots	Upgrade electrical service panel - without upsizing amperage capacity	$1,000 - $3,000 (Depends on pre-existing panel capacity rating/size)	Moderate
	Install new sub-panel	$800 - $2,000 (Depends on sub-panel capacity rating & number of breaker slots)	Moderate
Insufficient panel	Upsize electrical service panel	$3,000 - $5,000+	Low

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[42] Proposed solutions exclude complex panel optimization strategies that could involve an array of different technologies, installed in different configurations, depending upon site specific needs.

[43] Rough order of magnitude costs associated with labor and materials.

[44] High end estimates from Frontier Energy & Misti Bruceri & Associates, "2022 Cost-Effectiveness Study: Existing Single-family Residential Building Upgrades" (2022), pp. 22, available at: https://localenergycodes.com/content/resources.

[45] Low end estimates from E3, "Residential Building Electrification in California" (2019), pp. 59, available at: https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf

Issue	*Solution*[42]	*Cost Range*[43]	*Likelihood*
amperage capacity	amperage capacity		
Insufficient utility service capacity	Upsize utility distribution service capacity	$5,000 - $40,000+ (Highly variable - depends on the need for sub-surface trenching as well as upstream hardware upgrades to feeder circuit conductors & transformers)	Low
Permitting and related fees	Submit required plans, pay required permitting fee, be present for local code officer inspection following completion of work	$200 - $400+ (Highly variable - many contractors bill by the hour for permitting related time and expenses and costs typically increase with a project size)	Moderate
Miscellaneous needs	Cap existing gas service line, patch / fill drywall holes	$100 - $500	High

There are a few features worth noting relative to the *Table 28* above. The first is that the issues/solutions documented above do not include emerging panel optimization strategies due to their uncertain costs and heterogeneous nature. Second is that many of the quoted cost ranges are not based upon formal cost study data, as most published data sources do not itemize these types of miscellaneous expenses to this level of detail. As such, dollar amounts lacking a specific source reference have been derived from more anecdotal conversations with contractors and practitioners and have been included to depict the rough order of magnitude relative to overall project costs. It is worth noting that the various solutions mentioned in this table do not only involve electrical contractors but also potentially other trades including plumbers, carpenters, roofers, and general contractors. Finally, an important, yet difficult to quantify source of cost that is not accounted for here relates to the customer's time, which must be spent managing the logistical complexity of a project (i.e., soliciting bids, coordinating schedules, overseeing work, etc.).

Total Installed Costs

Estimating total installed costs for electrification retrofits presents challenges due to limited sample sizes and reliance on modeled data. The TECH Clean California dataset provides rare empirical insight, encompassing all contractor-completed projects with associated rebates. While the dataset lacks explicit cost breakdowns for labor and ancillary elements, it offers a valuable perspective on statewide electrification project cost distributions.

Figures 19 to *22* below illustrate the comparison across three widely cited studies for single-family and multi-family retrofits: Opinion Dynamic's California Heat Pump Residential Market Characterization and Baseline Study,[46] E3's Residential Building Electrification in California Study,[47] which captures average costs across different

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[46] Opinion Dynamics, Tierra Resource Consultants, Mitchell Analytics, California Public Utilities Commission (CPUC), "California Heat Pump Residential Market Characterization and Baseline Study" (2022), available at: https://opiniondynamics.com/wp-content/uploads/2022/06/OD-CPUC-Heat-Pump-Market-Study-Report-f.pdf.

[47] Energy+Environmental Economics (E3), "Residential Building Electrification in California" (2019), available at https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf

building vintages and climate zones, and the Local Energy Codes Cost-Effectiveness Study for Single and Multifamily Residential Building Upgrades,[48] which captures total installed cost between different energy efficient appliance models. The TECH data includes the median and interquartile range for retrofits with and without panel upgrades, while both Opinion Dynamics and Local Energy Codes' studies do not include panel upgrades in their estimates. While E3's report includes estimates for panel upgrades, they are only included for some building vintages. TECH program cost figures are generally higher than existing comparable literature cost estimates. For single-family ducted heat pumps for example, the median installed cost without a panel upgrade under the TECH program is nearly $20,000, which is more than $3,000 greater than the nearest study's estimate (E3). While the TECH ductless mini-split heat pumps project cost range was considerably lower than E3's estimate, this equipment type accounted for the smallest proportion of TECH's space heating projects. Ducted heat pumps were the most common end-use incentivized through TECH in single-family homes, accounting for nearly half of all observations in the dataset and over ten times more than any other space heating equipment type for single-family homes.

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[48] Frontier Energy, Misti Bruceri & Associates, "2019 Cost-Effectiveness Study: Existing Single-family Residential Building Upgrades, California Energy Codes and Standards" (2019). Available at https://localenergycodes.com/content/resources and Frontier Energy, Inc., Misti Bruceri & Associates, LLC, "2019 Cost-Effectiveness Study: Existing Multifamily Residential Building Upgrades, California Energy Codes and Standards" (2019). Available at https://localenergycodes.com/content/resources.

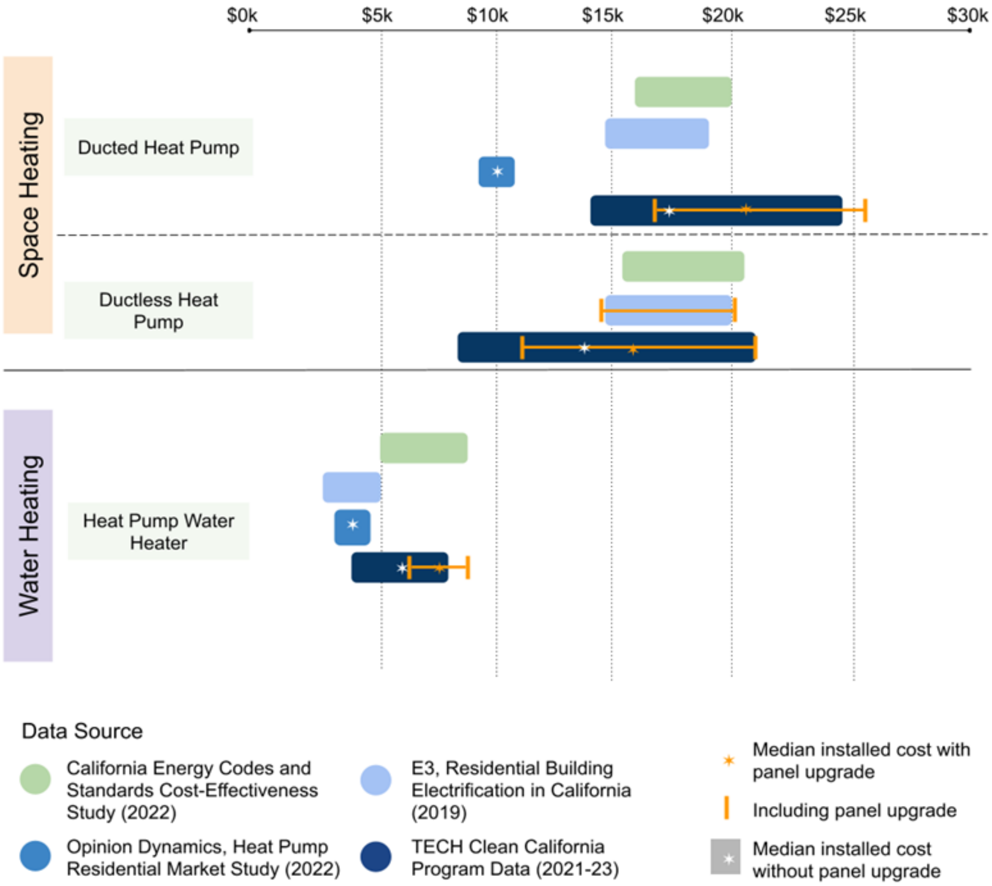

Figure 19. Total Residential Installed Costs for Single-family Buildings

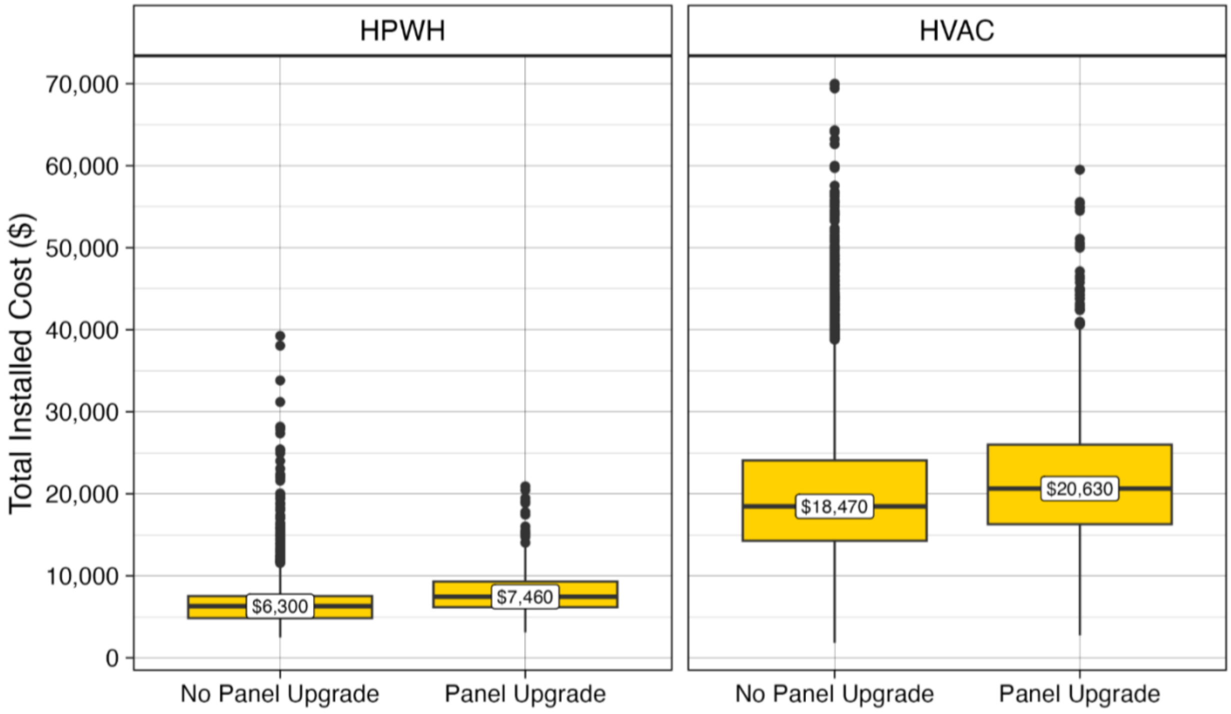

Figure 20. Total Residential Installed Costs for Single-family Buildings by End-Use and Panel Upgrade (TECH Clean California 2021-2023)

Although the median cost of multi-family installations under the TECH program do not appear significantly different from the reviewed studies' estimates, TECH's costs only capture project expenses borne by the occupant of each individual dwelling unit, while it is unclear whether the other studies' estimates are for the entire project or individual units (*Figure 21 and Figure 22*).

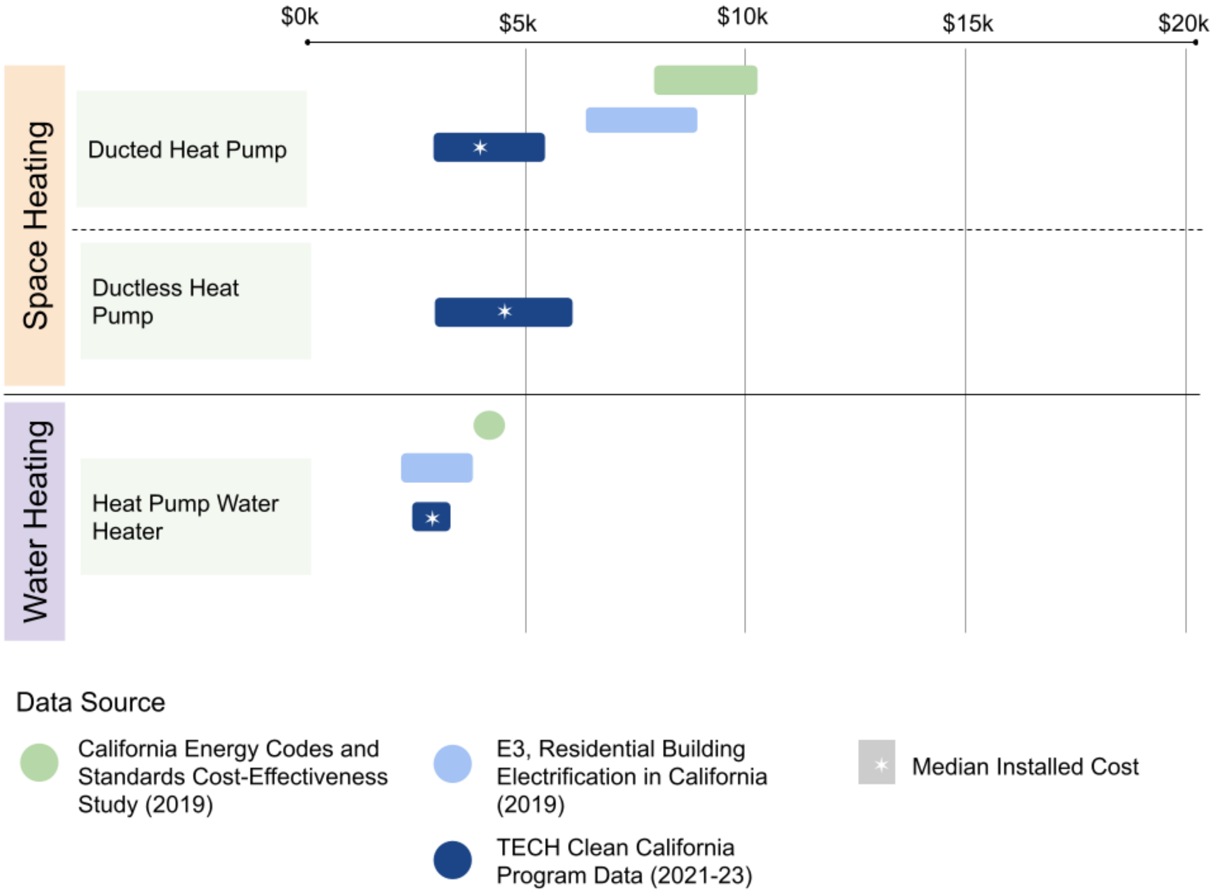

Figure 21. Total Installed Costs for Multifamily Buildings per Dwelling Unit

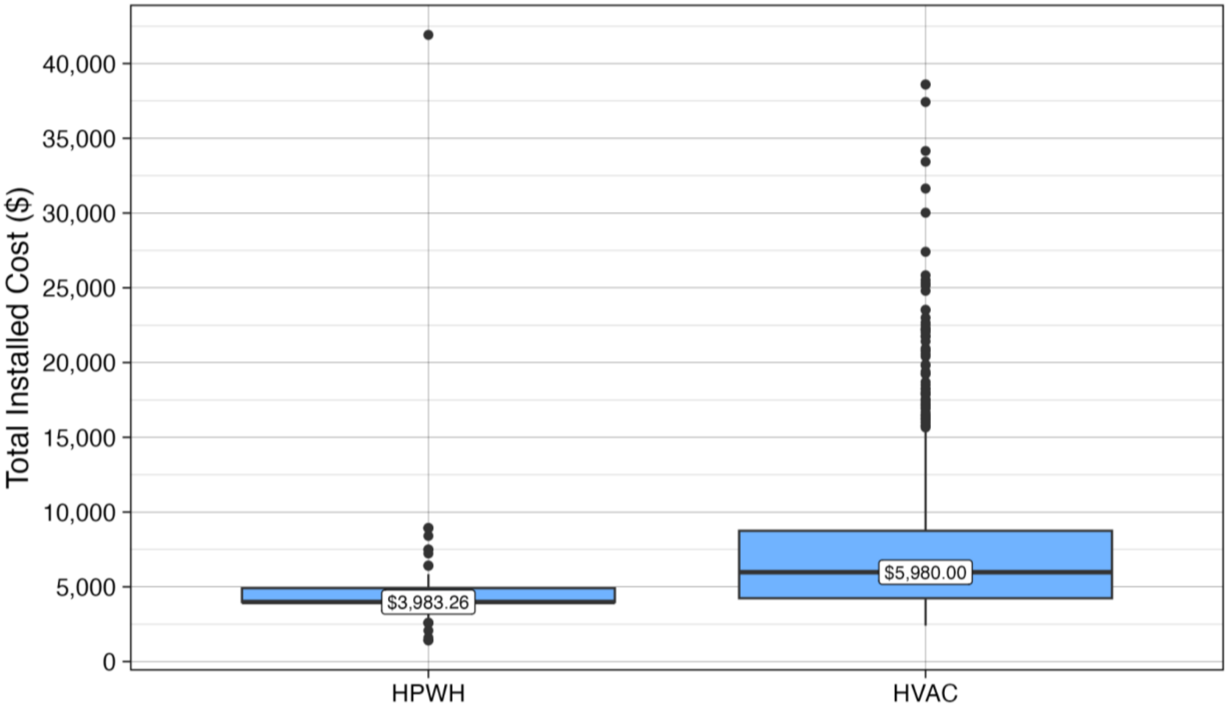

Figure 22. Total Residential Installed Costs for Multifamily Buildings per Dwelling Unit by End-Use (TECH Clean California 2021-2023)

Panel upgrades did not dramatically alter median installed costs in the TECH data. However, only 5.7% of single-family projects (1,417 of 24,711) and 0.4% of multi-family projects (106 of 265) included panel upgrades. These low percentages may indicate that either most buildings did not require panel upgrades, or that customers facing high panel upgrade costs chose not to proceed despite available incentives. The latter scenario suggests potential selection bias in completed TECH projects, with costs including panel upgrades potentially exceeding upper quartile estimates by a substantial margin.

Time disparities between studies partially explain cost differences. With the exception of Opinion Dynamics' 2022 single-family report, most cited reports date to 2019. In contrast, TECH program participation data spans from 2021-2023. California electrification costs likely increased during this period due to inflation and documented supply chain challenges related to the COVID-19 pandemic and, more recently, international trade tariffs. Within the TECH data, median single-family installed costs (excluding panel upgrades) increased over $3,000 between 2022 and 2023 for HVAC appliances, while the numbers of claims remained approximately the same in both years. This increase may reflect higher appliance costs from premium options entering the market or rising installation costs from project-specific requirements. Notably, Opinion Dynamics' 2022 study lists single-family retrofit costs significantly below TECH's lower quartile cost range, suggesting recent studies may underestimate actual costs while also highlighting temporal cost evolution or the possibility of markup on install costs due to the presence of incentives.

Structural Cost Drivers

TECH Clean California's project cost data was further examined to assess whether building vintage or location in an equity priority community were significant cost drivers. TECH uses three categories for equity priority: TECH Equity Community designation; SB-535 CalEnviroScreen disadvantaged community *and* TECH Equity Community designation; and no equity priority community status.

Previous studies, such as E3's Residential Building Electrification study, differentiated between three building vintages: pre-1978, 1990, and new construction. The study assumed older building vintages (pre-1978) would require a panel upgrade. Several of these relationships were tested, with the results summarized in *Table 29*. The most striking finding was that retrofits of older building vintages in the TECH program were more likely to include a panel upgrade for both multi-family and single-family buildings, though the effect for single-family homes was notably smaller. This suggests that while building vintage may influence the probability of a panel upgrade, there are other relevant factors. For example, permit data review indicates single-family panel upgrades often serve purposes beyond the electrification of existing gas appliances (such as for the installation Level 2 EV charging), potentially diluting vintage as a predictor. Alternatively, this pattern may indicate selection bias—customers with prohibitively high panel upgrade costs may decline to proceed with projects.

When examining the impact of building vintage on total installed costs and controlling for equipment type, significant correlations were only observed for single-family projects, specifically for ductless mini-splits, heat pump water heaters, and packaged terminal heat pumps. Notably, all of these correlations were slightly negative. This indicates that although building vintage and equipment type can provide some insight into costs and panel upgrades, the relationships are weak, at least among TECH program data, and many other variables likely contribute to these outcomes. This is perhaps not surprising, given the advanced age of much of California's existing residential building stock relative to the anticipated service life-spans of originally installed electrical service panel and wiring hardware. Based upon these factors it is likely that many properties have already undergone at least one major round of electrical infrastructure upgrades since the time of their original construction.

Table 29. Summary of TECH Clean California Cost Driver Findings

Building Type	*Relationship*	*Analysis findings*
Single-family	Y = Panel Upgrade X_1 = Building Vintage Test = Logistic Regression	When the building vintage increases by one year, the log-odds of a panel upgrade decreases by 0.007867, holding all other variables constant, statistically significant. Older buildings are slightly more likely to have had a panel upgrade as part of a TECH project compared to newer buildings, but the effect is relatively small.
Single-family	Y = Panel Upgrade X_1 = Equity Status X_2 = Building Vintage	The interaction between equity status and building vintage does not have a statistically significant effect on the likelihood of requiring a panel upgrade. In other words, equity status does not substantially influence the relationship between building age and the need for a panel upgrade.

	Test = Logistic Regression	
Single-family	Y = Total Installed Costs X_1= Equity Status X_2 = Building Vintage Test = Linear Regression Model	No significant correlation was found between building vintage and total installed costs across different equity status categories. Building age does not appear to affect the overall installation costs for single-family homes.
Single-family	Y = Total Installed Costs X_1 = Building Vintage X_2 = Product Type Test = Pearson Correlation	The total installed cost for ducted mini-splits was slightly negatively correlated with building vintage (r = -0.038, p <1e05). The total installed costs for heat pump water heaters were slightly correlated with building vintage (r= -0.17, p<2.2e-16). The total installed costs for package terminal heat pumps were slightly correlated with building vintage (r=-0.087, p<4e-04). Ducted multi split, ductless mini-split, ductless multi split and small duct high velocity heat pumps had no significant correlation by building vintage on total installed cost. These weak correlations suggest that while building vintage can affect costs for certain products, it is not a strong predictor overall.
Multifamily	Y = Panel Upgrade X_1 = Building Vintage Test = Logistic Regression	As the year a building was constructed increases, the probability of a panel upgrade decreases. The relationship between building vintage and the likelihood of a panel upgrade is statistically significant (p<4.16e-10). For each additional year in building vintage, the odds of a panel upgrade are approximately 5.5% lower. The model suggests that as buildings get newer (with increasing year.built), the odds of needing a panel upgrade decrease.
Multifamily	Y = Panel Upgrade X_1 = Equity Status X_2 = Building Vintage Test = Logistic Regression	The interaction between independent variables of equity and building vintage does not have a statistically significant effect on the outcome of needing a panel upgrade.
Multifamily	Y = Total Installed Costs X_1= Equity Status X_2 = Building Vintage Test = Linear Regression Model	The interaction between independent variables of equity status and building vintage has a statistically significant effect on the dependent variable of total installed costs in multi-family projects. For every additional year vintage independent of equity status, the total installed cost decreases by $87.45 (p<1.34e-09). The difference in cost for multi-family projects that are categorized as both being DAC and TECH Equity relative to not being DAC or TECH Equity, is not statistically significant. Projects that are only listed as TECH Equity, are associated with much higher costs than those that are not DAC or TECH Equity (p<2e-16). The interaction between equity status and building vintage is only significant for TECH Equity Only equity status category (p<2e-16) indicating that the total installed cost decreases more rapidly with each additional year of building in the

		TECH Equity Only category.
Multifamily	Y = Total Installed Costs X_1 = Building Vintage X_2 = Product Type Test = Pearson Correlation	All product types had no significant correlation by building vintage on total installed cost.

Consumer Cost Considerations from Literature Review and Opinion Research

Previous research has identified multiple interconnected financial barriers affecting residential electrification adoption, with distinct impacts across different population segments. This section synthesizes findings from existing literature alongside qualitative data from renters—particularly those in disadvantaged communities who face heightened barriers due to split-incentive problems—and multi-family property owners who have undertaken electrification projects.

The net impacts of implementing different electrification measures on customers' combined gas and electricity utility bills can vary considerably. While electric appliances are generally more efficient than gas alternatives, several factors influence net costs, including marginal changes in electricity rates and the introduction of new end-use services. For example, households installing air conditioning for the first time will face higher electricity bills regardless of the appliance's efficiency, simply as a consequence of its use. Renter survey respondents who pay their own utilities consistently reported that their gas bills are substantially lower than electricity bills: 47% paid $50 or less monthly for natural gas compared to just 12% for electricity. This disparity translates into heightened cost anxiety, with 31% of participants expressing extreme concern about electricity bill affordability versus only 20% for natural gas bills (*Figure 23)*. These existing perceptions of electricity as more expensive create additional resistance to electrification among renters. The difference between electric and gas bill concern was statistically significant only at the extremes: respondents were significantly more likely to be extremely concerned about their electric bill (+11 pp, $p<0.001$) and significantly more likely to be not concerned about their gas bill (+13 pp, $p<0.001$). The middle categories, very concerned and somewhat concerned, showed no significant difference between the two bills ($p=0.66$ and $p=1.00$, respectively).

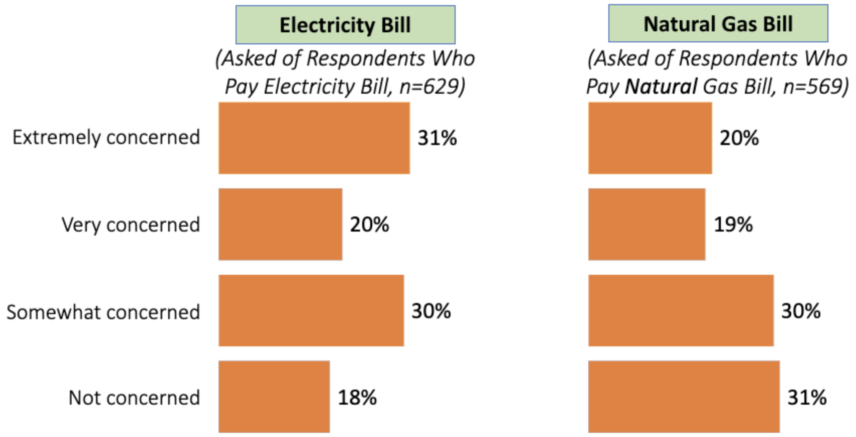

Figure 23. Renter Survey Results When Asked How Concerned They Are About Utility Bill

How electrification costs will ultimately be passed to renters remains uncertain and depends largely on housing laws governing rent increases from retrofits.[49] This concern is particularly acute because 70% of low-income Californians rent rather than own, and rent burdens have increased among a majority of households in recent years.[50] The limited affordable housing supply amplifies these concerns, as high upfront electrification costs could further reduce affordable housing availability by discouraging property owners from maintaining or developing affordable units. Survey data validated these cost concerns as decisive. Among renters who were initially interested in switching to electric appliances, approximately four-in-ten remained willing at a $75 monthly increase, while nearly all would accept just $5 more per month. Notably, potential savings proved less motivating: a $75 monthly savings enticed only slightly over half to consider switching, with just one-in-five expressing strong willingness (*Figure 24*). This asymmetry between cost sensitivity and savings responsiveness suggests that loss aversion and uncertainty about electrification benefits may impede adoption even when long-term economics are favorable.

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[49] Scavo et al., op. cit.; Greenlining Institute & Energy Efficiency for All, op. cit.; Nelson, H. & Gebbia, N. (2018). *Cool or school?: the role of building attributes in explaining residential energy burdens in California*. Energy Efficiency, 11, 2017-2032; French, E., op. cit.; Jones, B., et al. (2019). *California Building Decarbonization: Workforce Needs and Recommendations*. UCLA Luskin Center for Innovation & Inclusive Economics. https://innovation.luskin.ucla.edu/california-building-decarbonization/; Aitchinson, J., et al., op. cit.; Inclusive Economics (2021). *Los Angeles Building Decarbonization. Equity concerns, employment impacts, and opportunities. https://www.nrdc.org/sites/default/files/los-angeles-building-decarbonization-jobs-impacts-report-20211208.pdf*; Center for Sustainable Energy (2018). *Social Science Research: Latino Homeowners and Energy Efficiency Retrofits. https://sites.energycenter.org/program/social-science-research-latino-homeowners-and-energy-efficiency-retrofits*; Building Decarbonization Coalition (2020). *Decoding Grid Integrated Buildings Report. https://gridworks.org/wp-content/uploads/2020/02/Decoding-Grid-Integrated-Buildings_WEB.pdf*; Harwood, M., et al., op. cit.; Im, J., et al. (2017). *Energy efficiency in the US residential rental housing: Adoption rates and impact on rent.* Applied Energy, 205, 1021-1033; Melvin, J. (2018). *The split incentives energy efficiency problem: Evidence of underinvestment by landlords*. Energy Policy, 115, 342-352; Frank, M. & Nowak, S. (2016). *Who's Participating and Who's Not? The Unintended Consequences of Untargeted Programs*. ACEEE Summer Study on Energy Efficiency in Buildings. https://www.aceee.org/files/proceedings/2016/data/papers/2_542.pdf.

[50] Scavo, J., et al., op. cit.

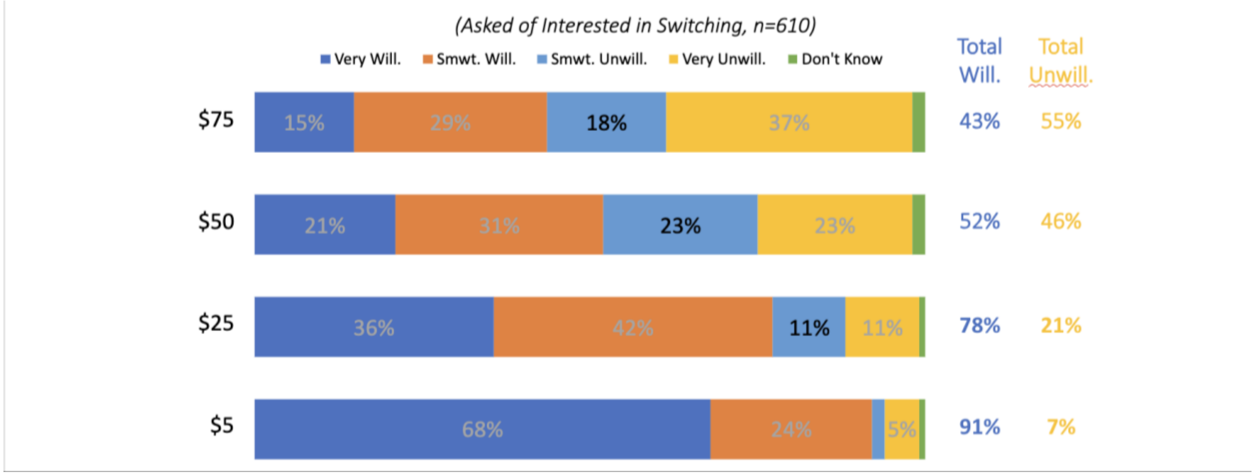

Figure 24. Renter Survey Results When Asked How Much They Are Willing To Pay Monthly To Switch

Even when renters have the ability to pursue electrification, limited access to funding remains a significant barrier—especially for low-income households. Property owners, while typically having greater access to capital, do not necessarily choose to invest. As a result, the split-incentive problem plays a central role in determining both who benefits and how decisions are made in renter-occupied housing.

Property owners were unanimous in their survey responses in saying that electrification projects must make financial sense to proceed, with cost-neutrality prioritized over environmental or tenant benefits. Participants explained that projects needed to benefit building owners financially through reduced owner-paid utility bills, improved building marketability, or opportunities to fund necessary repairs. Several large affordable housing providers exclusively pursued projects that saved building owners money—such as electrifying common spaces or water heating systems that owners pay for—rather than projects that reduced only tenant costs. Even with available incentives, these providers remained unmotivated to pursue electrification that benefited tenants without reducing owner expenses, illustrating how the split-incentive problem operates in practice.

Given these financial dynamics, incentives play a deciding role. Nearly every owner who completed electrification in existing buildings stated they would not have proceeded without incentives in place to ensure their financial viability. Incentives often enabled projects by covering already-planned upgrades, such as replacing aging equipment, making electrification financially feasible when it coincided with necessary repairs or appliance retirement.

However, multiple barriers impede effective incentive utilization. Insufficient knowledge of existing program offerings leaves many owners unaware of available funding. Rapid depletion of incentive funds within many programs forces some to abandon projects after the initial planning phase. Complicated, time-consuming application processes deter participation, particularly among smaller property owners. The structure of rebate programs also creates obstacles: several participants noted that rebates are not provided upfront, and despite available incentives, they could not afford to pay contractors and await reimbursement. Some small building owners avoided incentive programs altogether, believing applications took too long or that approved contractor costs exceeded the value of incentives.

Most critically, even when accessible, incentives often prove insufficient. Nearly all participants cited inadequate funding as the primary obstacle to project completion, with infrastructure upgrades like increasing electrical capacity representing the most commonly cited unfunded need. These electrical panel and service upgrades are frequently necessary prerequisites for electrification but remain poorly covered by incentive programs. This gap has led some owners to abandon or substantially scale back their electrification plans, even when motivated to proceed.

3.1.4 - Residential End Use Electrification Trends

National Heat Pump Adoption Trends

The most recent published peer reviewed academic literature on state-level heat pump adoption trends throughout the U.S. comes from researchers at the University of California Berkeley's Haas Energy Institute.[51] Their work is based upon analysis of 2020 vintage data published by the U.S. Department of Energy's (DOEs) Residential Energy Consumption Survey (RECS). As their findings shown in *Figure 25* illustrate, California was found to lag significantly behind other states throughout the country in terms of the proportion of existing households using heat pumps as their primary heating system. This study estimated there to be ~500,000 total households with heat pumps installed in California as of 2020.

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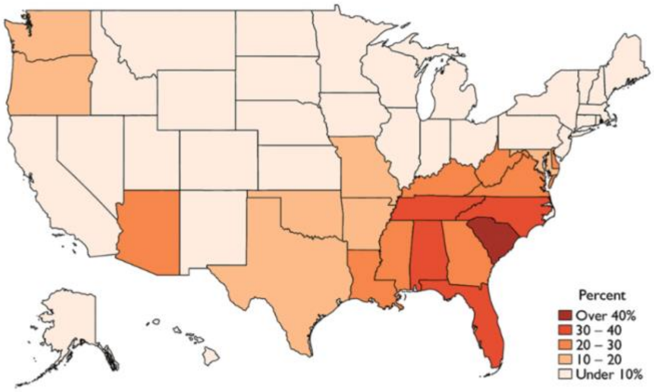
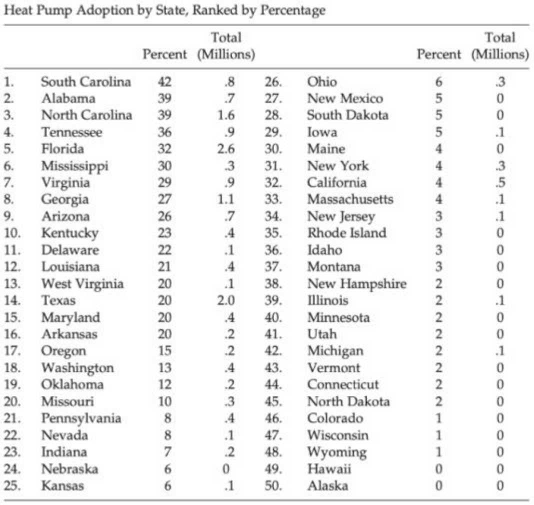
[51] Davis, Lucas W. "The economic determinants of heat pump adoption." *Environmental and Energy Policy and the Economy* 5, no. 1 (2024): 162-199.





Heat Pump Adoption by State, Ranked by Percentage

		Percent	Total (Millions)			Percent	Total (Millions)
1.	South Carolina	42	.8	26.	Ohio	6	.3
2.	Alabama	39	.7	27.	New Mexico	5	0
3.	North Carolina	39	1.6	28.	South Dakota	5	0
4.	Tennessee	36	.9	29.	Iowa	5	.1
5.	Florida	32	2.6	30.	Maine	4	0
6.	Mississippi	30	.3	31.	New York	4	.3
7.	Virginia	29	.9	32.	California	4	.5
8.	Georgia	27	1.1	33.	Massachusetts	4	.1
9.	Arizona	26	.7	34.	New Jersey	3	.1
10.	Kentucky	23	.4	35.	Rhode Island	3	0
11.	Delaware	22	.1	36.	Idaho	3	0
12.	Louisiana	21	.4	37.	Montana	3	0
13.	West Virginia	20	.1	38.	New Hampshire	2	0
14.	Texas	20	2.0	39.	Illinois	2	.1
15.	Maryland	20	.4	40.	Minnesota	2	0
16.	Arkansas	20	.2	41.	Utah	2	0
17.	Oregon	15	.2	42.	Michigan	2	.1
18.	Washington	13	.4	43.	Vermont	2	0
19.	Oklahoma	12	.2	44.	Connecticut	2	0
20.	Missouri	10	.3	45.	North Dakota	2	0
21.	Pennsylvania	8	.4	46.	Colorado	1	0
22.	Nevada	8	.1	47.	Wisconsin	1	0
23.	Indiana	7	.2	48.	Wyoming	1	0
24.	Nebraska	6	0	49.	Hawaii	0	0
25.	Kansas	6	.1	50.	Alaska	0	0

Figure 25. Reproduced from (Davis, 2024) depicting heat pump adoption by state. Notes: This map plots the percentage of households in each state that have a heat pump as their primary heating equipment. These data come from RECS (2020). Households are weighted using RECS sampling weights. [52]

More recent estimates from 2022, published by HARDI, a trade association for major heat pump manufacturers and distributors, place the total number of California households with installed heat pumps at ~800,000. Though it is important to note that these HARDI figures were not published in a peer reviewed journal with documented data sources and methods. Taking both of these market penetration figures at face value would suggest that, although there has been encouraging recent growth in the uptake of heat pump technologies throughout California within recent years, the market has not yet entered the phase of mainstream adoption.

According to standard technology diffusion theory, heat pumps, like many other types of new consumer technologies, would be expected to gain market share over time according to a sigmoidal growth pattern similar to that plotted in yellow in *Figure 26* below. Such a growth pattern implies the bell shaped curve of marginal adoption rates that is depicted in blue. This is commonly known as Rogers' Curve for the pioneering work of Everett Rogers, whose socio-technical theory developed labels for different characteristic classes of consumers on the basis of the timing of their adoption, as shown. Generally, *Mainstream* adoption can be said to have begun to occur once a technology achieves ~34% market share. Prior to this, the majority of adopters can either be described as either *Innovators* who are "willing to take risks, have the highest social status,... financial liquidity, are social and have closest contact to scientific sources and interaction with other innovators" or *Early Adopters* who "have the highest degree of opinion leadership,...higher social status, financial liquidity, advanced education and are more socially forward than late adopters."

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[52] Davis, Lucas W. "The economic determinants of heat pump adoption." *Environmental and Energy Policy and the Economy* 5, no. 1 (2024): 162-199.

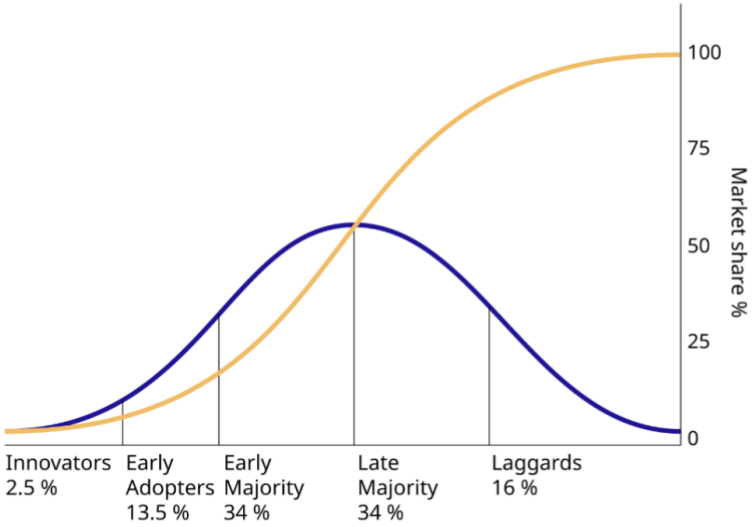

Figure 26. The diffusion of innovations according to Rogers. With successive groups of consumers adopting the new technology (shown in blue), its market share (yellow) will eventually reach the saturation level. The blue curve is broken into sections of adopters. [53]

Drivers of Heat Pump Adoption

One of the more interesting findings from the 2024 study by Davis is that, nationally, heat pump adoption rates do not appear to be as significantly correlated with household income levels than other types of high-efficiency or renewable energy technologies. This is demonstrated by the plots contained in Figures 27 and 28 below, reproduced from the paper, which show adoption rates for various technology segments binned by household income level using RECS data. Building off of this insight, results from a regression analysis indicate that local electricity rates as well as climatic conditions (numbers of heating and cooling degree days) were actually the two strongest predictors of heat pump adoption rates at the state level. Though here it is important to recognize that in many states, particularly in the south-east, utility gas service is not widely available. And thus, rates of heat pump adoption could be significantly affected by the ready availability of sufficient electrical service and panel capacity within existing buildings. Overall, however, Davis' results suggest that consumer sentiments towards the technology are mostly focused on straightforward performance considerations and operating cost.

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[53] Rogers Everett - Based on Rogers, E. (1962) Diffusion of innovations. Free Press, London, NY, USA.

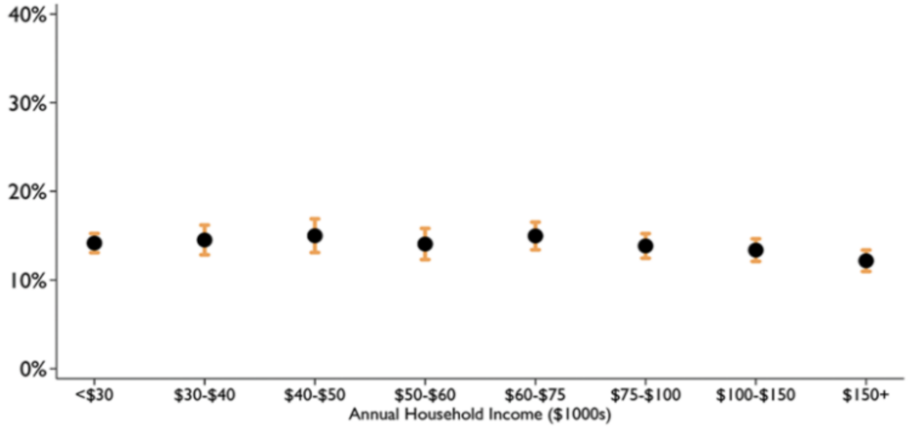

Figure 27. Heat pump adoption by household income level. [54]

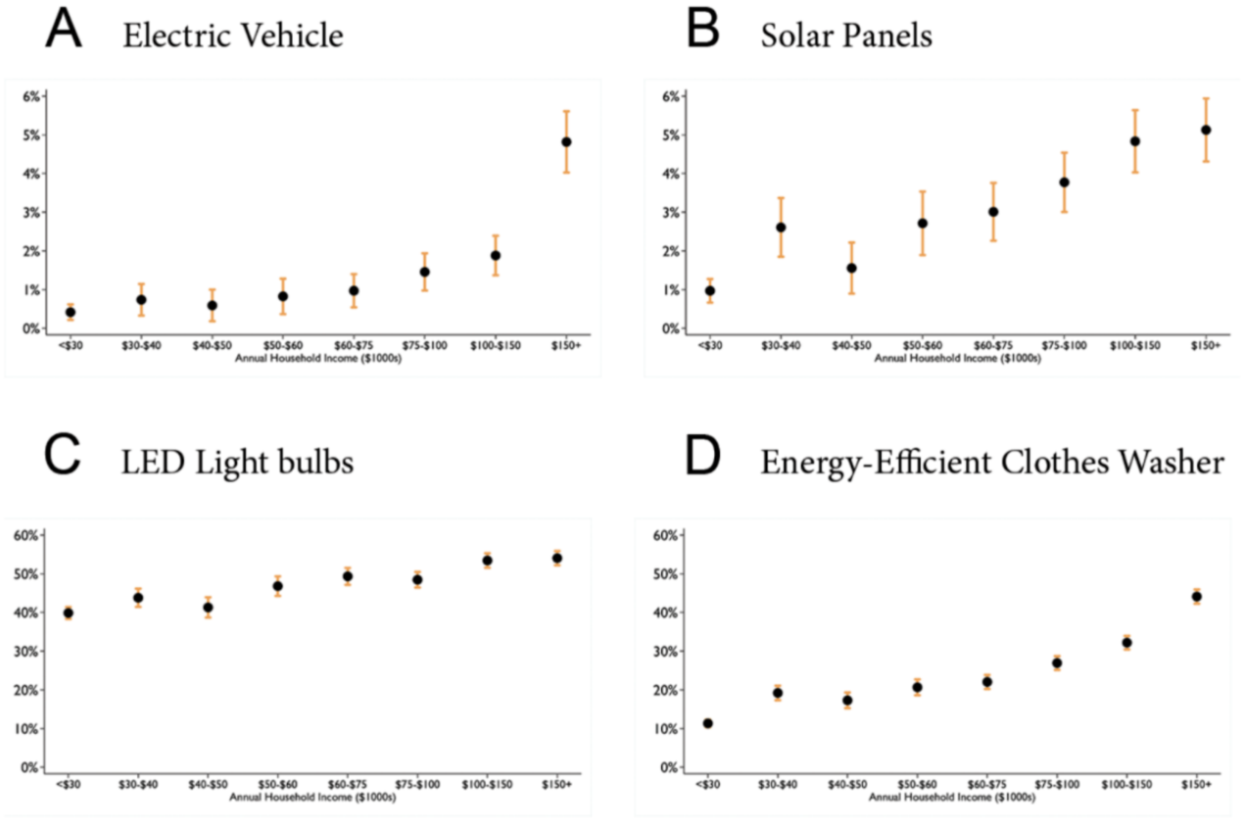

Figure 28. Adoption of other low-carbon technologies by household income. (A) Electric vehicles. (B) Solar panels. (C) LED light bulbs. (D) Energy-efficient clothes washer. [55]

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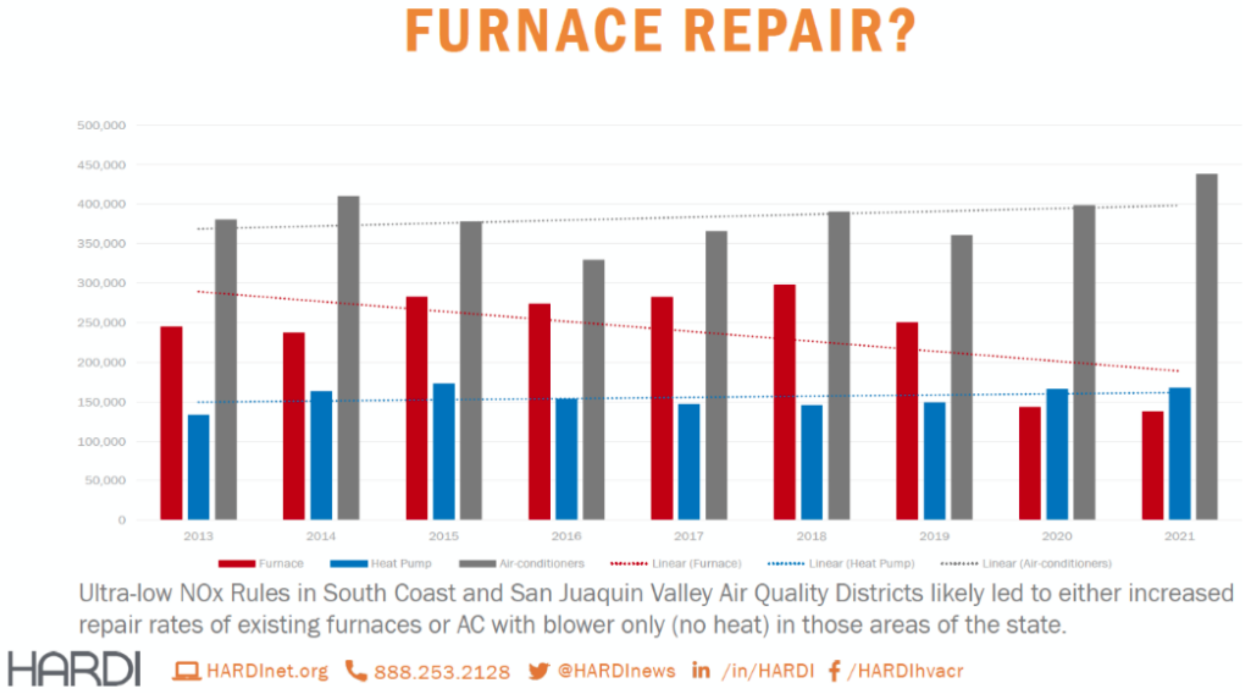
[54] Davis, Lucas W. "The economic determinants of heat pump adoption." *Environmental and Energy Policy and the Economy* 5, no. 1 (2024): 162-199.

[55] Davis, Lucas W. "The economic determinants of heat pump adoption." *Environmental and Energy Policy and the Economy* 5, no. 1 (2024): 162-199.

These findings have pros and cons within the context of California's current push to accelerate the electrification of space and water heating end-uses in the residential sector. A major pro is that the establishment of programs to provide financial incentives for heat pump adoption are unlikely to result in the same degree of biased participation as has been previously observed relative to other solar and EV financial incentives, for example. A major con, however, is that mainstream consumers are likely to be much more concerned about the implications of the state's already high, and recently increasing, electricity rates for the ongoing costs associated with operating new heat pump electrical equipment, despite their high coefficients of performance.

Changes in appliance adoption rates following the implementation of South Coast and San Joaquin Valley Air Quality Districts' ultra-low NOx rules provides a case study of California consumers' appliance preferences. In HARDI's 2022 presentation to the California Energy Commission *Figure 29* they illustrate the decline of furnace sales since 2019 as a result of the districts' regulations. However, heat pump sales do not increase in the absence of new furnace sales. HARDI suggests that this may be due to either increased repair rates of existing furnaces, prolonging the useful life of the appliance to avoid an electric alternative, or the elimination of heating (electing for an AC with blower only) in those areas.


FURNACE REPAIR?

Ultra-low NOx Rules in South Coast and San Juaquin Valley Air Quality Districts likely led to either increased repair rates of existing furnaces or AC with blower only (no heat) in those areas of the state.

Figure 29. Furnace, heat pump, and air-conditioner sales in California over time reported by HARDI.

California Heat Pump Adoption Trends

Based on findings from the CEC's longitudinal California Energy Consumption Database, the proportion of residential electricity fuel share (the proportion of electricity consumption to combined electricity and gas consumption) has been increasing, as overall electricity consumption has increased and gas consumption has declined.[56] This is a useful, albeit imperfect metric, given that year-to-year fluctuations in energy consumption are highly dependent on interannual changes in weather conditions and economic activity. This may signal that households are adopting more electric end-uses (including air conditioning installation, electrification of existing gas appliances, and all- or more-electric new construction) or are relying more on electricity-powered appliances as opposed to gas.

Data on specific end-use electrification is limited; the most up-to-date estimates for clothes drying, cooking, water heating and space heating end-uses from surveys such as the American Housing Survey[57] and the Residential Appliance Saturation Survey[58] are from 2019. The American Community Survey (ACS) provides the most up to date measure of space heating electrification (2022). While the US Energy Information Administration's Residential Energy Consumption Survey (RECS) 2020 study captures detailed statistics on electric appliance adoption in its microdata, it is limited by its smaller sample size (18,500 for the entire country) and less up-to-date data year.

According to the ACS' estimates, approximately 4.1 million households in California were using electric space heating as their primary heating fuel in 2022, with only 540,079 additional households adopting electric space heating since 2015.[59] The 2023 ACS 1-Year Estimate noted no significant difference from the 2022 estimate within the margin of error. Meanwhile, the RECS estimated there to be ~500,000 total households with heat pumps installed in California as of 2020. More recent estimates from 2022, published by Heating, Air-Condition and Refrigeration Distributors International (HARDI), a major heat pump manufacturer and distributor trade association, place the total number of California households with installed heat pumps at ~800,000. Placing these estimates within the context of the ACS' 2022 household estimates, heat pumps make up between ~12 to 20% of electric heating end-uses.

Though overall electrification of space heating is modest, demographic, and building type adoption trends illustrate the composition of census tracts in which there has been significant electrification progress over the last decade. Relying on the American Community Survey once again, a Welch's t-test was conducted at the 0.01 significance level, while adjusting for unequal variances, examining the relationship between building characteristics (multi-family buildings and building vintage), income, and race and electric space heating adoption between 2017 5-year ACS and 2022 5-year ACS *(Table*

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[56] California Energy Commission. California Energy Consumption Database. Residential Gas and Electricity Consumption (1990 - 2022). Available at: https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/california-energy-consumption-dashboards-0

[57] U.S. Census Bureau. (2024). American Housing Survey for California (2015, 2017). Available at: https://www.census.gov/programs-surveys/ahs.html.

[58] California Energy Commission. (2009, 2019). "Residential Appliance Saturation Survey" Available at: https://www.energy.ca.gov/programs-and-topics/programs/residential-appliance-saturation-survey.

[59] U.S. Census Bureau. (2024). *American Community Survey (2015 - 2022) Survey 1-year Home Heating Fuel Survey.* Retrieved from https://data.census.gov/table/ACSDP1Y2022.DP04

30). Consistent with Davis' findings,[60] heat pump adoption was not significantly different across different median household income levels.

Notably, only building type and building vintage revealed a significant difference in electric space heating adoption. More specifically, the proportion of households that use electric space heating in census tracts with a high proportion of residential buildings with 2 to 4 units, has declined, while electric heating appliance use in census tracts with a high proportion of single-family homes show no significant change between these two periods. This finding suggests that while single-family homes have maintained steady rates of electric heating fuel adoption, smaller multi-family buildings have experienced a decline, indicating that electrification efforts in the multi-family residential setting may face greater challenges and more robust efforts may be required to stimulate electrification adoption. Additionally, this change likely reflects a shift away from older resistance-based electrical heating systems and towards newer gas-powered furnaces.

Table 30. Results of Independent Samples t-test Between 2017 5-year ACS and 2022[61]

	Summary of results
DAC Status	There is no significant difference in the change in the proportion of heating fuel in households that are in the DAC census tract compared to households not in DAC census tracts.
Race	There is no significant difference in the change in the proportion of heating fuel in households by race.
% of earners in family	There is no significant difference in the change in the proportion of heating fuel in households by percent of earners in a family
Median Income	There is no significant difference in the change in the proportion of heating fuel in households by household median income within the Census Tract.
Building Type	Only households who live in buildings with 2 to 4 units have a significant difference in the change of electric space heating fuel. Households within tracts where multi-family 2- to 4 units are the majority are most likely to adopt gas heating end-uses instead of electric heating end-uses.
Building Vintage	All building vintages were significantly different between 2017 and 202 5-year ACS electric heating fuel proportion of electric space heating fuel except for 1980 to 1989. Households in building vintages before 1979 declined in electric space heating in 2022 compared to 2017.

3.1.5 - Consumer Preferences

There are numerous stakeholders within the building electrification space, and their relationships shape the knowledge, values, beliefs, and barriers around electrification and electrification adoption. The first examination of consumer preferences was conducted through a literature review, entailing a review of more than 80 publications. The review culminated in the identification of several gaps and the prioritization of two populations for more in-depth study: multi-family property owners and renters.

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[60] Davis, Lucas W. "The economic determinants of heat pump adoption." *Environmental and Energy Policy and the Economy* 5, no. 1 (2024): 162-199.

[61] U.S. Census Bureau. (2024). American Community (2017 and 2022) Survey 5-year Home Heating Fuel Survey. Retrieved from https://data.census.gov/table/ACSDP5Y2022.DP04

Overall, the literature suggests that consumer and installer levels of awareness about fuel-substitution technologies vary. Some studies indicate that consumers and installers both know them well[62], while others find that knowledge is more moderate.[63] Renters generally do not have the right to initiate renovations or retrofits and are therefore dependent on the owner's decisions. This includes most structural, equipment, or appliance upgrades.[64] Owners typically provide appliances but are not obligated to electrify. While some retrofit work may require renter permission, existing regulations often allow certain improvements to proceed with only renter notification, such as those under the Primary Renovation Work, Capital Improvement, Rehabilitation Work, and Seismic Retrofit Work programs. This can increase rent burden and risk of harassment.[65] Rental agreements also influence incentives for electrification. In master-metered buildings, utilities are often billed as part of rent rather than individually, meaning that the financial motivation to electrify individual units differs from individually metered units.[66] While some energy efficiency programs target rental properties, research shows they rarely benefit low-income tenants unless explicitly designed to do so.[67] Retrofitting can also increase rents, and current policies do not prevent landlords from passing retrofit costs onto renters. As a result, renters—especially low-income households—face higher energy burdens, financial stress, harassment, and potential displacement.[68]

Overall, few studies examined how owners, ranging from small "mom-and-pop" landlords to large corporate landlords, make electrification decisions. Key questions remain: who drives these decisions? What financial considerations are critical? Which policies or incentives are influential? And what funding mechanisms could prevent cost pass-through to renters? Concrete information on residential electrification costs, including utility impacts, is scarce. While some studies address decarbonization costs and incentives for low-income households, more research on perceptions of cost and affordability could better inform policy.

Gaps identified in the literature report were reviewed with Steering Committee members and used to shape the qualitative focus areas for the opinion research task. While not all gaps could be fully addressed within the scope of this project, two key areas were prioritized: (1) the experiences of renters—particularly those in disadvantaged communities—who face the greatest barriers to electrification due to the split-incentive problem, and (2) the perspectives of multi-family property owners, who manage housing for these renters and encounter high barriers to electrification because of the technical complexity of projects in multi-family buildings compared with single-family homes.

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[62] Miller, A., & Higgins, C., op. cit.

[63] Opinion Dynamics, op. cit.

[64] Samarripas, S., & Jarrah, A., op. cit.; Scavo, J., et al., op. cit.; McKibbin, A., op. cit.; ARUP, op. Cit.

[65] Scavo, J., et al., op cit.; ARUP, op. cit.; Kirk, C., op. Cit.

[66] Scavo, J., et al.; McKibbin, A., op. Cit.

[67] Samarripas, S., & Jarrah, A., op. cit.; ARUP, op. cit.; Chuang, Y., et al. (2022). Are Residential Energy Efficiency Upgrades Effective? An Empirical Analysis in Southern California. Journal of the Association of Environmental and Resource Economists, 9 (4).

[68] Mast, B., et al., op. cit.; Samarripas, S., & Jarrah, A., op. cit.; York, D., et al., op. cit.; Scavo, J., et al., op. cit.; McKibbin, A., op. cit.; Harwood, M., op. cit.; Nelson, H., & Gebbia, N., op. cit.; Im, J., et al., op. cit.; ARUP, op. cit.; French, E., op. Cit.

Renter Survey Findings

Survey findings on currently installed appliances found that natural gas and propane are commonly used to power a variety of household appliances, with some notable differences in consumer concerns and costs associated with these fuels. The most frequently used natural gas and propane appliances among the survey group included ovens, stoves, hot water heaters, and built-in heaters. The survey revealed that over half of respondents are open to replacing their current natural gas or propane appliances with electric versions if the switch comes at no additional cost (Figure 30). There was some variation by appliance type, but even for those with the lowest level of desire to change to electric versions (clothes dryers and range top), a plurality is open to switching if it comes at no cost. Hot water heaters had the largest amount of respondents having no opinion (38%) and only 40% wanting to switch. Overall, pluralities of renters are open to replacing all of the appliances tested in the survey, with the greatest willingness to switch to electric cooling and heating systems. Interest in switching to an electric stove was particularly surprisingly high with 46% interested compared to 27% not interested.

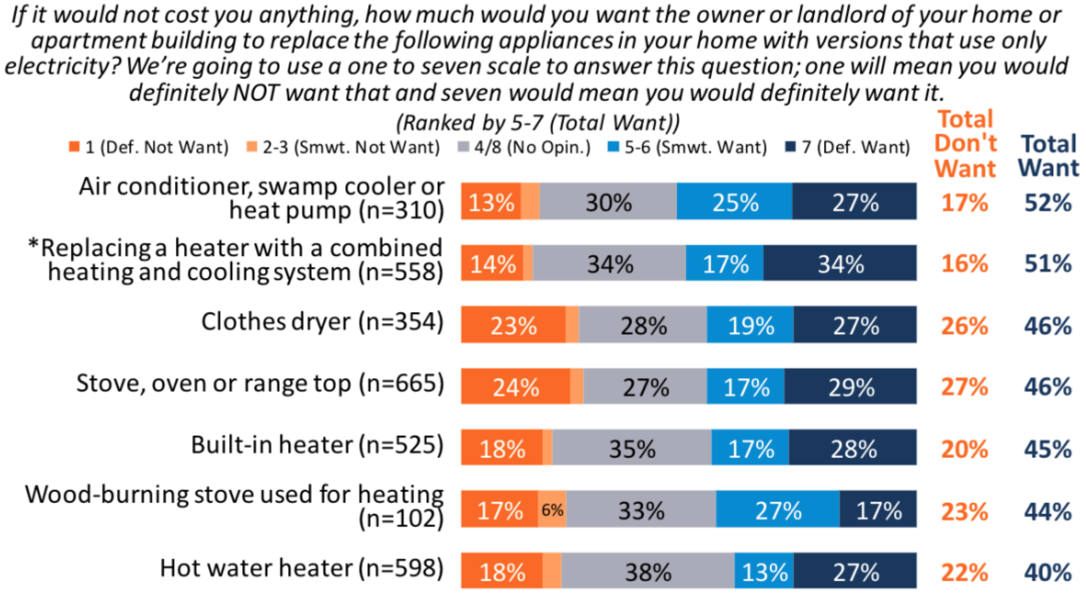
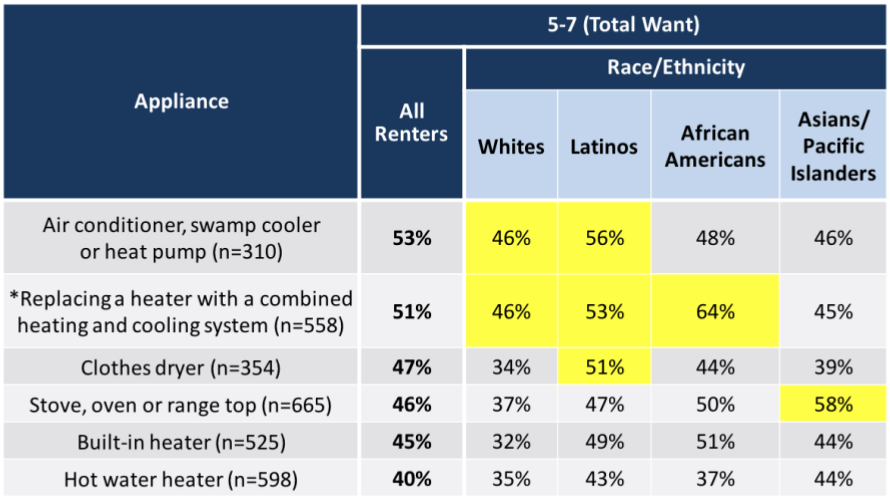


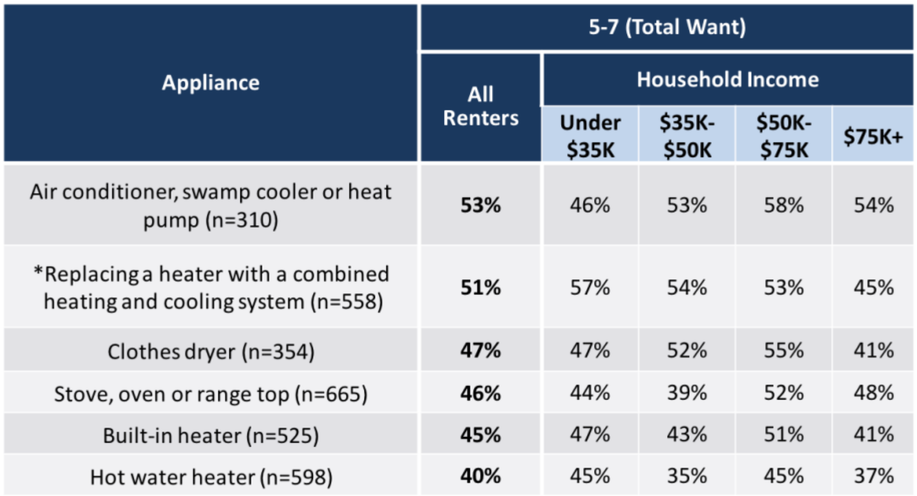
Figure 30. Survey results when participants are asked if they are interested in switching to electric appliances if it came at no cost.

Initial appliance attitudes varied by race, ethnicity, income and age. Latino respondents generally identified themselves as being more interested in switching to electric appliances than white respondents, with responses from African American and Asian/Pacific Islander respondents varying more by appliance type (*Figure 31)*. A slightly higher percentage of households with annual incomes between $50,000 and $75,000 expressed interest in switching to electric appliances across the board (*Figure 32)*. However, the exception was the combined replacement of heating and cooling systems, for which households earning under $35,000 annually expressed a greater desire. Lastly, younger respondents were substantially more open to switching to electric appliances than older respondents, in addition to valuing the environmental benefits of electric appliances more than older age groups.



Appliance	5-7 (Total Want)				
	All Renters	Race/Ethnicity			
		Whites	Latinos	African Americans	Asians/ Pacific Islanders
Air conditioner, swamp cooler or heat pump (n=310)	**53%**	46%	56%	48%	46%
*Replacing a heater with a combined heating and cooling system (n=558)	**51%**	46%	53%	64%	45%
Clothes dryer (n=354)	**47%**	34%	51%	44%	39%
Stove, oven or range top (n=665)	**46%**	37%	47%	50%	58%
Built-in heater (n=525)	**45%**	32%	49%	51%	44%
Hot water heater (n=598)	**40%**	35%	43%	37%	44%

Figure 31. Interest in switching by race/ethnicity and appliance



Appliance	5-7 (Total Want)				
	All Renters	Household Income			
		Under $35K	$35K-$50K	$50K-$75K	$75K+
Air conditioner, swamp cooler or heat pump (n=310)	**53%**	46%	53%	58%	54%
*Replacing a heater with a combined heating and cooling system (n=558)	**51%**	57%	54%	53%	45%
Clothes dryer (n=354)	**47%**	47%	52%	55%	41%
Stove, oven or range top (n=665)	**46%**	44%	39%	52%	48%
Built-in heater (n=525)	**45%**	47%	43%	51%	41%
Hot water heater (n=598)	**40%**	45%	35%	45%	37%

Figure 32. Interest in switching by household income and appliance

When respondents were asked about the different aspects of choosing an appliance, safety and reliability were top priorities (Figure 33), though at least 77% responded that they found all aspects tested in the survey as extremely or very important.

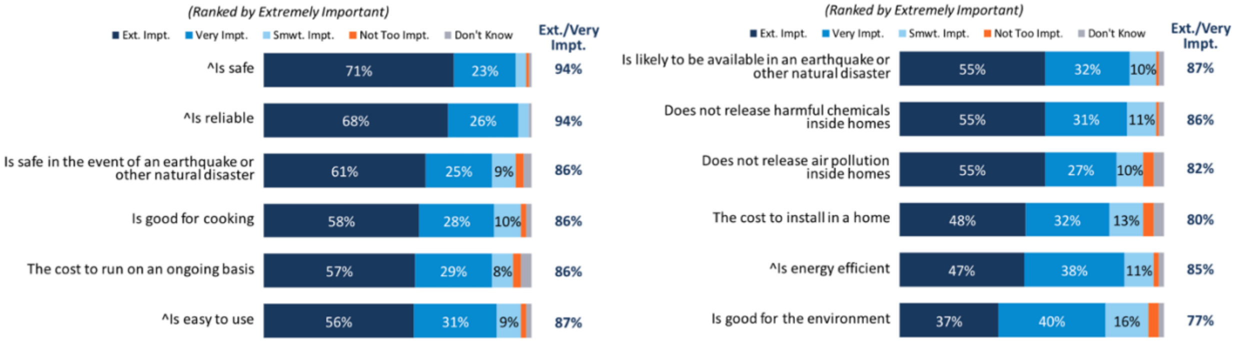


Figure 33. Respondents Ranking Importance of Considerations When Choosing an Appliance

Of the 434 respondents interested in switching out a gas appliance, the top reasons for wanting to switch stemmed from worries about gas leaks, general safety risks, better functionality, the potential for higher long-term costs associated with maintaining gas-powered appliances and the positive environmental impact. By large margins, electricity fits some of those attributes, namely it is seen as better for the environment, less polluting, less likely to release chemical pollutants inside homes and generally safer than gas. It is also seen as easier to use and more energy efficient. On the other hand, those who prefer to retain their gas appliances most often cited cost and performance as key factors in their decision. Respondents who did not want to switch to electric appliances indicated that gas appliances are perceived as more reliable in their performance and in the case of grid-related power outages, and overall, less expensive on an ongoing basis.

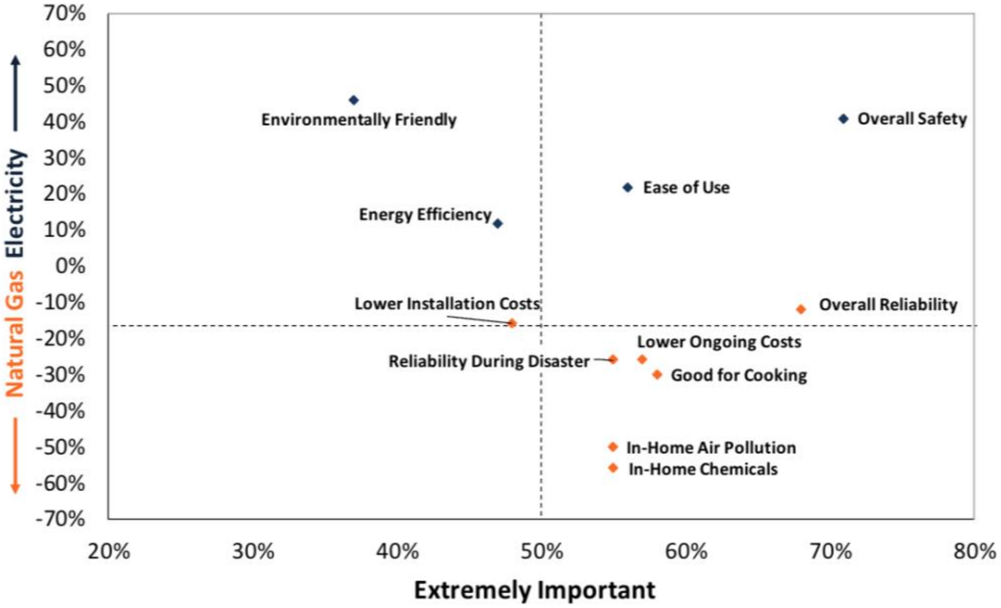


Figure 34. Comparison of Importance Aspects of Appliances with Assessments of Electricity vs. Natural Gas

Respondents received messaging about the benefits of electric appliances and the dangers of gas stoves and carbon monoxide emissions, the effects of other emissions on indoor air quality, climate change, future generations, cost volatility, benefits of induction stoves on cooking experience, expert opinions, second-hand smoke, already existing community bans on use of natural gas in new buildings, and impacts on extreme weather and benefits of switching to electric-powered systems. Of these different messaging options, the most impactful themes about switching to electric appliances related to the dangers of gas stoves and carbon monoxide and the benefits of electric-powered heating for improving indoor air quality and maintaining cooler indoor temperatures during extreme high heat events. (*Figure 34).* Direct messaging about climate change was somewhat weaker than other themes. Messaging had the biggest impact on interest in switching clothes dryers, hot water heaters, and stoves, ovens, and ranges (*Figure 35*).

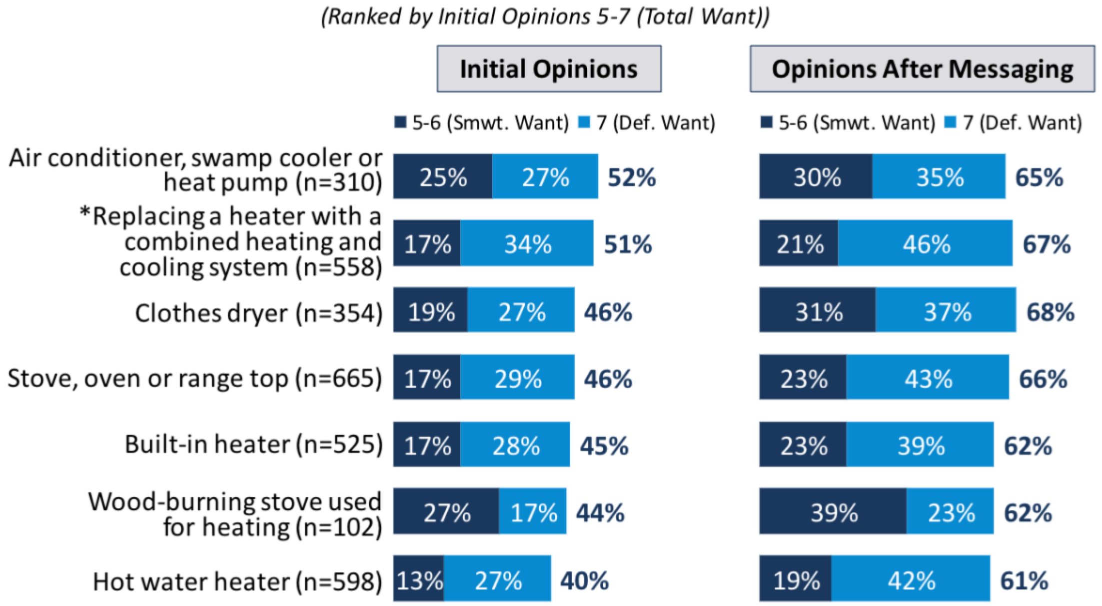


Figure 35. Survey Responses When Asked If They'd Be Interested In Switching At No Cost Before and After Messaging

Lastly, cost is a deciding factor for all respondents. Just about four-in-ten of the respondents who were interested in switching to electric appliances after messaging would still be willing if it cost $75 per month, but nearly all would be willing to pay $5 per month more. Savings were less impactful in motivating adoption; offering a $75 monthly savings only enticed just a little over half to say they'd be "willing to switch", and only two-in-ten as "very willing".

Multifamily Property Owner Interview Findings

Following the survey of renters in high-priority communities, new questions emerged around the experiences and motivations of multi-family property owners in pursuing electrification projects. FM3 conducted in-depth interviews with 15 property owners between September 10, 2024, to January 24, 2025. Interviewees included a mix of private landlords with several small properties, as well as larger affordable housing providers, both non-profit and one for-profit, who collectively manage over 10,000 units statewide.

In terms of the type of electrification project, most owners interviewed had undertaken some form of electrification or energy conservation work, primarily in their older vintage buildings. Eleven out of the 15 participants had either completed or were in the process of converting space and/or water heating systems to electric, primarily using heat pump technology. Nine of the 11 were working on or had installed heat pump space heating, ten of the 11 had installed or were planning on installing heat pump water heaters, with a combined eight having done or pursuing both (*Figure 36*). For many, a motivation for installing electric air source heat pumps was the possibility of offering cooling services at the same time.

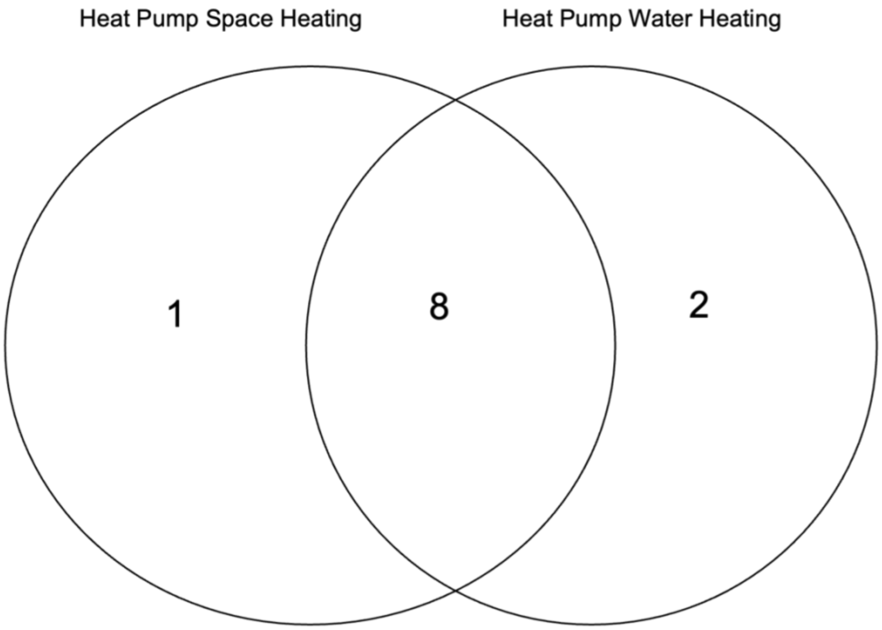


Figure 36. Projects completed or planning on being completed by interviewed multi-family property owners

Five participants had previously replaced gas stoves, and one had replaced a gas dryer. Two had installed EV charging stations, eight had added solar panels, and nearly all had upgraded their buildings' electrical capacities and infrastructure. While all the building owners interviewed had embarked on electrification projects in some form or another, most have not fully electrified any of their legacy buildings. Moreover, many who own multiple legacy buildings have only pursued an electrification project in between one and a few of their buildings due to financial and logistical constraints, such as limited space, inadequate electrical infrastructure, or challenges relocating tenants. Participants noted additional hurdles to further electrification including contract-based restrictions on electrifying shared laundry facilities, and to a lesser extent, issues including asbestos or lead abatement.

Property owners were unanimous: electrification projects must make financial sense for them to proceed. Cost-neutrality was prioritized over benefits to the environment or to the tenants. Several participants explained that the project had to benefit the building owner financially, meaning reducing utility bills for the owner, rather than only the tenants, improved building marketability, or an opportunity to fund already existing necessary repairs. A few large affordable housing providers only pursue electrification projects that save money for the building owner—not just the tenant. This included projects to electrify common spaces or water heating, which is often paid by the building owner. These housing providers were not motivated, even with incentives, to pursue electrification projects that may reduce costs for tenants but not owners. Some owners also mentioned a desire to future-proof buildings against anticipated future appliance electrification mandates, particularly for new developments, which were generally reported as being required to go fully electric.

Environmental sustainability was a commonly cited motivation among non-profit providers, some of whom emphasized goals like grid neutrality and emissions reduction. However, all acknowledged that these ideals were secondary to cost considerations. Few saw electrification as a meaningful selling point to future buyers in large part because they are not able to raise the rent as a result of renovations or upgrades. Electrification was also largely not seen as a "selling point" to renters. A few said rental tenants would appreciate air conditioning if it was installed, otherwise they did not anticipate electrification attracting tenants.

Minimizing tenant disruption was also mentioned as being a top priority for most property owners. More intensive retrofit projects can also sometimes necessitate costly tenant temporary re-locations. Many property owners selected projects specifically because they wouldn't require tenant relocation, and some rejected projects outright to avoid such complications. Other tenant-related concerns included water and power shutoffs, noise, in-unit access, changes in aesthetics, and possibly increases in electricity costs. Nearly all participants mentioned trying to avoid these impacts as much as possible. Participants that did relocate tenants cited the additional burden of cost in covering relocation and subsidizing the differential cost, saying "sometimes we have to relocate tenants for as much as a year."

Participants did report some instances of pushback from tenants as a result of the installation of electric stoves. Building owners attribute this to some tenants' cultural preferences for the use of gas in cooking and lack of familiarity with how to cook on an electric stove. To address this, owners emphasized the importance of providing induction-compatible cookware and education on using electric stoves. Resistance was generally seen as transitional, with concerns fading once new tenants moved in.

Despite these concerns, several participants reported positive outcomes for tenants, such as improved safety by removing the dangers associated with gas appliances, and the addition of air conditioning. In a few cases, electrification projects were associated with lowering utility costs (while just as many, if not more, mentioned higher costs—especially with the introduction of air conditioning).

The other most referenced specific challenge, mentioned by nearly every housing provider, large or small, was the need to increase building utility service capacity to accommodate electric conversions. While a few volunteered that incentives have provided enough funding to increase electric capacity, many others said the incentives did not cover enough of this cost. This led them to abandon electrification projects.

Staffing limitations also presented a major hurdle. Several larger housing providers shared that they lacked the internal personnel to manage incentive applications or oversee new installations. Participants also mentioned a lack of maintenance staff to manage new systems or who have expertise with new technology.

Another almost universal source of frustration that was reported by participants was the difficulty of working with their local utility providers, which included PG&E, SoCal

Edison, and LADWP on projects that required upgrades in utility electrical service capacity. They described working with electric utilities as “a nightmare,” “painful,” and “terrible.” Participants cited non-responsiveness, delays getting approvals, and the need for new equipment installation that further delayed project competition timelines. All participants said projects took longer to complete than anticipated, mostly attributing delays to the utility companies. A few participants mentioned missing out on incentive availability windows or missing incentive deadlines because utilities did not provide the information or services they needed on time.

Beyond their interactions with utilities, several participants shared various obstacles with state and municipal codes, permits, and approvals. One participant reported that they wanted to install window mounted heat pumps that might not meet the required permanent heat source codes. Other participants cited that buildings that are on historic preservation lists face additional challenges, such as making any changes to building envelope, or changes to the facade visible from the street. To install window units, in those cases, would require making custom made windows, which are reported as three to four times more expensive.

3.1.6 - Discussion

The results from this study demonstrate that while the physical infrastructure required to support electrification exists in many California homes, significant financial, structural, and informational barriers still exist which are likely to prevent widespread adoption, particularly among disadvantaged communities and residents of multi-family buildings.

Early Adoption vs. ‘Natural Adoption’ in Existing Buildings

While rebates and incentives for electrification are primarily available to single-family households, their overall impact on space heating electrification remains limited. In 2022, approximately 4.1 million housing units—around 30% of all California households—used electric space heating as their primary heating fuel. The ACS does not specify appliance types, so this category includes built-in electric units, portable electric heaters, and heat pumps. These households encompass new all-electric homes, units that previously lacked space heating, and those that converted from gas to electric heating. However, only a small portion of this growth can be attributed to incentive-driven adoption (Table 31). Most residential electric space heating appears to result from “natural adoption,” occurring independently of available incentives. Overall, residential space heating electrification rose by just 3.4%—a rate insufficient to meet California’s climate and decarbonization goals (*Table 32*).

Table 31. Total Electrification Incentive Claims and Households Electric Space Heating

	2019	*2020*	*2021*	*2022*	*2023*	*Total (2019-2023)*
Space heating claims by household (CEDARS)	83	6,057	9,087	5,989	619	21,835
Space heating claims by household (TECH)	N/A	N/A	439	10,568	9,968	20,975

Occupied housing units using electric space heating (ACS)	3.5M		4M	4.1M		

Table 32. Percent of Electric Space Heating Attributed to Incentive Claims

	2019	*2020*	*2021*	*2022*
% of households using electric space heating (ACS)	26.6%	N/A	29.7%	30%
Estimated % of electric space heating attributed to incentive claims	0.002%	NA	0.39% (includes claims for both 2020 and 2021)	0.41%

Despite more than $550 million in electrification incentives allocated between 2021 and 2023 (excluding public utility budgets), the modest share of incentive-driven adoption suggests several key findings. First, there is insufficient funding to support mass market adoption. To accelerate adoption to mass market penetration levels, substantially higher funding levels will likely be required, particularly to support retrofits in existing buildings. Otherwise, the fundamental economics of electrification will have to improve as a result of changes in primary fuel costs as well as those for the purchase of new electrical end-use equipment. Second, the TECH program's relatively static project completion rates, despite a near-doubling of its budget between 2022 and 2023, suggest there are limitations associated with existing program designs. The bottleneck appears not to only be insufficient funding, but program accessibility and structure—including issues such as contractor capacity, application complexity, cash flow timing, and the mismatch between incentive levels and project costs. Without addressing these systemic barriers, simply increasing funding is unlikely to significantly accelerate adoption at the pace required to meet California's decarbonization goals. While natural adoption for space heating alone has not thus far distinguished greatly by DAC, race, or income, typically early adoption is attributed to those who have higher social status, and financial liquidity.[69] Future electrification costs, such as stranded gas assets will disproportionately burden lower-income and disadvantaged communities. Lastly, most CEDARS incentive claims have not been concentrated in disadvantaged areas. This indicates that even the small share of incentive-driven adoption has not effectively reached households most in need of financial support.

Program Design: Piecemeal Approaches and the Upstream Paradox

Current electrification programs, including those offered through TECH, primarily support incremental, end-use-specific measures, such as space and water heating, with limited offerings for whole-home retrofits, panel upgrades, or cooking electrification. Most available residential incentives target space heating/cooling (42%) and water heating (27%) measures. This fragmented approach does not account for the broader costs or planning required for comprehensive electrification, such as electrical service upgrades or load management strategies. As a result, programs encourage piecemeal decision-making rather than supporting households in developing coordinated and

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[69] Rogers Everett - Based on Rogers, E. (1962) Diffusion of innovations. Free Press, London, NY, USA.

comprehensive electrification plans. More recent developments have illustrated programmatic efforts for more comprehensive incentives. TECH has taken steps to address these gaps, notably by introducing HEEHRA rebates on April 11, 2025, which include coverage for electrical infrastructure costs. However, as of December 18, 2025, all available rebates were fully reserved and awaiting lottery selection and reservation review. The EBD Statewide Direct Install Program also intends to cover electrical wiring and panel upsizing, however it is unclear when the first home retrofits are expected to begin.

Most consumers make electrification decisions when existing equipment fails and requires replacement. These decisions therefore occur “on the margin” (piecemeal), so to speak, rather than as part of a long-term strategy to transition all existing fossil-fueled end-use equipment. This incremental behavior produces two recurring outcomes. First, electrical panel capacities and other building electrical infrastructure constraints are often overlooked until a new appliance exceeds available limits, thus constraining future electrification potential. Second, when these types of upgrades are eventually required, they are typically pursued reactively and without significant advanced planning or consideration. This often results in inefficient investment decisions that can increase long-term energy use such as with panel upsizing projects that install excess capacity beyond that which is necessary. Existing programs do not equip building decisionmakers with knowledge and incentives to optimize existing electrical capacity through low-power equipment, load management software, circuit control technologies, multifunctional systems, and whole-home energy efficiency upgrades, before defaulting to costly capacity expansion projects. Additionally, the role of ancillary and coordination costs remain largely unaddressed. Program designs overlook the time, planning, and utility coordination required for permitting, electrical upgrades, and incentive timing, factors that can delay or deter participation. While single-family homeowners may defer costly upgrades and proceed incrementally, multi-family properties face higher upfront costs, greater logistical complexity, and the added risks of tenant disruption or the need to pass-through costs to recoup expenses. Expanding whole-building retrofit support and aligning program timelines with utility coordination requirements will be critical to overcoming these barriers and enabling equitable electrification across building types.

Recent shifts in incentive delivery methods from downstream incentives to primarily midstream have had mixed effects. While the TECH Clean California has had healthy participation among disadvantaged and low-income communities, participation in CEDARS programs has been almost nonexistent—only 0.5% of 2023 fuel-substitution claims were flagged as DAC or low-income. This suggests that upstream program designs, while administratively efficient, fail to necessarily reach priority populations without additional structural support mechanisms. This tension, between administrative simplicity and equitable targeting, highlights a core “upstream paradox.” Upstream programs minimize end-user engagement, but in doing so, they lose visibility into who benefits, whether installations occur, and how incentives translate into actual savings. The lack of geographic precision in CEDARS EE reporting requirements prevents meaningful evaluation of program equity outcomes and may even allow benefits to be concentrated in higher-income areas already predisposed toward electrification.

Multifamily Institutional and Technical Challenges

Analysis of ACS data shows that building type and vintage are key determinants of electric space heating adoption. Between 2017 and 2022, census tracts with a high share of 2–4 unit residential buildings experienced a decline in electric space heating, while adoption among single-family homes remained relatively stable. This divergence indicates that electrification in smaller multi-family buildings faces distinct structural, financial, and institutional barriers. It may also reflect a transition away from aging electric resistance systems toward newer gas furnaces, underscoring the risk of regressing back to fossil fuels for key end-uses in the absence of stronger policy and financial support for multi-family electrification.

Findings from the electrical panel readiness analysis further reinforce these trends. Only about ⅓ of multi-family structures can be considered “electrification-ready” based on estimated panel size distributions across individual dwelling units. Many multi-family buildings, especially those in disadvantaged communities, are older, smaller, and less likely to have received permitted electrical infrastructure upgrades. These characteristics are consistent with patterns of deferred maintenance in lower-income areas, where limited financial resources and split ownership incentives constrain investment in long-term improvements.

Incentive structures compound these disparities. Multi-family properties have access to fewer available rebates and are associated with lower participation rates than are single-family home oriented programs. The combination of declining electric heating adoption within the sector and limited incentive uptake suggests that current programs are failing to meet the needs of the multi-family sector. The persistent split incentive problem, where owners absorb the upfront retrofit costs while tenants benefit from energy savings, further discourages investment. For larger or older buildings that require centralized systems or major electrical upgrades, even generous incentives may not offset the high capital costs.

Beyond cost barriers, multi-family electrification projects encounter greater technical and administrative complexity than single-family retrofits. Interviews with multi-family property owners consistently noted longer timelines, extensive permitting requirements, and high coordination demands with utilities. Additionally, property owners all emphasized cost neutrality as a prerequisite for electrification and identified permit delays, utility coordination, and large-scale infrastructure needs as key deterrents.

Panel Optimization Strategies

There are a large and growing number of building energy system hardware and software solutions to address problems of insufficient panel main breaker capacity and available branch circuit breaker spaces. They include smart panels, smart breakers, circuit control units, outlet splitters and more. These technologies can collectively be referred to as “panel optimization strategies.” This is because it is possible for one or more of them to be implemented in different configurations to address panel capacity and/or space constraints of varying levels of severity. The successful implementation of panel optimization strategies as a viable alternative to a panel upsizing project requires a number of conditions to align, however. These include, but are not necessarily limited to:

1. Both the customer and the contractor must have an awareness of their existence and a willingness to pursue them.
2. Their combined cost of implementation must be competitive with the cost of a more conventional panel upsizing project.
3. They must be able to achieve code compliance.
4. Inspectors must be aware of them and able to permit them if applicable.

In addition to these conditions, there may be instances where the customer is faced with the inability to use different appliances concurrently or be forced to accept potential performance degradations (i.e., power throttling) during periods of peak energy consumption. Moreover, many of these technologies are currently only offered by newer companies (start-ups, in some cases) that lack an established track record of performance and serviceability. This can be a concern for some customers, as the equipment must be relied upon to deliver critical energy services within homes. The degree to which any or all of these issues might be a limiting factor for a significant proportion of Californians whose residences have intermediate panel capacities is currently unknown. At the moment, there are not many incentives for customers or contractors to deviate from panel upsizing as the default approach to resolving these types of capacity constraints when adding new electrical loads. This is with the notable exception of instances where a panel upsizing project would trigger the need for utility distribution infrastructure cost upgrades, which can be significant and would have to be borne, in part, by the customer in accordance with local utility tariff rules.

Low-power Electrical Appliances

Within the context of residential electrical end-use appliances, the term “low-power” is typically used to refer to equipment that do not need to be hard wired into a dedicated branch circuit within the electrical service panel and are able to be plugged into standard 120V/15-20 Amp rated wall outlets. Depending upon the end-use involved, different engineering strategies can be used to reduce equipment power draw and operate within these constraints. For example, many low-power heat pump water heater units make use of much larger and more heavily insulated storage tanks, to compensate for the longer recharge cycle times implied by their lower power condenser units. Depending upon their specific patterns of use, some customers may not even perceive the differences in capability between low and high powered equipment alternatives. However, some others might, and it is likely that the differences could be viewed as deficiencies in performance. This could be a significant concern in terms of the market development for these types of equipment. Particularly if households are unaware of the fundamental differences between the new electric technology that they are substituting for their existing gas powered equipment and, perhaps, were under the impression that they would be “like-for-like” replacements. More research is likely needed to assess customer perceptions of the relative performance of these types of new low power equipment offerings as they become available and see more widespread adoption.

Conditional Shifts in Consumer Attitudes

Prevailing literature and public perception often portray renters as reluctant to adopt electrification, citing concerns about cost, disruption, and cultural attachment to gas cooking appliances. However, this project’s survey results suggest that reality may be more nuanced. When electrification measures were framed in terms of their potential health, safety, and comfort benefits, many tenants expressed openness to the transition, challenging prior assumptions that renters are inherently resistant to these types of changes. This finding underscores the importance of how electrification is communicated and highlights the potential for program design and messaging to shape consumer receptivity. Notably, cooking electrification attitudes diverged from expectations. While prior studies identified strong cultural attachment to gas cooking as a barrier, survey data revealed that Asian and Pacific Islander respondents were more open to electric cooking (58%) than white respondents (37%). This suggests that cultural narratives around gas use are not fixed and can shift when the benefits of electrification are clearly articulated or directly experienced.

Interviews with multi-family property owners provided additional perspective. While some owners reported initial tenant resistance, especially to electric stoves, many observed that this type of opposition diminishes over time and with experience, particularly when tenants relocate or when targeted education emphasizes the health and safety advantages of electric appliances.

Crucially, these shifts occurred primarily in contexts where the cost burden to tenants was minimal or eliminated. In other words, willingness to electrify is contingent on affordability. When financial barriers are removed, consumers demonstrate far greater openness than previously assumed. This finding reinforces the need for comprehensive cost-offsetting strategies that prevent cost pass-through to renters and ensure full cost parity between electric and gas options, not just at the point of appliance purchase but across the full spectrum of equipment installation and lifetime operational costs.

3.2 - Commercial Building Results

Commercial buildings represent a critical yet underserved component of California's decarbonization strategy. Despite comprising around 40% of building sector greenhouse gas emissions,[70] commercial electrification has received substantially less policy attention, research focus, and data collection efforts compared to the residential sector. This imbalance is particularly evident in the limited availability of comprehensive datasets tracking commercial energy consumption patterns, electrification costs, and incentive program uptake.

3.2.1 - Commercial Program Availability and Access

The project team's survey of the commercial building electrification landscape in California reveals a stark imbalance between levels of resource availability and program utilization. While commercial electrification program budgets far exceed those allocated to the residential sector, actual program participation remains remarkably low.

Analysis of rebate data from DSIRE, the only available dataset which comprehensively tracks the availability of commercial incentives at the time of this analysis, indicates that 120 active commercial rebates are currently available across six functional categories: whole building upgrades, electrical service panel upgrades, water heating equipment, space conditioning equipment, clothes drying equipment, and cooking equipment. Cooking equipment accounts for the highest number of active rebates, with 55 incentives available, followed by space heating and cooling measures, which together represent 41 active rebates. The average incentive values vary considerably by end-use: cooking equipment incentives range from $1,130 to $17,500 per project, while whole building incentives average $10,000 per facility. Whole building incentives apply to projects that involve converting all gas appliances and equipment to electric systems. Water heating rebates, critical for many commercial subsectors, average between $1,550 and $1,812 per unit (*Table 33*).

Table 33. Commercial Building Electrification Rebate Distribution by Functional Category and Average Minimum and Maximum Value

	Cooking	*Clothes Drying*	*Space Heating/Cooling*	*Water Heating*	*Electric Service Panel*	*Whole Building*
Active Rebates	55	1	41	19	3	1
Average Incentive Price	$1,130-$1,312 per unit $17,500 per project	$300 per unit	$592 per unit $750 per project	$1,550 - $1,812 per unit	$1,333 per unit	$10,000 per facility

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[70] California Air Resources Board, 2018, Greenhouse Gas Emission Inventory - Query Tool for years 2000 to 2018 (11th Edition), Available at: https://ww2.arb.ca.gov/sites/default/files/classic/cc/ghg_inventory_trends_00-18.pdf

While commercial building electrification programs have a far larger total budget than is available for the residential sector, they also have far fewer claims and overall fewer incentives offered. CEDARS' database is the only publicly available dataset that tracks commercial electrification claims in California. While TECH Clean California has offered commercial incentives since October 2023, these claims are not currently available in any of their public datasets. In 2022, the commercial electrification budget documented in CEDARS was double the residential electrification budget (over $55 million more), despite having 2% of the number of claims that same year. The small number of claims in CEDARS (*Table 34)* may reflect the higher costs expended for each equipment unit installed. Alternatively, they could reflect property owner concerns about potential operating cost increases that could arise from switching to a more expensive fuel. Nevertheless, the reasons behind this lack of uptake for existing available commercial electrification incentives remain unclear. Additionally, the impact of COVID-19 may also be responsible for a lag in commercial claims and only a gradual rebound in 2023, 3 years after the onset of the pandemic. Another interesting pattern is that while commercial claims have declined since 2019 to 2023, the overall electrification budget for the commercial sector has more than tripled. Additionally, EE claims have also continued to rise and while they did decline in 2020, they rebounded in 2021 and 2022, however declining once again in 2023 although it was an all-time high for EE budgets. Researchers consulted with CPUC staff to discuss these findings but were unable to arrive at a single conclusive explanation.

Table 34. Commercial Building Electrification Incentive Claims and Budgets, CEDARS

Year	*Total EE Budget*	*Total EE Claims*	*Total Electrification Budget*	*Total Electrification Claims*
2017	$498,670,284	318,752	$5,589,499	1,238
2018	$421,587,893	234,924	$5,601,738	2,628
2019	$385,031,381	180,194	$9,828,179	2,428
2020	$284,060,568	52,143	$8,024,990	376
2021	$339,747,242	65,557	$17,447,317	1
2022	$467,236,085	70,791	$22,851,100	173
2023	$511,071,108	10,665	$33,185,825	299

An analysis of different commercial subsectors as shown in Table 35 revealed highly uneven rates of program participation. The "miscellaneous" building category consistently dominated claims from 2016 through 2023, accounting for 2,191 claims, or almost 90% of total claims in 2019 alone. Large offices showed sustained but modest participation, with 66 claims in 2023. However, several critical subsectors exhibited minimal engagement: food stores recorded zero claims after 2020, restaurants had no claims reported in 2022-2023, and retail establishments similarly showed zero participation in recent years. This pattern possibly indicates that current program structures fail to address the specific needs and barriers facing different commercial building types.

Table 35. Commercial Building Electrification Incentive Claims by Building Type (CEDARS)

	2016	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*Total*
College	20	9	1	0	0	0	0	0	30
Food Store	112	13	51	41	9	0	0	0	226
Health Care	10	63	4	1	1	0	29	0	108
Large Office	144	126	7	6	6	1	40	66	396
Lodging	51	44	62	44	27	0	19	0	247
Miscellaneous	220	562	2370	2191	300	0	81	159	5883
Restaurant	26	37	59	78	20	0	0	0	220
Retail	50	24	4	11	9	0	0	0	98
School	231	150	7	71	2	0	4	73	538
Small Office	201	62	6	1	1	0	0	1	272
Warehouse - Refrigerated	5	9	1	1	1	0	0	0	17
Warehouse - Unrefrigerated	1	0	0	0	0	0	0	0	1
Total	1071	1099	2572	2445	376	1	173	299	

Over the period captured in available data, the distribution of commercial electrification claims has shifted dramatically toward a single equipment category despite broader program offerings (Figure 37). Heat pump water heaters now dominate claims in the most recent three-year period, even though currently available rebates are predominantly structured to incentivize cooking and space heating/cooling equipment. This narrow focus represents a marked departure from earlier program years, when rates of claims exceeded 1,000 per year and encompassed a diverse equipment mix including water source heat pumps, packaged terminal heat pumps, and multiple cooking end-uses. This pattern adds another layer of complexity to the narrative around program underutilization: expanded funding and increased rebate category diversity have failed to translate into either higher participation rates or a broader spectrum of electric equipment adoption.

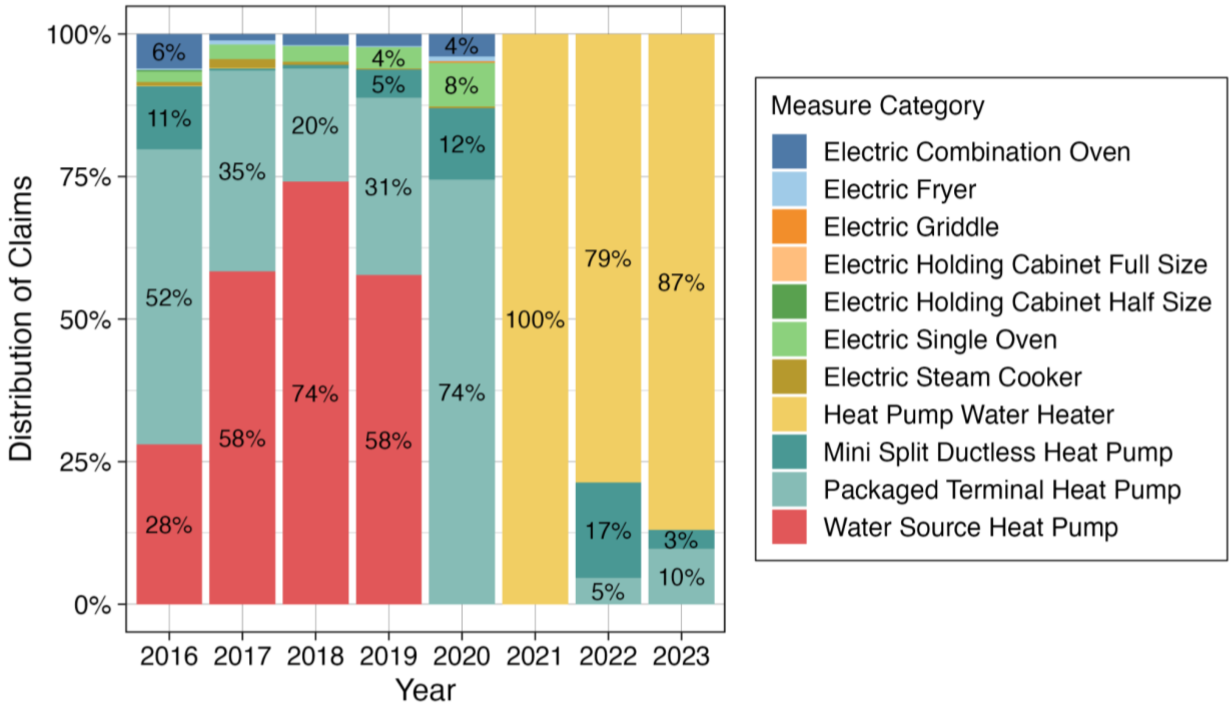

Figure 37. Commercial Claims by Measure Category (CEDARS)

Delivery type distribution reveals that direct install programs have historically been the primary mechanism for commercial electrification, though downstream approaches have gained traction in recent years (Figure 38). The shift in delivery mechanisms has not, however, translated into increased overall participation, suggesting that program design issues extend beyond those related to simple points of access.

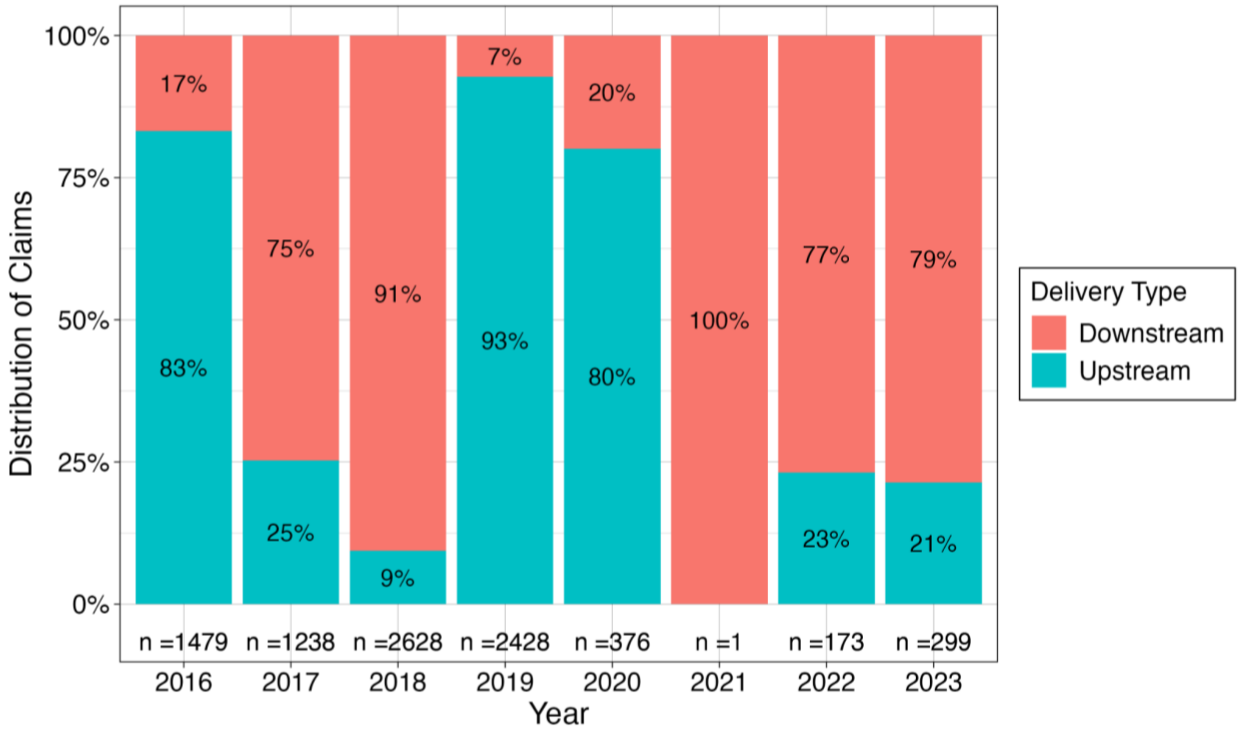

Figure 38. Commercial Claims by Delivery Type (CEDARS)

3.2.2 – Commercial Building Electrification Costs

There is currently no empirical data source which reliably reports the costs of different commercial electrification projects and measures. Estimates in this report were assembled from the 2021 Reach Code Cost-Effectiveness Analysis on Non-Residential Alterations for the California Energy Codes and Standards. However, this resource only provides estimates for a few commercial building types and thus is not exhaustive of the range of costs that could be faced by the variety of commercial building types and appliance configurations.[71]

The Reach Code Cost-Effectiveness Analysis found the incremental costs of electrification across most commercial building subsectors to still be very high. The financial burden associated with electrification is particularly pronounced for full-service restaurants, schools, colleges, hotels, and hospitals that rely on kitchen facilities (*Table D1, Appendix D*). The study estimates an incremental cost, per facility, of $60,835 for Quick-Service Restaurants and $123,855 for Full-Service Restaurants. With over 50,000 restaurant establishments with IOU utility accounts, based upon these cost figures the estimated minimum total cost to electrify the restaurant sector alone would exceed $3 billion, of which, approximately $727 million would be associated with restaurants located in disadvantaged community census tracts. Medium office buildings face total incremental electrification costs of $158,078 per facility. These costs tend to be driven primarily by the need to replace gas boilers ($111,562) and service water heaters ($15,283), along with the need for substantial electrical infrastructure upgrades

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[71] PS2 Engineers, TRC Companies, “2021 Reach Code Cost Effectiveness Analysis: Non-Residential Alterations, California Energy Codes and Standards” (2021). Available at https://localenergycodes.com/content/resources.

($31,233). Stand-alone retail establishments demonstrate more favorable cost profiles, with total incremental costs per facility of negative $137 (indicating potential cost savings). This is primarily due to the favorable economics of replacing existing packaged HVAC systems. Similarly, some hotel configurations show negative incremental costs, suggesting these subsectors should be prioritized for near-term electrification efforts. Warehouse facilities face moderate incremental costs of $15,003 per facility, with electrical infrastructure upgrades representing a substantial portion ($6,231) of this total. The 17,930 unrefrigerated warehouse facilities and 452 refrigerated warehouse facilities represent significant electrification opportunities if targeted financial mechanisms can be leveraged to address upfront cost barriers.

Lastly, schools and colleges rely heavily on kitchen facilities for food service operations, facing electrification cost structures similar to restaurants. Furthermore, healthcare facilities present additional complexities due to critical infrastructure requirements and 24/7 operational demands. The lack of detailed cost data for these subsectors represents a critical policy gap, as these institutions serve disadvantaged communities and cannot easily absorb substantial capital expenditures.

3.2.3 - Commercial Electrification Trends

Across all of California's commercial sectors, climate zones, and counties, electricity consumption as a fraction of total primary energy use (gas + electricity) has cumulatively declined since 2006 due to overall increases in the volume of gas consumption and proportional declines in electricity usage, as shown in Figure 39. Figure 40 shows that in 2006, electricity consumption accounted for over 37% of total commercial energy consumption, progressively declining to around 31% in 2022.

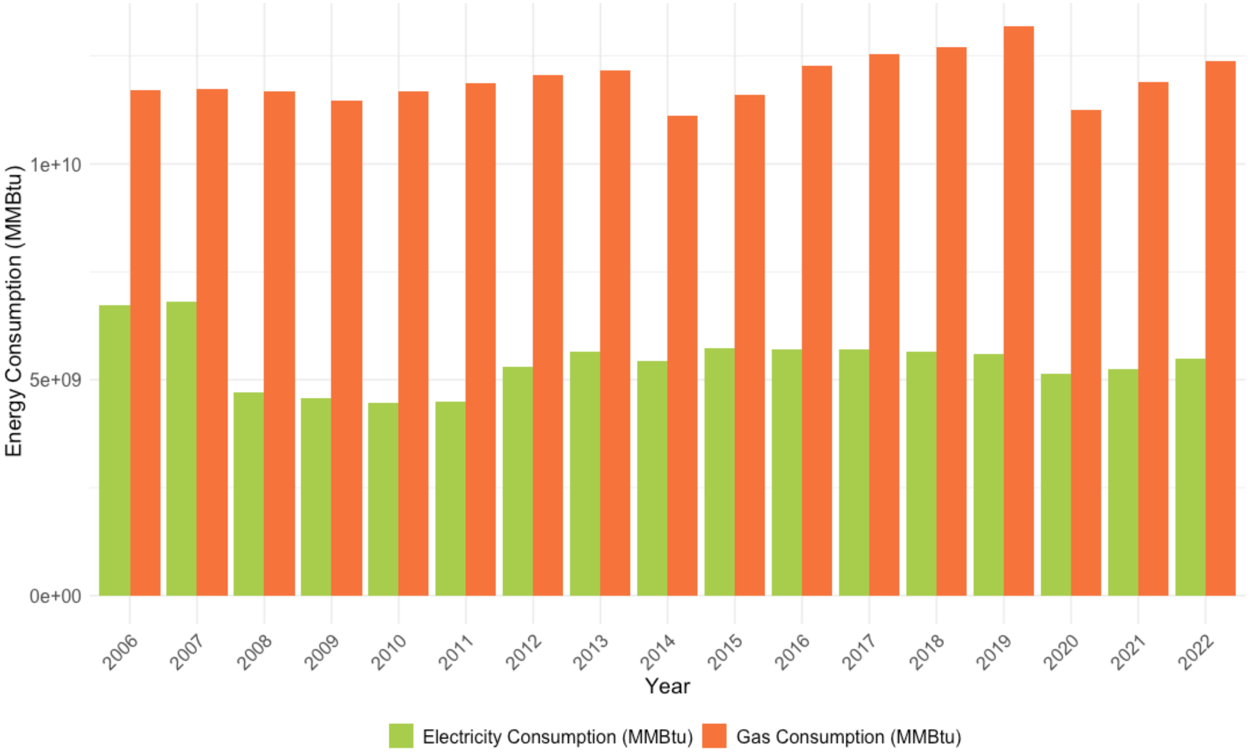

Figure 39. Commercial Energy Consumption between 2006 and 2022, ECDMS[72]

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[72] California Energy Commission. California Energy Consumption Database. Commercial Gas and Electricity Consumption (1990 - 2022). Available at: https://ecdms.energy.ca.gov/elecbyutil.aspx

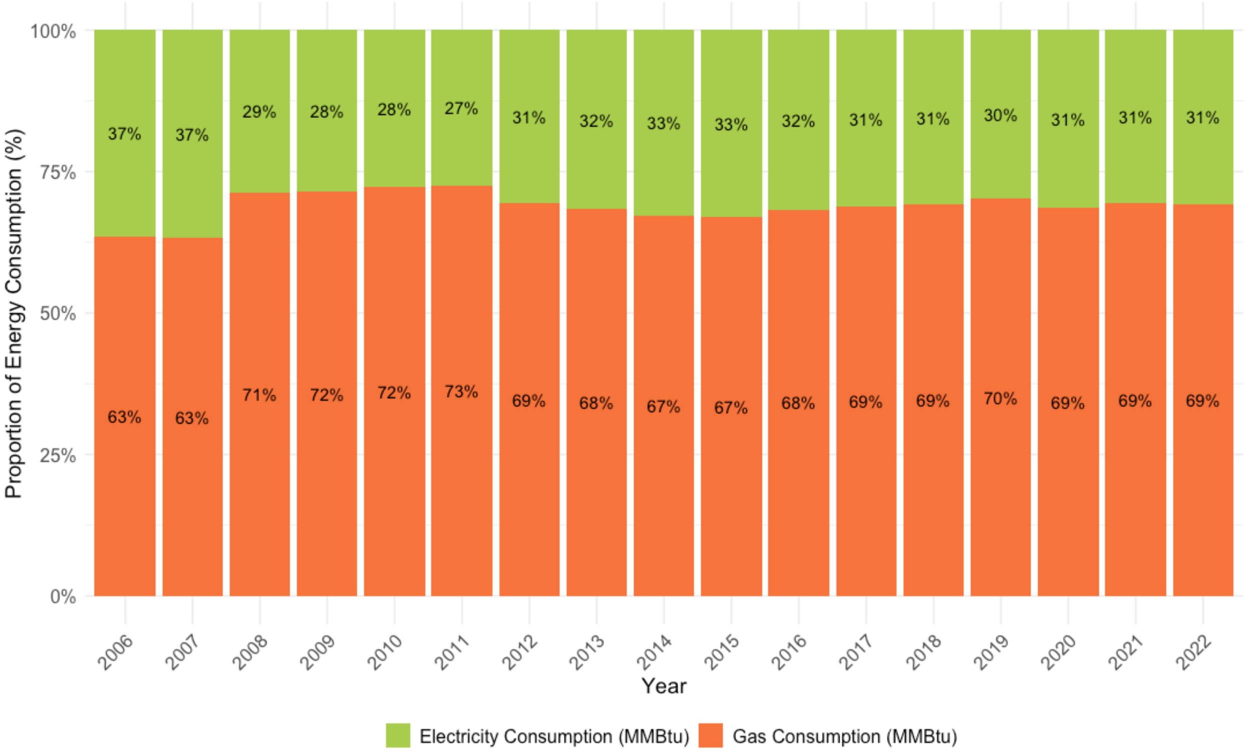

Figure 40. Proportion of Commercial Energy Consumption between 2006 and 2022, ECDMS[73]

A dramatic shift occurred between 2006 and 2011, electricity consumption decreased while natural gas remained stable, which could possibly be explained by improvements in lighting energy efficiency. However, IOU account-level data demonstrates continued erosion of electric fuel share across all CEUS subsectors between 2015 and 2021 from a continued rise in gas consumption (*Figure 41)*.

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[73] California Energy Commission. California Energy Consumption Database. Commercial Gas and Electricity Consumption (1990 - 2022). Available at: https://ecdms.energy.ca.gov/elecbyutil.aspx

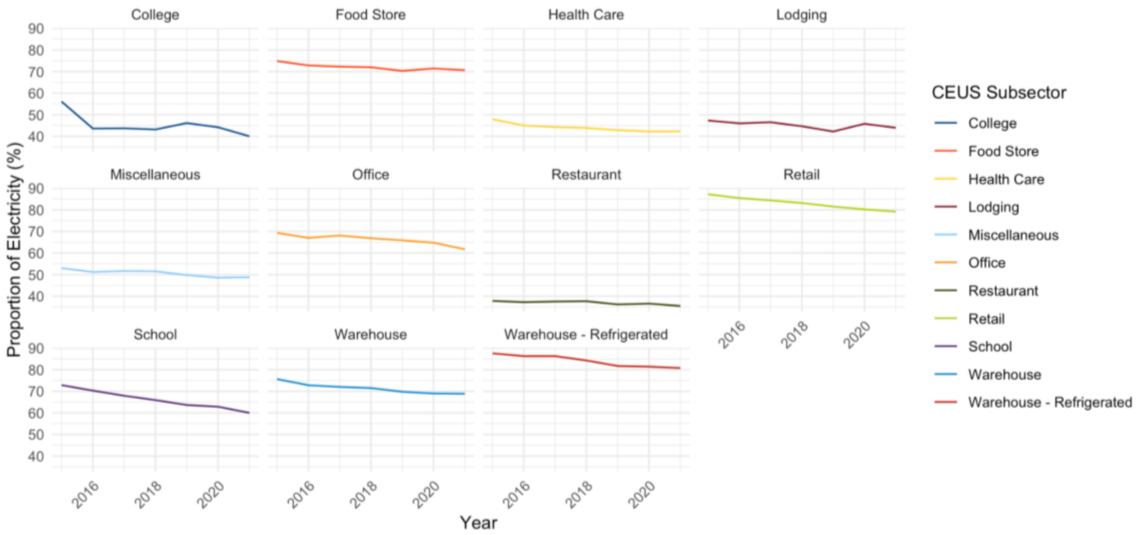


Figure 41. Proportion of Electricity of Total Energy Consumption by CEUS Subsector

Comparing DAC and non-DAC tracts, there are minimal differences in inter-annual variation for this metric (*Figure 42*). The relationship between the share of electricity consumption and disadvantaged community status varies slightly by commercial building type. A detailed count of gas and electric commercial accounts by year and CEUS subsector, disaggregated by DAC and non-DAC tracts, is included for reference in *Table D3 in Appendix D*. For food store and miscellaneous buildings, disadvantaged communities represented in the account-level utility consumption data used less electricity as their total share of energy consumption their counterparts in non-disadvantaged communities. This relationship is reversed in college, offices, restaurants, and schools. There was minimal difference in the share of electricity consumed between the community statuses for retail, lodging, and warehouses.

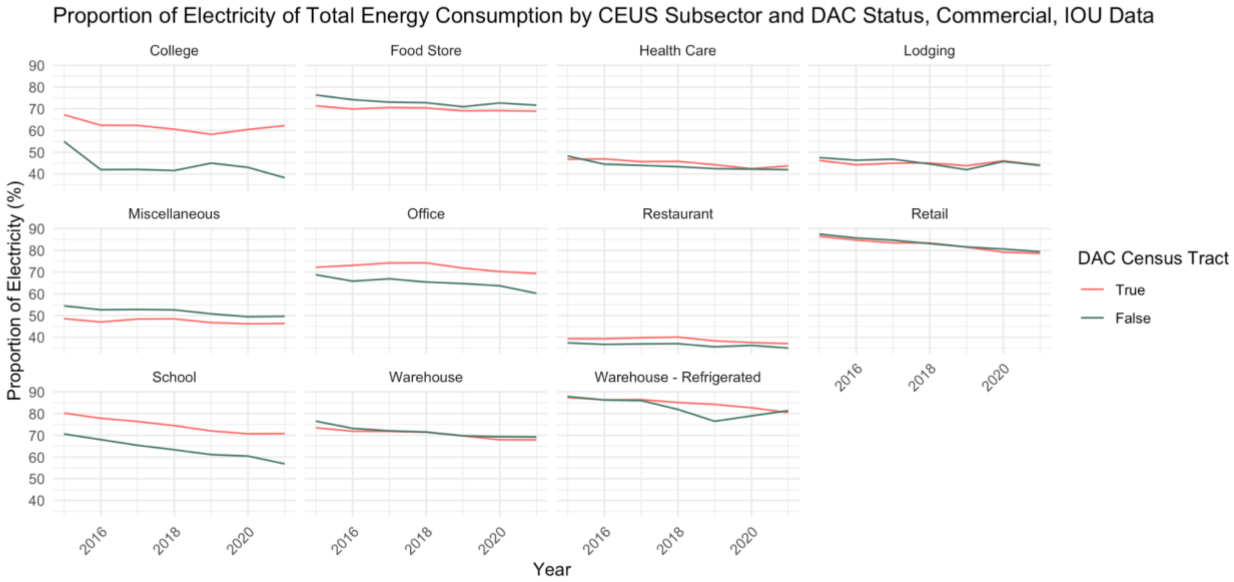
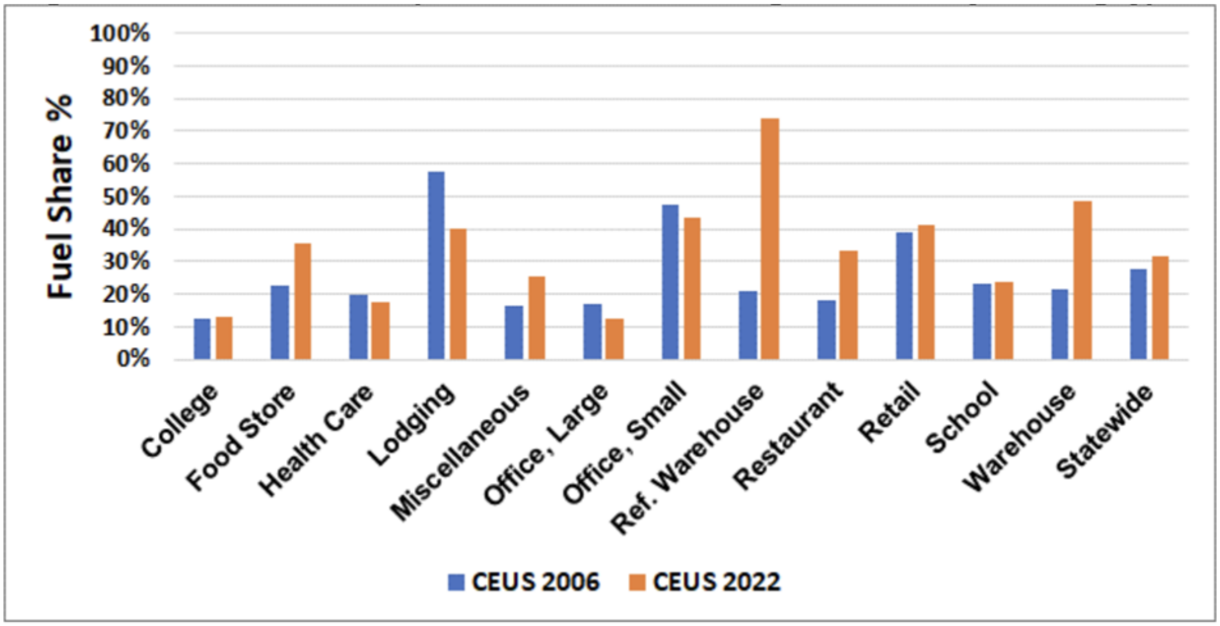


Figure 42. Proportion of Commercial Electricity to Total Utility Consumption for DAC and non-DAC tracts by CEUS Subsector, Utility Account Data

By end-use, electric space heating fuel share has increased for commercial subsectors where space heating is not a major end-use energy services category. This trend suggests a potential shift in heating technologies or operational practices within those subsectors. Specifically, electric space heating's fuel share rose from about 28% to approximately 31%, with the most significant increases observed in warehouses, restaurants, refrigerated warehouses, and food stores as shown in Figure 43. Conversely, lodging and office buildings, which both have substantial and consistent space heating energy demands, experienced notable declines in electric heating fuel share. Subsectors with significant heating needs—precisely those where electrification would yield substantial greenhouse gas reductions—continue to favor gas equipment.



Source: 2022 CEUS and 2006 CEUS

Figure 43. Cross-CEUS Comparison of Electric Heating Fuel Share by Building-type[74]

Electric water heating fuel share declined from 41% to 40% between 2006 and 2022, with specific decreases in colleges, healthcare, offices, and retail sectors, as shown in Figure 44. This trend is particularly concerning given the critical role water heating plays in commercial building energy consumption and the availability of mature heat pump water heater technology. The subsectors experiencing the greatest declines—colleges, healthcare, and offices—represent exactly those building types where water heating loads are substantial and consistent, offering significant decarbonization potential. The marginal decline in electric water heating share, despite technological improvements in heat pump water heater efficiency and performance, suggests that non-financial barriers or non-technological barriers may be constraining adoption. Possible factors include lack of installer familiarity, concerns about equipment reliability in high-demand applications, and inadequate electrical infrastructure in existing buildings.

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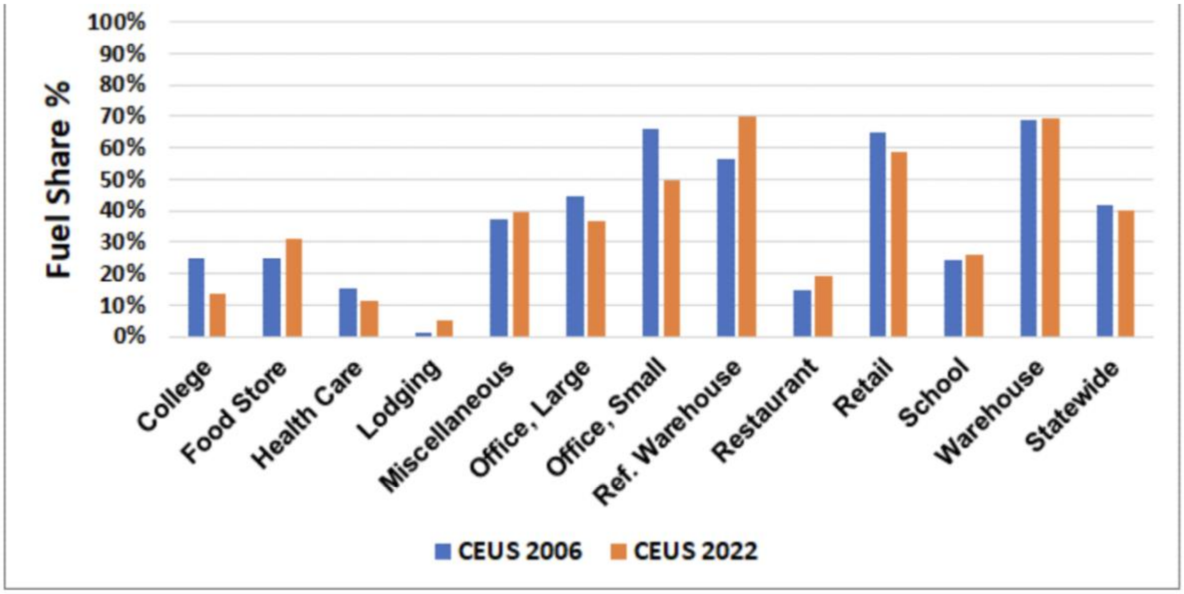
[74] Ibid.



Source: 2022 CEUS and 2006 CEUS

Figure 44. Cross-CEUS Comparison of Electric Water Heating Fuel Share by Building-type[75]

Comparing the two vintages of the CEUS there have increases in electricity usage among restaurants. However, the overall impact of this trend on the electric fuel share remains minimal. *Figure 45* below illustrates the penetration of electric cooking and gas cooking by building type for the 2006 and 2022 CEUS. Penetration refers to whether an end-use is present at the survey site, or not. The penetration of gas cooking equipment, in other words the presence of gas-fueled end-uses, has slightly increased statewide, particularly in colleges, but has unexpectedly declined in restaurants. The decline in gas use among restaurants is an encouraging trend, suggesting a shift away from gas cooking in this sector. This may be driven by fuel substitution in existing establishments or by the disproportionate closure of older restaurants that primarily relied on gas-based end uses. However, the overall decrease in gas usage has not significantly impacted the electric fuel share in the utility account data, which shows a decline of only 2.34% between 2015 and 2021 (see *Figure 41* above).

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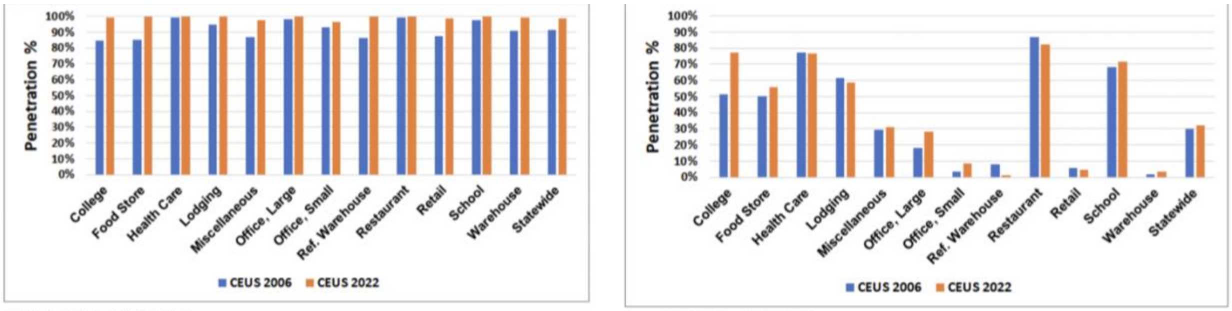
[75] Baroiant, Sasha, Daniel Mort, Taghi Alereza, Don Dohrmann (ADM Associates, Inc.). 2023. 2022 California Commercial End-Use Survey (CEUS). California Energy Commission. Publication Number: CEC-200-2023-017.



Source: 2022 CEUS and 2006 CEUS

Source: 2022 CEUS and 2006 CEUS

Figure 45. Cross-CEUS Comparison of Electric and Gas Cooking Equipment Penetration by Building Type[76]

3.2.4 - Identifying a Priority Subsector

This analysis presents the results of a comprehensive prioritization framework designed to guide decarbonization efforts across California's commercial building sector. The framework evaluates eleven commercial subsectors across multiple dimensions that reflect both environmental impacts and practical implementation considerations. This prioritization framework assesses each commercial subsector—College, Food Store, Health Care, Lodging, Miscellaneous, Office, Refrigerated Warehouse, Restaurant, Retail, School, and Unrefrigerated Warehouse—using seven key metrics. The seven dimensions analyzed include:

- CO_2 Emissions: Quantifies each subsector's contribution to climate change through greenhouse gas emissions from natural gas combustion
- Ambient NO_x Emissions: Measures outdoor air pollutants that affect regional air quality and public health
- Indoor NO_x Emissions: Evaluates indoor air quality impacts, particularly from unvented gas appliances
- Emissions Exposure Risk for Residential Populations: Assesses the number of nearby residents who would benefit from reduced air pollution
- Exposure of Sensitive Populations: Considers cumulative health risks for vulnerable communities already facing multiple environmental and social stressors
- Worker Vulnerability: Examines potential impacts on low-wage workers who may face both economic challenges and health risks
- Electric Grid Outage Vulnerability: Evaluates how reliance on electric appliances might affect operations during power shutoffs
- Technology Readiness: Assesses the availability and maturity of electric alternatives and the feasibility of integrating them into existing buildings

Together, these metrics provide a multidimensional view of where and how electrification efforts could deliver the greatest benefits while accounting for practical implementation challenges. The following sections present detailed findings for each metric.

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[76] 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.

Prioritization Framework Results

The sections below present results for each of the seven prioritization framework metrics across all commercial subsectors. Values were ranked from 1 to 11, where 1 represents the highest priority and 11 the lowest. In the table for each metric, the top three ranks are highlighted using shades of green—darkest for rank 1, medium for rank 2, and lightest for rank 3.

CO_2 Emissions

Natural gas combustion in commercial buildings produces CO_2, a greenhouse gas that contributes to climate change. Replacing gas-fired appliances with zero-emission electric alternatives would eliminate these direct emissions from buildings. While CO_2 mixes uniformly throughout the atmosphere and affects global warming regardless of emission location, climate change creates unequal consequences. Different regions face varying levels of climate impacts, vulnerability to extreme weather, and capacity to adapt and prepare. In 2021, commercial facilities served by the three IOUs produced over 13 million tons of CO_2. The analysis examined both total emissions by subsector and average emissions per facility (*Table 36*). When ranked by total emissions, office buildings emerge as the largest contributor to CO_2, followed by restaurant and health care facilities. This ranking reflects both the prevalence of these facility types and their gas consumption patterns. Office buildings represent a substantial portion of the commercial building stock and collectively consume significant amounts of natural gas for heating, cooling, and other end uses. However, the picture changes when examining average emissions per facility. Colleges produce the most CO_2 per facility, followed by health care and lodging facilities. This indicates that while there may be fewer college campuses compared to offices or restaurants, each campus generates substantially more emissions due to the higher energy demands of their buildings, on average. Retail facilities and refrigerated warehouses show the lowest average and total emissions per facility. Despite having substantial total emissions due to their large numbers, individual retail stores tend to be smaller and less energy-intensive than other facility types. Refrigerated warehouses use the smallest share of gas relative to their total energy consumption compared to other subsectors, with fewer applications that rely on gas.

Table 36. Existing Commercial Building CO2 Emissions Estimates

CEUS Subsector	CO_2 Emissions (Tons)	Ranking by Total Subsector Emissions	Average CO_2 Emissions per Facility (Tons)	Ranking by Average Emissions
College	1,361,106.38	5	217.85	1
Food Store	417,280.31	9	31.07	5
Health	1,717,368.55	3	118.45	2
Lodging	599,594.97	6	67.37	3
Miscellaneous	1,649,946.57	4	26.87	8
Office	3,839,108.50	1	28.32	7

Refrigerated Warehouse	39,690.34	11	11.21	10
Restaurant	2,245,885.72	2	29.43	6
Retail	471,479.08	8	7.90	11
School	498,625.68	7	31.83	4
Unrefrigerated Warehouse	246,262.25	10	15.86	9
Total	13,086,348.34			

Ambient NOx

Natural gas combustion produces oxides of nitrogen (NO_x), which react chemically in the atmosphere to create ground-level ozone. The presence of ozone at ground level can harm human, plant, and animal health. NO_x also reacts to form nitrate particles, acid aerosols, and nitrogen dioxide (NO_2), all of which cause respiratory problems. Additional environmental impacts include acid rain formation, nutrient overload in water bodies, reduced visibility from atmospheric particles, and contributions to global warming. While NO_x emissions harm local populations most directly, prevailing winds can transport these pollutants over long distances. Replacing gas appliances with zero-emission electric equipment eliminates these direct emissions. As indicated in Table 37, office buildings produce the highest total ambient NO_x emissions, followed by miscellaneous facilities and restaurants. This ranking largely mirrors the CO_2 emissions pattern. When examining per-facility averages, the rankings shift considerably. Colleges emit the most NO_x per facility, followed by health care and lodging facilities. This pattern closely tracks the per-facility CO_2 rankings, confirming that larger, more energy-intensive facilities produce proportionally more air pollutants. Refrigerated warehouses and retail facilities show the lowest total emissions, while retail facilities have the lowest per-facility average. These patterns reflect both the number of facilities and their individual operational characteristics.

Table 37. Ambient NOx Emissions Estimates

CEUS Subsector	Total Ambient NO_x Emissions (Tons)	Ranking by Total Subsector Emissions	Average Ambient NO_x Emissions per Facility (Tons)	Ranking by Average Subsector Emissions
College	1,516.79	5	0.24276442	1
Food Store	346.95	9	0.02583183	6
Health	1,827.94	4	0.12607363	2
Lodging	571.19	6	0.06417914	3
Miscellaneous	2,185.87	2	0.03560283	4
Office	3,426.13	1	0.02527727	7

Refrigerated Warehouse	74.63	11	0.02108099	9
Restaurant	1,865.31	3	0.02444024	8
Retail	507.27	7	0.00849771	11
School	424.81	8	0.02712015	5
Unrefrigerated Warehouse	215.8	10	0.01390118	10
Total	12,962.69			

Indoor NOx

Unvented gas appliances, particularly gas stoves, produce and release NO_x indoors, where it directly affects occupants' air quality and health. Unlike ambient emissions that disperse outdoors, indoor NO_x concentrations can reach harmful levels in poorly ventilated spaces. Replacing gas appliances with zero-emission electric alternatives eliminates these emissions and substantially improves indoor air quality. Therefore, indoor air quality improvements represent a critical co-benefit of electrification. This analysis calculated both minimum and maximum emission estimates to account for uncertainty in usage patterns and ventilation conditions. Researchers also computed minimum and maximum averages per facility to understand the range of potential indoor exposure levels.

Restaurants dominate indoor NO_x emissions by a substantial margin, ranking first across all metrics, as seen in Table 38. This reflects the intensive use of gas cooking equipment in commercial kitchens, where stoves, ovens, grills, and other appliances operate for extended periods in enclosed spaces. The gap between restaurants and other subsectors is particularly pronounced, with both minimum and maximum emission values substantially higher than any other category. Food stores rank second, also driven by gas cooking equipment used in bakery sections, prepared food areas, and delis. Health care and retail facilities follow with moderate indoor emissions, while office buildings show relatively low indoor NO_x despite their high ambient emissions. This difference reflects the limited presence of unvented gas appliances in offices compared to their substantial gas use for heating and other vented applications. Lodging facilities demonstrate moderate indoor emissions, likely from restaurant facilities within hotels and food preparation areas. Guest exposure may be limited compared to worker exposure in kitchen areas.

Table 38. Indoor NOx Emissions Estimates

CEUS Subsector	*Minimum Indoor NO_x Emissions (Tons)*	*Maximum Indoor NO_x Emissions (Tons)*	*Ranking by Subsector Total Emissions (Median)*	*Minimum Average Indoor NO_x Emissions per Facility (Tons)*	*Maximum Average Indoor NO_x Emissions per Facility (Tons)*
College	0.59	15.61	8	2.50E-03	9.50E-05
Food Store	2.07	54.4	2	4.05E-03	1.54E-04

Health	0.94	24.78	3	1.71E-03	6.50E-05
Lodging	0.76	19.91	6	2.24E-03	8.50E-05
Miscellaneous	0.85	22.32	5	3.64E-04	1.38E-05
Office	0.72	19.01	7	1.40E-04	5.33E-06
Refrigerated Warehouse	0.09	2.32	10	6.55E-04	2.49E-05
Restaurant	21.93	577.01	1	7.56E-03	2.87E-04
Retail	0.86	22.58	4	3.78E-04	1.44E-05
School	0.46	12.19	9	7.78E-04	2.96E-05
Unrefrigerated Warehouse	0.02	0.62	11	4.00E-05	1.52E-06
Total	29.29	770.75			

Emissions Exposure Risk for Residential Populations

Eliminating gas combustion from commercial facilities produces significant public health co-benefits by reducing residential populations' exposure to indoor and ambient air pollutants, particularly NO$_x$ and particulate matter (PM). The magnitude of these health benefits depends on how many people live near different types of commercial facilities and stand to benefit from reductions in exposure. Researchers assessed exposure risk by identifying all residential properties within 200 meters of commercial facilities, using total residential square footage as a proxy for the size of potentially affected populations. The rationale behind the choice of this buffer distance is discussed in this report’s methodology section.

Table 39 contains the computed exposure risk values for the total residential square footage of parcels located in proximity to facilities within each commercial subsector. The values in the table are disaggregated on the basis of whether or not the parcels were located within DACs.

When commercial subsectors were ranked relative to their corresponding total square footage values, there was a high level of agreement between rankings for DACs and non-DACs. In both cases, the Miscellaneous, Office, and Retail subsectors consistently appeared in the top three. Office buildings have the largest nearby residential populations, ranking first in both DACs and non-DACs. Restaurants rank third. These top three subsectors consistently appear across both DAC and non-DAC rankings, indicating similar spatial relationships between commercial facilities and residential areas regardless of community disadvantage status. Refrigerated Warehouses show the smallest nearby residential populations, followed by Colleges and Lodging. This pattern reflects these facilities' typical locations in industrial zones, campus settings, or commercial corridors with less dense residential development nearby. The strong correlation between DAC and non-DAC rankings suggests that commercial facility distribution patterns, rather than community characteristics, primarily drive exposure risk. However, the absolute numbers of exposed residents differ, with non-DAC populations generally larger than DAC populations across most subsectors. Lodging facilities rank ninth in both categories, indicating relatively low concentrations of nearby residents. Hotels often cluster in commercial or tourist districts rather than residential neighborhoods, limiting their air quality impact on permanent residential populations.

Table 39. Final output CEUS Subsector level emissions exposure risk rankings.

CEUS Subsector	*Total Exposed Proximity Population (Living <= 200 m to Facilities) in DACs*	*Ranking in DACs (by Largest Sum)*	*Total Exposed Proximity Population (Living <= 200 m to Facilities) in Non-DACs*	*Ranking in Non-DACs (by Largest Sum)*
College	216,788	10	832,105	10
Food Store	1,143,072	6	1,668,935	6
Health Care	776,467	7	1,347,455	7
Lodging		9		9
Miscellaneous		2		2
Office	2,100,532	1	4,225,703	1
Refrigerated Warehouse	126,944	11	149,740	11
Restaurant	1,839,567	3	2,822,792	3
Retail	1,531,921	4	2,687,493	4
School	1,002,629	5	1,969,781	5
Unrefrigerated Warehouse	547,827	6	773,949	6

Exposure of Sensitive Populations

The impact of air quality pollutant emissions on burdened communities is more comprehensively understood when considered within the broader context of cumulative exposure —including both chemical stressors (such as contaminants in water, soil, and consumer products) and non-chemical stressors (such as social determinants of health, including social connectivity and access to resources).[77] For instance, the risk of health effects from poor air quality is greater among populations considered sensitive, such as people with heart or lung disease, children, older adults, and people who are active outdoors.[78] The Exposure of Sensitive Populations Index combines NO_x emissions data with spatial information about vulnerable populations to identify which subsectors' emissions pose the greatest cumulative risk. Higher index values indicate subsectors whose emissions disproportionately affect already-burdened communities.

In Table 40, Miscellaneous facilities show the highest Exposure of Sensitive Populations Index, ranking first. This diverse subsector includes the broadest range of commercial business types and end-uses. As a result, it likely encompasses numerous facilities that

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[77] The Lancet Regional Health - Americas 2024; 30: 100666. Published Online 11 January 2024. https://doi.org/10.1016/j.lana.2023.100666.

[78] US Environmental Protection Agency. Air Quality Index: A Guide to Air Quality and Your Health. February 2014. https://www.airnow.gov/sites/default/files/2018-04/aqi_brochure_02_14_0.pdf.

are embedded within residential neighborhoods. Colleges rank second, followed by Health Care facilities in third. Both subsectors serve as major employers in urban areas, which explains their deep integration into large residential communities. When combined with their higher emissions rates, their significant impact on sensitive populations becomes clear. Retail facilities rank last despite their moderate emissions and residential proximity. This indicates retail establishments tend to locate in more affluent areas with lower concentrations of sensitive populations.

Table 40. Exposure of Sensitive Populations Index Results

CEUS Subsector	*Exposure of Sensitive Populations Index*	*Ranking*
College	3,146,074.5	2
Food Store	1,156,927.9	8
Health	2,816,627.6	3
Lodging	1,616,543.9	5
Miscellaneous	5,520,947.1	1
Office	1,383,731.7	7
Refrigerated Warehouse	53,9074.3	9
Restaurant	215,4582.8	4
Retail	369,027.8	11
School	1,570,119.6	6
Unrefrigerated Warehouse	413,648.4	10

Worker Vulnerability

Replacing fossil fuel end uses across commercial subsectors may impact workers in multiple ways. Businesses facing higher operational and capital costs might reduce employment to offset expenses. However, eliminating fossil fuel use would also reduce workers' exposure to harmful air pollution. In this analysis, researchers used monthly employee wages as a proxy for their vulnerability. This is because lower wages correlate with limited healthcare access, reduced access to healthy food, and increased exposure to air pollution. Additionally, low-wage workers more often work in higher-risk occupations, facing greater exposure to occupational hazards and climate-related health issues.[79,80,81]

Normalized scores for both average wages and total employment within each subsector were computed and then combined to create a comprehensive worker vulnerability metric (Table 41). Lower wages indicate higher vulnerability, while higher employment numbers indicate more workers potentially affected. Restaurants show the highest worker vulnerability, ranking first with the lowest wages and substantial employment numbers. However, beginning April 1, 2024, employees at fast-food restaurants—including limited-service restaurants that are part of a chain with at least 60 establishments nationwide—are required to be paid a minimum of $20 per hour. This

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[79] Jbaily, A., Zhou, X., Liu, J. et al. 2022. Air pollution exposure disparities across US population and income groups. Nature 601, 228–233. https://doi.org/10.1038/s41586-021-04190-y

[80] Schulte PA, Chun H. 2009. Climate change and occupational safety and health: establishing a preliminary framework. *J Occup Environ Hyg*. 6(9):542–554. doi: 10.1080/15459620903066008

[81] Ndugga, Nambi, Pillai,Drishti et al. 2023 Climate-Related Health Risks Among Workers: Who is at Increased Risk? Kaiser Family Foundation. Accessed at: https://www.kff.org/racial-equity-and-health-policy/issue-brief/climate-related-health-risks-among-workers-who-is-at-increased-risk/#

wage increase was implemented after the initial analysis for this metric was conducted; therefore, the data does not reflect the impact of this change.[82] Food Stores rank second, also combining low wages with significant employment. The top three ranking shifts when examining individual metrics versus combined scores. Restaurants, Food Stores, and Lodging have the lowest wages regardless of employment levels. However, when combining wage and employment scores, Offices enter the top three, displacing Lodging. This change reflects Offices' disproportionately high employment numbers despite moderate wages. While Lodging employees though showing low wages, the subsector's smaller workforce size reduces the total number of workers affected. Colleges rank last in worker vulnerability, indicating both relatively high wages and lower total employment numbers in facilities with gas end uses.

Table 41. Normalized Wage and Employment Scores by CEUS Subsector.

CEUS Subsector	*Normalized Wage Score*	*Normalized Employment Score*	*Summed Scores*	*Ranking*
College	0.056	0.063	0.119	11
Food Store	0.970	0.033	1.003	2
Health Care	0.0125	0.193	0.205	10
Lodging	0.854	0.009	0.863	5
Miscellaneous	0.294	0.152	0.446	9
Office	0.00	1.000	1.000	3
Refrigerated Warehouse	0.353	0.000	0.353	8
Restaurant	1.000	0.211	1.211	1
Retail	0.797	0.156	0.953	4
School	0.317	0.140	0.456	7
Unrefrigerated Warehouse	0.491	0.112	0.603	6

Electric Grid Outage Vulnerability Risk

Replacing fossil fuel appliances across commercial subsectors could increase facilities' vulnerability to electrical grid outages, potentially causing operational downtime or temporary closures. This concern has grown as California utilities implement Public Safety Power Shutoffs (PSPS) to prevent wildfire ignition during high-risk conditions. Researchers analyzed the spatial correlation between historical PSPS outages on distribution circuits and nearby commercial facilities to assess how grid vulnerability might affect different subsectors.

Figure 46 plots the cumulative outage duration information for all of the circuits in the PSPS shutoff dataset that could be matched to the circuits within the assembled IOU centerline dataset (n = 718 matches from N = 1,410 circuits in the full PSPS dataset). Circuits colored in darker shades of red indicate those experiencing longer cumulative duration PSPS outage events over the 10-year period between 2013-2023. The circuit

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[82] California Labor Code § 1474, added by Assembly Bill 1228, 2023–2024 Regular Session (Cal. 2023), effective April 1, 2024

level data form the basis of the scoring calculations discussed in the previous methodology section.

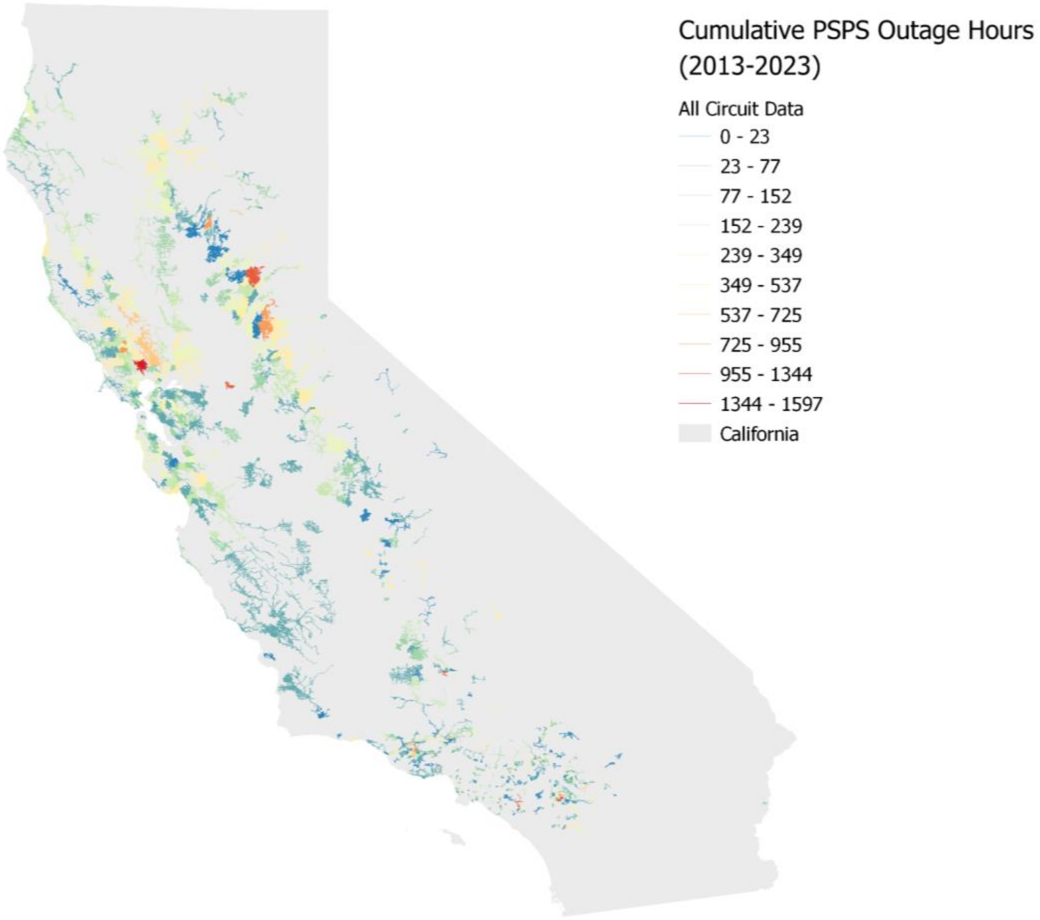


Figure 46. Cumulative PSPS related outage hours by three-phase distribution circuit from 2013-2023. Circuits are colored from blue to red on the basis of increasing cumulative total PSPS outage hours endured over the ten-year period

Table 42 provides an illustration of the total cumulative duration of outage hours experienced by facilities which were able to be linked to the available PSPS shutoff data via the nearest neighbor circuit association rule. These values represent the sum of PSPS outage events (in hours) experienced over the ten-year coverage period of the available data. An associated set of rankings is provided for each subsector. These were computed on the basis of the largest number of outage hours, summed across all facilities (DAC and non-DAC) within each subsector.

For both DACs and non-DACs, the top two subsectors with the highest cumulative PSPS outage hours are the same: Office and Miscellaneous. The third-ranked subsector diverges slightly, restaurants in DACs and retail in non-DACs, but the difference in cumulative PSPS outage hours between them is minimal. These results highlight an important point about geographic distribution and subsector prevalence. The cumulative PSPS outage hours appear to be driven less by the inherent vulnerability of specific facility types and more by how common and widespread those facilities are across tracts. In other words, subsectors with more facilities experience more total outage hours simply because they are more frequently present. The small differences between DAC and non-DAC rankings further suggest that this pattern holds consistently across both groups.

Table 42. Final output CEUS Subsector level grid outage vulnerability rankings.

CEUS Subsector	*Total Cumulative PSPS Outage Hours for Facilities in DACs*	*Ranking in DACs (by Largest Sum)*	*Total Cumulative PSPS Outage Hours for Facilities in Non-DACs*	*Ranking in Non-DACs (by Largest Sum)*
College	11,151	10	119,128	9
Food Store	20,330	5	172,057	6
Health Care	17,998	8	156,346	7
Lodging	12,852	9	104,018	10
Miscellaneous	32,614	2	221,663	2
Office	32,630	1	222,940	1
Refrigerated Warehouse	7,675	11	37,081	11
Restaurant	29,800	3	194,555	4
Retail	28,253	4	197,449	3
School	18,143	7	175,236	5
Unrefrigerated Warehouse	19,858	6	146,632	8

Technology Readiness

Facilities within different commercial subsectors consume varying amounts of gas to deliver different categories of end-use services. For each category, the technologies available to replace existing gas appliances and equipment vary in their stages of engineering development and commercial readiness. This current state of technological readiness and commercial viability for substitute electric appliances and equipment is a key factor in determining which commercial subsectors should be prioritized for future electrification. In addition, there are also concerns about the challenges associated with integrating these new technologies into existing buildings. To quantify these concerns, several criteria were developed to capture different aspects of the feasibility of electrification for each subsector. These criteria included the quantification of:

1) The technological readiness of substitute electric appliances and equipment for different gas end-use categories.
2) The distribution of gas consumption volumes among different gas end-use categories.
3) The average size of facilities in terms of building square footages.
4) The average age of facilities in terms of building construction vintages.

Higher prioritization scores correspond to higher building readiness and less technical difficulty. Here, a lower raw unitless score signifies a less zero emission appliance ready by TRL score and end use distribution. A more zero emission appliance ready has a higher score. As shown in Table 43, miscellaneous, refrigerated warehouse and health care have notably the lowest rankings, given the nature of processing end-uses within these subsectors and that they are the least technologically ready among end-use types. Unrefrigerated warehouses and offices, which predominantly rely on space heating and cooling and water heating end-uses have the highest technology readiness scores.

Table 43. Technology readiness rankings by CEUS Subsector.

CEUS Subsector	*Technology Readiness Score*	*Ranking*
College	3.002841	8
Food Store	2.357683	7
Health Care	3.282299	9
Lodging	1.986911	6
Miscellaneous	3.911891	11
Office	1.372131	2
Refrigerated Warehouse	3.6	10
Restaurant	1.96961	5
Retail	1.501538	4
School	1.384831	3
Unrefrigerated Warehouse	1.170588	1

End-Use Diversity

End-use diversity scores are directly derived from the 2006 CEUS natural gas consumption breakdown. End use diversity scores are highest for subsectors that have the highest variation in end-uses. Table 44 shows miscellaneous, being a highly diverse and open-ended sector unsurprisingly ranks the highest. Food store ranks third because it has equal heating, water heating, and cooking. Cooking surprisingly is a large share of overall gas consumption (37.5%) due to baking and food processing needs for food stores, which adds to the level of complexity of different end-uses.

Table 44. Final output CEUS Subsector level grid outage vulnerability rankings.

CEUS Subsector	*End-Use Diversity Score*	*Ranking*

College	4.538417	5
Food Store	5.42232	3
Health Care	4.989654	4
Lodging	3.832017	8
Miscellaneous	6.271782	1
Office	3.230715	10
Refrigerated Warehouse	5.5175	2
Restaurant	3.445246	9
Retail	4.060544	6
School	3.975714	7
Unrefrigerated Warehouse	2.880336	11

Median Building Size

Median building size differs slightly by DAC and Non-DAC (Table 45). However, in both cases refrigerated warehouses, warehouses and lodging given have the same top 3 building sizes, given the amount of square footage and floor space for all of them.

Table 45. Median building size by DAC, Non-DAC, and CEUS Subsector.

CEUS Subsector	*Non-DAC Median Building Size*	*Ranking*	*DAC Median Building Size*	*Ranking*	*All Median Building Size*	*Ranking*
College	11562.5	4	9597	4	10579.75	4
Food Store	8610	8	4955	11	6782.5	10
Health Care	9600	6	8085	5	8842.5	6
Lodging	18629	1	13003.5	3	15816.25	1
Miscellaneous	8515.5	9	6178	8	7346.75	8
Office	10107	5	8020	6	9063.5	5
Refrigerated Warehouse	13432	3	13164	2	13298	3
Restaurant	7774	10	6000	10	6887	9
Retail	9464.5	7	7936	7	8700.25	7
School	6397	11	6038	9	6217.5	11

Unrefrigerated Warehouse	16270	2	13744	1	15007	2

Median Building Vintage

Table 46 shows commercial buildings in DACs are consistently older than those in non-DACs. The smallest gap is between lodging and restaurants which are more proximate in building vintage, those still newer in non-DAC census tracts. Strikingly, the oldest building vintage sector are schools for DAC and non-DAC.

Table 46. Median Building Vintage by DAC, Non-DAC, and CEUS Subsector.

CEUS Subsector	*Non-DAC Median Building Vintage*	*Ranking*	*DAC Median Building Vintage*	*Ranking*	*All Median Building Vintage*	*Ranking*
College	1976	6	1969	6	1972.5	6
Food Store	1972	8	1963	9	1967.5	8
Health Care	1978	3	1970	4	1974	4
Lodging	1967	10	1964	8	1965.5	10
Miscellaneous	1971	9	1962	10	1966.5	9
Office	1979	1	1972	3	1975.5	3
Refrigerated Warehouse	1977	4	1969.5	5	1973.25	5
Restaurant	1977	4	1975	1	1976	2
Retail	1974	7	1967	7	1970.5	7
School	1966	11	1959	11	1962.5	11
Unrefrigerated Warehouse	1979	1	1974	2	1976.5	1

Average Therms per Premise

Table 47 shows average therms per premise doesn't vary too much between DAC and non-DAC. Consistently, Colleges, Health Care and Lodging have the highest average per therms. All these results are not entirely surprising given that these sectors have the highest 24/7 use, require constant backup power, and have the closest to residential energy use patterns.

Table 47. Average therms per premise by DAC, Non-DAC, and CEUS Subsector.

CEUS Subsector	*Non-DAC Average*	*Ranking*	*DAC Average Therms*	*Ranking*	*All Average Therms per Premise*	*Ranking*

	Therms per Premise		*per Premise*			
College	41802.87	1	7583.422	3	24693.146	1
Food Store	5773.264	4	4440.541	6	5106.9025	4
Health Care	21481.21	2	17481.91	1	19481.56	2
Lodging	12321.68	3	9556.018	2	10938.849	3
Miscellaneous	4856.767	8	4087.878	7	4472.3225	7
Office	5441.601	6	2764.528	9	4103.0645	8
Refrigerated Warehouse	1465.032	10	3084.134	8	2274.583	10
Restaurant	5119.978	7	4995.108	4	5057.543	6
Retail	1341.704	11	1454.219	11	1397.9615	11
School	5745.613	5	4463.628	5	5104.6205	5
Unrefrigerated Warehouse	2905.583	9	2437.091	10	2671.337	9

Prioritization Framework Tool Development

Recognizing that individual stakeholders are likely to have varying perspectives on the metrics as they relate to their own priorities for electrification, the Research Team developed an associated tool for exploring the metric data developed for the framework. The tool allows users to adjust three primary elements: (1) the inclusion of metrics (e.g. should median building size be included or excluded from consideration in the prioritization process?), (2) the weight of a metric (e.g. are metrics related to emissions more important in electrification prioritization than metrics related to difficulty?), and (3) the directionality of a metric (e.g. should a higher technology readiness score be associated with higher prioritization or lower prioritization?). The tool was explicitly designed in this way to include features that would allow users to explore different combinations, weights, and directionalities of the included metrics. Its development was an iterative process, informed by multiple rounds of feedback from CARB staff.

Because most of the raw inputs associated with the various prioritization metrics are represented in different units, the tool applies a min-max normalization procedure. This establishes a common unit space for each metric regardless of their initial unit values while preserving the original distribution shapes of each metric across the commercial subsectors. The result is a score ranging from 1-100 for each commercial subsector along each metric. The tool provides individual metric scores for each commercial subsector as well as a total score for each commercial subsector derived from all included metrics. The total score for each commercial subsector is calculated by summing the normalized scores of each metric. That total score value is then normalized again using the min-max method to generate an overall 1-100 priority score.

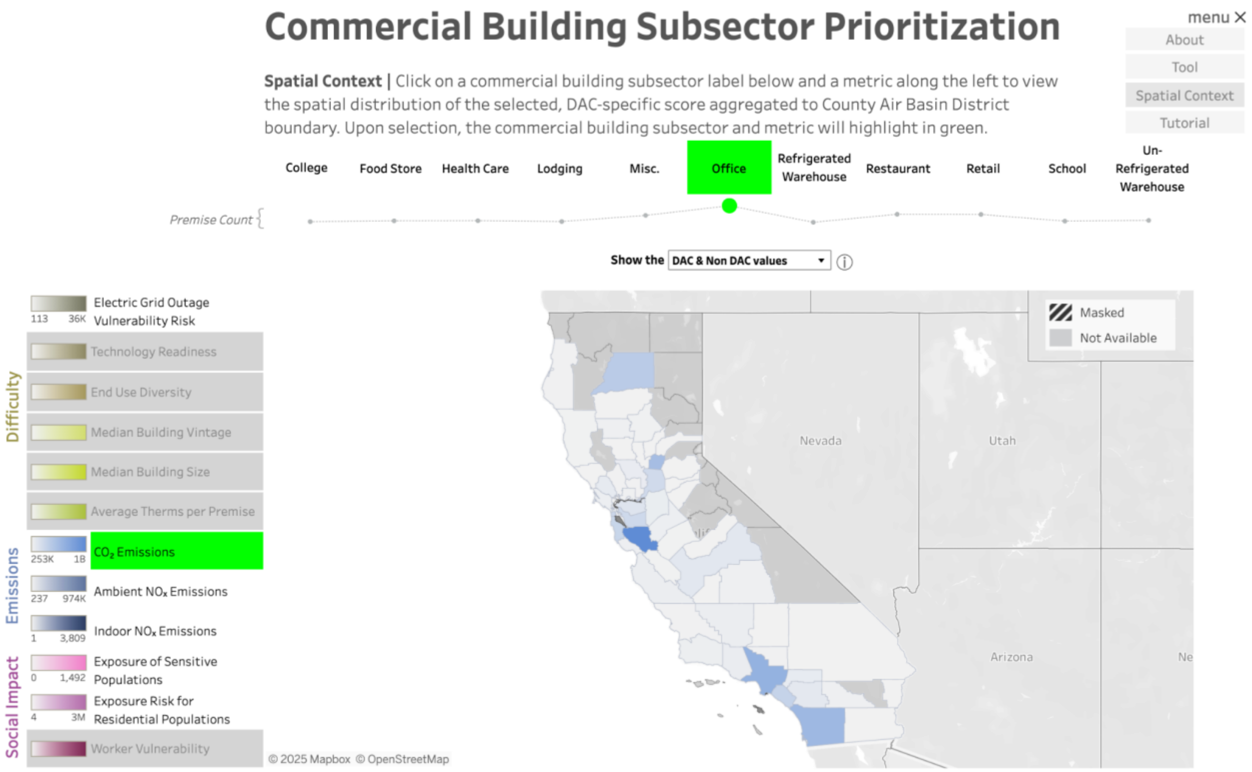
This final normalization is performed to simplify interpretation of the final prioritization results.

In its default configuration, the tool is set up such that each category of metric (Difficulty, Emissions, and Social Impact) contributes equally to the analysis. Because the Difficulty category contains six metrics while Emissions and Social Impact each contain three metrics, the rescaling of the 1-100 scores by the number of available metrics per category gives equal importance to each category. The weighting feature in the tool allows users to change this default setting and either reweight individual metrics or all metrics in a given category. In addition to default weights, the tool defaults to particular metric directionalities determined by the research team. These default directionality settings prioritize minimizing costs and technical difficulty while maximizing social benefits related to air quality and health vulnerability. These default directionality settings are listed in *Table 48*.

Table 48. Prioritization Framework Default Metric Directionality

Metric Category	*Metric*	*Directionality (= High Priority)*	*Priority*
Difficulty	Electric Grid Outage Vulnerability Risk	Low electric grid outage vulnerability risk	Minimize cost
	Technology Readiness	More zero emission appliance ready	Minimize difficulty
	End Use Diversity (Variance)	Less diverse gas end uses	Minimize cost & difficulty
	Median Building Vintage	High median building vintage (newer buildings)	Minimize difficulty
	Median Building Size	Low median building size (smaller buildings)	Minimize cost & difficulty
	Average Therms per Premise	Low average gas consumption	Minimize cost & difficulty
Emissions	CO_2 Emissions	High CO_2 emissions	Maximize social benefit
	Ambient NOx Emissions	High ambient NOx emissions	Maximize social benefit
	Indoor NOx Emissions	High indoor NOx emissions	Maximize social benefit
Social Impact	Exposure of Sensitive Populations	Sensitive populations more exposed to subsector emissions	Maximize social benefit
	Emissions Exposure Risk for Residential Populations	More residents exposed to subsector emissions	Maximize social benefit
	Worker Vulnerability	High worker vulnerability	Maximize social benefit

In addition to the tool's main data view, a spatial context page is available, which allows users to view the underlying metric values aggregated to relevant County Air Basin Districts. The page is meant to provide greater transparency in the spatial distribution of metrics that were originally calculated at a finer geographic scale than the state (Electric Grid Outage Vulnerability Risk, CO_2 Emissions, Ambient NO_x Emissions, Indoor NO_x Emissions, Exposure of Sensitive Populations, and Exposure Risk for Residential Populations). The values available on that page represent the raw, pre-scaled values in their native units as described in *Table 9*. *Figure 47* below provides a snapshot of the spatial context page with the CO_2 Emissions metric and Office commercial subsector selected.



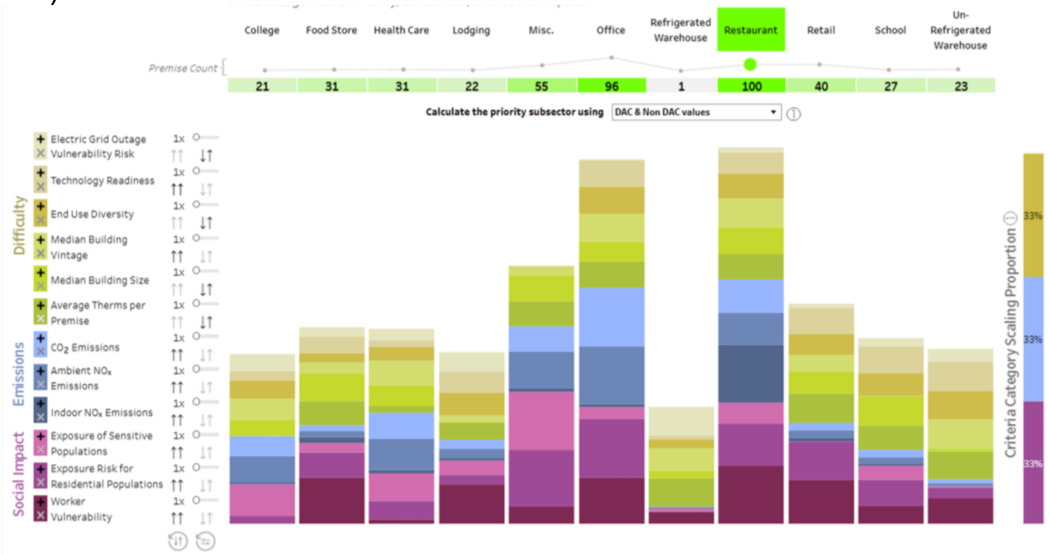
Commercial Building Subsector Prioritization

Spatial Context | Click on a commercial building subsector label below and a metric along the left to view the spatial distribution of the selected, DAC-specific score aggregated to County Air Basin District boundary. Upon selection, the commercial building subsector and metric will highlight in green.

Show the DAC & Non DAC values

Figure 47. Snapshot of the spatial context page with the CO2 Emissions metric and Office commercial subsector selected.

The interactive tool's default parameterization, which was set up to reflect policymaker objectives for regulation and incentive program design, ranked Restaurant highest (*Figure 48*).



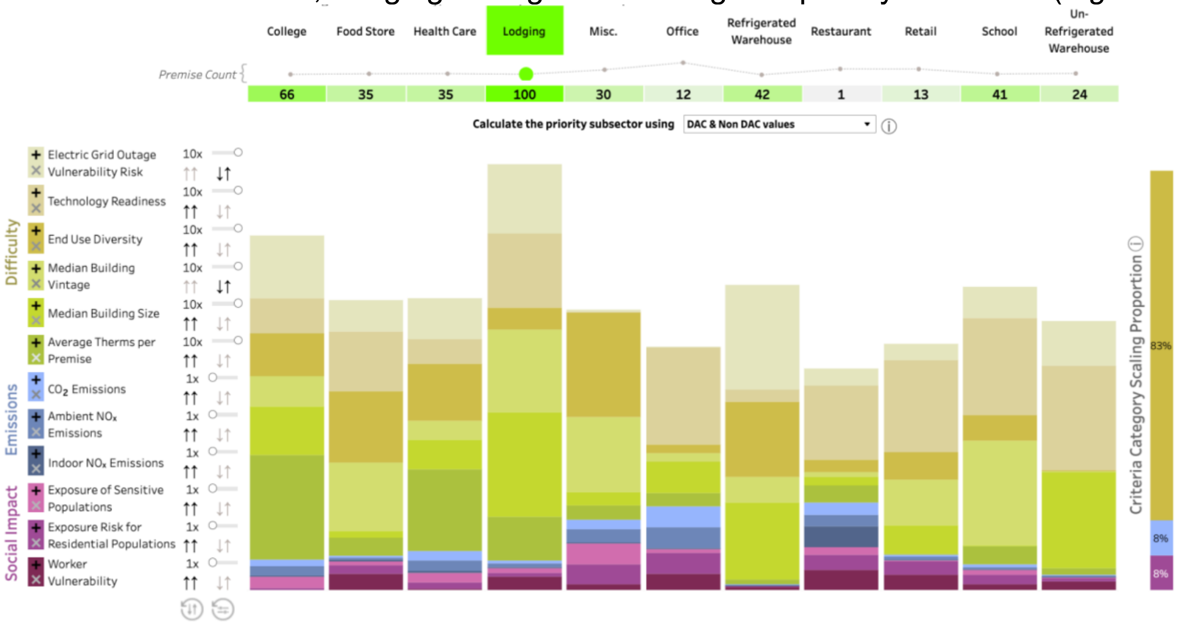
Calculate the priority subsector using DAC & Non DAC values

Figure 48. Interactive Tool with Default Directionality and Weighting

Priority Subsector Identification

One of the objectives for this project was the identification of a single "priority subsector" that would be the focus of a more detailed electrification feasibility assessment. The selection of this priority subsector required a different approach than the policy-focused prioritization framework discussed previously. Rather than seeking to identify the subsectors with the highest environmental impacts or social benefits, the research team instead sought to identify the subsector whose further study would most likely yield the greatest insights for future research and policy development. This selection process involved internal discussions among the Research Team, CARB staff, and the Technical Advisory Committee, along with targeted use of the interactive prioritization framework tool. By prioritizing a subsector that presents the greatest opportunity for in-depth analysis from site visits and stakeholder engagement, the Research Team aims to generate insights that will help address key electrification challenges. This approach, while distinct from a purely policy-driven ranking, ensures that the selected subsector provides the most valuable foundation for future research and regulatory advancements.

To identify a subsector offering maximum returns to learning, the team adjusted the tool's weights and directionalities to emphasize difficulty factors: older building vintages, larger building sizes, greater end-use diversity, and higher gas consumption intensity (average annual therms per premise). All difficulty-related criteria received a weight factor of 10, while emissions and social impact metrics retained their original weights and directions. The team prioritized technology-ready subsectors to focus the feasibility assessment on electrification processes rather than equipment market readiness. Under this modified framework, Lodging emerged as the highest-priority subsector (*Figure 49*).



Calculate the priority subsector using DAC & Non DAC values

Figure 49. Interactive Tool Prioritizing Difficulty of Electrification

Characteristics Supporting Selection of Lodging as the Priority Subsector

The Lodging subsector in the CEC's California Commercial End Use Survey includes buildings with NAICS codes related to guest accommodation, food services, and related hospitality services. This encompasses hotels and motels, casino hotels, bed-and-breakfast inns, other traveler accommodations and rooming and boarding houses, dormitories, and workers' camps. The selection of the Lodging subsector was further validated by additional background research on the subsector. Lodging facilities can often comprise spaces that possess important defining characteristics of several other commercial subsectors. For example, a single hotel can contain a restaurant or other dedicated commercial food preparation spaces, retail stores, gyms, pool, and spa areas, on–premise commercial laundry facilities, and offices. Additionally, lodging facilities can be analogous in some cases to the multi-family residential sector. These patterns are clearly illustrated by *Figure 50*, which contains a floorplan for the lower level of a typical lodging facility.

The choice of Lodging as a priority subsector is therefore likely to maximize the returns to learning, associated with the feasibility assessment site visits and interviews that will be conducted in the latter phases of the project. In addition to the diversity of end uses previously discussed, lodging facilities also possess a significant diversity in terms of their physical building characteristics - i.e., the total number of units, number of floors, luxury scale, amenities (e.g. pool/spa, offers breakfast, on-premise laundry, conference rooms), ownership type (e.g. chain, independent), and the tenure of occupants (e.g. long-term boarding house, short-term hotel). These can all be drawn upon to systematically develop a representative sample of different facility typologies to be investigated as part of the study.

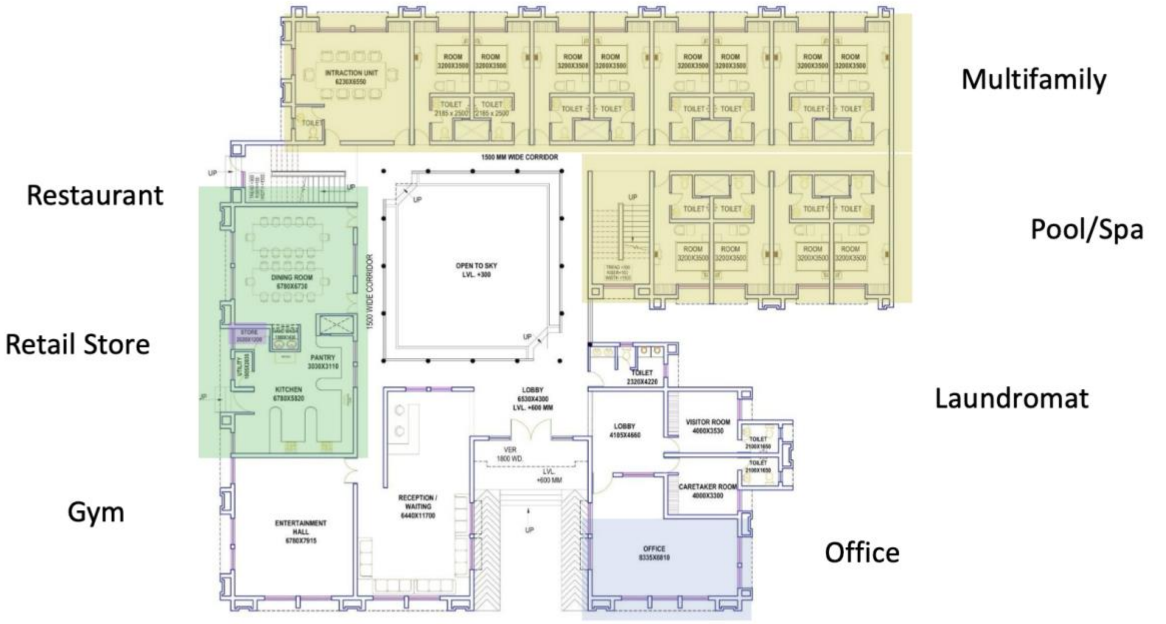


Image Source: Imagination Shaper

Figure 50. Example of Lodging Lower Level Floor Plan

Analyzing the lodging subsector within the context of the CEUS reveals distinct energy use patterns that highlight its potential as a valuable focus for further investigation. [83] Between the 2006 and 2022 CEUS, the share of electric heating fuel in lodging declined from 58% to 40%–the largest drop across all sectors. Conversely, the gas heating fuel

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[83] Measures of fuel share in the CEUS are on the basis of square footage–gas and electric fuel share do not sum to 100%.

share increased from 32% to almost 60%.[84] The fuel share remained mostly stable for gas water heating, while electric water heating saw a slight decline. Additionally, the penetration of miscellaneous gas equipment rose from 58% to 82%, whereas miscellaneous electric equipment remained largely unchanged.[85]

A preliminary literature review indicated a scarcity of examples of fully electrified lodging buildings, in contrast to other commercial buildings such as restaurants,[86] university buildings,[87,88] and hospitals,[89] which have implemented all-electric systems. The only identified fully-electric hotel is the Hotel Marcel in New Haven, Connecticut,[90] while in California the examples available publicly are select end-use electrification upgrades.[91] Further research and analysis are essential to assess barriers and feasibility of electrification in the lodging subsector, with the potential of offering valuable insights for other subsectors and a diverse range of end-use electrification.

3.2.5 - Priority Subsector Feasibility Assessment

Lodging Subsector Background and Landscape

The lodging subsector makes up over 5% of California's commercial floor area, at approximately 43,827,000 m^2 (471,706 kft^2) as of 2022.[92] Determining the precise number of lodging facilities proves challenging due to inconsistent reporting across data sources. The American Hotel and Lodging Association's (AHLA) latest available data identifies 6,778 hotel properties with a total of 571,794 rooms in California.[93] IBISWorld, in contrast, claims 14,055 hotel and motel businesses,[94] 406 bed-and-breakfast inns,[95] and 36 casino hotels.[96] CoStar property data identified 7,308 California hotels.

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[84] Commercial End Use Survey, 2022, pg. 98-99. Available at: https://www.energy.ca.gov/sites/default/files/2024-02/2022%20CEUS%20Final%20Report_ada.pdf

[85] Commercial End Use Survey, 2022, pg. 104. Available at: https://www.energy.ca.gov/sites/default/files/2024-02/2022%20CEUS%20Final%20Report_ada.pdf

[86] "Chipotle Moves Away from Gas with All-Electric Restaurant Design." Lisa Jennings, Restaurant Business, Apr. 11, 2023. Available at: https://restaurantbusinessonline.com/operations/chipotle-moves-away-gas-all-electric-restaurant-design.

[87] "How Three UC Campuses Are Phasing out Fossil Fuels." University of California, Feb. 1, 2024, Available at: https://www.universityofcalifornia.edu/news/how-three-uc-campuses-are-phasing-out-fossil-fuels.

[88] https://news.stanford.edu/stories/2024/09/electrical-upgrades-will-help-stanford-achieve-climate-goals

[89] "Nation's 1st All-Electric, Zero-Emission Hospital Coming to Irvine in 2025." ABC7 Los Angeles, Apr. 29, 2024. Available at: https://abc7.com/uci-health-irvine-all-electric-hospital-medical-campus/14736397/.

[90] "How Hotel Marcel Is Becoming the First Net Zero Hotel in the U.S." KONE Corporation, Feb. 25, 2025. Available at: https://www.kone.com/en/news-and-insights/stories/decarbonizing-hotel-marcel.aspx.

[91] "Property in Palm Springs, CA Installs Fully-Integrated Heat Pump Water Heater That Runs on Environmentally Safe R-134a Refrigerant." American Power Solutions, Feb. 13, 2024. Available at: https://www.americanpowersolutions.com/single-post/property-in-palm-springs-ca-installs-fully-integrated-heat-pump-water-heater-that-runs-on-environme.

[92] 2022 CEUS, p. 74

[93] American Hotel & Lodging Association. (n.d.). California's Hotel Industry by the Numbers. American Hotel & Lodging Association. https://economic-impact.ahla.com/reports/states/california.pdf

[94] IbisWorld (n.d.). *Hotels & Motels in California—Market Research Report (2015-2030) | IBISWorld*. Retrieved August 5, 2025, from https://www.ibisworld.com/united-states/industry/california/hotels-motels/11190/

[95] IbisWorld. (n.d.). *Bed & Breakfast & Hostel Accommodations in California—Market Research Report (2015-2030) | IBISWorld*. Retrieved August 5, 2025, from https://www.ibisworld.com/united-states/industry/california/bed-breakfast-hostel-accommodations/14959/

[96] IBISWorld. (n.d.). *Casino Hotels in California—Market Research Report (2015-2030) | IBISWorld*. Retrieved August 5, 2025, from https://www.ibisworld.com/united-states/industry/california/casino-hotels/11191/

Lodging Classification Systems

There are multiple approaches to differentiating between hotel types. Coldwell Banker Richard Ellis (CBRE), the world's largest commercial real estate services and investment firm, provides the following classifications: full-service, limited-service, all suite, extended stay, convention, and resort.[97] Meanwhile, STR, a subsidiary of CoStar Group focused on providing market data for the hotel industry, applies a "chain scale": luxury, upper upscale, upscale, upper midscale, midscale, and economy.[98] These classification methods are generally on the basis of amenities offered, tenure of guests, and price range. The Building Owners and Managers Association (BOMA) classifies buildings in the following way:[99]

- Class A – The most prestigious buildings competing for premier office users with rents above average for the area. Buildings have high-quality standard finishes, state-of-the-art systems, exceptional accessibility, and a definite market presence.
- Class B – Buildings competing for a wide range of users with rents in the average range for the area. Building finishes are fair to good for the area and systems are adequate, but the building does not compete with Class A at the same price.
- Class C – Buildings competing for tenants requiring functional space at rents below the average for the area.

Independent of these categories are the hotel's brand affiliation and ownership model. Across the United States, roughly 70% of hotel rooms are brand-affiliated, though this ratio varies widely by price point.[100] Branded rooms are particularly popular in the midscale segment, while less than half of luxury-class (39%) and economy class (49%) hotels carry a brand.[101] Of the 70%, roughly 80% are franchised operations.[102] The various classifications are presumed to be strongly related to the buildings' energy consumption and end-use appliance decisions, and as a function of both, their utility expenses.

Lodging Existing Building Stock

In California, the hotel sector is extensive and varied, ranging from small, independently managed motels to large chain-operated full-service hotels. Results from CoStar show that more than half of California's hotels are small (under 50 rooms), built before 1990, and independently operated, with a majority falling into Building Class C. Class C buildings are often older, have more significant deferred maintenance and renovation

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[97] Robert Mandelbaum & Joe Snider. (2024, April 1). *Gaining Control of Utility Costs*. Retrieved August 5, 2025, from https://www.cbre.com/insights/briefs/gaining-control-of-utility-costs

[98] CrowdStreet Advisors. (n.d.). Understanding the Four Major Hotel Types. Property Perspectives. https://www.crowdstreet.com/resources/properties-perspectives/understanding-the-four-major-types-of-hotel-real-estate

[99] Building Owners and Managers Association (BOMA) International, "Building Class Definitions." https://www.boma.org/building-class-definitions

[100] Jan Freitag. (2023, October 25). *Half of US Economy-Class Hotel Rooms are Unbranded*. CoStar. https://www.costar.com/article/1112230909/half-of-us-economy-class-hotel-rooms-are-unbranded

[101] Jan Freitag. (2023, October 25).

[102] JLL. (n.d.). Why More Hotels Are Owned by Franchisees. Hotel-Online. Retrieved August 5, 2025, from https://www.hotel-online.com/press_releases/release/why-more-hotels-are-owned-by-franchisees/

needs, and may be located in less desirable areas.

Roughly 65% of hotels offer gas-intensive amenities. These amenities are disproportionately present in properties with more rooms, higher hotel class, or more recent vintages. However, many economy and midscale hotels—even those with fewer than 50 rooms—also exhibit high diversity of gas end-use amenities, underscoring the breadth of electrification opportunities. *Figure 51* illustrates overall trends in all hotels by class and location. Over half of hotels are Economy to Midscale and are located in Suburban or Small Town areas.

Figure 51. Frequency of Lodging Buildings by Hotel Location Type and Hotel Class

The majority of California hotels are classified as Class B or C, with Class C representing the largest share in terms of the number of facilities, as shown in *Figure 52*.

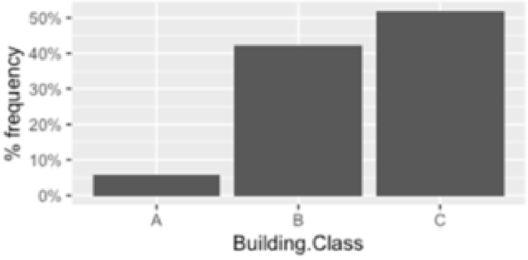

Figure 52. Frequency of Lodging Buildings by Building Class (CoStar)

Figure 53 provides a comprehensive overview of the lodging sector statewide. The data shows key metrics including the distribution of properties across different classifications, revealing patterns in building age, size, and operational characteristics that define California's hotel landscape. More than half of California’s hotels are small (under 50 rooms), built before 1990, and independently operated, with a majority falling into Building Class C. Building Class C hotels are on average older, with few rooms, and have been renovated less recently (*Figure 54*).

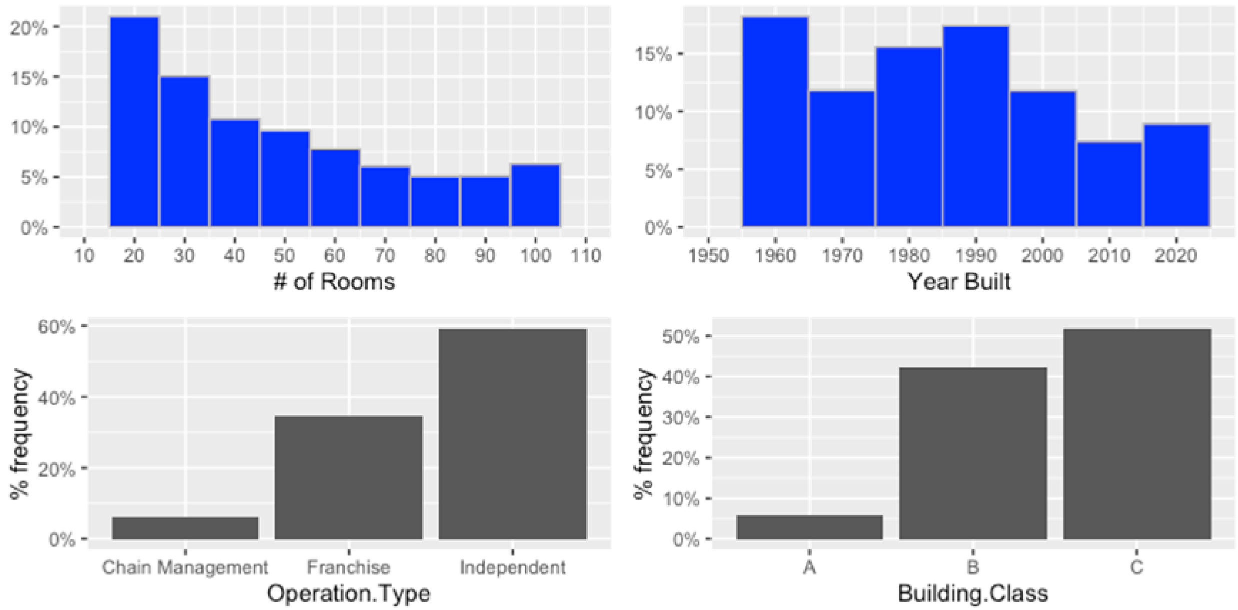

Figure 53. Lodging Sector Statewide Overview Metrics

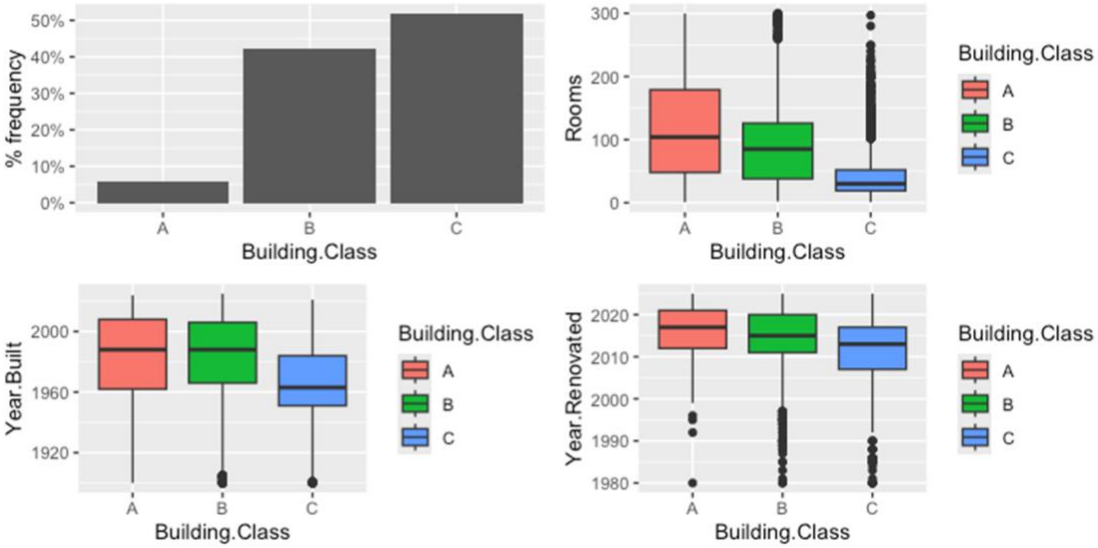

Figure 54. Lodging Sector Statewide Overview Metrics by Building Class

Lodging End-Uses

Based on the 2022 CEUS, the lodging sub-sector constitutes 6.7% of statewide gas consumption (as displayed in *Figure 55* below), and 4.5% of statewide electricity consumption.[103] While ranking sixth among twelve building types in annual gas usage, lodging ranks fifth in gas intensity at 33.9 kBTU per thousand square feet.[104] Both

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[103] 2022 CEUS, p. 7

[104] 2022 CEUS, p. 6

electric and gas energy intensities declined among lodging sector facilities between 2016 and 2022.[105]

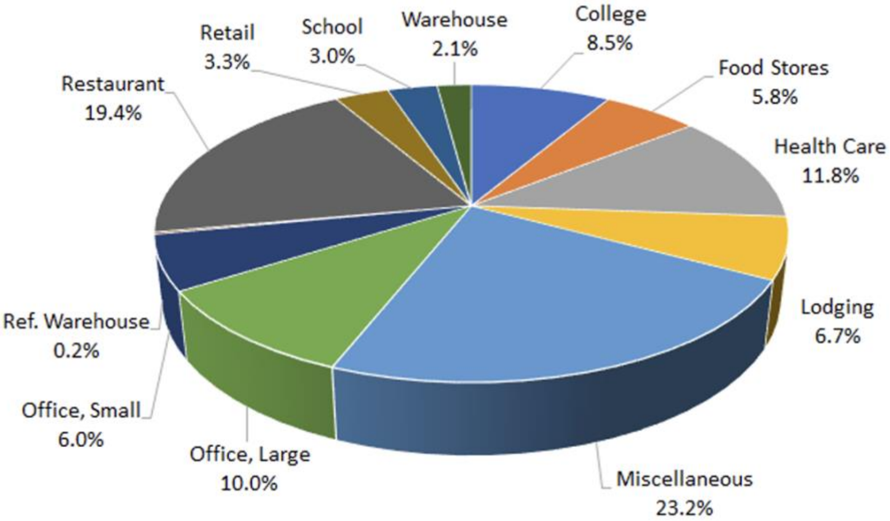
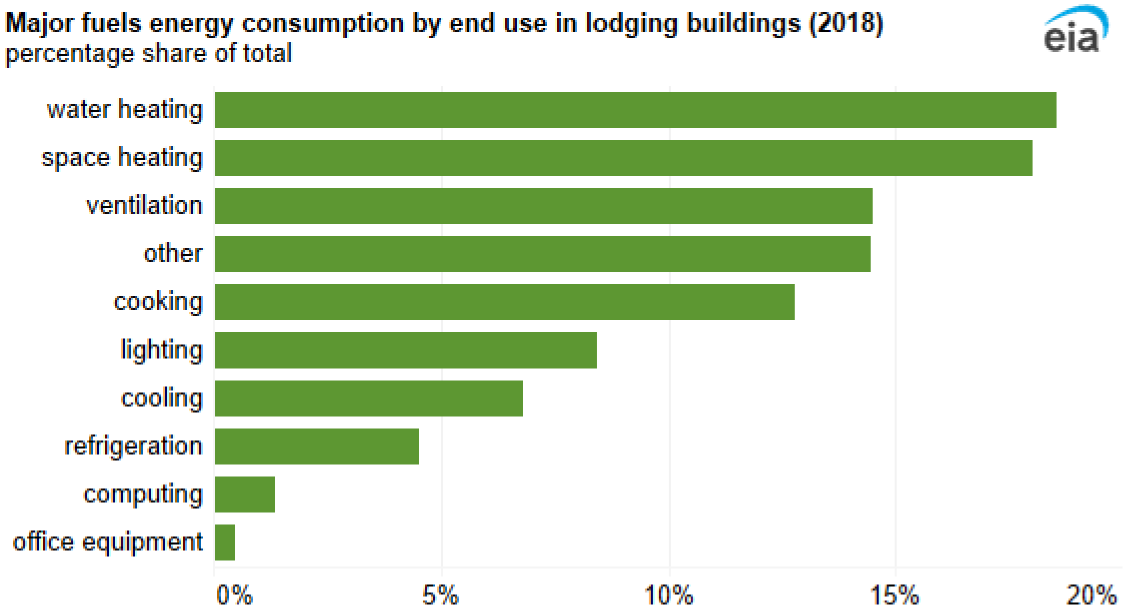


Figure 55. Statewide Commercial Gas Use by Building Type

Across the United States, water heating, space heating, and ventilation combined make up more than 50% of total fuel energy consumption in lodging subsector, as illustrated in *Figure 56* below from the US Energy Information Administration – Commercial Buildings Energy Consumption Survey (EIA CBECS).



Data source: U.S. Energy Information Administration, *Commercial Buildings Energy Consumption Survey*

Figure 56. Major Fuels Energy Consumption by End Use in Lodging Buildings (2018), EIA

The 2022 CEUS provides fuel share by end-use specific to California's commercial building stock. This is calculated on the basis of the percentage of total floor space that

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[105] 2022 CEUS, p. 94

includes a given end-use. Non-electric fuels (including propane, fuel oil, and gas) are used for heating, commercial cooking, and water heating; gas accounts for more than 50% fuel share for each end-use (*Figure 57* below).

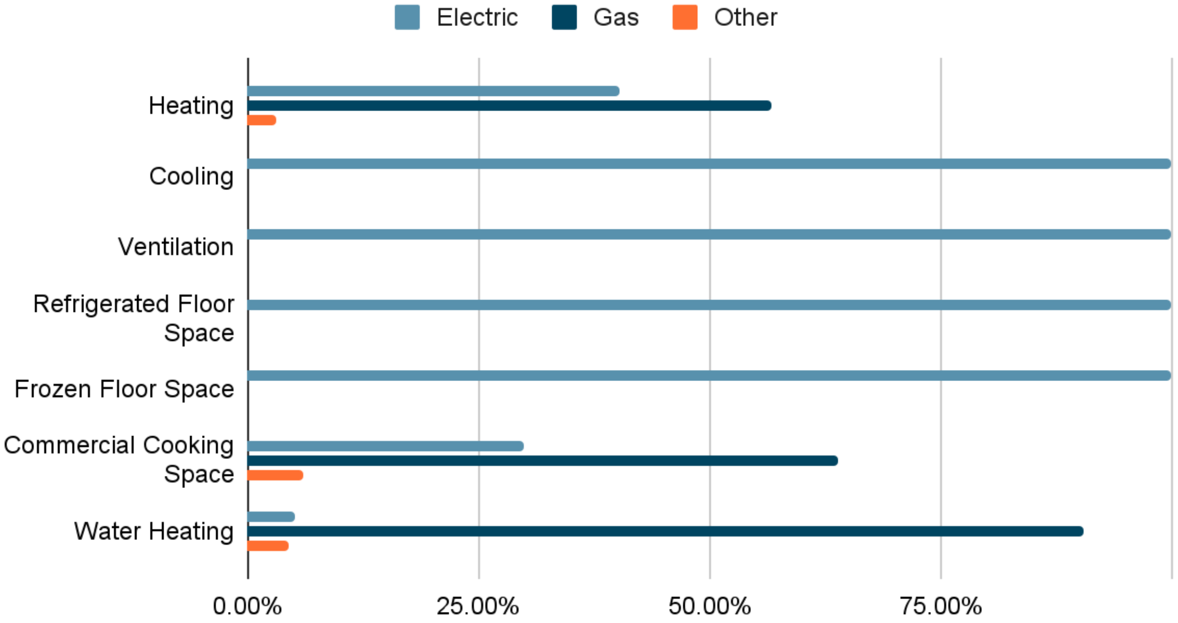

Figure 57. Lodging End Use Fuel Share (2022 CEUS Appendix K)

Figure 58 offers another approach to analyzing the makeup of gas consumption among lodging buildings. Using data from the 2006 CEUS, as the 2022 report did not include this information, it provides the breakdown of natural gas usage by end-use for lodging and all commercial buildings as context. Water heating makes up the largest portion of lodging sector facility consumption, followed by heating, cooking, and miscellaneous. The larger share of gas usage for water heating may be due to the continuous and substantial demand for hot water—for guest showers, laundry services, kitchens, dishwashing, and sometimes spas or pools.

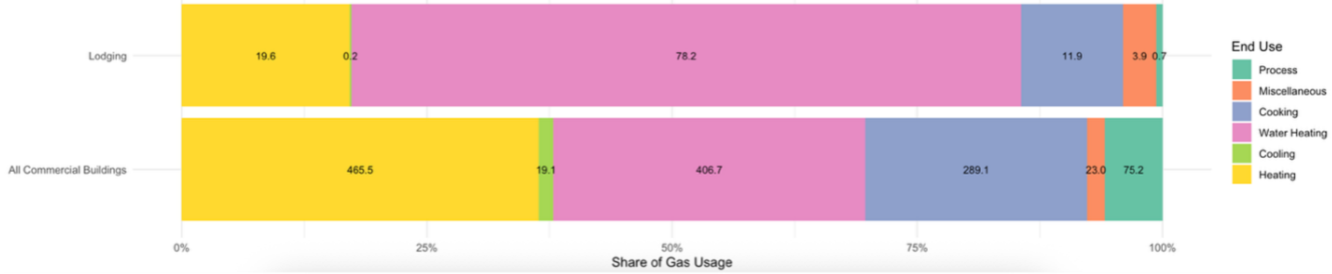

Figure 58. Statewide Natural Gas Usage (MTherms) by End-Use[106]

Space Heating and Cooling

Lodging space heating and cooling system designs are informed by several factors: performance needs, capacity, occupancy, available space, budgets, water availability,

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[106] Itron, Inc., KEMA, ADM Associates, & James J. Hirsch & Associates. (2006, March). California Commercial End-Use Survey Report. California Energy Commission. https://planning.lacity.gov/eir/CrossroadsHwd/deir/files/references/C19.pdf

building height, utility rates, and codes and standards requirements.[107] For instance, a hotel may use packaged unitary air conditioners for guest rooms, rooftop units for meeting rooms and restaurants, and a central plant system for the lobby, corridors, and other common spaces. Hotel guest rooms may also have several types of space heating equipment such as packaged terminal air conditioners (PTAC), a vertical terminal air conditioner (VTAC) or a variable refrigerant flow (VRF) HVAC system (*Image 1*).[108]

Image 1. Typical Hotel HVAC Appliance Alternatives[109]

The primary source of information on the distribution of space heating and cooling equipment in lodging buildings is the US EIA CBECS. *Figure 59* and *Figure 60* below summarize the surveyed equipment types for heating and cooling, respectively, across the United States. Individual space heaters were the most common heating equipment in lodging buildings (32%), followed by packaged heating units (31%), heat pumps (29%), furnaces (26%), and boilers (24%). Less than 5% of buildings use district heat and duct reheat, respectively.[110]

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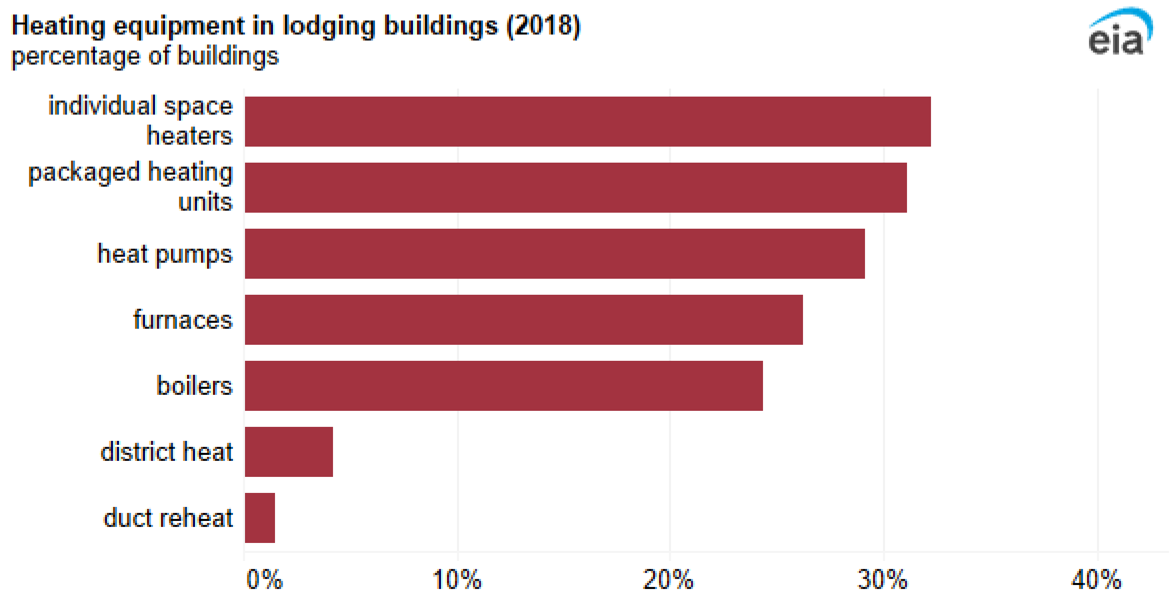
[107] A. Bhatia. "HVAC Design Aspects: Choosing a Right System," 2020. Accessible at: https://www.pdhonline.com/courses/m149/m149content.pdf

[108] A. Bhatia. (2020)

[109] "Understanding Your HVAC Options: Hotel Guestrooms." BASE4, 10 July 2019, https://www.base-4.com/understanding-your-hvac-options/.

[110] U.S. Energy Information Administration—EIA - Independent Statistics and Analysis. (n.d.).



Data source: U.S. Energy Information Administration, *Commercial Buildings Energy Consumption Survey*
Note: More than one type of heating equipment may apply.

Figure 59. Heating Equipment in Lodging Buildings (2018), EIA

Individual air conditioners were used for cooling in 50% of lodging buildings, with packaged air conditioners used in nearly 35%, residential-type central air conditioners in over 20%, heat pumps in just under 20%, and central chillers, district chilled water, and swamp coolers in less than 10% combined.[111] Curiously, the data indicate that the percentage of buildings with heat pumps for heating and for cooling are unequal; nearly 30% of buildings use heat pumps for heating, but less than 20% for cooling.

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[111] U.S. Energy Information Administration—EIA - Independent Statistics and Analysis. (n.d.).

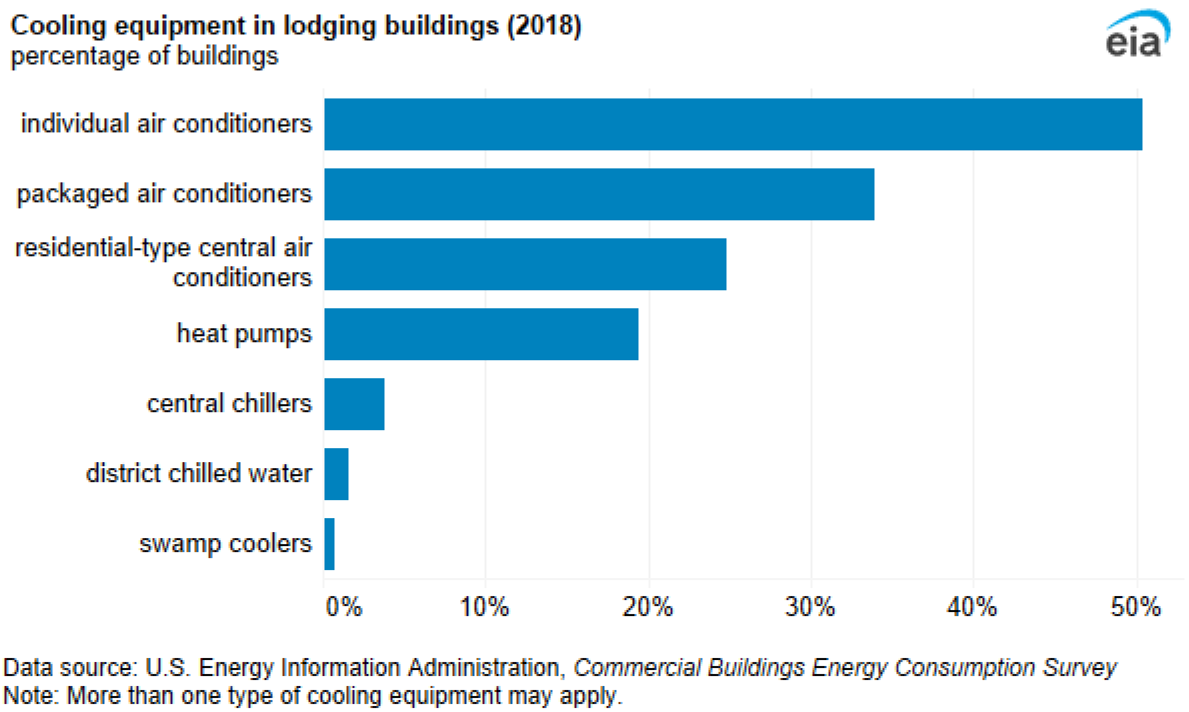

Figure 60. Cooling Equipment in Lodging Buildings (2018), EIA

Water Heating End-Use

Hotel water heating systems must be designed to meet enormous peak demands, despite only a fraction of those peaks being used on an average day.[112] The characteristic of the end uses – showers, laundry, dish washing – inform the equipment requirements. Commercial water heating equipment includes storage water heaters, instantaneous water heaters and hot water supply boilers, and unfired hot water storage tanks.[113] The most common commercial electric water heating technologies include an integrated heat pump with a water tank packaged as a single unit, and a split heat pump water heater with a water tank.[114] Electric resistance heating with storage is an additional electric option.[115] Brand hotels may follow water heating appliance specifications. Hilton, IHG, and Hyatt do not have any specific preferences.[116] In contrast, tankless gas water heating has been a requirement for all Marriott-managed hotels since 2015. Marriott's design specifications promote a two-tier water heating, i.e., preheating domestic water to 125°F for general usage including all guestrooms, and

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[112] Trejos, Nancy. “How Hotels Ensure Hot Showers for Thousands of Guests.” USA TODAY, https://www.usatoday.com/story/travel/hotels/2018/12/03/hot-showers-hotels/2154259002/. Accessed 22 Aug. 2025.

[113] “Commercial Water Heating Equipment.” Energy.Gov, https://www.energy.gov/eere/buildings/commercial-water-heating-equipment. Accessed 22 Aug. 2025.

[114] Zhu, Yanrong, et al., South Coast Air Quality Management District, 2022, “Residential and Commercial Building Appliances”, 2022 Air Quality Management Plan (AQMP), Available at: https://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2022-air-quality-management-plan/final-2022-aqmp/buildings_final.pdf?sfvrsn=22

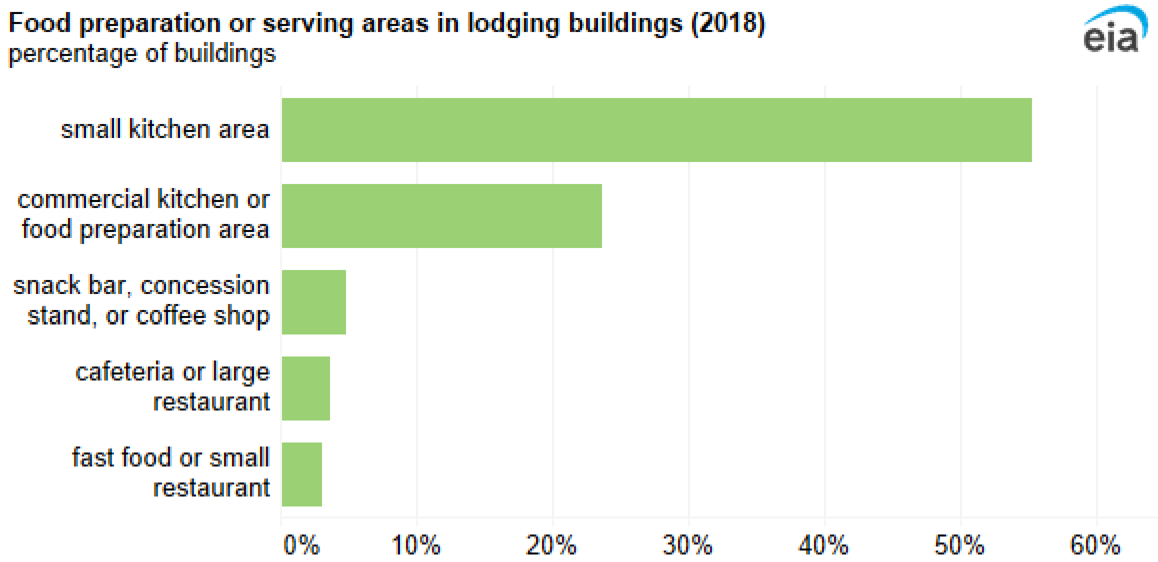
[115] Zhu, Yanrong, et al., South Coast Air Quality Management District, (2022)

[116] “Understanding Your HVAC Options: Hotel Guestrooms.” BASE4, 10 July 2019, https://www.base-4.com/understanding-your-hvac-options/.

boosting domestic hot water to 140°F through another set of tankless unit(s) for laundry and kitchen zones.[117]

Cooking End-Use

More than 20% of surveyed lodging buildings across the United States have a commercial kitchen or food preparation area, as seen in *Figure 61* below.[118] Meanwhile, nearly 60% of lodging facilities in California have gas cooking equipment.[119] The majority of continental breakfast kitchen set-ups are already predominantly electric.[120] Hospitality foodservice kitchen designs are generally similar to other foodservice categories: catering kitchens are similar to institutional kitchens; restaurants in hospitality locations are similar to full-service restaurants.[121]



Data source: U.S. Energy Information Administration, *Commercial Buildings Energy Consumption Survey*
Note: More than one type of food preparation or serving area may apply.

Figure 61. Food Preparation or Serving Areas in Lodging Buildings (2018), EIA

There are significant upfront and operational costs associated with cooking equipment electrification. Upgrading the main distribution panel and the service drop from the utility feeder to the building can be a significant cost: average electrical upgrade costs per site are $40,000 for institutional kitchens, and $160,000 for quick-service.[122] Peak demand increases are found to range from 50 to 71% between institutional to full-service restaurants, with an average of 65% peak demand increase across restaurant categories.[123] Energy demand increases may be slightly mitigated by changes to ventilation needs. As an added benefit, electric cooking appliances require less

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[117] Marriott Hotels, (2020), "Plumbing Standards", Global Design Strategies, Design Standards, Chapter 15B.1. Available at: https://www.gustavopreston.com/wp-content/uploads/2020/11/Marriott-Hotels-USCA-Plumbing.pdf

[118] U.S. Energy Information Administration—EIA - Independent Statistics and Analysis. (n.d.).

[119] 2022 CEUS

[120] Monsur, Joe, Paul Kuck, and Scott Honegger. "All-Electric Commercial Kitchen Electrical Requirements Study." CalNEXT, December 21, 2022.

[121] Monsur, Joe, et al., CALNEXT, (2022)

[122] Monsur, Joe, et al., CALNEXT, (2022), pg. 3

[123] Monsur, Joe, et al., CALNEXT, (2022), pg 17

ventilation than gas-based alternatives, meaning kitchen vents can be run less frequently and at lower power. [124]

Hotel staff preferences and training are a particular consideration for the electrification cooking appliances. Chefs and kitchen staff may be concerned about sacrificing food quality or preparation methods without gas-fueled appliances. Some hotels may also contract third-party organizations for dining operations – introducing an additional stakeholder in the planning process.[125]

Other End Uses

Over 80% of lodging facilities in California are expected to have miscellaneous gas equipment, the highest miscellaneous gas equipment penetration relative to the other building types.[126] Laundry is either conducted on-premise, off-premise, or in some combination. The speed at which laundry can be done and limited space are the most significant concerns among hotel staff interviewed by Miele.[127] Approximately 64% of surveyed lodging buildings by the US EIA CBECS had laundry spaces.[128] Over 30% of hotels interviewed by Miele were using domestic washing machines and tumble dryers for their on-premise appliances.[129] Some hotels may have gas-heated ironing equipment.[130] Pools and spas use significant energy, particularly the circulation pumps and heating systems.[131] Cost-effective technologies for reducing energy use include solar thermal heating systems and heat pump pool heating systems. Existing pool and spa systems are regulated by the US DOE and California Energy Commission; pool pumps must meet certain appliance standards to support efficiency.[132]

Diversity of End-Uses

Using CoStar data, California hotel amenities were flagged for potential gas end uses (e.g., pools, spas, restaurants, bars, meeting/event spaces, kitchens), and hotels were categorized by their diversity of gas end use (basic, normal, high). CoStar contained a list of amenities for each property and the unique values across the dataset included: fully-equipped kitchen, outdoor pool, room service, hot tub, restaurant, on-site bar, meeting event space, wedding venue, pool, spa, on-site casino, and waterpark. The team created a diversity of gas end use flags based on the following criteria:

- Basic: No listed amenities beyond the standard room heating, which is common to most hotels in California;
- Normal: At least one listed amenities;

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[124] Better Buildings Initiative. "Electrifying Commercial Kitchens Across Sectors." Beat Blog (blog), February 1, 2023. https://betterbuildingssolutioncenter.energy.gov/beat-blog/electrifying-commercial-kitchens-across-sectors.

[125] Bulger, Neil. "Electrification of Nonresidential Space Heating: Designer Interview Report." PG&E, 2050 Partners, Red Car Analytics, April 2023.

[126] 2022 CEUS, p. 104

[127] Miele. "Could Your Hotel Benefit from an On-Premise Laundry?" n.d. https://www.miele.com.au/media/ex/gb/Professional/Landing_pages/Hotel/OPLguide.pdf.

[128] U.S. Energy Information Administration—EIA - Independent Statistics and Analysis. (n.d.).

[129] Miele. "Could Your Hotel Benefit from an On-Premise Laundry?" n.d. https://www.miele.com.au/media/ex/gb/Professional/Landing_pages/Hotel/OPLguide.pdf.

[130] Schweid, P. (1972). Should You Install a No-Iron Laundry? Cornell Hotel and Restaurant Administration Quarterly, 13(2), 39-43. https://doi.org/10.1177/001088047201300211 (Original work published 1972)

[131] Energy Code Ace. "Nonresidential, Single-family and Multifamily Pool and Spa Heating." Title 24 Part 6, 2025 https://energycodeace.com/download/261476/file_path/fieldList/ECA%2BPool%2Band%2BSpa%2BFact%2BSheet%2BWEB.pdf

[132] Energy Code Ace, Title 24 Part 6 (2025)

- High: At least one listed amenities that likely use additional space, water, and cooking heating (kitchens, pools, laundry, etc.)

On average, hotels offer 1-2 amenities that likely require space heating, cooking, or water heating equipment. About 65% of them offer at least one amenity that likely has a gas end use (Figure 62).

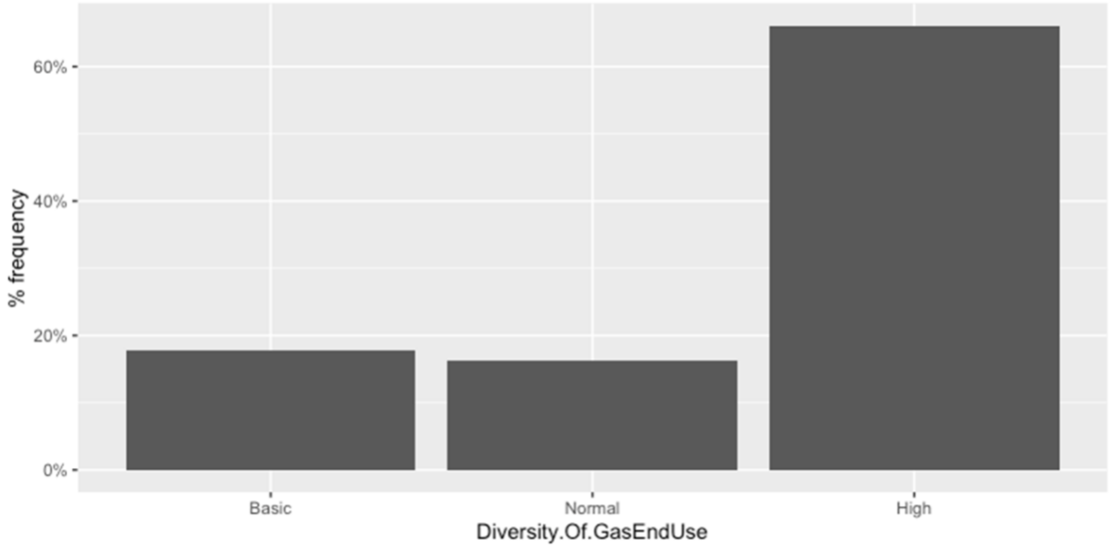

Figure 62. Diversity of Gas End-Uses in Lodging Sector (CoStar)

Hotels with a high diversity of gas end-use amenities typically have more rooms, ranging from 50 to 100, were built around 1980, and have been renovated around 2015, if at all (Figures 63 to 65). These hotels tend to have more recent vintages. Smaller buildings, often with fewer rooms and less diverse gas-powered amenities, also tend to be older, more in need of renovation, and located in less desirable areas.

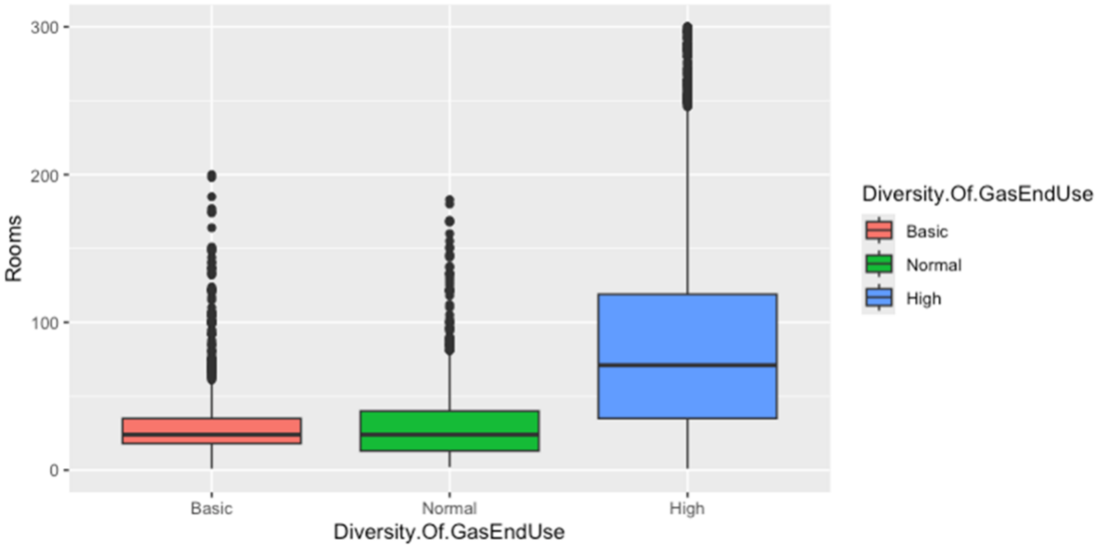

Figure 63. Diversity of Gas End-Uses by Number of Rooms in Lodging Sector (CoStar)

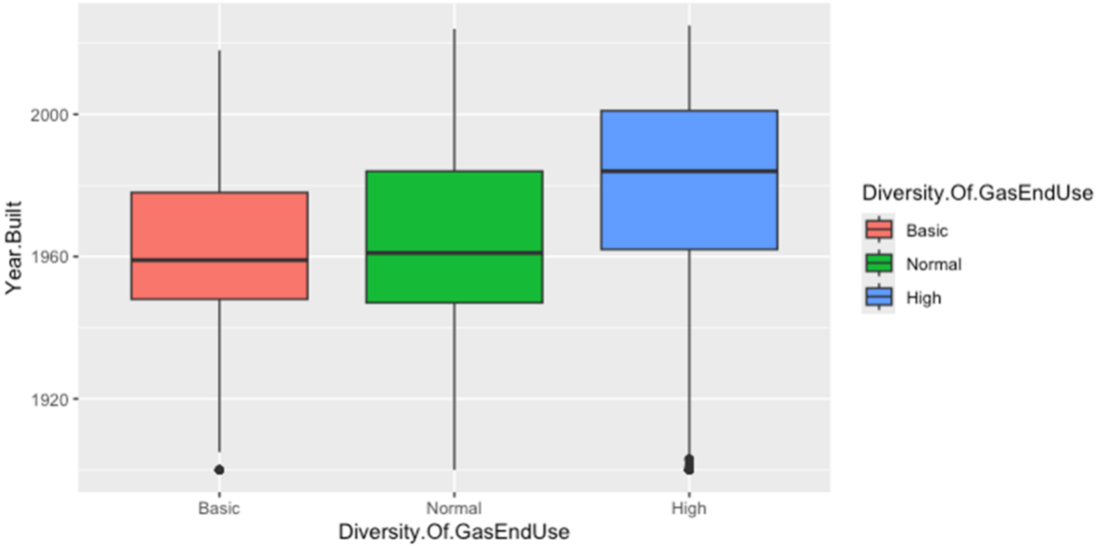

Figure 64. Diversity of Gas End-Uses by Year Built in Lodging Sector (CoStar)

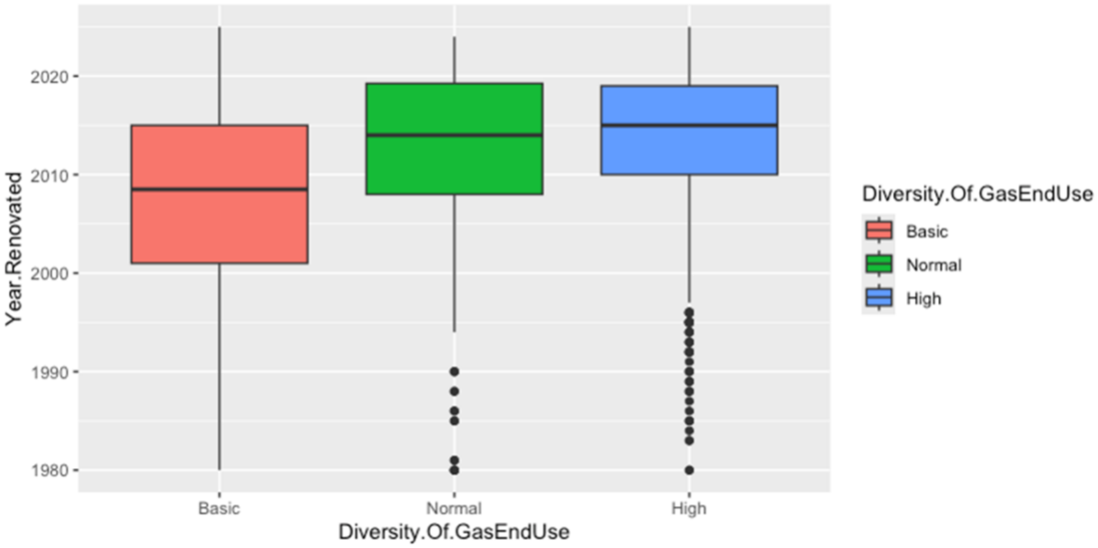

Figure 65. Diversity of Gas End-Uses by Year Renovated in Lodging Sector (CoStar)

Roughly 25% of hotels have restaurants on site, but typically only luxury and full-service chain hotels actually own these onsite restaurants. In the majority of cases these restaurants are owned and operated by an external third-party. Chain hotel operators and managers often do not control individual energy retrofit decision-making, as those decisions may be part of more centralized corporate strategies. Figure 66 below shows the relationship between the California climate zone and the diversity of gas end use. Climate zone 8, which is Inland Los Angeles and Orange County, contains the largest number of hotels. This concentration suggests that regional targeting of electrification programs may be effective, particularly in inland Southern California where both hotel density and cooling demands are high.

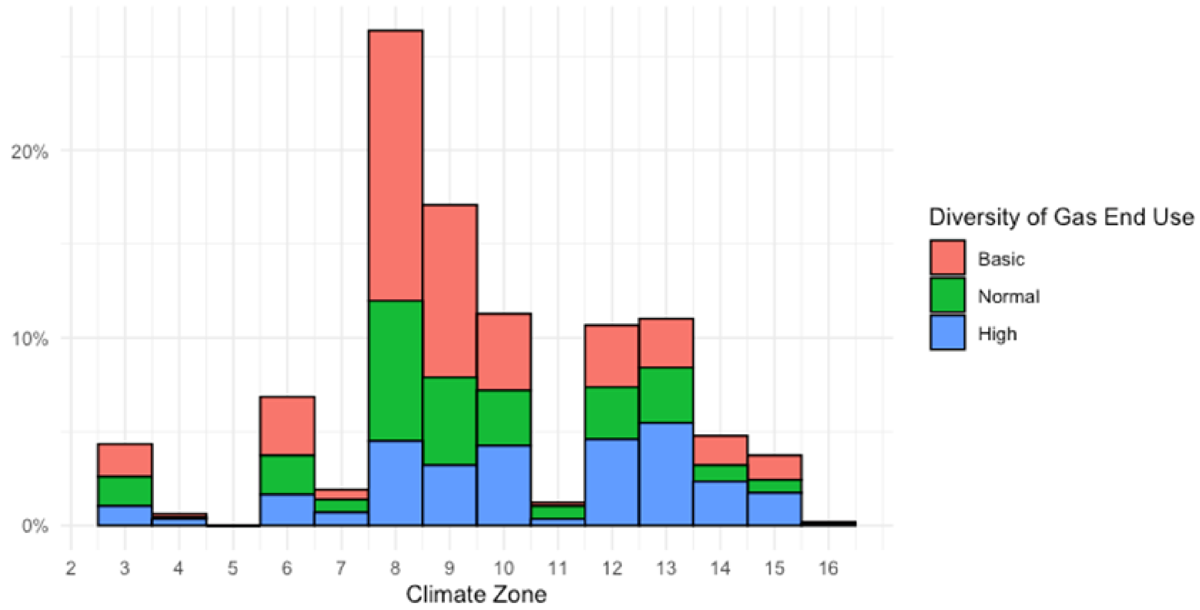

Figure 66. Diversity of Gas End-Uses by Climate Zone

Lodging Utility Expenses

Analysis of utility expenses includes electricity, gas/fuel, steam, water/sewer, and other. US hotel utility expenses as a percent of total revenue in 2023 ranged from 2.9 to 4.2% based on a sample of 2,000 properties.[133] Utility costs were greatest for convention and resort properties due to the range of services and amenities offered, but the impact was less significant (2.9% of total revenue) due to their diversity of income sources and higher average daily rates. Meanwhile, limited-service and extended-stay hotels spent the least on utilities, but their utility expenses averaged roughly 4.0% of revenue, given low diversity of income sources and lower average daily rates. In addition to the above considerations, mechanical, electrical, and plumbing (MEP) system design and building automation systems are also potential factors shaping utility expenses. CBRE finds that resort and convention facilities tend to have more centralized MEP systems with greater capacity for engineering staff and building automation systems, in contrast to limited service and extended stay properties, with more decentralized systems and limited staff.[134]

Electricity and gas/fuel make up a combined 72.5% of utility expenses at a 58.9% and 13.6% share, respectively. The average retail price of electricity for commercial customers has increased consistently since 2020 by over 20% in the cost per kilowatt hour.[135] California electricity retail rates are significantly higher than other states–

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[133] Robert Mandelbaum & Joe Snider. (2024, April 1).

[134] Robert Mandelbaum & Joe Snider. (2024, April 1).

[135] Electricity data browser—Average retail price of electricity. (n.d.). U.S. Energy Information Administration. Retrieved August 7, 2025, from https://www.eia.gov/electricity/data/browser/?agg=0,1&geo=g&endsec=vg&freq=M&start=200101&end=202311&ctype=linechart&ltype=pin&rtype=s&pin=&rse=0&maptype=0#/topic/7?agg=0,1&geo=g&endsec=vg&linechart=ELEC.PRI

California's average commercial customer price is nearly 85% higher than the national average for January 2025.[136] The average retail price of gas for commercial customers has been less consistent–prices increased substantially through 2023, though have declined in the years following.[137]

It is also worthwhile noting that utility bill structures may vary across utility service territories and per service agreements. Further, commercial utility contracts are often tied to both energy consumption and peak load. Peak load "demand" charges can make up a significant portion of a hotel's bill.[138] There are various demand charge designs; tariffs may specify more complex designs, such as demand charges that vary by time of day, season, or incorporate declining or inclining tiers.[139] Information on the significance of demand charges across the lodging subsector was not identified, though demand charges across the commercial sector that exceed 50% of the customer's bill are common.[140] InterContinental Hotel Group San Francisco reported demand charges amounting to 30-40% of electricity costs.[141] Particularly in the context of uncertain market conditions, hotel owners and operators are motivated to reduce or manage the growth of utility expenses.

Equity Evaluation of California Lodging Sector

When examining only hotels located in DACs, the pool of hotels narrows to 3,872 properties. Nearly half of these hotels have high diversity of gas end-use amenities and are still concentrated in small and suburban towns (Figure 68). Hotels in DAC have a far higher share of basic amenities and a normal diversity of gas end-uses compared to the entire sample (Figure 67). This is consistent with the fact that a majority of hotels located in DACs are C class and less likely to have as many amenities as A and B close hotels.

CE.US-ALL.A~ELEC.PRICE.US-RES.A~ELEC.PRICE.US-COM.A~ELEC.PRICE.US-IND.A&columnchart=ELEC.PRICE.US-ALL.A~ELEC.PRICE.US-RES.A~ELEC.PRICE.US-COM.A~ELEC.PRICE.US-IND.A&map=ELEC.PRICE.US-ALL.A&freq=A&ctype=linechart&ltype=pin&rtype=s&pin=&rse=0&maptype=0

[136] Electric Power Monthly. (n.d.). U.S. Energy Information Administration. Retrieved August 7, 2025, from https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a

[137] U.S. Price of Natural Gas Sold to Commercial Consumers (Dollars per Thousand Cubic Feet). (n.d.). U.S. Energy Information Administration. Retrieved August 7, 2025, from https://www.eia.gov/dnav/ng/hist/n3020us3m.htm

[138] Robert Mandelbaum & Joe Snider. (2024, April 1).

[139] National Renewable Energy Laboratory. (n.d.). How to Estimate Demand Charge Savings from PV on Commercial Buildings. National Renewable Energy Laboratory. https://docs.nrel.gov/docs/fy17osti/69016.pdf

[140] National Renewable Energy Laboratory. (n.d.).

[141] Stem. (2021, March 17). InterContinental Hotel Group Case Study. Stem. https://www.stem.com/case-studies/intercontinental-hotel/

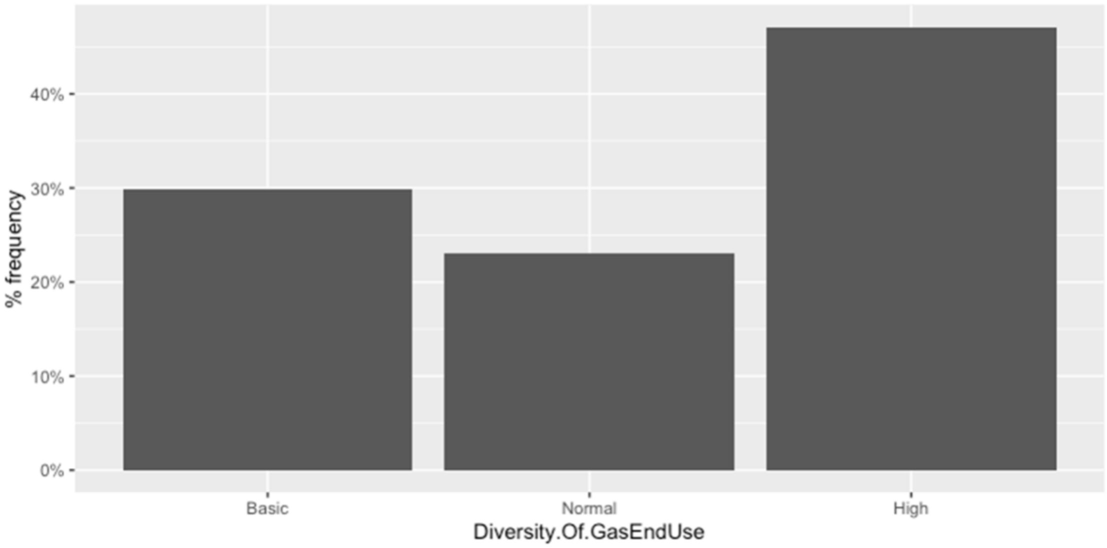

Figure 67. Diversity of Gas End-Use in Hotels in DACs

Interstate and resort locations have the highest proportion of hotels with a high diversity of gas end-use amenities, albeit representing about 10% of all hotels in this category (Figure 68). These properties are typically built between 1960 and 1985, have 25-75 rooms, and 1-2 gas end use amenities (Figures 69 – 71).

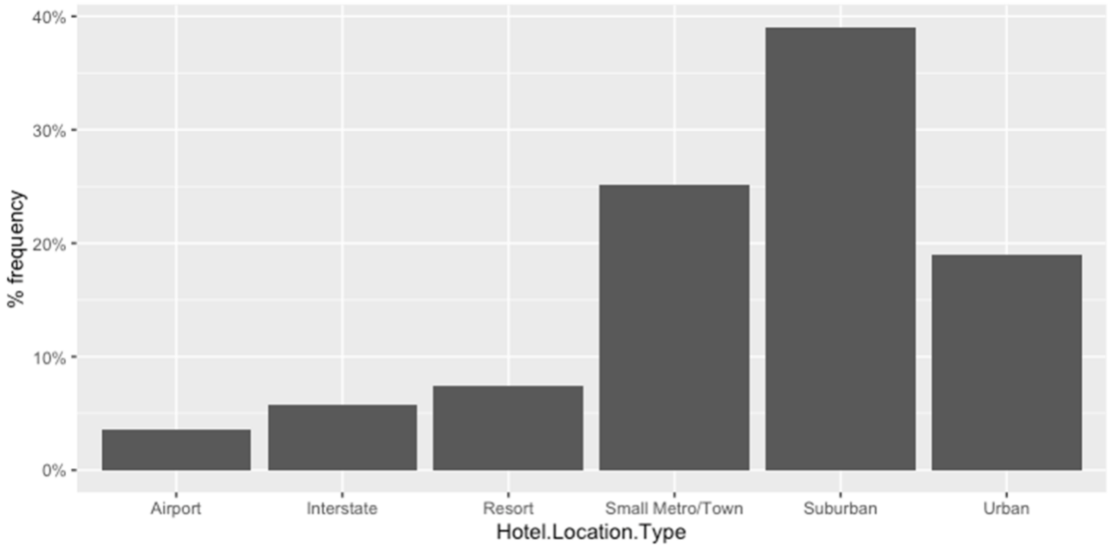

Figure 68. Hotel Location Type in DACs

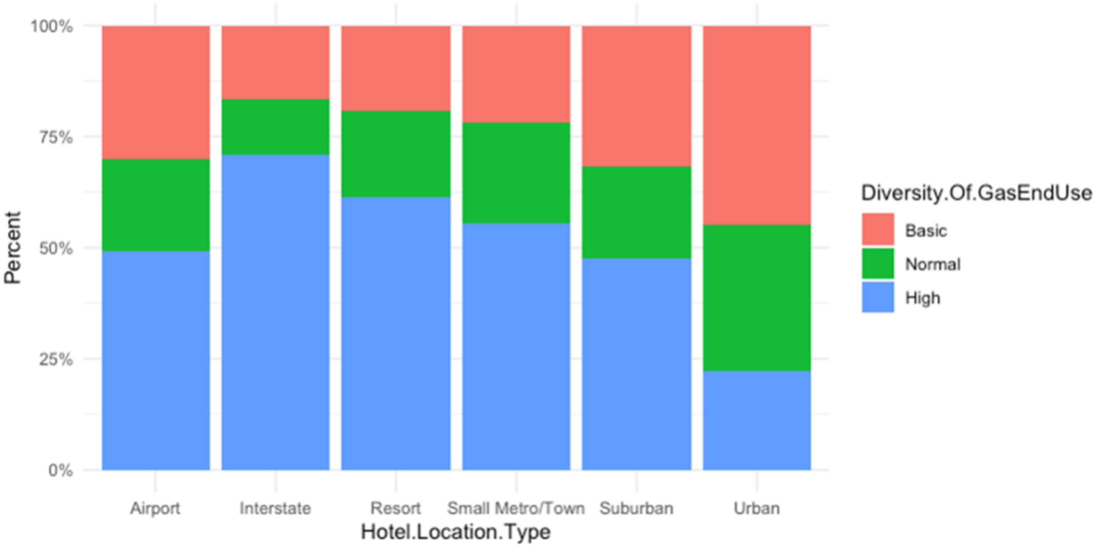

Figure 69. Percent of Diversity of Gas End-Use by Hotel Location Type in DACs

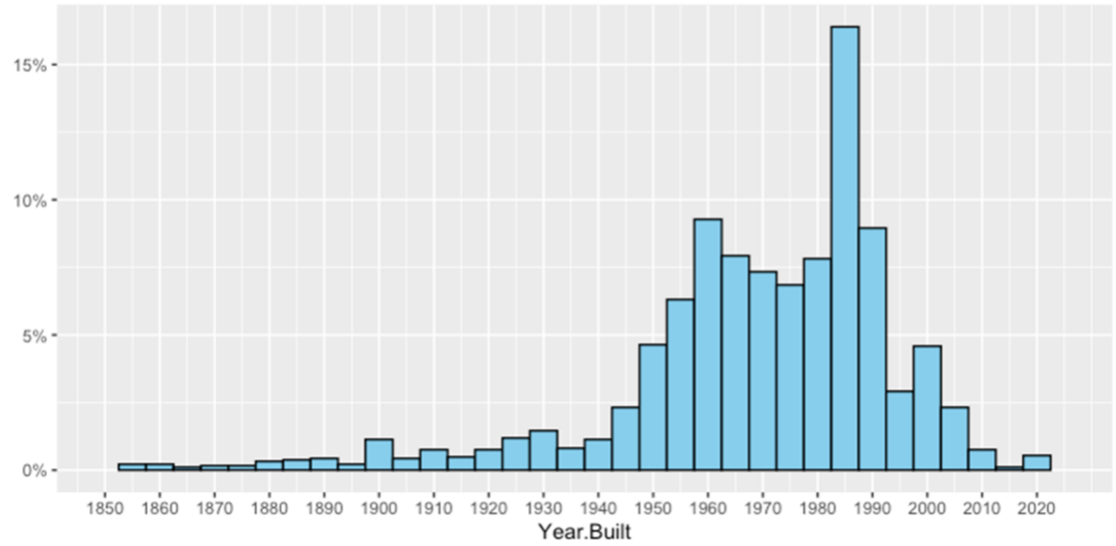

Figure 70. Distribution of Building Vintage of Hotels in DACs

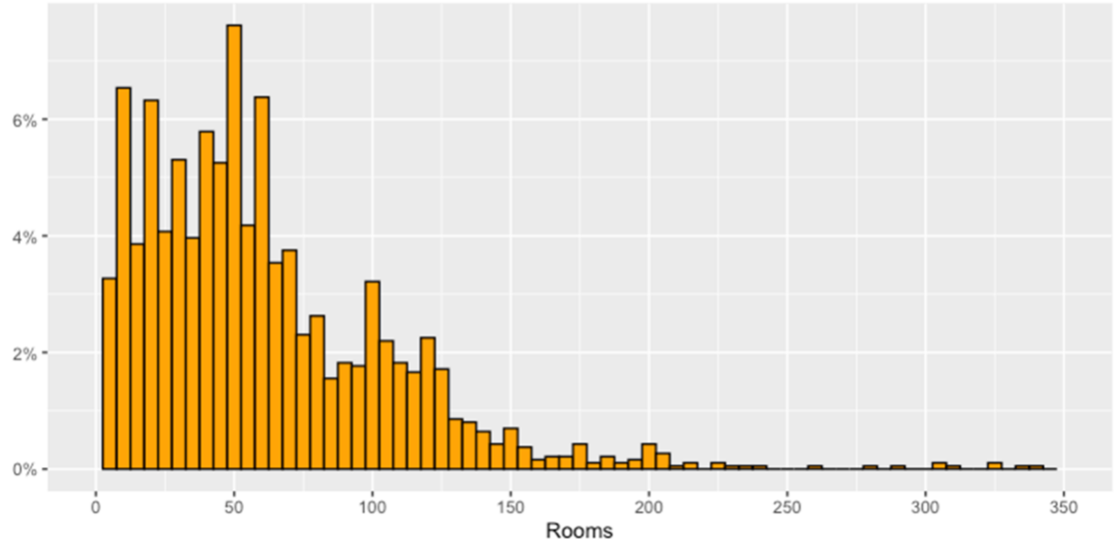

Figure 71. Distribution of Rooms of Hotels in DACs

When further narrowing the analysis of only economy-scale hotels in DACs, this group was found to represent 16% of all hotels statewide (1,153 total). Within this group, 349 hotels stand out for their high diversity of gas end-uses. These hotels are concentrated in inland Southern California climate zones, which face hotter, drier conditions and higher cooling demands. Most are independently managed, Class C properties built between 1960–1985, with 25–75 rooms, and they are heavily clustered in small towns and suburban areas. This combination of age, energy burden, and community location makes them especially promising for targeted electrification outreach that can deliver both environmental and equity benefits. Figures 72 - 73 below illustrates information about hotels only in disadvantaged communities, and is categorized by number of rooms, year built, number of stories, and climate zone.

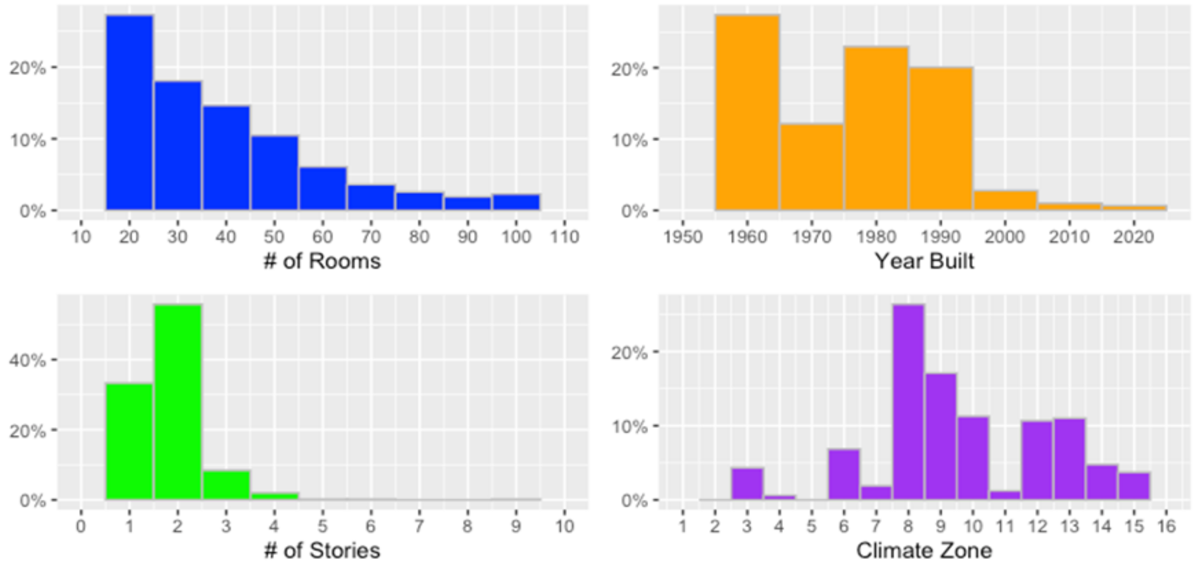

Figure 72. Lodging sector equity subset overview metrics in Economy-Scale Hotels in DACs

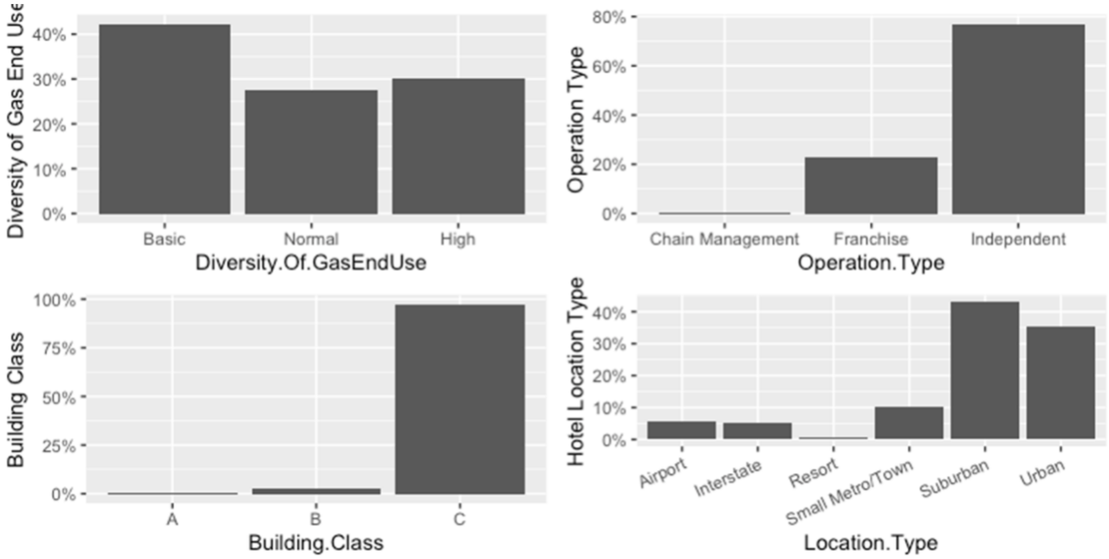

Figure 73. Distributions of Gas End Use Diversity, Operation Type, Building Class, and Location Type for Economy Scale Hotels in DACs

Lodging Ownership Structure

While lodging buildings are primarily owned by independent operators, further examination of the owner names in CoStar revealed a more consolidated pattern of ownership.

Figure 74. Frequency of Single Word and Bigrams Across Owner Name Fields by Operation Type in Lodging Subsector, CoStar

After filtering out common generic words from the owner's name fields in the CoStar dataset, an analysis of single-word and two-word frequencies revealed notable patterns in the ownership structure of California's lodging sector (Figure 74). Over 2,000 of the 6,571 active lodging properties listed in CoStar included the surname "Patel" in the owner's name. This does not reflect a single-family but rather many distinct families who share a common surname and trace their roots to Gujarat, India. Historical accounts, such as Mahendra K. Doshi's Surat to San Francisco: How the Patels from Gujarat Established the Hotel Business in California, 1942–1960, describe how early immigrants in the 1940s leased and eventually purchased hotels. By chance, these initial ventures proved successful, encouraging future waves of immigrants from that region to enter the hotel business, a pattern that has often continued across generations.[142]

Other trends in the dataset, including frequent references to terms like "family trust," "trust," "investments," and institutional names such as "Blackstone," indicate that a substantial portion of the lodging market is held by larger investment entities with multi-property portfolios. These findings suggest that many independently owned properties in California are part of broader portfolios, which can make direct outreach about site-level initiatives, such as electrification, more complex.

Engagement Findings

Outreach across the hotel sample generated more than one hundred eighty-one call attempts, multiple virtual conversations, and at least fifteen site visit attempts. While the volume of activity was high, the depth of engagement varied. No interview lasted the anticipated thirty minutes. Information from brief calls was catalogued into key takeaways. Hotel contacts were uniformly unresponsive to email requests for interviews or written feedback. Several properties proved unreachable due to closures, rebranding, or ownership changes.

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[142] https://archive.is/NuXFI#selection-727.549-727.756

An extenuating circumstance worth noting is that the timing of the outreach coincided with unprecedented federal activity in the Los Angeles metropolitan area. The CARB lodging outreach occurred from early August through the start of September 2025. This study's premise, a government-funded research activity focused on the hospitality sector, thus created substantial barriers. Phone calls, site visits, and interactions between the research team and lodging staff were characterized by skepticism, fear of unknown motives, and a general lack of willingness to engage or permit access to information or site facilities. The sites that resulted from the sampling, by definition of being in DAC areas, Class B and C buildings, and independently owned, did not yield the level of engagement anticipated during the design of the research.

With this context, barriers to contact were significant. Many calls went unanswered or to voicemail. In numerous cases, managers or owners declined participation citing lack of time or competing operational priorities. In some instances, the general manager was also staffing the front desk, providing little feasibility for spending any amount of time with the interview request. Independent hotels in particular were difficult to reach, reflecting both limited staffing and the absence of corporate structures to route inquiries.

For those properties and partners who did engage, barriers shifted from logistics to substance. Owners and managers pointed to financial constraints, capacity limits, and skepticism about new technologies as reasons for hesitation. Feedback from vendor and association partners reinforced this picture. Even when programs are available, field realities, installation challenges, and perceived operational risks often stand in the way of adoption.

Taken together, this experience highlights both the persistence required to make initial contact with operators and the importance of aligning program design with on-the-ground realities once conversations are underway.

The following section synthesizes findings that blend the original survey lenses of decision-making and organizational structure, capital planning and financial considerations, awareness and information gaps, physical building and grid infrastructure, operations, maintenance and capacity, guest experience, and reliability regulatory, utility, and external factors. Since these topics proved to be inseparable, the findings capture the relationships between these categories and offer new groupings of findings and recommendations.

Virtual Interviews

While outreach efforts produced more than one hundred call attempts across the hotel sample, the number of completed interviews was limited. In most cases, hotel operators and owners either did not respond to repeated voicemails or were unavailable at the time of contact. Where conversations did occur, several themes emerged that help explain the lack of deeper participation:

- Financial constraints: A number of owners indicated that they were unwilling or unable to commit resources. Energy and water upgrades were often seen as unaffordable, especially for smaller, independently operated properties.

- Time limitations: Managers frequently noted that staffing shortages and day-to-day operational demands left them without the bandwidth to entertain discussions about programs or potential improvements.
- Management availability: General managers who responded were curious and open to brief conversations but they did not have time for the full set of questions. However, they had limited information as the owner does all the decision-making. Often the general manager, property manager, or owner are rarely on-site or available even for the on-site staff to contact.
- Decision-making process: Upgrades are usually only pursued when required for compliance or in response to equipment failure.
- Low interest or competing priorities: Some decision-makers expressed little enthusiasm for engagement, either because sustainability initiatives were not perceived as urgent, or because they were focused on other pressing business needs.
- Property status changes: Several properties were permanently closed, undergoing ownership transitions, or re-branded under new management, which made engagement either impractical or impossible.
- Unique challenges: Hostels typically had restricted entry to the buildings and access to the property; whereas larger hotels had a highly decentralized management structure with dedicated community teams that spread out information and decision-making abilities

These barriers help explain why, despite a high volume of outreach, the overall number of substantive interviews and site visits remained modest.

In addition to direct hotel outreach, engagement with associations and vendors such as the California Hotel & Lodging Association (CHLA), as well as a handful of their service provider members, provided a deeper view of the sector’s realities. Their input highlighted structural challenges, operator constraints, and mismatches between energy equipment program design and on-the-ground realities.

California Hotel & Lodging Association (CHLA)

CHLA described how they act as a hub for connecting hotels to vendors. They emphasize using vendors as channels for outreach and maintain a legislative platform and bill-tracking capacity to keep operators informed of policy changes. Their nonprofit structure positions them as both an advocate and intermediary for hotel participation.

Vendor Member 1

One of their members listed as an energy management provider reported active work with utilities such as the City of Palo Alto and SCE on heat pump water heater programs. They noted that deep rebates drive approvals and uptake, but also that “hotel staff is so busy – they need to offload that work to a 3rd party.” They also stressed the role of financing tools, as well as the need for technical assistance and contractor training to build market capacity.

Mechanical Vendor 1

This vendor highlighted multiple friction points where field conditions diverge from program assumptions. This feedback proved highly beneficial because they stated that ten years ago, 30% of their business was small, independent "mom and pop" hotels, but they pivoted away from that market segment due to ownership constraints in adequately addressing and funding the required upgrades that align with even industry standard practice. Even for the remaining customers—who are not high-end or luxury property owners—they described how technology transitions, such as state standards moving from mid- to high-efficiency equipment, often trigger costly ancillary work such as venting and piping redesigns. They emphasized that high-efficiency equipment can be "touchy," requiring more careful installation and ongoing support.

At the property level, heat pump systems face space and operational constraints. Mechanical rooms may be too small or co-located with laundry facilities where dust and debris cause failures. Feedback gathered suggested that operator sentiment is split: "people are 50/50 happy with heat pumps—so the on-the-ground attitude is 50/50—then they think they have to 'babysit' the equipment."

They also noted that many owners "don't pay attention to bills" and are disconnected from the side of the business that would inform energy decisions. Building engineers, meanwhile, are often focused only on immediate operations: "every energy management system (EMS) or controller gets bypassed because the first time they don't work, they get bypassed and never changed."

They suggested that more rigorous feasibility studies and screening criteria are needed to match technology to building realities, rather than pushing solutions that do not fit.

Site Visits

As stated previously, the backdrop of federal ICE activities, contract delay and time constrain severely limited the site visit component of the research. A limited number of in-person site visits were attempted across the sample, representing ten properties in Los Angeles and nearby Orange counties. Although ten site visits were attempted, no staff interaction, whether scheduled or unscheduled, resulted in a full conversation or inspection. Even where there was an opportunity for a self-guided inspection of the property, the researchers felt it inappropriate to walk the facility actively taking photos or video documentation of the site, given the sensitivity of current events in Los Angeles.

Conversations with front desk staff, managers, and maintenance personnel highlighted the day-to-day realities of hotel operations, from limited staff capacity to deferred maintenance challenges. While interviews were often brief, site visit attempts confirmed many of the barriers heard through virtual outreach, including concerns about cost, disruption to guest experience, and the difficulty of navigating new technologies without trusted contractor support. These direct observations helped validate vendor and association feedback by showing how operational pressures translate into reluctance or disengagement at the property level.

Detail of Sites Visited

Hotel #1
City: Los Angeles, CA 90011 (South LA)
Year Built: 1980s
Setting: Urban
Operation Type: Hotel (Economy / Independent)
Number of Rooms: in the range of 20-50
Amenities: Room Service
CalEnviroScreen Status: Top 25% (DAC)

Engagement Summary: The site visit began with a phone call to confirm in advance that the motel staff would be onsite and open to an interview. The research staff spoke with the front desk contact, at which point communicated that owner/manager was unavailable. Contact information was left for follow-up, but no return call was received and no follow-up request was accommodated. The visual appearance of the property was observed to be in fair condition, with window unit space conditioners in each room, lending itself to modular retrofits with minimal disruption to occupancy. Central water heating was observed to be located on the back of the facility in a residential-style water heating exterior closet with an exhaust vent. Adjacent to this was the overhead power supply terminating inside the building. The front desk was not comfortable with on-site photos, so a google street-view image is below.

Hotel #2
City: Los Angeles, CA 90004 (Hollywood Area)
Year Built: 1920s
Setting: Urban
Operation Type: Hostel (Economy / Independent)
Number of Rooms: less than 10
Amenities: Business Center; Patio; Public Access Wi-Fi; Fully-Equipped Kitchen
CalEnviroScreen Status: Top 25% (DAC)

Engagement Summary: Project team called ahead to confirm site visit. However, there was no answer to the doorbell after two attempts and waiting outside for 10 minutes. Team left a voicemail and an automated text reply but no further contact. Areal maps showed centralized equipment despite being a small facility.

Hotel #3
City: Los Angeles, CA 90014 (Downtown LA)
Year Built: 1900s
Setting: Urban
Operation Type: Hotel (Economy / Independent)
Number of Rooms: in the range of 10-20
Amenities: Restaurant
CalEnviroScreen Status: Top 25% (DAC)

Engagement Summary: The owner expressed low interest and limited understanding of electrification concepts as a default owner after repossessing the property from the previous site manager. The onsite contact and owner knew very little about the facility, where equipment was, and had no immediate plans to change any equipment if it was working today.

Hotel #4
City: Huntington Park, CA 90255
Year Built: 1950s
Setting: Urban
Operation Type: Hotel (Economy / Independent)
Number of Rooms: in the range of 20-50
Amenities: Business Center; Restaurant
CalEnviroScreen Status: Top 25% (DAC)

Engagement Summary: Team called ahead to confirm visit. However, no one present at front desk during two visits on two different days. During follow-up, a call answered and disconnected during introduction. Site visit confirmed restaurant on-site, but possibly separate establishment. It appeared that they shared utility infrastructure between the hotel and restaurant.

Hotel #5
City: Los Angeles, CA 90028 (Hollywood Area)
Year Built: 1950s
Setting: Urban
Operation Type: Hostel (Economy / Independent)
Number of Rooms: in the range of 20-50
Amenities: Patio; Public Access Wi-Fi; Fully-Equipped Kitchen
CalEnviroScreen Status: Top 25% (DAC)

Engagement Summary: Manager was reluctant to engage on the phone, but scheduled site visit. On arrival stated he was too busy to talk and requested TEC consultants to leave if not staying on the premise. With online validation, the team confirmed that each room has a gas cooking appliance.

Hotel #6
City: Glendale, CA 91201
Year Built: 1950s
Setting: Suburban
Operation Type: Hotel (Economy / Independent)
Number of Rooms: in the range of 20-50
Amenities: Meeting / Event Space
CalEnviroScreen Status: Top 25% (DAC)

Engagement Summary: Spoke with the manager who provided the owner’s contact. The team coordinated a time for a site visit at that point with the manager. When calling that number arriving onsite, the number led back to the front desk. Nobody at the front desk and a message forwarded but no reply. Site visit yielded little insight.

Hotel #7
City: Anaheim, CA 92802
Year Built: 1980s
Setting: Resort
Operation Type: Hotel (Economy / Franchise)
Number of Rooms: in the range of 100-200
Amenities: Business Center; Pool
CalEnviroScreen Status: Top 25% (DAC)

Engagement Summary: Scheduled site visit with manager and on arrival spoke with front desk. The staff stated the manager was unavailable. The team asked if photos could be taken and the front desk stated they said no. On a walk through the facility, the team confirmed the pool, hot tub, and presence of an on-site restaurant, but was unable to enter the kitchen, or enter the self-service laundry area. Of note, via online research showed the presence of extensive solar arrays on both buildings.

Hotel #8
City: Anaheim, CA 92802
Year Built: 1980s
Setting: Resort
Operation Type: Hotel (Upper Midscale / Franchise)
Number of Rooms: in the range of 100-200
Amenities: Business Center; Fitness Center; Pool; Patio; Meeting/Event Space; Public Access Wi-Fi; Smoke-Free; Hot Tub
CalEnviroScreen Status: Top 25% (DAC)

Engagement Summary: Team met front desk staff after confirming that at least one contact was onsite that was familiar with the facility. Met with the site manager but they stated they were uncomfortable with photos. A brief conversation ensued about the upgrades, and they said they were primarily focused on customers and bookings. When beginning to ask questions related to customer experience and general approaches to scheduling upgrades and impacts on customers, they received a call and said they needed to address a customer issue and said they wouldn’t be of much help in the future. Upon exiting the facility, the team confirmed the pool, dining area which included more than a buffet, as well as an outdoor pool.

Hotel #9
City: San Pedro, CA 90731
Year Built: 1990s
Setting: Suburban
Operation Type: Hotel (Upscale / Franchise)
Number of Rooms: more than 200
Amenities: Business Center; Fitness Center; Pool; Restaurant; Room Service; On-Site Bar; Public Access Wi-Fi; Smoke-Free; Hot Tub

CalEnviroScreen Status: Top 25% (DAC)

Engagement Summary: After multiple calls with the front desk, and back and forth voicemails and a brief conversation with the general manager, a site visit was scheduled. Mornings after 9am and before 3pm was the preferred time to meet. The front desk greeted the team and called the general manager. After waiting for 15 minutes, they said he was not available and in meetings for the rest of the day. The site visit yielded minimal insights.

Hotel #10
City: Los Angeles, CA 90033 (North-East of Downtown LA)
Year Built: 2020s
Setting: Urban
Operation Type: Hotel (Upscale / Franchise)
Number of Rooms: in the range of 100-200
Amenities: Business Center; Fitness Center; Pool; Restaurant; Patio; On-Site Bar; Meeting/Event Space; Public Access Wi-Fi; Smoke-Free; Hot Tub; Fully-Equipped Kitchen
CalEnviroScreen Status: Top 25% (DAC)

Engagement Summary: General Manager referred team to Operations Manager for site visit. Appointment scheduled, but the contact was offsite with vendors, and no management team was available at the time for a meeting.

3.2.6 - Discussion

High costs and low program uptake.

This analysis reveals a striking paradox at the heart of California's commercial electrification efforts: despite comparable electrification budgets to the residential sector, commercial programs demonstrate remarkably low participation rates and declining electrification trends. Additionally, energy efficiency budgets and electrification budgets have declined since 2020, revealing less investment than in prior years, even as the challenges facing commercial electrification have become more apparent, suggesting a shift from traditional market incentive program design due to the underutilization of these programs.

Several interconnected factors contribute to this underutilization, but the most fundamental issue is the dramatic mismatch between available incentives and actual electrification costs. Available incentives are inadequate to address the prohibitive cost of electrification for commercial buildings. *Table 49* below illustrates CEUS subsectors that have higher marginal costs of electrification compared to replacement with the previous gas-fueled end-use and whether incentive costs cover marginal costs, where data is available. For all sectors with higher marginal costs, currently available incentives are inadequate to cover the cost of electrification.

Table 49. CEUS Subsector Total Electrification Costs Relative to Gas End-Uses and Incentives[143]

CEUS Subsector	*Higher Marginal Cost of Electrification*	*Incentive Could Cover Marginal Cost*	*Number of IOU Gas Accounts in 2021*
College	Unknown	Unknown	4,118
Food Store	Unknown	Unknown	2,393
Health Care	Unknown	Unknown	8,681
Office	Yes	No	114,527
Lodging	No	Yes	6,464
Miscellaneous	Unknown	Unknown	54,261
Refrigerated Warehouse	Unknown	Unknown	452
Restaurant	Yes	No	50,449
Retail	No	Yes	28,081
School	Unknown	Unknown	32,491
Unrefrigerated Warehouse	Yes	No	17,930

Across all subsectors where marginal cost data exists, current incentives fail to cover electrification costs in the majority of cases. Office buildings, restaurants, and unrefrigerated warehouses all demonstrate marginal costs that exceed available rebates by factors of ten or more. The high upfront costs documented in the Reach Code Cost-Effectiveness Analysis (*Table D1, Appendix D*) present significant financial barriers, particularly for subsectors like restaurants ($60,835-$123,855 per facility) and medium office buildings ($158,078 per facility). These costs far exceed typical rebate values—cooking equipment incentives range from $1,130 to $17,500 per project, while whole building incentives average $10,000 per facility. Only retail establishments and certain hotel configurations show cost profiles where existing incentives could meaningfully influence adoption decisions (however it is noted that even those potential influences are not as impactful as indicated in this analysis).

This financial burden poses particular challenges for businesses, particularly small establishments and those serving low-income communities, as they may lack the capital to invest in electrification without resorting to loans. This is especially pronounced for full-service restaurants, schools, colleges, hotels, and hospitals that rely on kitchen facilities.

Consumption trends and infrastructure concerns.

Between 2006 and 2022, the proportion of electricity in total commercial energy consumption declined from over 37% to approximately 31% (*Figure 41*). This shift reflects both a reduction in overall electric consumption and a concurrent increase in gas use (*Figure 42*). At the subsector level, the share of electricity used for space

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[143] Marginal cost estimates derived from: TRC Companies, P2S Engineers, California Energy Codes and Standards, "2021 Reach Code: Cost-Effectiveness Analysis: Non-Residential Alterations", supra.

heating rose only in building types where heating is a relatively minor end use, such as warehouses, restaurants, and food stores, while it declined in lodging and office buildings, where heating demands are substantial and consistent. This pattern indicates that subsectors with higher heating needs continue to rely on gas equipment rather than adopting electric alternatives.

Similarly, the share of electric water heating fell slightly, from 41% to 40% over the same period, with notable declines in colleges, healthcare facilities, offices, and retail buildings—sectors characterized by significant water-heating loads and high decarbonization potential.

While part of the overall reduction in electricity use may be explained by efficiency improvements in electric equipment or fluctuations in weather patterns, the trend also suggests that market and investment decisions in the commercial sector may be shifting away from electrification despite sustained state policy support. Several factors help explain the persistence of gas systems. California's average commercial electricity price is roughly 85% higher than the national average, making gas appear more cost-effective in the short term, even though its lifecycle costs are higher when environmental externalities are considered. Additionally, many property owners remain unfamiliar with modern electric technologies or uncertain about the reliability of equipment and adequacy of existing electrical infrastructure.

The relationship between fuel-use patterns and electrification costs also warrants closer examination. Subsectors with lower electricity shares often face higher incremental costs to electrify, though this relationship varies with building characteristics. For example, office buildings consume less gas overall than full-service restaurants but face greater electrification costs because they typically require replacement of large gas boilers and upgrades to electrical service. This suggests that existing infrastructure and system design are reinforcing dependence on gas in certain building types.

Finally, grid reliability concerns remain a legitimate barrier, especially for facilities where continuous operation is essential. Healthcare facilities, food stores, and lodging establishments face substantial risks from power interruptions. Among commercial subsectors, office buildings and miscellaneous facilities experience the highest cumulative hours of Public Safety Power Shutoff (PSPS) events, whereas refrigerated warehouses are least affected, reflecting their differing geographic exposure to high fire-risk areas.

Equity considerations.

While DAC and non-DAC tracts show relatively similar electrification trends, this parity masks important disparities. The Exposure of Sensitive Populations Index shows that miscellaneous facilities, colleges, and healthcare facilities disproportionately affect already-burdened communities—subsectors deeply integrated into residential neighborhoods and serving vulnerable populations.

Spatial analysis reveals that office buildings, miscellaneous facilities, and retail establishments have the largest nearby residential populations in both DAC and non-DAC areas, though absolute numbers of exposed residents are generally larger in non-DAC areas, likely reflecting California's overall population distribution. For the lodging, refrigerated warehouse, and miscellaneous building subsectors, buildings in disadvantaged communities show greater gas dependence than their non-DAC counterparts, while the relationship reverses for offices, restaurants, and schools—patterns warranting investigation into building vintages, ownership structures, and historical investment patterns.

Lodging as a priority subsector and feasibility assessment.

The lodging sector assessment revealed implementation challenges extending beyond this subsector to commercial electrification broadly. Stakeholder engagement during this study highlights systemic barriers that may affect program uptake as well. Researchers made over 180 call attempts and 15 site visit attempts, yet no interview achieved the anticipated 30-minute duration, and substantive conversations remained rare. California's lodging sector is concentrated in independently operated Class C properties, with over a quarter having owners with multiple properties. When general managers simultaneously staff front desks, they lack bandwidth for program exploration, and multi-property owners are less likely to be present on-site. The consistent refrain that operators are "too busy" to engage reflects genuine time constraints and potentially limited perceived value. Many vendors noted that owners "don't pay attention to bills" and remain disconnected from energy costs. This operational reality suggests that traditional program outreach approaches which assume decisionmaker availability, capacity, or willingness to engage may be fundamentally mismatched to commercial sector realities. Vendors emphasized the need for third-party intermediaries: "hotel staff is so busy—they need to offload that work to a third party." Rather than expecting property owners to initiate engagement, programs may need to work through trusted vendor relationships, industry associations, or turnkey service providers managing the full project cycle.

The financial barriers articulated by hotel operators and vendors add crucial context to the Reach Code’s cost estimates. While that analysis estimated moderate incremental costs for some hotel configurations (with some showing negative costs due to favorable HVAC replacement economics), field feedback reveals that these estimates may not capture the full scope of real-world project costs. Mechanical Vendor 1's description of cascading requirements, in which efficiency standard changes trigger venting redesigns, piping modifications, and mechanical room reconfigurations, illustrates how seemingly straightforward equipment replacements can escalate into comprehensive renovation projects and potentially interrupt revenue streams for independent hotels that are more likely to operate on slimmer margins than chains or franchises. Ten years ago, 30% of their business was small, independent "mom and pop" hotels, but they moved away from that market segment due to ownership constraints in adequately addressing and funding the required upgrades that align with even industry standard practice. If professional contractors find this market segment economically unviable due to chronic underinvestment in building maintenance and systems, incentive programs focused solely on equipment rebates are unlikely to change the fundamental economics. This further suggests the need for more comprehensive intervention models that address deferred maintenance, building system upgrades, and electrical infrastructure improvements as integrated packages rather than isolated equipment replacements.

Lastly, the prevalence of split incentive problems takes specific forms in the lodging context. Roughly 25% of hotels have restaurants on site, but typically only luxury and full-service chain hotels actually own these onsite restaurants. In the majority of cases these restaurants are owned and operated by an external third-party, creating fragmented decision-making even within single properties.

Implications for broader commercial electrification strategy.

The analysis reveals substantial heterogeneity across commercial subsectors in emissions profiles, operational characteristics, workforce composition, and electrification feasibility. This diversity challenges the effectiveness of uniform program designs and suggests the need for subsector-specific strategies.

The prioritization framework demonstrated how different policy objectives lead to different subsector rankings. When prioritizing total emissions reductions, offices, restaurants, and healthcare facilities emerge as top priorities. When focusing on per-facility impacts, colleges, healthcare, and lodging ranked highest. Worker vulnerability highlighted restaurants, food stores, and offices. This multidimensional complexity underscores the impossibility of identifying a single "correct" priority subsector without first clarifying policy goals and weighting different objectives.

The lodging feasibility assessment's limited success in generating deep engagement should not be interpreted as a failure of research design but rather as an important finding in itself. The barriers encountered, limited availability, time constraints, financial pressures, skepticism about new technologies, and operational focus on immediate survival, represent fundamental characteristics of the commercial property landscape, particularly for smaller, independently operated buildings. These realities suggest that achieving California's commercial building decarbonization goals will require substantially different approaches than those that have generated modest success in the residential sector. The complexity of commercial buildings, diversity of ownership and operational structures, split incentive problems, and limited decision-maker capacity create compounding barriers that incremental program improvements are unlikely to overcome.

Significant data limitations.

Several key data gaps limit a comprehensive quantitative analysis of the commercial sector. The lack of publicly available TECH Clean California commercial claims data hinders evaluation of program performance and participation trends since October 2023. Empirical data on actual electrification project costs are also scarce—particularly for building types not covered by the Reach Code Cost-Effectiveness Analysis—making it difficult to assess financial barriers across the full range of commercial subsectors. In addition, the CEDARS database offers limited insight into the causes of the sharp decline in commercial electrification claims since 2019. Although the COVID-19 pandemic may have contributed to reduced participation, incentive uptake remained minimal as recently as 2023. The concurrent tripling of electrification program budgets during a period of declining participation remains unexplained, and data on the share of allocated budgets actually spent on claims are not publicly available.

Focusing the analysis on CEUS subsectors presents several limitations in assessing energy consumption due to the substantial variation within specific NAICS codes categorized under a single CEUS sector. For instance, tracts with four-year colleges and community colleges exhibit vastly different energy consumption practices due to the presence of different research labs, facilities, and resources. However, both types of institutions are categorized as "colleges" within the CEUS framework. This lack of granularity obscures the specific nuances of commercial buildings, making it difficult to adequately assess the needs of this sector, particularly in disadvantaged communities.

4 - Recommendations

A continuation of the status quo or hasty efforts to expedite this transition will likely come at the expense of California's disadvantaged communities. Addressing the persisting gap between existing policy-supported electrification and the State's long-term goals necessitates a holistic approach to building decarbonization that is coordinated across the energy system and state agencies. The policy recommendations presented below are responsive to analysis on existing residential and commercial building electrification uptake, costs, and incentive programs; the statewide distribution of residential electric service panel capacities; the design and analysis of a multi-dimensional prioritization framework for the commercial sector; and opinion research focused on beliefs towards electrification among renters in disadvantaged communities, experiences of electrification retrofits for multi-family property owners and a feasibility assessment of the lodging subsector via interviews, site visits and a market analysis. These are presented within three categories: policy changes, research needs, and technology development needs. Table 50, at the end of this section, below provides a summary of the policy recommendations, identifying the relevant building types and necessary governmental partners to coordinate implementation.

Policy Changes

- **Establish a clear end goal of zero emissions for all domestic end-use appliances and equipment and develop a long-term statewide plan to achieve this transition.** The current regulatory push to support zero-emission space and water heating in California is laudable. However, the remaining end-uses make up a still-significant share of total combined domestic gas consumption (~10%). Emissions from this remaining gas combustion pose significant public health impacts and create long-term barriers to strategic gas infrastructure decommissioning and accurate electrical distribution resource planning. The passage of Senate Bill 1221 (September 2024) is a testament to the need for coordination between equipment regulations and electric and gas system planning. The bill will deploy zonal decarbonization pilot projects wherein selected neighborhoods will voluntarily adopt zero-emission equipment alternatives, and the gas corporation will be authorized to cease providing service to these customers.[144] A strategy for comprehensive building decarbonization, beyond select end uses, is needed across the state, not just for selected "zones." Continuing with a piecemeal approach to regulating and incentivizing both residential and commercial end-use electrification may result in spiraling retail gas rates for customers, as a consequence of uncertain future gas consumption forecasts and improperly sized investments in gas infrastructure.[145] Such an outcome could ultimately be effective at motivating the electrification of all end-uses–but would do so in a way that creates unnecessary hardship, most expressly for low-income and disadvantaged communities. A coordinated, statewide decarbonization framework would enable building owners, contractors, and utilities to plan proactively for equipment replacement, panel upgrades, and load management participation. Policy mechanisms and incentive structures should be designed to accelerate gas appliance retirement—and not unintentionally prolong the repair or continued use of gas-fueled equipment. Options include linking incentives to equipment age, requiring the retirement of gas appliances that have exceeded their expected service life at the time of property transfer, or scaling incentives based on existing equipment age and retrofit complexity. Such measures would provide predictability to market actors, reduce costs, and ensure that California's building decarbonization proceeds efficiently, equitably, and in alignment with long-term emissions goals.

- **Increase incentives and other financial support mechanisms for replacing polluting cooking end-uses in residential and commercial buildings.** As one of the only appliances with direct indoor emissions, gas stoves emit nitrogen dioxide, methane, and benzene, resulting in significant harm to human health. Meanwhile, commonly held beliefs around public opposition to cooking electrification may be over-emphasized. Contrary to commonly held beliefs about public opposition, research from this study shows that nearly half of surveyed California renters in disadvantaged communities would welcome cooking appliance electrification, though specific type of appliance was not specified, at no cost. Further, in residential buildings, electrified cooking appliances are likely to consume one of the largest amounts of panel amperage capacity relative to other electrification retrofits. Thus, the electrification of this end-use should be addressed proactively in residential buildings to motivate strategic panel optimization or upgrades. Electrifying large loads earlier in the process of other electrification efforts can facilitate decisions that are more favorable to whole-building electrification. At the same time, cooking end-use incentives may need to be paired with financial support for service panel

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[144] Gas corporations: ceasing service: priority neighborhood decarbonization zones SB-1221, California Legislature, Senate (2024). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202320240SB1221

[145] California Public Utilities Commission. "2024 Joint Agency Staff Paper: Progress Towards a Gas Transition: A White Paper Supporting the CPUC's Long-Term Gas Planning Rulemaking R.20-01-007". Joint Agency Staff Gas Transition White Paper. February 2024. Accessed at: https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M525/K660/525660391.pdf

optimization or upgrades.

- **Increase overall incentives and financing for commercial business that offset upfront and soft costs.** The commercial sector is insufficiently funded given the anticipated high marginal costs of electrification. At the same time, commercial incentives that are available are underutilized. Hotel operators interviewed for this study consistently cited cost as a barrier. Rebates or direct-install programs that cover most or all equipment costs (e.g., “free water heater” programs) are critical for uptake. Additionally, many independent, small commercial businesses lack capital necessary to fund upfront equipment upgrades. Expanding use of vendor-backed financing or utility on-bill repayment is critical to improve financial and capacity support. Soft costs are also a major inhibitor to commercial businesses, especially given that they can vary in their structure, income flow, and time. Incentives should also provide funding for feasibility studies, permitting, and design work, since these are often as burdensome as equipment costs. Programs should incorporate pre-screening and feasibility studies with structured assessments to match technologies to building realities (e.g., space constraints, piping, venting, water hardness). This avoids "wrong solutions to the wrong problems" that vendors warned against.

- **Commercial program design should be expanded to include both pre- and post-retrofit phases to ensure successful and sustained electrification outcomes.** Pre-retrofit activities should incorporate structured feasibility assessments that evaluate site-specific factors such as space constraints, electrical capacity, piping and venting configurations, and water quality. These assessments help match technologies to real-world building conditions, avoiding costly design errors, installation delays, or mismatched system selections that can compromise performance. Integrating these evaluations early in the process also enables programs to identify potential barriers to electrification and offer targeted technical assistance or financing options to address them. Post-retrofit support is equally critical to maintaining performance and building market confidence. Programs should offer multi-year service packages, performance guarantees, or maintenance support agreements that reduce perceived risks for property owners and operators. Many commercial and multi-family building operators remain hesitant to adopt new or unfamiliar equipment that may require specialized servicing or involve uncertain operational costs. Providing ongoing technical support and clear performance accountability can help overcome this hesitation, improve persistence of savings, and ensure that electrified systems deliver reliable, long-term value.

- **Eliminate all incentives for replacement of existing domestic gas appliances with more efficient, new gas-powered equipment.** The CPUC reduced incentives for natural gas energy efficiency measures in residential and commercial new construction beginning in 2024 but has not ruled on policy for existing building retrofits. The State should no longer incentivize early retirement and replacement of existing domestic gas appliances with more efficient gas appliances. Maintaining incentives for gas efficiency measures locks in emissions from long-lived gas appliances and delays the transition to building decarbonization. Regulations based on zero-GHG or zero-NO_x emissions are only as effective in advancing decarbonization as the associated turnover rate of the existing gas equipment.

- **Tailor commercial program design and future appliance regulations to subsector-level and eliminate "one-size-fits-all" approach.** The commercial sector is highly diverse in size, composition, and complexity. Program design and interventions must be tailored to each subsector and the diversity within it. Programs that recognize subsector diversity can more accurately target incentives, technical support, and performance metrics — improving uptake rates and cost-effectiveness compared to generic programs. Tailored approaches are also essential for advancing equity, as smaller and disadvantaged business owners often face greater barriers to participation due to limited access to information, financing, and technical resources. Subsector-specific differences extend beyond business models to include workforce needs, building characteristics, and operational priorities. Each subsector may require different types of contractors, design engineers, and maintenance staff with specialized skills; program design can help cultivate this workforce through targeted training and development pipelines. Likewise, older buildings, mixed-use properties, and leased spaces often face physical or ownership constraints that limit retrofit feasibility. Programs should therefore enable modular or phased approaches to electrification, emphasizing retrofit readiness ahead of full deployment rather than mandating one-size-fits-all replacements. Finally, installation models must minimize operational downtime, as many commercial facilities—particularly those serving customers or guests—are highly sensitive to disruptions. Phase-out rules should be coordinated with updates to plumbing, venting, and structural codes to reflect real-world retrofit conditions and facilitate practical implementation.

- **Explore the development of new utility rate tariffs specifically designed to promote electrification that guarantee cost neutrality (or savings) while requiring full equipment electrification.** Existing utility tariffs that promote electrification are primarily tied to adjusting the times of household electricity use, or the baseline allowance (and corresponding price) of energy used for essential end uses. This approach is effective in managing new electric loads anticipated from electrification and managing peak electricity demand period usage, but there is a greater opportunity remaining to advance electrification through rates. Low- and middle-income customers would benefit from protections that guarantee households who electrify will continue to pay the amount of their previous combined electric and gas bill with an annual increase no more than the rate of inflation. This protection could be guaranteed over a certain period (i.e., 10 years) depending on customer status, such as California Alternate Rates for Energy (CARE)/ Family Electric Rate Assistance (FERA) enrollment. Furthermore, the creation of dynamic tariffs that reflect the system costs of the power system can also leverage smart controls available in new electric appliances to both meet customer preferences and minimize infrastructure costs for ratepayers.

- **Include additional non-energy benefits within electrification specific program evaluation processes and metrics.** Most electrification initiatives in California are funded through CPUC-regulated, ratepayer-supported energy efficiency portfolios that rely on evaluation frameworks originally designed for traditional efficiency measures. These frameworks primarily assess cost-effectiveness based on energy savings, overlooking broader social and health benefits associated with building electrification. In May 2024, the CPUC adopted the Societal Cost Test (SCT) as an informational tool for evaluating distributed energy resources (DERs). The SCT incorporates important factors such as the social cost of carbon, methane leakage, statewide air quality benefits, and the social discount rate—representing an important step toward more comprehensive valuation. However, the SCT does not yet account for other significant non-energy benefits, such as improvements to indoor air quality, occupant health, and safety outcomes that result from removing gas combustion equipment. Moreover, while the Commission piloted use of the SCT in its 2021 Integrated Resource Planning process, its application has not been extended to ongoing proceedings or to energy efficiency program evaluations. To accurately and equitably evaluate the impacts of electrification, the CPUC and related agencies should expand cost-effectiveness criteria to explicitly include additional non-energy benefits and integrate these metrics into energy efficiency and electrification program evaluation processes. Further research is needed to develop consistent methodologies for quantifying these benefits—particularly the health impacts of gas appliance removal and the role of indoor air quality improvements (e.g., reduced NOx and PM2.5 exposure). Doing so would enable California's electrification programs to more fully capture their societal value and better inform future policy and investment decisions.

- **Explore new engagement and outreach strategies, especially in the commercial sector.** Program outreach and uptake remain a major gap in both residential and commercial sectors. Programs should leverage trusted intermediaries by working through associations like the California Apartment Association (CAA) or CHLA who may have established vendors with existing credibility and communication channels to building operators. In the commercial sector, engagement should be tailored for independently owned businesses, recognizing that small "mom and pop" businesses are harder to reach in the lodging subsector, as well as in other subsectors. Support programs should include dedicated concierge-style outreach, ideally with third-party technical assistance that reduces burden on sometimes limited staff. Additionally, messaging should be simplified to focus on operational reliability and bottom-line savings first, rather than leading with policy mandates or abstract sustainability framing. Renter surveys and property manager interviews showed that costs were the most important factor when deciding to switch from a gas-fueled to an electric-fueled appliance. For commercial buildings that are corporate franchises, the integration of electrification goals into their sustainability platforms will help drive uptake—local operators often won't act unless corporate ownership directs them, or ancillary influences such as online booking platforms or industry/government policy persuades adoption of these specific practices.

- **Explore new cost-share models to avoid rent increases and potential tenant displacement.** Electrification measures can be expensive, particularly within multi-family contexts, so it is critical to consider cost-sharing models that can ensure that retrofit costs are borne equitably between property owners, building tenants, and the utility. While renters use and live in the upgraded apartments, landlords ultimately keep and own the appliances. Therefore, it is important to be critical of how costs are passed onto tenants. Cost-share models devised to implement mandatory seismic retrofits for soft-story multi-family buildings in different municipalities are an excellent example. For instance, the Los Angeles Housing Department's Seismic Retrofit Work Cost Recovery Program established that total seismic retrofit costs were shared between tenants and property owners and placed limits on consequential rent increases.[146] Additionally, the CEC Equitable Building Decarbonization Direct Install Program guidelines include tenant protections for participating property owners. These protections restrict rent increases, prohibit evictions, and limit construction to under 30 days to minimize tenant disruption. These protections should be extended to other multi-family and renter-occupied electrification retrofit contexts.

- **Develop a roadmap for requiring the future inclusion of intelligent components within electric service panels**. New building electrical codes should begin to incorporate requirements for intelligent panel components. A first step in this direction could be the requirement of smart breakers or grid-interactive capabilities for key end-use loads that are the most suited to demand response/load-shifting programs, such as water heating. The phase-in of such code requirements should be timed to coincide with the phase-in of any proposed regulations that would affect the sales or use of gas appliances for these end uses. The California Energy Commission load management standards (LMS) play a critical role in this transition. In the long term, all newly constructed homes should be equipped with full smart panel hardware, as it serves as the most logical and effective point for both homeowners and grid operators to dynamically manage electrical loads.

- **Increase transparency around utility methods for assessing the need for grid infrastructure capacity upgrades.** Currently, there is considerable uncertainty as to whether or not the increased loads associated with new building electrification measures are likely to trigger the need to upgrade local

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[146] "The Seismic Retrofit Work Program" Los Angeles Housing Department. Accessed at: https://housing2.lacity.org/rental-property-owners/the-seismic-retrofit-work-program

grid distribution infrastructure hardware components (pole-top step-down transformers, service drop conductors, capacitor banks, etc.). The costs associated with upgrading these hardware components can be non-trivial, and a significant share of the cost is currently borne by the customer pursuing electrification upgrades. Currently, the state’s investor-owned utilities' Integrated Capacity Analysis (ICA) and Grid Needs Assessment (GNA) processes occur without sufficient transparency in terms of the analytical methods, assumptions, and data being used to quantify these constraints. In order to further operationalize load management capabilities of the community and behind-the-meter assets, an equal emphasis is required to holistically evaluate the grid architecture of hardware, software, and networking solutions. Moving forward, these assessments should be conducted out in the open, with publicly accessible code and data, so that third-party experts can review and comment on key methodologies and assumptions conducive to the long-term transition needed for decarbonization.

- **Improve data collection, access, and sharing to better coordinate the targeting of electrification incentives with the needs for long-term gas infrastructure planning**. Mandates and statewide incentive programs are carried out largely irrespective of geography. Yet, the geographic coordination of electrification measures will be fundamental to long-term energy affordability for utility customers as a result of the fixed revenue requirements for gas distribution infrastructure operations and maintenance. Further, strategic gas infrastructure planning would benefit from data on where electrification has occurred with accurate, detailed coordinates. Preliminary review of CEDARS back-end geographic data suggests that a majority of claims have not been tracked by installation location, failing to realize a fundamental opportunity to increase utility understanding of their customers’ end uses. Since 2023, CEDARS administrators have added more geographic and demographic specific fields in their public dataset including the EPA Flag, which identifies claims installed in a zip code; the Residential Low Income Flag, which identifies whether a household meets income definition for low income rate (CARE or FERA); and the Hard To Reach Flag, which identifies whether the measure was installed in a hard to reach location. These additional fields have not been applied to previous years of CEDARS and still greatly constrain the ability to examine trends over time. Additionally, the reliability of those fields still remains questionable given that the analysis of CEDARS back-end geographic data revealed that a majority of claims have not been tracked by installation location. Improved geographic data collection coupled with data sharing between all electrification program administrators and gas system operators would facilitate more coordinated and equitable long-term infrastructure management decisions.

- **Incentivize holistic planning around household power capacity constraints**. Right now, most consumers make electrification decisions on the margin. This means that they frequently do not have a long-term plan for the electrification of all their existing fossil-fueled energy end-uses. This type of marginal thinking generally leads to two types of outcomes. Firstly, panel capacity constraints are more-or-less ignored when choosing the replacement electrical appliance until the marginal choice of equipment exceeds the available capacity. This pattern could compromise the homeowner's ability to electrify other appliances in the future. Secondly, panel capacity issues tend to be addressed through reactionary decisions to upgrade in the face of emergency appliance replacement events. These situations can lead to the buildout of unnecessary electrical capacity and reactive purchasing decisions that favor readily available but inefficient, high-energy appliances. Building decision-makers should be familiar with and incentivized to consider the suite of strategies available to optimize their existing panel capacity or minimize the size of upgrades, including options for low-power appliances, load management hardware/software systems, circuit controllers, multifunctional equipment, and whole-home efficiency retrofits.[147]

- **Improve relevant data collection and transparency across all program administrators.** Energy efficiency incentive uptake data is available for investor owned utilities, RENs, some CCAs and the TECH Clean California program. However, nearly 40% of statewide energy efficiency expenditures come from POUs. Unfortunately, there is no public, centrally hosted data source for the electrification budgets, expenditures, or claims of POUs, creating a significant gap in the evaluation of electrification programs across the state. The TECH Clean California claim data offers the most detailed information available on any publicly tracked electrification program. However, the transparency of its budget data is more limited. The online budget report provides a real-time snapshot of the budget status, including funding, reservations, and incentive dispersal by building type, as well as funds allocated to equity initiatives. To effectively evaluate historical trends and the rate at which funds are reserved, and incentives are dispersed, it is essential to have at least quarterly, archived budget updates.

- **Establish funding to pilot a heat pump water heater installation training and maintenance stipend.** Heat pump water heaters require annual maintenance after installation. Because these systems are more complex and differ significantly from traditional gas tank water heaters, plumbers may need additional training to maintain them properly. Beyond training, the ongoing cost of maintenance is also a concern. Households that receive installation incentives are still responsible for continued maintenance costs and for learning how to care for the new equipment. Establishing a pilot program that provides both workforce training and stipends for disadvantaged households could support broader adoption of heat pump water heaters while also advancing workforce development. Overall investment in workforce development is critical especially in the commercial sector, so that installers can properly size, commission, and educate operators on new equipment— combatting the widely-

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[147] Feinstein, Laura et al. Solving the Panel Puzzle: Avoiding and streamlining electric panel and service upsizing to accelerate building decarbonization. SPUR Policy Brief May 2024

held perception that such systems have overly burdensome maintenance demands or are more susceptible to failure.

- **Encourage the adoption of local government policies that accelerate the pace of decarbonization.** Local governments have the authority to pass local reach codes and building performance standards to comprehensively meet state and local climate targets. However, California's AB 130 (2025) has created a significant barrier by freezing cities and counties from establishing more restrictive building standards for residential units from October 2025 through June 2031, effectively blocking new local electrification and energy efficiency requirements during a critical period for climate action. Despite this constraint, local governments should continue to play a role in addressing small to medium sized buildings where possible, and pursue shorter-range demonstrations to test policy recommendations within their remaining authority. As California's SB 48 is anticipated to create building performance policies, local governments play a role in addressing small to medium sized buildings, and shorter-range demonstrations to test the above policy recommendations. The European Commission's Energy Performance of Buildings Directive (EPBD) contains novel approaches to buildings in the form of a smart readiness indicator (SRI).[148] Encouraging building owners and tenants to have relevant information about the building's capability of electrifying and interacting with the grid is a key aspect of market transformation to a decarbonized future–both at the building and grid interface.

- **Coordinate electrification and distributed energy resource deployment to address affordability and grid reliability.** As energy rates rapidly escalate and uncertainty in grid stability rises, to effectively manage incremental electric load and reduce household energy burdens through the full valuation of DERs, such as solar and battery storage, in low-income households and communities. This comprehensive, coordinated strategy, or "loading lanes" approach yields significant interactive effects, resulting in lower system costs and decreased energy consumption.[149] To support this, regulatory bodies must foster a DER-favorable climate that effectively prevents avoidable capital investments by utilities, which often result in record profits and unnecessary rate hikes for consumers.[150]

- **Coordinate service panel capacity upsizing processes within utility-administered electrification incentive programs.** Multi-unit residential property owners cited electrical capacity upgrades as the most challenging and time-consuming aspect of their electrification projects. Many noted that existing

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[148] European Commission, "Smart Readiness Indicator" (webpage), available at: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator_en

[149] 2024 ACEEE Summer Study on Energy Efficiency in Buildings, Clarke et al., "Identifying Barriers That Impede Cost-Effective, Holistic, and Equitable Building Performance and Zero Carbon Goals in Low-Income and Disadvantaged Communities."

[150] Costa, Marc et al. From Loading Order to Loading Lanes: Rethinking the Energy Transition and Unlocking Smart Local Energy Markets for Communities of Concern. ACEEE Summer Study on Energy Efficiency in Buildings. 2024.

incentives do not cover the full cost of these upgrades, leading some to abandon electrification efforts altogether. A nearly universal frustration was the experience of working with utility providers, with frequent delays that often jeopardized eligibility for time-sensitive incentives. These compounding barriers create a significant burden, even for the most committed property owners. Expanding the limited incentives currently available for panel upgrades is especially critical for lower-income households and those in DACs, as these homes are more likely to be older and in need of upgrades. Aligning and expanding these incentives and better coordinating them with utility service panel upgrade processes, will help streamline what is currently a costly, time-consuming, and under-resourced effort.

Research Needs

- **Study real world power utilization from different electrified appliance / equipment configurations.** Current code requirements for panel capacities are based on enabling concurrent usage of all electric appliances. To evaluate electrical service panel capacity requirements for electrification, it is necessary to examine real-world usage behaviors in all-electric homes. Such an analysis would require bulk access to utility meter interval data in concert with household-level information about installed end-use electrical appliances and equipment. Results could be used to inform future code requirements and load management strategies related to electrification.

- **Study the long-term composition of at-home EV charging demand**. Electric vehicle (EV) charging is likely to be a major driver of residential service panel upgrades. There is a need to better link transportation planning research to energy system planning efforts. Issues of concern include: customer preferences for vehicle size and range–as larger vehicles with larger ranges tend to have larger batteries with higher charger power requirements; charging expectations–as many families have multiple vehicles that will need to be electrified and may need simultaneous dual vehicle charging; and the average daily commute distance among EV adopters. In addition, the potentially significant energy system benefits from the coordination and integration of bidirectional (vehicle-to-grid) charging infrastructure and protocols should be included in the scope of future studies.

- **Study consumer satisfaction with low-power and smart electric appliance alternatives**. Electric appliance alternatives offer new options to consumers that they have not had before with gas appliances in the form of low-power and/or smart features. These options can provide benefits to individual households and to the grid. The advantages and tradeoffs associated with these appliance types merit further study. For instance, low-power appliances have significant potential to mitigate the need for panel upgrades in many older buildings with small capacity panels. However, these appliances' ability to provide the exact same end-use energy services is not always straightforward. For example, the replacement of a gas water heater with a 110-v heat pump water heater may require a larger sized tank to support the same volumetric flow rates of hot water due to longer recharge cycles; and the replacement of a conventional gas clothes dryer with a 110-v heat pump dryer may require longer drying times. More research is needed to understand the different dimensions of equipment performance that are of customer concern, as well as how these performance indicators vary across end uses and fuel sources.

- **Study opportunities to increase electrification benefits through integrated building envelope upgrades.** Currently, many electrification policies and programs are structured in a manner that prioritizes adoption rates/installed units as metrics of progress. This enables new electric end-use appliances, particularly those used for air and water heating, to be installed in buildings with inefficient thermal envelopes. Further study is needed to quantify how building envelope characteristics influence the load growth and cost impacts of electrification across different building types and climates. Understanding these interactions would help identify where envelope improvements, such as insulation, air sealing, or window upgrades, can most effectively reduce peak demand, improve occupant comfort, and ensure grid reliability. Integrating efficiency and electrification strategies will be essential to maintaining energy affordability and resilience, especially in underserved communities and areas vulnerable to extreme heat events.

- **Study small commercial business owners' perspectives, beliefs, and priorities for electrification.** Small commercial businesses are greatly understudied, including building owner, occupant, maintenance technician and other contractor dynamics. There was no identified study that evaluated commercial business owners' views toward electrification, nor their awareness of local, regional, or state building decarbonization targets and policies. Current commercial incentive program uptake is minimal. Redressing this trend requires understanding not only commercial business owners' awareness of such programs, but specific barriers to adoption of currently available incentives. Examining ownership structures for commercial businesses will shed light on the role of split incentive issues and considerations related to commercial tenant turnover rates. In particular, additional study is needed regarding commercial cooking appliances, which pose the most significant opportunity to reduce indoor NOx emissions in the commercial sector.

- **Study approaches to define equity priority commercial businesses for future incentive program eligibility criteria.** Assessing equity priorities within the context of commercial electrification will require a more nuanced approach than within the residential sector. Commercial facilities may employ and serve significant equity priority populations yet be located outside of disadvantaged communities. There are currently no commercial electrification incentive programs which prioritize facilities based on equity considerations. In comparison, multiple residential programs apply equity eligibility conditions, including income and disadvantaged community (DAC) status. This research would evaluate how equity concerns should be interpreted within the context of commercial properties and establish eligibility criteria for small commercial incentive programs.

- **Further on-the-ground data collection of electric service panel capacities within small commercial buildings.** CARB has recently funded research seeking to understand nonresidential building retrofit needs to support zero-emission equipment. This work will have important implications for existing and planned state policy initiatives. Yet, research in this area must recognize the insufficiency of currently available data, in particular, for the estimation of electric service panel capacity. It is critical that future research involve ground-truth data collection efforts focused on observing installed equipment in different building types throughout the state.

- **Further study of miscellaneous end use appliances, especially within the context of health care and miscellaneous subsectors.** The California Commercial End Use Survey does not report in detail on miscellaneous and process-related gas equipment, which can include dryers, dehydrators, kilns, clothes dryers, pool heaters, incinerators, lanterns, and fireplaces. As electrification proceeds, it’s imperative to have a comprehensive understanding of all gas-powered end-uses, their saturation in the commercial sector, and the availability of electric and/or other zero-emission substitutes.

- **Further reference datasets on all-electric buildings.** As agencies such as the CEC and U.S. Energy Information Agency conduct broad-scale market surveys, there is a lack of reference datasets on all-electric building end-use, energy-use intensities, and hourly load data. This data is critical for short-term and long-term load forecasting and the assessment of impacts from fuel substitution measures in buildings. Both through energy simulation, and, more importantly, through measured data of all-electric buildings, a curated repository of this data is necessary to inform future research, policy, and decarbonization pathways in the building-grid transformation.

- **Comprehensive building cost study.** Future studies should aim to better understand the full costs associated with building upgrades in order to more accurately estimate the funding needed for incentive programs. Funding is often quickly depleted and existing incentives are typically insufficient, particularly for multi-family properties. A clearer picture of the overall timeline, experience, and comprehensive costs will support the design of more effective incentive programs and inform households what to anticipate when electrifying. Additionally, the outcome of this study may improve the design and amounts allocated to incentives to ensure that multi-family building owners and households are not left making difficult “tipping point” decisions about whether the available incentives are enough to move forward with an upgrade.

- **Comprehensive study of renter and household electrification experiences and preferences.** Several questions remain about how renters' decisions to electrify intersect with other priorities. Future research should examine renters' preferences for new homes and how their desire for electric appliances compares with other types of home upgrades. Additionally, exploring renter opinions through the lens of political orientation could provide valuable insights into who is more or less likely to electrify and how programs can be better designed and targeted. While there has been opinion research on property owners' experiences with electrification, little is understood about renters' perspectives. For renters who pursue electrification, there is limited knowledge on navigating incentives, managing landlord relationships, and the consequences of retrofit. Another concern is that households, renters and home-owners, experiencing issues after electrification found that companies providing appliances lacked meaningful follow-up. Future studies should examine the existing support systems for consumers after they convert to electric appliances and what improvements are needed.

Technology Development Needs

- **Develop new load management hardware and software solutions for use within multi-family residential properties pursuing comprehensive electrification.** In many single-family residential properties, circuit splitting hardware can prevent the need for panel upsizing. However, this hardware only makes sense to use with loads which are unlikely to be in concurrent use, with the most common configuration (in single-family contexts) involving electric dryer units and EV chargers. Within multi-family property contexts, however, EV chargers are unlikely to be wired into the dwelling unit sub-panel, and dryer units may be installed in communal spaces and wired to the house loads panel. With these differences in mind, multi-family property load management solutions may need to be implemented at the building level and additionally focus on house loads. This suggests that new hardware and/or deployment strategies might need to be developed and evaluated.

- **Explore synergies between grid architecture and buildings.** As the transition towards zero-emission appliances accelerates, new technologies call for connecting research needs across disciplines that have historically been performed in isolation. Within the context of grid architecture, the research needs for the gas transition require a consistent integration of grid impacts across all home appliance research. This field needs a more equitable human-centered approach to building-grid integration, driven by people-centered needs, as opposed to a grid-focused approach that dictates how people *should* interact with energy.

Table 50. Summary of Policy Recommendations

Type of Policy Recommendation	Recommendation	Relevant Building Types	Coordination Needed[151]
Policy Change	Statewide Plan for All Domestic Gas End-Uses	SF, MF	CARB, CEC, CPUC, HCD
Policy Change	Residential Cooking Electrification Incentives	SF, MF	CPUC, Local Agencies, HCD
Policy Change	Commercial Electrification Incentives to Offset Upfront and Soft Costs	Commercial	CEC, CPUC, Local Agencies, HCD
Policy Change	Pre- and Post-Retrofit Commercial Electrification Program Design	Commercial	CEC, CPUC, Local Agencies, HCD
Policy Change	Eliminate Gas Appliance Efficiency Incentives	SF, MF, Commercial	CPUC, CAETFA
Policy Change	Subsector Tailored Commercial Program Design	Commercial	CEC, CPUC, Local Agencies, HCD
Policy Change	Utility Rate Tariffs to Promote Electrification	SF, MF	CPUC
Policy Change	Electrification Incentive Evaluation	SF, MF, Commercial	CARB, CPUC, Local Agencies
Policy Change	Engagement and Outreach Initiatives	MF, Commercial	CEC, CPUC, Local Agencies, HCD
Policy Change	Electrification Cost-Share Models	MF	CPUC, Local Agencies
Policy Change	Intelligent Panel Components Roadmap	SF, MF	CEC, CPUC
Policy Change	Grid Infrastructure Capacity Transparency	None	CPUC
Policy Change	Gas Infrastructure Coordination	SF, MF, Commercial	CEC, CPUC, Local Agencies
Policy Change	Holistic Household Energy System Planning	SF, MF	CEC, Local Agencies, HCD, CAETFA
Policy Change	Incentive Program Data Collection and Access	SF, MF, Commercial	CARB, CEC, CPUC, Local Agencies, CAETFA
Policy Change	Comprehensive Small Commercial Electrification Pilot	Commercial	CPUC, Local Agencies, CAETFA
Policy Change	Heat Pump Water Heater Pilot	MF, Commercial	CARB, CEC, Local Agencies
Policy Change	Local Government Policies and Standards	SF, MF, Commercial	CEC, Local Agencies
Policy Change	Coordinated Decarbonization Strategies	SF, MF	CARB, CEC, CPUC, Local Agencies, HCD, CAETFA
Policy Change	Coordinated Panel Capacity Upsizing within Utility-Administered Programs	MF, Commercial	CPUC
Research Needs	Real World Power Utilization	SF, MF	CEC

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[151] Local agencies refers to local and regional entities, such as local governments, air districts, CCAs, and RENs.

Research Needs	At-Home EV Charging Demand	SF, MF	CARB, CEC, CPUC
Research Needs	Low-Power and Smart Electric Appliance Alternatives	SF, MF, Commercial	CARB, CEC
Research Needs	Integrated Building Envelope Upgrades	SF, MF	CARB, CEC, CPUC
Research Needs	Small Commercial Business Owners	Commercial	CPUC
Research Needs	Equity Commercial Business Definition	Commercial	CARB, CPUC
Research Needs	Small Commercial Service Panel Capacity	Commercial	CPUC
Research Needs	Miscellaneous Commercial Gas End-Uses	Commercial	CARB, CEC
Research Needs	All-Electric Building Reference Datasets	SF, MF, Commercial	CARB, CEC, CPUC, Local Agencies
Research Needs	Comprehensive Renter Opinions	SF, MF, Commercial	CARB, CEC, CPUC
Research Needs	Comprehensive Building Costs	MF	CARB, CEC, CPUC
Research Needs	Households That Electrify	SF, MF	CARB, CEC, CPUC
Technology Development Needs	Grid Architecture and Building Synergy	SF, MF, Commercial	
Technology Development Needs	Load Management Solutions for Electrified Multi-Family Buildings	MF	

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Glossary of Terms, Abbreviations, and Symbols

Terms

Term	Definition
Building vintage	A period in which a building was built. It can refer to a specific year or a time span.
CEUS subsector	Commercial building categories grouped by building characteristics in the CEC-commissioned California Commercial End Use Survey.
Claim	A unique observation in either the TECH or CEDARS database, reporting a claimed incentive measure. CEDARS and TECH define a claim as a unique equipment model number installed at a unique address, except claims in CEDARS that are noted as ‘NMEC-pop,’ which encompass multiple claims at a net-metering site.
Downstream rebate	An incentive that is claimed directly by the customer.
Dwelling unit	A residential housing unit. For instance, a residence in a multi-family building.
Electrification	The replacement of technologies that combust fossil fuels with electrically powered alternatives.
Electrification project cost	The total cost of an electrification project, which can include direct equipment costs as well as costs related to disposal, electrical upgrades, permitting, and labor.
Electrification rate	The rate at which technologies that combust fossil fuels are replaced with electrically-powered alternatives.
End-use	The consumer use of a technology or energy consumption I.e., “space heating end-uses.”
Equipment unit	Quantity of installed technology (e.g., one heat pump)
Fuel-substitution	When all or a portion of an existing energy source is converted from one CPUC-regulated fuel to another CPUC-regulated fuel.152
Fuel-switching	When an existing energy source is converted to another energy source. May involve non-utility fuels such as propane.153
Incentive	Financial incentives include rebates, free loaner programs, monthly bill credits, low-interest loans, and tax credits to encourage/promote electrification.
Incentive uptake	The use of a financial incentive by consumer, contractor, manufacturer, or distributor.
Layered incentive	An incentive that is or can be stacked with other incentive programs toward the cost of an electrification project. Stackability is dependent on a given program’s design.
Marginal cost	The cost difference between a gas and its comparable electric technology.
Measure category	Specific appliance associated with an end-use. I.e., “packaged terminal heat pump.”
Midstream rebate	A rebate-style incentive provided to wholesale distributors or contractors with the intention of decreasing the ultimate costs borne by consumers.
Multifamily or multi-unit	A residential building composed of two or more dwelling units.
Natural uptake	The adoption of electrification technologies without an incentive.

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[152] CPUC, “Fuel Substitution in Energy Efficiency” (webpage), available at https://www.cpuc.ca.gov/about-cpuc/divisions/energy-division/building-decarbonization/fuel-substitution-in-energy-efficiency.

[153] Ibid.

Program administrator	Entities that are accountable for energy efficiency program performance. This includes utilities, state and local government agencies, nonprofits, community choice aggregators (CCAs), and regional energy networks (RENs).
Rebate	A type of financial incentive that partially refunds a paid amount. Rebates can be delivered downstream, midstream, or upstream.
TECH Equity Community154	Households that meet at least one of the following attributes: live in a Disadvantaged Community (DAC) census tract; have incomes either at or below 80% of statewide median or below a threshold designated as low-income by Department of Housing and Community Development; are located in a Low-Income Community based on California Climate Investments Priority Populations 2023 Map; uses income-qualified CARE or FERA utility rate (single-family only); participated in Energy Savings Assistance Program (single-family only); hard-to-reach community and renter (multi-family only); in affordable multi-family housing defined by California Solar on Multifamily Affordable Housing Program.
Total installed cost	Upfront capital costs that include equipment, labor, permitting, additional installation materials, and if applicable, electrical infrastructure upgrades, which range from electrical wiring to electrical panel upgrades.
Upstream rebate	A rebate-style incentive provided to manufacturers with the intention of decreasing the ultimate costs borne by consumers.
Whole-building electrification rebate	A rebate-style incentive to promote energy upgrades that include more than one fuel switching measure.

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[154] TECH Clean California. “Equity Budget and Spending” (webpage) available at: https://techcleanca.com/public-data/equity-budget-and-spending/

Abbreviations

3C-REN = Tri-County Regional Energy Network
ACS = American Community Survey
AHS = American Housing Survey
BayREN = Bay Area Regional Energy Network
BDC = Building Decarbonization Coalition
CCA = Community Choice Aggregation
CEC = California Energy Commission
CEDARS = California Energy Data and Reporting System
CEUS = California Commercial End Use Survey
CMUA = California Municipal Utilities Association
CPUC = California Public Utilities Commission
DOE = Department of Energy
E3 = Energy and Environmental Economics, Inc.
ECDMS = Energy Consumption Data Management System
EE = Energy Efficiency
EIA = Energy Information Administration
HVAC = Heating, Ventilation, and Air Conditioning
HOMES = Home Efficiency Rebates
HEEHRA = Home Electrification and Appliance Rebates
IOU = Investor-Owned Utility
LADWP = Los Angeles Department of Water and Power
NAICS = North American Industry Classification System
NREL = National Renewable Energy Laboratory
PA = Program Administrator
PG&E = Pacific Gas and Electric
POU = Publicly Owned Utility
RASS = Residential Appliance Saturation Survey
REN = Regional Energy Network
RCEA = Redwood Coast Energy Authority
SCE = Southern California Edison
SCG = Southern California Gas
SDG&E = San Diego Gas and Electric
SIC = Standard Industrial Classification
SoCalREN = Southern California Regional Energy Network
TECH = TECH Clean California

Appendices

Appendix A: Residential Methods

Table A1. Summary of Reviewed Electrification Cost Studies and Reports

Source	Cost Estimate Methodology	Cost Definition(s)	Geographic Region	Building Vintage and Type
US Energy Information Administration (EIA), Updated Buildings Sector Appliance and Equipment Costs and Efficiencies (2023)	Synthesized wide range of sources and input from industry stakeholders, including government, R&D organizations, and manufacturers.[155]	Retail equipment costs, total installed cost (retail equipment + labor installation cost), and maintenance costs for installed base (in-use), current standard (minimum efficiency allowed by US DOE), typical (average efficiency and cost), and high (highest efficiency available) units.[156]	National with some distinction for North/South for HVAC	New construction and replacement markets where available; Building vintages are not otherwise included[157]
Energy+Environmental Economics (E3), Residential Building Electrification in California: Consumer economics, greenhouse gasses and grid impacts (2019)[158]	Conducted building simulations, using NREL's BeOpt software and the DOE's EnergyPlus simulation engine with modeling assumptions primarily based on the 2014 Building America House Simulation Protocols and building prototypes from CEC's Title 24 Energy Code.[159] Building technology cost-estimations were derived from published equipment costs, and market and professional costs.[160]	Capital costs, including installation, permitting, labor and retrofit costs, as well as the avoided cost of natural gas infrastructure (in-home and interconnections for the utility) for all-electric new construction homes.	Six climate zones in California: San Francisco (CZ3), San Jose (CZ4), Sacramento (CZ12), Coastal Los Angeles (CZ06), Downtown Los Angeles (CZ09), Riverside (CZ10)	Pre-1978 vintage homes, 1990s homes, and new construction complying with California's 2019 Title 24 building code[161] Residential low-rise buildings, including single-family homes and two-story apartment buildings with six to eight units

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[155] US Energy Information Administration (EIA), "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies" (2023), p. 6, available at https://www.eia.gov/analysis/studies/buildings/equipcosts/pdf/full.pdf.
[156] Id., pp. 6-7
[157] Id., p. 429
[158] E3, "Residential Building Electrification in California" (2019), supra.
[159] Id., pp. iii, 18.
[160] Id., p. 24.
[161] Ibid.

Rocky Mountain Institute (RMI), The Economics of Electrifying Buildings: How Electric Space and Water Heating Supports Decarbonization of Residential Buildings (2018) [162]	Modeled one year of energy use for water heating, space heating, and air conditioning, and integrated device and installation costs to estimate the 15-year net present cost of different electrification scenarios under various electric rate structures in four locations.[163]	15-year net present cost, including the present value of fixed costs (device and installation costs), energy costs, and incremental gas infrastructure costs.[164]	Four cities across the US: Oakland, CA; Houston, TX; Providence, RI; and Chicago, IL.	Retrofit (poorly insulated), new construction (well-insulated, efficient) Single-family homes (2,401 sq. ft) with centrally ducted heating and air conditioning
Opinion Dynamics, California Heat Pump Residential Market Characterization and Baseline Study (2022)	Two systematic, multi-round, interactive research studies with air-source heat pumps contractors and heat pump water heat contractors; as well as telephone interviews with heat pump technologies trade allies; market-rate and low-income new construction trade allies; and heat pump program staff.[165]	Cost breakdown by equipment removal, equipment units, installation labor, and materials, ducting modifications, as well as natural gas, electric, and ventilation modifications.	California	Pre-1978 single-family homes[166]

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[162] Billimoria et al., Rocky Mountain Institute (RMI), “The Economics of Electrifying Buildings: How Electric Space and Water Heating Supports Decarbonization of Residential Buildings” (2018), available at http://www.rmi.org/insights/reports/economics-electrifying-buildings/.

[163] Id., p. 65.

[164] Id., pp. 47, 65.

[165] Id., p. 6.

[166] Opinion Dynamics, Tierra Resource Consultants, Mitchell Analytics, California Public Utilities Commission (CPUC), "California Heat Pump Residential Market Characterization and Baseline Study" (2022), available at: https://opiniondynamics.com/wp-content/uploads/2022/06/OD-CPUC-Heat-Pump-Market-Study-Report-f.pdf. pp. 72, 90. Other building types were referenced in the report, however, for the purposes of specific cost estimates, only a single-family home and a two-person household living in a residence with a garage were used.

Frontier Energy, Inc. Misti Bruceri & Associates, LLC. 2019 Cost-Effectiveness Study: Existing Multifamily Residential Building Upgrades (2019)[167]	Energy simulations using California Building Energy Code Compliance Residential (CBECC-Res) 2019.1.3 and 2022.0.1 compliance simulation tools. The Statewide CASE Team developed a basis of design for all prototypes described in section 4.2 and developed incremental costs for the heat pump replacement measures based on 2019 report on residential building electrification in California (Energy & Environmental Economics, April 2019), pricing information provided from Sacramento Municipal Utility District's (SMUD's) electric appliance incentive program (SMUD, 2020), online equipment pricing, and contractor outreach.	Cost breakdown includes disposal, electrical upgrade, and labor costs. Costs for service panel upgrades are not included.	Statewide, modeled for all climate zones	pre-1978, 1978–1991, and 1992–2010 vintages 8-unit 2-story garden-style multi-family prototype

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[167] Frontier Energy, Inc., Misti Bruceri & Associates, LLC, "2019 Cost-Effectiveness Study: Existing multi-family Residential Building Upgrades, California Energy Codes and Standards" (2019). Available at https://localenergycodes.com/content/resources.

Frontier Energy, Inc. Misti Bruceri & Associates, LLC. 2019 Cost-Effectiveness Study: Existing Single-family Residential Building Upgrades (2019)[168]	The Reach Codes Team performed energy simulations using the California Building Energy Code Compliance – Residential (CBECC-Res) 2019.1.2 and 2022.0.1 compliance simulation tools. Measure costs were obtained from various sources, including prior reach code studies, past Title 24 Codes and Standards Enhancement (CASE) work, local contractors, internet searches, past projects, and technical reports.	Includes equipment cost, electrical upgrade, permitting, and labor.	Statewide, modeled for all climate zones	Pre-1978, 1978-1991, 1992-2010 vintages One single-family prototypes: one-story 1,665 square feet
StopWaste, Accelerating Electrification of California's Multifamily Buildings (2021)	Multi-case study	Estimated costs for electrical infrastructure upgrades and utility service upgrades for multi-family properties, including ancillary costs.	California	Pre-1950; 1950 to 1974;1974 to 2010; 2010 to present
Lawrence Berkeley National Laboratory (LBNL), The Cost of Decarbonization and Energy Upgrade Retrofits for US Homes (2021)	Convenience Sample: Project data was obtained for 1,739 projects, from 15 states and 12 energy programs, with a total of 10,512 individual measures.	Labor, equipment, materials and other costs.	National	1970 one-story single-family homes with wood frame construction

Table A2: Summary of Building Electrification Adoption Survey and Databases

Survey	Survey size	Sampling method	Sampling frame
CEC Energy Consumption Database (ECDB) 1990–2022	Census — all metered utility accounts statewide	Mandatory utility sales reports to CEC from all IOUs and most POUs	Administrative census; no sampling. Full statewide coverage by sector, fuel, county, and utility territory
ACS 5-Year Estimates 2013–2017; 2018–2022	~300,000–400,000 housing unit interviews	U.S. Census Bureau Master Address File (MAF)	Stratified systematic sample; monthly draws within county strata; 60

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[168] Frontier Energy, Misti Bruceri & Associates, "2019 Cost-Effectiveness Study: Existing Single-family Residential Building Upgrades, California Energy Codes and Standards" (2019). Available at https://localenergycodes.com/content/resources.

	per 5-year period in California		monthly samples pooled; Weighted to Census Bureau housing unit and population controls; statewide and sub-county
ACS 1-Year Estimates 2016–2022	~60,000–80,000 housing unit interviews per year in California	U.S. Census Bureau Master Address File (MAF)	Same stratified systematic design as 5-year; 12 monthly samples pooled. Weighted to Census Bureau housing unit and population controls; state and geographies ≥65,000 population only
RECS 2009	~1,200–1,500 CA households	USPS Delivery Sequence File (DSF), supplemented by area-based frames	Multi-stage area probability sample; energy consumption verified via Energy Supplier Survey (utility billing records). Weighted to CPS/ACS occupied housing unit totals; California state-level
RECS 2015	No CA state-level estimates	Redesigned DSF-based frame; new PSUs (not comparable with 2009)	Multi-stage area probability sample; self-administered web and paper; ESS billing data match. Weighted to CPS housing unit totals; Census division level only
RECS 2020	CA subsample size not separately reported)	Updated DSF-based frame supplemented by web address frame	Multi-stage area probability sample; self-administered web and paper; ESS billing data match. Weighted to ACS occupied housing unit totals by state and housing type; all 50 states
American Housing Survey (AHS) 2015, 2017, 2019, 2021	No CA state-level sample; LA MSA ~3,000–5,000 units per cycle; remaining CA units in national sample only	Census 2010 housing unit counts and building permit data; ~500 PSUs (counties/county groups) nationally	Two-stage probability design; PSU then housing unit selection; biennial longitudinal panel; CAPI/CATI. Weighted to HUD/Census housing unit totals; national and LA MSA only
CEC RASS 2009	24,464 individually metered households; 1,257 master-metered households	Customer billing records from PG&E, SCE, SDG&E, SoCalGas, and LADWP; stratified by utility territory, CEC forecasting climate zone, dwelling type, and dwelling age	Stratified random sample within strata; self-administered mail and online survey; Conditional Demand Analysis (CDA) combining survey responses with utility billing records. Weighted to stratum population totals; CA IOU and LADWP residential sector
CEC RASS 2019	39,682 individually metered households; 303 master-metered households	Customer billing records from PG&E, SCE, SDG&E, SoCalGas, LADWP, and SMUD; same stratification as	Stratified random sample within strata; self-administered online and mail survey; CDA combining survey responses with AMI billing

		2009 plus EV and solar PV ownership strata	records. Weighted to stratum population totals; CA IOU, LADWP, and SMUD residential sector

Appendix B: Residential Results

Table B 1. Single-family cost estimates across studies

Year	Study	Vintage	Panel Upgrade	Range Represents	Equipment Type	Min	Max	Median	Average
2022	Cost-Effectiveness Report		No	Variation By Efficiency Type	Heat Pump Water Heater	5844	8442		
2022	Cost-Effectiveness Report		No	Variation By Efficiency Type	Ductless Mini-Split	17412	21342		
2022	Cost-Effectiveness Report	Pre-1978	No	Variation By Efficiency Type	Ducted Heat Pump	17825	20802		
2019	E3	1990	No	Variation By Climate Zone	Heat Pump Water Heater	3800	4700		
2019	E3	Pre-1978	No	Variation By Climate Zone	Heat Pump Water Heater	3800	4700		
2019	E3	1990	No	Variation By Climate Zone	Ducted Heat Pump	14000	175000		
2019	E3	Pre-1978	Yes	Variation By Climate Zone	Ductless Mini-Split	15500	20500		
2022	Opinion Dynamics	Pre-1978	No	Quoted Min Max From Contractors	Heat Pump Water Heater	1400	5825	3894	3908
2022	Opinion Dynamics	Pre-1978	No	Quoted Min Max From Contractors	Ducted Heat Pump	3132	37900	9800	11534
2021-2023	Tech Clean California	All Vintages	No	Min Max And Interquartile Range	Heat Pump Water Heater	4850	7532	6300	6652
2021-2023	Tech Clean California	All Vintages	No	Min Max And Interquartile Range	Ducted Heat Pump	14890	24426	18828	20310
2021-2023	Tech Clean California	All Vintages	No	Min Max And Interquartile Range	Ductless Mini-Split	8676	21173	14475	15771
2021-2023	Tech Clean California	All Vintages	Yes	Min Max And Interquartile Range	Ducted Heat Pump	17000	26215	20946	22639

2021-2023	Tech Clean California	All Vintages	Yes	Min Max And Interquartile Range	Ductless Mini-Split	11167	22161	16717	17682
2021-2023	Tech Clean California	All Vintages	Yes	Min Max And Interquartile Range	Heat Pump Water Heater	6174	9305	7455	8164

Table B 2. Multifamily cost estimates across studies

Year	Study	Vintage	Panel Upgrade	Range Represents	Equipment Type	Min	Max	Median	Average
2019	Cost-Effectiveness Report		No	Variation By Efficiency Type	Heat Pump Water Heater	4018	4155		
2019	Cost-Effectiveness Report		No	Variation By Efficiency Type	Ducted Heat Pump	8731	10725		
2019	E3	Pre-1978	No	Variation By Climate Zone	Heat Pump Water Heater	3300	4200		
2019	E3	1990	No	Variation By Climate Zone	Heat Pump Water Heater	3400	4300		
2019	E3	Pre-1978	Yes	Variation By Climate Zone	Ducted Heat Pump	6500	8000		
2019	E3	1990	No	Variation By Climate Zone	Ducted Heat Pump	12500	15000		
2021-2023	Tech Clean California	All Vintages	No	Min Max And Interquartile Range	Ducted Heat Pump	4235	8747	5980	7062
2021-2023	Tech Clean California	All Vintages	No	Min Max And Interquartile Range	Ductless Mini-Split	4800	8900	6900	7295
2021-2023	Tech Clean California	All Vintages	No	Min Max And Interquartile Range	Heat Pump Water Heater	3983	4909.4	3983	4480

Table B 3. Demographics of renter survey respondents

Characteristic	%
Gender	
Male	50%
Female	50%
Race / Ethnicity	
Hispanic or Latino	61%
Caucasian or White	15%
Asian or Pacific Islander	10%

African American or Black	9%
More than one group	3%
Native American or Indigenous	1%
Other	1%
Age	
18–24	12%
25–29	13%
30–34	11%
35–39	8%
40–44	9%
45–49	6%
50–54	7%
55–59	7%
60–64	9%
65–74	13%
75+	5%
Region	
Los Angeles	36%
Central Valley	31%
LA Area	17%
San Diego	7%
Bay Area	6%
Sacramento / North	3%
Annual Household Income (2022)	
Under $7,500	3%
$7,500–$9,999	1%
$10,000–$14,999	4%
$15,000–$24,999	4%
$25,000–$34,999	10%
$35,000–$49,999	15%
$50,000–$74,999	29%
$75,000–$99,999	18%
$100,000–$150,000	7%
$150,000 or more	3%
DK/NA	5%
Housing Type	
Apartment	46%
Single-family detached	37%
Condominium	8%
Townhouse	6%
Mobile home	1%

Other / DK/NA	2%
Units in Building (multifamily only, n=483)	
2–5 units	10%
6–10 units	22%
11–20 units	24%
21–50 units	29%
More than 50 units	12%
DK/NA	3%
Household Size	
1 (live alone)	11%
2	24%
3	21%
4	19%
5	14%
6	7%
7	2%
8+	2%
Survey Language	
English	83%
Spanish	14%
Chinese	1%
Vietnamese	1%

Appendix C: Commercial Methods

Table C1. DOE Technology Readiness Level (TRL) classifications and definitions

Relative Level of Technology Development	*Technology Readiness Level*	*TRL Definition*	*Description*
System Operations	TRL 9	Actual system operated over the full range of expected conditions.	The technology is in its final form and operated under the full range of operating conditions. Examples include using the actual system with the full range of wastes in hot operations.
System Commissioning	TRL 8	Actual system completed and qualified through test and demonstration.	The technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental testing and evaluation of the system with actual waste in hot commissioning. Supporting information includes operational procedures that are virtually complete. An Operational Readiness Review (ORR) has been successfully completed prior to the start of hot testing.
System Commissioning	TRL 7	Full-scale, similar (prototypical)	This represents a major step up from TRL 6, requiring demonstration of an actual system prototype in a relevant

		system demonstrated in relevant environments.	environment. Examples include testing full-scale prototype in the field with a range of simulants in cold commissioning. Supporting information includes results from the full-scale testing and analysis of the differences between the test environment, and analysis of what the experimental results mean for the eventual operating system/environment. Final design is virtually complete.
Technology Demonstration	TRL 6	Engineering/pilot-scale, similar (prototypical) system validation in relevant environments.	Engineering-scale models or prototypes are tested in a relevant environment. This represents a major step up in a technology’s demonstrated readiness. Examples include testing an engineering scale prototypical system with a range of simulants. 1 Supporting information includes results from the engineering scale testing and analysis of the differences between the engineering scale, prototypical system/environment, and analysis of what the experimental results mean for the eventual operating system/environment. TRL 6 begins true engineering development of the technology as an operational system. The major difference between TRL 5 and 6 is the step up from laboratory scale to engineering scale and the determination of scaling factors that will enable design of the operating system. The prototype should be capable of performing all the functions that will be required of the operational system. The operating environment for the testing should closely represent the actual operating environment.
Technology Development	TRL 5	Laboratory scale, similar system validation in relevant environments.	The basic technological components are integrated so that the system configuration is similar to (matches) the final application in almost all respects. Examples include testing a high-fidelity, laboratory scale system in a simulated environment with a range of simulants and actual waste. Supporting information includes results from the laboratory scale testing, analysis of the differences between the laboratory and eventual operating system/environment, and analysis of what the experimental results mean for the eventual operating system/environment. The major difference between TRL 4 and 5 is the increase in the fidelity of the system and environment to the actual application. The system tested is almost prototypical.
Technology Development	TRL 4	Component and/or system validation in laboratory environments.	The basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of ad hoc hardware in a laboratory and testing with a range of simulants and small scale tests on actual waste. Supporting information includes the results of the integrated experiments and estimates of how the experimental components and experimental test results differ from the expected system performance goals. TRLs 4-6 represent the bridge from scientific research to engineering. TRL 4 is the first step in determining whether the individual components will work together as a system. The laboratory system will probably be a mix of on hand equipment and a few special purpose components that may require special handling, calibration, or alignment to get them to function.
Research to Prove Feasibility	TRL 3	Analytical and experimental critical function and/or	Active research and development (R&D) are initiated. This includes analytical studies and laboratory-scale studies to physically validate the analytical predictions of separate

		characteristic proof of concept.	elements of the technology. Examples include components that are not yet integrated or representative tested with simulants.1 Supporting information includes results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions for critical subsystems. At TRL 3 the work has moved beyond the paper phase to experimental work that verifies that the concept works as expected on simulants. Components of the technology are validated, but there is no attempt to integrate the components into a complete system. Modeling and simulation may be used to complement physical experiments.
Basic Technology Research	TRL 2	Technology concept and/or application formulated.	Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are still limited to analytic studies. Supporting information includes publications or other references that outline the application being considered and that provide analysis to support the concept. The step up from TRL 1 to TRL 2 moves the ideas from pure to applied research. Most of the work is analytical or paper studies with the emphasis on understanding the science better. Experimental work is designed to corroborate the basic scientific observations made during TRL 1 work.
Basic Technology Research	TRL 1	Basic principles observed and reported.	This is the lowest level of technology readiness. Scientific research begins to be translated into applied R&D. Examples might include paper studies of a technology’s basic properties or experimental work that consists mainly of observations of the physical world. Supporting Information includes published research or other references that identify the principles that underlie the technology.

Appendix D: Commercial Results

Table D 1. California Energy Codes and Standards Cost Summary Estimates, Commercial[169,170]

	All Gas / Mixed-Fuel Measure	*Mixed-Fuel Cost*	*Electrification Retrofit Measure*	*All-Electric Cost*	*All Electric Incremental Cost*
Medium Office Building	Boilers	$45,508	Central heat pump water heater with electric resistance booster	$157,070	$111,562
	Service Water Heater	$73,479	Central heat pump water heater	$88,762	$15,283
	Electrical Upgrades	$0	Wiring, distribution boards, transformers	$31,233	$31,233
	Total	**$118,987**		**$277,065**	**$158,078**
Stand-Alone Retail	Packaged single zone AC and gas furnace	$176,229	Packaged single one heat pump	$173,617	-$2,612
	Storage gas water heater	$1,255	Point of use electric resistance water heater	$1,723	$468
	Electrical upgrades	$0	Wiring for storage water heater	$2,007	$2,007
	Total	**$177,484**		**$177,347**	**-$137**
Warehouse	Packaged single zone AC and gas furnace	$56,013	Packaged single zone heat pump	$60,462	$4,449
	Gas heaters, exhaust-only ventilation	$6,529	Electric radiant heaters, exhaust only ventilation	$10,958	$4,429
	Storage water heater with gas storage	$1,255	Point of use electric resistance	$10,958	-$106
	Electrical upgrades	$0	Wiring for warehouse HVAC and storage water heater	$6,231	$6,231
	Total	**$63,797**		**$78,800**	**$15,003**
Quick-Service	Packaged Furnace, Direct Expansion A/C	$120,811	Packaged heat pump	$128,154	$7,343

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[169] Cost estimates exclude annual maintenance costs over appliances lifetime.

[170] All estimates from: PS2 Engineers, TRC Companies, "2021 Reach Code Cost Effectiveness Analysis: Non-Residential Alterations, California Energy Codes and Standards" (2021). Available at https://localenergycodes.com/content/resources.

Restaurant	Gas storage water heater - One 150 kBtu/hr heater - One 100-gallon tank	$21,860	Heat pump water heaters with storage tank Two 120-gallon tanks	$27,963	$6,103
	French fryer (4) Griddle, single sided (2) Half-size electric convection oven (1)	$21,291	French fryer (4) Griddle, single sided (2) Half-size electric convection oven (1)	$42,815	$21,524
	Electrical Upgrades	$0	Electrical Upgrades	$25,865	$25,865
	Total	**$163,962**		**$224,797**	**$60,835**
Full-service Restaurant	Packaged furnace, direct expansion A/C	$160,889	Packaged heat pump	$161,013	$123
	Gas storage water heater with recirculation loop 400 kBtu/hr heater (2) 200-gallon tank	$38,088	Heat pump water heaters with storage tank Colmac CxV-5 (4) Tota 750 gallons of primary storage 5 kW electric resistance loop heater (1) 120-gallon loop tank (1)	$161,943	$123,855
	Underfired broiler French fryer (2) Griddle, single-sided Broiler, salamander Oven, convection double deck (1) Oven, range (2) Range, six open burners (2) Range, stock pot (2)	$52,383	Chain broiler (1) French fryer (2) Broiler, salamander (1) Oven, convection double deck (1) Oven, induction range (2) Range, six burner induction cooktop (2) Range, induction stock pot (2)	$99,959	$47,576
	Electrical Upgrades	$0	Electrical Upgrades	$37,213	$37,213
	Total	**$251,360**		**$460,128**	**$208,768**
Small Hotel (1980s and 1990s Vintage)	Replace PTACs and wall furnaces	$408,151	Replace PTACs with PTHPs. Decommission wall furnaces.	$227,317	-$180,834
	Gas water heater with storage	$36,303	Heat pump water heater with storage	$101,446	$64,842
	Electrical Upgrades	$0	Wiring and distribution for central DHW heat pump water heater.	$8,240	$8,240
	Total	**$444,754**		**$337,003**	**-$107,751**
Small Hotel (2000s Vintage)	Central furnace + Split AC	$699,398	Split heat pump	$611,888	-$87,510
	Gas water heater with storage	$36,603	Heat pump water heater with storage	$101,446	$64,842

	Electrical Upgrades	$0	Wiring and distribution for central DHW heat pump water heater	$8,240	$8,240
	Total	**$736,002**		**$721,573**	**-$14,428**

Table D 2. Commercial Electrification Marginal Costs and Incentives

CEUS Subsector	*End Use*	*Electrification Marginal Cost*		*Incentives (across building types)*
Lodging		*Lodging 1980s and 1990s Vintage*	*Lodging 2000s Vintage*	
	Space Heating	-$180,834	-$87,510	$592 per unit $750 per project
	Water Heating	$64,842	$64,842	$1,556 - $1,788 per unit
	Electric Upgrades (wiring and distribution for central heat pump water heater)	$8,240	$8,240	$0
	Whole Building			$10,000 per unit
Medium Office	Water Heating (central heat pump water heater with electric resistance booster and central heat pump water heater)	$126,845		$1,556 - $1,788 per unit
	Electric Upgrades (wiring, distribution boards, transformers)	$31,233		$0
	Whole Building	-		$10,000 per unit
Unrefrigerated Warehouse	Heating	$8,878		$592 per unit $750 per project
	Water Heating	-$106		$1,556 - $1,788 per unit
	Electric Upgrades (wiring for storage water heater)	$6,231		$0
	Whole Building			$10,000 per unit
Restaurants		Full-Service Restaurant	Quick-Service Restaurant	
	Heating	$123	$7,343	$592 per unit $750 per project
	Water Heating	$123,855	$6,103	$1,556 - $1,788 per unit
	Cooking Equipment	$47,576	$21,524	$200 per foot

				$383 per heating element $1,134-$1,341 per unit $17,500 per project
	Electric Upgrades (wiring for storage water heater)	$37,213	$25,865	$0
	Whole Building			$10,000 per unit
Retail	Heating	-$2,612		$592 per unit $750 per project
	Water Heating	$468		$1,556 - $1,788 per unit
	Electric Upgrades (wiring for storage water heater)	$2,007		$0
	Whole Building			$10,000 per unit

Table D 3. Commercial Gas and Electricity Accounts by DAC Census Tracts, CEUS Subsector and Year

Year	CEUS Subsector	DAC Census Tract	Gas Accounts	Electricity Accounts	Proportion (%) of Electricity of Total Energy Consumption
2015	College	FALSE	3840	7211	54.92
2015	College	TRUE	571	1091	67.24
2016	College	FALSE	3886	7455	41.97
2016	College	TRUE	569	1134	62.39
2017	College	FALSE	3926	7649	42.05
2017	College	TRUE	570	1164	62.33
2018	College	FALSE	3905	7865	41.57
2018	College	TRUE	586	1268	60.57
2019	College	FALSE	4024	8208	44.97
2019	College	TRUE	617	1350	58.20
2020	College	FALSE	3898	7720	43.03
2020	College	TRUE	584	1164	60.45
2021	College	FALSE	3582	6856	38.24
2021	College	TRUE	536	1097	62.22
2015	Food Store	FALSE	1719	3077	76.36
2015	Food Store	TRUE	739	1262	71.36
2016	Food Store	FALSE	1714	3074	74.17
2016	Food Store	TRUE	746	1309	69.89
2017	Food Store	FALSE	1725	3103	73.05
2017	Food Store	TRUE	746	1346	70.58

2018	Food Store	FALSE	1759	3240	72.78
2018	Food Store	TRUE	746	1400	70.38
2019	Food Store	FALSE	1805	3344	70.95
2019	Food Store	TRUE	787	1484	69.03
2020	Food Store	FALSE	1745	3098	72.66
2020	Food Store	TRUE	763	1378	69.13
2021	Food Store	FALSE	1655	2944	71.63
2021	Food Store	TRUE	738	1359	68.87
2015	Health Care	FALSE	6100	8686	48.24
2015	Health Care	TRUE	2108	2652	46.75
2016	Health Care	FALSE	6222	9083	44.48
2016	Health Care	TRUE	2141	2812	46.92
2017	Health Care	FALSE	6342	9540	43.93
2017	Health Care	TRUE	2160	2890	45.65
2018	Health Care	FALSE	6460	9857	43.34
2018	Health Care	TRUE	2154	2995	45.82
2019	Health Care	FALSE	6651	10352	42.44
2019	Health Care	TRUE	2223	3111	44.20
2020	Health Care	FALSE	6698	10036	42.22
2020	Health Care	TRUE	2200	3007	42.43
2021	Health Care	FALSE	6517	9604	41.95
2021	Health Care	TRUE	2164	2972	43.66
2015	Hotel	FALSE	5105	6393	47.51
2015	Hotel	TRUE	1358	1528	46.24
2016	Hotel	FALSE	4937	6410	46.31
2016	Hotel	TRUE	1365	1570	44.17
2017	Hotel	FALSE	5088	6556	46.78
2017	Hotel	TRUE	1376	1618	44.92
2018	Hotel	FALSE	5103	6577	44.58
2018	Hotel	TRUE	1369	1670	45.05
2019	Hotel	FALSE	5362	6869	41.95
2019	Hotel	TRUE	1402	1672	43.77
2020	Hotel	FALSE	5272	6669	45.74
2020	Hotel	TRUE	1395	1587	46.04
2021	Hotel	FALSE	5092	6329	43.90
2021	Hotel	TRUE	1372	1523	44.08
2015	Miscellaneous	FALSE	41164	99364	54.43
2015	Miscellaneous	TRUE	13779	39412	48.55
2016	Miscellaneous	FALSE	40988	103549	52.63

2016	Miscellaneous	TRUE	13813	41558	47.00
2017	Miscellaneous	FALSE	41065	106711	52.78
2017	Miscellaneous	TRUE	13800	43333	48.37
2018	Miscellaneous	FALSE	41591	110403	52.58
2018	Miscellaneous	TRUE	13897	44909	48.46
2019	Miscellaneous	FALSE	42958	114682	50.79
2019	Miscellaneous	TRUE	14480	46656	46.72
2020	Miscellaneous	FALSE	42488	109202	49.41
2020	Miscellaneous	TRUE	14394	44284	46.19
2021	Miscellaneous	FALSE	40322	105153	49.64
2021	Miscellaneous	TRUE	13939	43991	46.31
2015	Office	FALSE	89977	484331	68.76
2015	Office	TRUE	22206	131917	72.19
2016	Office	FALSE	89307	505127	65.82
2016	Office	TRUE	22412	142373	73.09
2017	Office	FALSE	88971	525026	66.88
2017	Office	TRUE	22294	150905	74.17
2018	Office	FALSE	90509	561011	65.41
2018	Office	TRUE	22440	164324	74.21
2019	Office	FALSE	94414	597713	64.70
2019	Office	TRUE	23809	175139	71.83
2020	Office	FALSE	95171	564657	63.68
2020	Office	TRUE	23902	159460	70.21
2021	Office	FALSE	91354	541589	60.21
2021	Office	TRUE	23173	159913	69.36
2015	Refr Warehouse	FALSE	263	541	87.89
2015	Refr Warehouse	TRUE	196	697	87.45
2016	Refr Warehouse	FALSE	244	541	86.29
2016	Refr Warehouse	TRUE	199	754	86.33
2017	Refr Warehouse	FALSE	234	536	86.02
2017	Refr Warehouse	TRUE	208	796	86.45
2018	Refr Warehouse	FALSE	246	558	81.95
2018	Refr Warehouse	TRUE	200	788	85.13
2019	Refr Warehouse	FALSE	255	571	76.48
2019	Refr Warehouse	TRUE	209	807	84.24
2020	Refr Warehouse	FALSE	255	548	78.96
2020	Refr Warehouse	TRUE	221	764	82.71
2021	Refr Warehouse	FALSE	242	510	81.40
2021	Refr Warehouse	TRUE	210	723	80.50

2015	Restaurant	FALSE	37800	43943	37.41
2015	Restaurant	TRUE	10208	11038	39.30
2016	Restaurant	FALSE	38194	46314	36.70
2016	Restaurant	TRUE	10213	11713	39.27
2017	Restaurant	FALSE	38683	48156	36.92
2017	Restaurant	TRUE	10352	12352	39.77
2018	Restaurant	FALSE	39528	50110	37.03
2018	Restaurant	TRUE	10476	12869	40.05
2019	Restaurant	FALSE	41774	52572	35.60
2019	Restaurant	TRUE	11144	13354	38.29
2020	Restaurant	FALSE	41361	49545	36.26
2020	Restaurant	TRUE	11001	12402	37.56
2021	Restaurant	FALSE	39705	46419	35.02
2021	Restaurant	TRUE	10744	11959	37.07
2015	Retail Store	FALSE	22498	54601	87.48
2015	Retail Store	TRUE	7862	18658	86.45
2016	Retail Store	FALSE	21955	55528	85.69
2016	Retail Store	TRUE	7827	19565	84.72
2017	Retail Store	FALSE	21569	56397	84.69
2017	Retail Store	TRUE	7851	20303	83.43
2018	Retail Store	FALSE	21457	57228	83.09
2018	Retail Store	TRUE	7778	21076	83.38
2019	Retail Store	FALSE	21884	59592	81.55
2019	Retail Store	TRUE	8021	21793	81.51
2020	Retail Store	FALSE	21676	55783	80.61
2020	Retail Store	TRUE	7988	20280	79.16
2021	Retail Store	FALSE	20423	51079	79.37
2021	Retail Store	TRUE	7658	19253	78.57
2015	School	FALSE	27372	61153	70.63
2015	School	TRUE	6042	18876	80.25
2016	School	FALSE	27704	62259	68.03
2016	School	TRUE	6131	19347	77.85
2017	School	FALSE	27594	63722	65.43
2017	School	TRUE	6110	19531	76.37
2018	School	FALSE	27251	62144	63.37
2018	School	TRUE	6115	19141	74.48
2019	School	FALSE	27094	62740	61.14
2019	School	TRUE	6162	20229	72.04
2020	School	FALSE	26174	59327	60.47

2020	School	TRUE	6010	19082	70.73
2021	School	FALSE	26432	58816	56.88
2021	School	TRUE	6059	19498	70.84
2015	Unrefrigerated Warehouse	FALSE	12042	27669	76.54
2015	Unrefrigerated Warehouse	TRUE	6047	14660	73.48
2016	Unrefrigerated Warehouse	FALSE	11951	28677	73.21
2016	Unrefrigerated Warehouse	TRUE	6050	15693	71.91
2017	Unrefrigerated Warehouse	FALSE	11936	29552	72.11
2017	Unrefrigerated Warehouse	TRUE	6007	16448	71.83
2018	Unrefrigerated Warehouse	FALSE	12056	30518	71.53
2018	Unrefrigerated Warehouse	TRUE	6048	16825	71.48
2019	Unrefrigerated Warehouse	FALSE	12388	31913	69.80
2019	Unrefrigerated Warehouse	TRUE	6247	17243	69.76
2020	Unrefrigerated Warehouse	FALSE	12309	29902	69.39
2020	Unrefrigerated Warehouse	TRUE	6169	15942	67.98
2021	Unrefrigerated Warehouse	FALSE	11935	27994	69.25
2021	Unrefrigerated Warehouse	TRUE	5995	15345	67.90

Appendix E: Renter and Multifamily Property Owner Surveys and Interviews

Renter Survey Questions

Hello, I'm calling from _______, a public opinion research company. We are not telemarketers trying to sell anything or asking for a donation of any type. UCLA is conducting a survey of residents in your community to learn more about residents' concerns and priorities. The survey will be used to help shape future policies in your community. All responses will be completely anonymous. (**IF RESPONDENT REPLIES IN SPANISH, xxx OR xxxx, FOLLOW THE PROCEDURE FOR HANDING OFF TO THE APPROPRIATE SPEAKING INTERVIEWER.)** May I speak to ______________? **YOU MUST SPEAK TO THE PERSON LISTED**. **(IF NOT AVAILABLE, ASK:)** "May I please speak to the person in the household who is most responsible for paying the bills each month?" (**IF NOT AVAILABLE, ASK:** "May I speak to another adult in the household?")

Before we begin, could you please tell me if I have reached you on a cell phone? **(IF YES:** Are you in a place where you can talk safely?)

Yes, cell and in safe place 1
Yes, cell not in safe place **TERMINATE**
No, not on cell 2
(DON'T READ) DK/NA/REFUSED **TERMINATE**

To make sure that everyone is represented in this survey, can you please tell me your ZIP Code? **(OPEN-END; CONFIRM THAT ZIP CODE IS ON ELIGIBILITY LIST)**

Next, do you own or rent the home where you live?

Own 1
Rent 2
(DON'T READ) DK/NA/REFUSED 3

TERMINATE IF QC IS CODED 1 OR 3

Next, as a reminder, this is not a marketing call and I'm not going to try to sell you anything. I am going to ask you some questions about the types of appliances you have at your home and how they are powered. For each one I mention, please tell me if you have that kind of appliance at your home. If you are not sure or you do not have that kind of appliance in your home you can tell me that instead. **(RANDOMIZE)**

	YES	**NO**	**DON'T KNOW**
An oven, stove, and/or range top that uses natural gas or propane	1	2	3
A hot water heater that uses natural gas or propane	1	2	3

An air conditioner, swamp cooler or heat pump that uses natural gas or propane 1 2 3

	<u>YES</u>	**<u>NO</u>**	**DON'T <u>KNOW</u>**
A wood-burning stove used for heating	1	2	3
A built-in heater that uses natural gas or propane	1	2	3
A clothes dryer that uses natural gas or propane	1	2	3

PARTICIPANT MUST BE CODED 1 ON AT LEAST 1 ITEM IN QD, OTHERWISE TERMINATE

(ASK IF QDc IS CODED 1)
E. Do you have an air conditioner that is mounted in the window, a built-in/central system or something else?

Window 1
Built-in/Central 2
Something else 3
(DON'T READ) DK/NA 4

(RESUME ASKING ALL RESPONDENTS)
Now, again just to make sure everyone is represented in this survey, what is your gender identity?

Male 1
Female 2
Non-binary or other 3
(DON'T READ) Prefer not to answer 4

Which of the following categories best describes the ethnic or racial group with which you identify yourself? **(READ ALL RESPONSE CHOICES; DO NOT RANDOMIZE)**

Hispanic or Latino 1
African American or Black 2
Caucasian or White 3
Asian or Pacific Islander 4
Native American or Indigenous 5
More than one ethnic or racial groups 6
A different ethnic or racial group **(SPECIFY AND RECORD:__________)** 7
(DON'T READ) Prefer not to answer 8

In what year were you born?

2005-1999 (18-24) 1
1998-1994 (25-29) 2
1993-1989 (30-34) 3

1988-1984 (35-39)	4
1983-1979 (40-44)	5
1978-1974 (45-49)	6
1973-1969 (50-54)	7
1968-1964 (55-59)	8
1963-1959 (60-64)	9
1958-1949 (65-74)	10
1948 or earlier (75+)	11
(**DON'T READ**) Prefer not to answer	12

If it would not cost you anything, how much would you want the owner or landlord of your home or apartment building to replace the following appliances in your home with versions that use only electricity? We're going to use a one to seven scale to answer this question; one will mean you would definitely NOT want that and seven would mean you would definitely want it. You can use a four if you do not have an opinion either way. **(READ ITEMS FROM QD CODED 1 "YES") (RANDOMIZE)**

	Def Not Want 1	**2**	**3**	**No Opinion 4**	**5**	**6**	**7**	**Def Want 8**	**(DK/ NA)**
Stove, oven or range top	1	2	3	4	5	6	7	8	
Hot water heater	1	2	3	4	5	6	7	8	
Air conditioner, swamp cooler or heat pump	1	2	3	4	5	6	7	8	
Wood-burning stove used for heating	1	2	3	4	5	6	7	8	
Built-in heater	1	2	3	4	5	6	7	8	
Clothes dryer	1	2	3	4	5	6	7	8	

(IF QDd OR QDe CODED 1)
Replacing a heater with a combined heating and cooling system 1 2 3 4 5 6 7 8

(IF ANY ANSWER IN Q4 CODED 1-3 OR 5-7)
Thinking about your **(INSERT ONE ITEM RANDOMLY FROM Q4 THAT IS CODED 1-3 OR 5-7)**, in a few of your own words, what would be the primary reason why you would **(IF CODE 1-3:** "not want"**)(IF CODE 5-7:** "want"**)** that appliance changed to be powered only with electricity? **(OPEN-END; RECORD VERBATIM RESPONSES; PROBE FOR SPECIFICS)**

(RESUME ASKING ALL RESPONDENTS)
Next, I am going to mention some aspects of different fuels could be used by appliances in your home or other homes. For each aspect, tell me if you think it is a better description of **(ROTATE:** [ ] natural gas, [ ] electricity**)** or both equally. **(RANDOMIZE)**

NATURAL **BOTH** **(DON'T**

	GAS	ELEC.	EQUALLY	KNOW)
Is safer overall	1	2	3	4
Is more reliable	1	2	3	4
Is more energy efficient	1	2	3	4
Is easier to use	1	2	3	4
(SPLIT SAMPLE A ONLY)				
Is better for the environment	1	2	3	4
Releases harmful chemicals inside homes	1	2	3	4
Is more likely to work in an earthquake or other natural disaster	1	2	3	4
Costs less to install in a home	1	2	3	4
(SPLIT SAMPLE B ONLY)				
Is making climate change worse in California	1	2	3	4
Releases air pollution inside homes	1	2	3	4
Costs less to use on an ongoing basis	1	2	3	4
Is better for cooking	1	2	3	4

(RESUME ASKING ALL RESPONDENTS)
Now, I am going to read you a similar list of aspects of different appliances, and for each one, please tell me how important each one is to you personally when choosing an appliance: extremely important, very important, somewhat important or not too important. **(RANDOMIZE)**

	Extremely Important	Very Imp.	Smwt Imp.	Not Too Imp.	Don't Know
Is safe	1	2	3	4	5
Is reliable	1	2	3	4	5
Is easy to use	1	2	3	4	5
Is energy efficient	1	2	3	4	5
(SPLIT SAMPLE A ONLY)					
Is good for the environment	1	2	3	4	5
Does not release harmful chemicals inside homes	1	2	3	4	5
Is likely to be available in an earthquake or other natural disaster	1	2	3	4	5
The cost to install in a home	1	2	3	4	5
(SPLIT SAMPLE B ONLY)					
Does not release air pollution inside homes	1	2	3	4	5
Is safe in the event of an earthquake or other natural disaster	1	2	3	4	5
The cost to run on an ongoing basis	1	2	3	4	5
Is good for cooking	1	2	3	4	5

(RESUME ASKING ALL RESPONDENTS)
Next, I am going to mention some reasons why some people think it is better for homes to have electric appliances instead of natural gas-powered appliances. For each one I mention, please tell me if it makes you more inclined to want electric appliances, if there

would be no cost to your household. If you do not believe the statement, or if it has no effect on your thinking one way or the other, please tell me that instead. **(IF MORE INCLINED, ASK:** Is that much more or just somewhat?) (**RANDOMIZE) (DON'T READ "LESS INCLINED" AND DON'T KNOW OR NO ANSWER**)

MUCHSMWT (DON'T READ) (DON'T
MORE MORE LESS DON'T NO READ)
INCL. INCL. INCL. BELIEVE EFFECT DK/NA

(INDOOR AIR) Appliances that use gas, such as stoves and dryers emit harmful methane and benzene, which are powerful greenhouse gases, that cause cancer, asthma, and other respiratory illnesses. In fact, one out of every five cases of childhood asthma in California is linked to gas appliances. 1 2 3 4 5 6

(CLIMATE CHANGE) Homes and buildings are the second-largest source of climate pollution in the state. Using appliances that are powered only by electricity are better for the environment than appliances that burn fossil fuels such as gas. 1 2 3 4 5 6

(FUTURE GENERATIONS) In many ways, our young people are facing an uncertain future when it comes to the climate and environment. This is an important step for making California a healthier, greener community for our children and grandchildren. 1 2 3 4 5 6

(COST VOLATILITY) As we saw over the last year, there can be big spikes in prices for natural gas used by home appliances leading to surprise bills that can be hundreds of dollars more than customers have experienced just a couple of months before. Home electric bills are more stable and allow households to budget and plan their finances. 1 2 3 4 5 6

(CARBON MONOXIDE) Unlike electric appliances, appliances that use natural gas can result in carbon monoxide poisoning inside homes. So much so, that California Health and Safety Code requires every home to have equipment to detect it and to prevent illness or death. 1 2 3 4 5 6

MUCHSMWT (DON'T READ) (DON'T
MORE MORE LESS DON'T NO READ)
INCL. INCL. INCL. BELIEVE EFFECT DK/NA

(ASK IF QDa CODED 1)
(INDUCTION) New electric stoves work a lot better than the old versions some of us are used to seeing. In fact, compared to gas stoves, the new electric-powered induction stoves boil water faster, hold more consistent heating temperature and are better at going quickly from high heat to low heat. Switching to electric can result in an even better cooking experience. 1 2 3 4 5 6

(SPLIT SAMPLE A ONLY)
(EXPERTS) Air quality scientists in California are calling for homeowners to switch to electric appliances because of the dangerous impacts of using gas appliances for our health and our air quality. 1 2 3 4 5 6

(SECOND-HAND SMOKE) Even when gas stoves are off, they are leaking dangerous chemicals at levels that are worse than breathing second-hand smoke. This is even more dangerous for people living in smaller apartments with limited air flow. Electric appliances help keep seniors, children, and everyone else safe at home. 1 2 3 4 5 6

(SPLIT SAMPLE B ONLY)

(BANS) Many communities are banning appliances that use natural gas in new buildings because of the threat they cause to health and the environment. We all deserve the same level of protection so we have healthy, safe homes. 1 2 3 4 5 6

(EXTREME WEATHER) With intense heat waves becoming more common in California, it is more important than ever to have solutions for seniors, low-income families, and others to keep cool in summer. Electric-powered systems can provide very efficient, inexpensive cooling and heating in a single system, providing vital safety and comfort during hot summer months in ways that gas-powered furnaces cannot. 1 2 3 4 5 6

(RESUME ASKING ALL RESPONDENTS)

Now that you have heard more about it, let me ask you again: if it would not cost you anything, how much would you want the owner or landlord of your home or apartment building to replace the following appliances with versions powered only be electricity in your home? Again, please use a 1 to 7 seven scale: 1 means you would definitely NOT want that and 7 would mean you would definitely want it. You can use a 4 if you do not have an opinion either way. **(READ ITEMS FROM QD CODED 1 "YES")**

	Def Not Want 1	**2**	**3**	**No Opinion 4**	**5**	**6**	**7**	**Def Want 8**	**(DK/ NA)**
Stove, oven or range top	1	2	3	4	5	6	7	8	
Hot water heater	1	2	3	4	5	6	7	8	
Air conditioner, swamp cooler or heat pump	1	2	3	4	5	6	7	8	
Wood-burning stove used for heating	1	2	3	4	5	6	7	8	
Built-in heater	1	2	3	4	5	6	7	8	
Clothes dryer	1	2	3	4	5	6	7	8	

(IF QDd OR QDe CODED 1)

Replacing a heater with a combined heating and cooling system 1 2 3 4 5 6 7 8

(ASK IF ANY ITEM IN Q9 CODED 5-7)

You have been asked about your interest in electric appliances if they resulted in no costs to your household. But, it is possible that if a landlord or property owner chooses to switch some appliances to electric, some of those costs could end up being passed down to renters. Next suppose that switching to electric appliances resulted in an additional cost of _____________ **(READ EACH, RECORD)** per month for your household. Would you be very willing, somewhat willing, somewhat unwilling, or very unwilling to pay that amount? **(DO NOT ROTATE, READ IN ORDER; STOP ONCE RESPONDENT REPLIES "VERY WILLING")**

	VERY WILL	**SW WILL**	**SW UNWLL**	**VERY UNWILL**	**(DK/ NA)**
75 dollars	1	2	3	4	5
50 dollars	1	2	3	4	5
25 dollars	1	2	3	4	5
5 dollars	1	2	3	4	5

(ASK IF ANY ITEM IN Q9 CODED 1-3; SKIP IF ANY ITEM IN Q10 CODED 1)
(IF Q10 NOT ASKED: "You have been considering your interest in electric appliances if they resulted in no costs to your household. But, it is"**)(IF Q10 ASKED:** "It is"**)** possible that if a landlord or property owner chooses to switch some appliances to electric, there could be a savings passed down to you as a renter. Next suppose that switching to electric appliances resulted in a savings for you of _____________ **(READ EACH, RECORD)** per month for your household. Would you be willing or unwilling to switch for a savings of that amount? **(IF WILLING/UNWILLING, ASK:** Is that very **WILLING/UNWILLING** or just somewhat?) **(DO NOT ROTATE, READ IN ORDER; STOP ONCE RESPONDENT REPLIES "VERY WILLING")**

	VERY WILL	**SW WILL**	**SW UNWLL**	**VERY UNWILL**	**(DK/ NA)**
5 dollars	1	2	3	4	5
25 dollars	1	2	3	4	5
50 dollars	1	2	3	4	5
75 dollars	1	2	3	4	5

(RESUME ASKING ALL RESPONDENTS)
The final questions are for classification purposes only.

Does your household pay the bill for the electricity you use or is that paid by the landlord?

Household pays	1
Landlord pays	2
(DON'T READ) DK/NA	3

(ASK IF Q12 CODED 1)
How concerned are you about your household's ability to afford the costs of your electricity bill on a regular basis? **(READ RESPONSE CODES IN ORDER)**

Extremely concerned	1
Very concerned	2
Somewhat concerned	3

Not concerned	4
(DON'T READ) DK/NA	5

(ASK IF Q12 CODED 1)
Based on what you know or just taking a guess, how much is your electricity bill in an average month? If you don't know, you can tell me that instead.

$50 or less	1
$51-$100	2
$101-$200	3
More than $200	4
Don't know	5

(RESUME ASKING ALL RESPONDENTS)
Does your household pay the bill for the natural gas you use or is that paid by the landlord?

Household pays	1
Landlord pays	2
(DON'T READ) DK/NA	3

(ASK IF Q15 CODED 1)
How concerned are you about your household's ability to afford the costs of your natural gas bill on a regular basis? **(READ RESPONSE CODES IN ORDER)**

Extremely concerned	1
Very concerned	2
Somewhat concerned	3
Not concerned	4
(DON'T READ) DK/NA	5

(ASK IF Q15 CODED 1)
And based on what you know or just taking a guess, how much is your natural gas bill in an average month? If you don't know, you can tell me that instead.

$25 or less	1
$26-50	2
$51-$100	3
More than $100	4
Don't know	5

(RESUME ASKING ALL RESPONDENTS)
How many people other than you live in your household?

Zero/Live alone	1
1	2

2	3
3	4
4	6
5	7
6	8
More than 6	9
(DON'T READ) DK/NA	10

What type of building do you live in?

Single-family detached home	1
Apartment	2
Condominium	3
Townhouse	4
Mobile home	5
Other **(SPECIFY _____)**	6
(DON'T READ) DK/NA	7

(ASK IF Q20 CODED 2, 3, OR 4)
Approximately how many units are there in your **(IF Q19 CODED 2: "**apartment**")(IF Q19 CODED 3: "**condominium**")(IF Q19 CODED 4: "**townhouse**")** building or complex?

2-5	1
6-10	2
11-20	3
21-50	4
More than 50	5
(DON'T READ) DK/NA	6

(RESUME ASKING ALL RESPONDENTS)
Lastly, just to ensure that we include a wide mix of people in this survey, please stop me when I read the range that includes your household's total annual income before taxes in 2022:

Under $7,500	1
$7,500 - $9,999	2
$10,000 -$14,999	3
$15,000 - $24,999	4
$25,000 - $34,999	5
$35,000 - $49,999	6
$50,000 - $74,999	7
$75,000 - $99,999	8
$100,000 - $150,000	9
$150,000 or more	10
(DON'T READ) DK/NA	11

THANK AND TERMINATE

Language:

English	1
Spanish	2
XX	3
XX	4

REGION

LA	1
LA Area	2
Bay Area	3
San Diego	4
Sac’to/North	5
Central Valley	6

MEDIA MARKET

LA	1
SF	2
SD	3
SAC	4
OTHER	5

CONTACT METHOD

Email	1
Text	2
Phone	3
Postcard	4

CALENVIROSCREEN SCORE

PLACEHOLDER FOR OTHER DATA GROUPS

Multifamily Property Owner Questions

1. What kind of property/properties do you or your organization/company own? Approximately how many tenants are in your property/properties? Do your tenants pay their own electricity or gas bills, or does it vary?

2. Please describe the steps you have taken to electrify the appliances at the property/properties that you or your organization/company owns. What was the process like?
3. **Follow-up if needed:**
4. How long did it take?
5. Did you have to make other changes to the property, such as upgrading your electrical panel(s), adding solar and/or storage, or remediating other issues such as lead or asbestos?
6. Was there any impact on your tenants during the time the changes were being made?

7. Did you participate in any public or non-profit programs to help you make those changes? What kind of help did you get? How did you hear about those programs? Would you have made the changes without those programs?

8. Why did you change the appliances that you did? **(If did not change some:** Why did you not change the other appliances from gas to electricity? Are there others you want to change in the future but didn't now?**)**

9. What were your top priorities in choosing the kinds of appliances to install at your property/properties? In general, do those priorities align better with electric-powered appliances or gas-powered appliances? **(IF NOT MENTIONED:** To what degree did you consider the environmental benefits of one type of appliance or another?**)**

10. Do you think the changes you made will impact the resale value of your property/properties and you have/will see a return on your investment?

11. Did your tenant(s) express any opinions about having gas or electric appliances before you made the changes? If so, what were they? Do you have any sense if they are happy with the changes or not?

12. What do you think are the top priorities of your tenant(s) when it comes to their appliances?

13. Was any of the costs of switching shared with your tenant(s)? Do you sense they have had any monthly cost changes from switching?

14. If a property owner was considering these kinds of changes, what advice would you have for them?

Appendix F: Lodging Sector Assessment Survey Questions

Email Template

Subject: Invitation to Participate in a Research Survey on Hotel Electrification

Dear [Recipient Name],

We invite you to participate in a short survey focused on the unique challenges and opportunities related to building electrification in the lodging and hotel sector. This effort is part of a research initiative funded by the California Air Resources Board (CARB) and conducted in collaboration with UCLA.

Your insights will help inform state policy and program design, with the goal of improving access to funding and resources that support cost-effective, business-friendly upgrades. The survey is designed to capture real-world perspectives from hotel owners, operators, and managers like you.

We greatly appreciate your time and expertise. Your input will directly shape strategies to make electrification more practical and beneficial for businesses across California.

Please let us know your availability in the next 1-2 weeks for a 30 minute or 1 hour call.

Thank you,

<<email signature>>

Virtual Interview Survey Questions

Decision-Making and Organizational Structure

Who holds authority, and how decisions are made across ownership, brand, and management layers.

1. What is your name and position at this property/organization?
2. How long have you been in your current role?
3. What are your main responsibilities regarding building operations or operating costs, including utilities?

Physical Building and Equipment

Technical feasibility, such as building layout, electrical capacity, and existing HVAC/plumbing systems.

4. For each of the following categories of energy services, what fuels and technologies (if known) are used in your facility?
    a. Space heating and cooling
    b. Water heating
    c. Cooking
    d. Laundry
    e. Misc
        i. Pool heating
        ii. Event spaces
        iii. Other
5. Have you recently upgraded or replaced any of these pieces of equipment? What was your experience? If the previous appliance was gas-fueled, did you consider an electric replacement?

Capital Planning and Financial Considerations

How improvements are budgeted, financed, and prioritized within hotel business models.

6. How are capital investment decisions made for building improvements or retrofits?

7. Please describe your project procurement process and funding sources (e.g., timeline, bidding process, specific contractors, etc.)
8. How do you finance the costs of a retrofit project?

Awareness and Information Gaps

Knowledge gaps about electrification options, benefits, and available resources or programs.

9. What factors make an electrification project more or less appealing to you (e.g., ROI, rebates, guest impact, funding, physical space considerations)?
10. When is the peak time of year for your business? How long does it last?
11. Do you have large seasonal (winter/summer) variations in your energy costs?
    a. Can you speak to the breakdown of these costs by fuel type and season?

Regulatory, Utility, and External Factors

Influences beyond the property's control, such as permitting, interconnection, or utility readiness.

12. Have utility power outages been an issue for your hotel?
    a. Can you describe your sources of backup power?
13. What is your experience with utility companies? (e.g., pain points, continuous coordination, involvement in your operations or projects, etc.

Operations, Maintenance, and Capacity

Availability of skilled staff or vendors to operate and maintain new electric systems.

14. How do you choose and train your maintenance staff?
15. Who would be the best person to contact to learn more about the operations or retrofit process on-site?

Site Visit Interview Questions

Building Infrastructure & Electrical Capacity

1. Can you show me your main electrical panel? Do you know its current capacity (amps) and if there's room for expansion to support additional electric loads?

2. Have you ever been told by your utility that an electrical service upgrade might be needed for new equipment? If so, what was the estimated cost or timeline?

Water Heating Systems (per HPWH checklist)

3. Where are your water heaters located, and what areas of the hotel do they serve (guest rooms, laundry, kitchens, spa, pool, etc.)?
4. What is the age and condition of your current water heating system(s)? Have you had issues with performance or maintenance?
5. If the water heating system is gas-fired, have you considered or looked into an electric or heat pump replacement in the past? What were the main concerns?

Plumbing, Venting, and Equipment Space

6. Are there space constraints (room size, clearance, ventilation needs) that could make installing new equipment difficult?

7. Would disconnecting or capping gas lines raise any safety, code, or insurance concerns for you?

Operations, Maintenance & Staffing

8. Who is responsible for maintaining your water heating and HVAC systems—on-site staff or outside contractors? Do they feel comfortable with newer electric or heat pump technologies?

9. Have you had issues with downtime or service interruptions that affect guest satisfaction (e.g., hot water shortages, long recovery times)?

Financial & Planning Barriers

10. How do you typically fund equipment replacement—planned capital projects, emergency replacements, or corporate approvals?

11. If incentives or rebates were available, what size or type of financial support would make an electric replacement competitive with gas?

Guest Experience & Risk Concerns

12. What are your biggest concerns about switching to electric water heating or HVAC—reliability, noise, recovery times, or guest comfort, for example?

13. Would any of these upgrades help your online listings or certifications that would be good for business or are there any other considerations.

Appendix G: Residential Panel Size Estimation Methodology Discussion and Details

At any point in time, there are going to be two primary drivers of panel related work. The first can be described as panel “replacements,” whereby, in the absence of significant load growth, an adequately sized panel would be allowed to remain in place until such point that its components fail, or the panel is otherwise physically destroyed due to some accident befalling the building. In either case, the defining characteristic of such a panel “replacement” would be the installation of new hardware without an increase in capacity from the previous. The second main driver is panel “upgrades,” whereby an existing panel is removed and replaced by a unit with a higher rated capacity. These types of upgrades can either occur upon the end-of-life of the existing panel or at some time pre-mature to this, most frequently, to accommodate the addition of major new loads.

Evidence from the panel records which was assembled suggests that at least in the recent historical period, panel upgrades tend to be far more common than panel replacements. Differentiating between end-of-life upgrades and premature upgrades, however, can be challenging based solely upon the types of information that is typically recorded within building permit records. There is sound reasoning to suggest that pre-mature upgrades are increasingly common during periods where new end-use technologies are beginning to achieve mass market adoption. Other reasons for upgrades beyond the addition of new loads include new requirements from updated building energy codes and changing best practices among electrical contractors.

Historically, the most significant sources of electrical load growth and panel upgrade requirements, were the mass adoption of refrigeration and central HVAC systems within homes beginning in the 1940’s and 50’s. Since this period, the load growth stemming from increases in new plug-loads has largely been counteracted by increases in end-use efficiency of lighting - with the introduction of compact fluorescents and LEDs – as well as among major end-use electrical appliances. Beginning in 1978, with the introduction of Title-24 building energy codes, minimum panel size requirements began to be phased in for new construction. Evolutions of NEC required minimal panel sizing calculations have also played a role in determining the relative frequency of panel upgrades versus replacements.

Traditional electrical service panels are relatively simple and robust technologies. They have a minimal number of moving parts and no integrated circuits. They consist primarily of solid-state breakers or fuses, conductors, fasteners, and an enclosure. As such, they can have surprisingly long service lifespans. In fact, many panels are found to have been in service for decades longer than the hardware had been certified for use by the manufacturer. In the case of extremely old homes (>100 years), it is almost certain that the electrical infrastructure of the building has been replaced/upgraded (potentially multiple times) since the time of its initial construction. This would, of course, mean that records of this work would be absent from a digitized permit record that, at best, spans only a quarter of this period. The question of whether this might lead to a structural bias in the predictions for older homes in DAC communities, due to their more advanced age, boils down to the question of whether the antecedent rates of panel upgrades within those communities were historically greater than they are today.

This is difficult to know for certain. However, if one considers each of the drivers of panel related work – they are both trending in a direction which would suggest that the rates of panel related work today should be as high or higher than they have ever previously been. This conclusion is based upon the distribution of home construction vintage years and awareness of the current rapid growth in panel capacity requirements to support the installation of DERs (solar + energy storage), the adoption fuel substitution measures, and most especially, the demand for EV charging – many of which are fundamentally new types of electrical equipment, without historical precedent so far as adoption rates are concerned.

Methodology Details

Our methodology for estimating the size of existing electric service panels in residential buildings operates from the bottom-up and is fundamentally based upon parcel level building attributes. It has been intentionally designed to complement previous program participation data and survey-based studies, to provide policy makers with a means of triangulation using estimates derived from fundamentally different approaches. As a general overview, the first step in the process is to establish an initial set of estimates for the as-built capacity of the electrical service panels at each property. These estimates are based on assumptions about the most common sizes of service panels installed in properties of different square footage ranges, built in different historical periods.

Following from this initial step, the likelihood that a previous panel upgrade may have occurred at each property since the time of its initial construction is assessed using a set of empirical probability density functions derived from a database of statewide panel upgrade building permits assembled as part of the research. These likelihoods are conditional upon the property's age and the CalEnviroScreen 4.0 (CES) composite percentile score of the census tract in which it is located.[171] For a small minority of properties, the existing panel size is assigned based on direct observations from the permit upgrade record. However, for the majority of properties, for which no permit data is available, a Boolean upgrade flag is assigned by sampling from the appropriate probability density function. In cases where a previous upgrade has been assessed as having likely occurred, a corresponding estimate of the existing service panel size is then derived by incrementing from the as-built panel size according to a range of commonly used panel sizes. The detailed procedure by which these upgrade likelihoods are calculated, and destination panel sizes selected is described both within the following sections as well as by material in the included appendix.

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[171] CalEnviroScreen 4.0 is a product of the California Environmental Protection Agency's Office of Environmental Health Hazard Assessment (OEHHA) that provides a comprehensive set of metrics for local energy burden and other measures of community disadvantage. Since its inception it has come into common use throughout the state as a means of assigning DAC status for purposes such as incentive program eligibility and funding allocations.

Parcel Data Processing

A proprietary database of statewide parcel level building attributes for California was obtained from CoreLogic via a license agreement with the California Energy Commission (CEC). The primary data sources used to assemble this database are county level tax assessor records and data sourced from other third-party brokers. Heterogeneity in the available attribute coverage of this dataset stems from the latitude afforded to individual county tax assessors to decide which parcel attributes are recorded, whether they are digitized, and how. Processing the CoreLogic parcel database for use in this type of analysis therefore involved the implementation of various quality control and standardization procedures.

In total, across all parcel use type designations and available geographies, the CoreLogic parcel database included identifiable attributes for 7,610,021 SF and 560,953 MF properties for the state of California. Of these, 7,240,031 (95.14%) SF properties and 506,315 (90.00%) could be incorporated into this analysis as they possessed non-null values for the following key attributes which are essential to the analytical methodology: use type, construction vintage year, total living area square footage, and total units (for MF properties). The geographic distribution of these missing attributes is not random but rather is correlated with the boundaries of certain counties. Figure G1 illustrates, at the county level, the percentage of SF (left) and MF (right) parcels for which panel size estimates were able to be generated; the parcels for which panel size estimates could not be generated were limited by the availability of parcel-level attributes.

Building Permit Data Processing

In most of the state’s municipalities, construction projects involving major electrical work, such as a service panel upgrade, must receive advanced permitting approval. Historical records of these types of building permit data are increasingly being made publicly available by municipal permitting authorities through open, online data platforms. These publicly available building permit datasets have the potential to be used to develop insights about the rate and extent of electrical service panel upgrades throughout the state, and to do so with a specific focus on the participation of disadvantaged communities. This contrasts with many other sources of panel upgrade data, which may be derived from program participation or public opinion research studies that can often be biased in terms of under-representing households in underserved communities.

The collection of building permit data involved an extensive manual process of searching for publicly available online data sources. This process was structured by first sorting a list of potential building permitting authorities – consisting of counties and census designated places – by their total populations and DAC populations, in descending order. In total, 56 different municipalities were identified which hosted historical permit records in a machine-readable format including key attributes which were identified as essential for the analysis. This included, at minimum, some indication of the permit issue date, work description, and some geographic identifier such as an Assessor Parcel Number (APN), latitude-longitude coordinates, or a street address.

Only 47 of the 56 municipalities were found to contain permit records that could readily be identified as being either for panel upgrades or other related electrical work.

Each unique source of raw permit data had its own processing considerations related to differences in provenance and structure. This required that each raw dataset be individually parsed to achieve the end goal of a single collated and standardized table or permit data. A critical component of the methodology involves assigning each collected permit to its relevant tax-assessor parcel record to establish a connection to building attributes such as use-type, construction vintage year, total floor area, etc. that are essential for inferring existing panel sizes. As introduced previously, different permit data providers made location data available in different formats. Where Lat/Lon coordinates were provided, these were reprojected into a standard reference coordinate system (EPSG:3310) and spatially joined the CoreLogic parcel boundaries. Where APNs were provided, these were used directly as the join key to the CoreLogic database. Finally, where address fields were provided, these were first parsed into a composite PostgreSQL standard address type and then fed to an online geocoding API. Geocoding request responses were then parsed based upon their match quality score (0-100), and validation checks were performed to ensure that the resulting Lat/Lon coordinates were within the state and municipality associated with the record. Records that did not pass this validation check were discarded.

Identifying Permits for Panel Upgrades and Related Measures

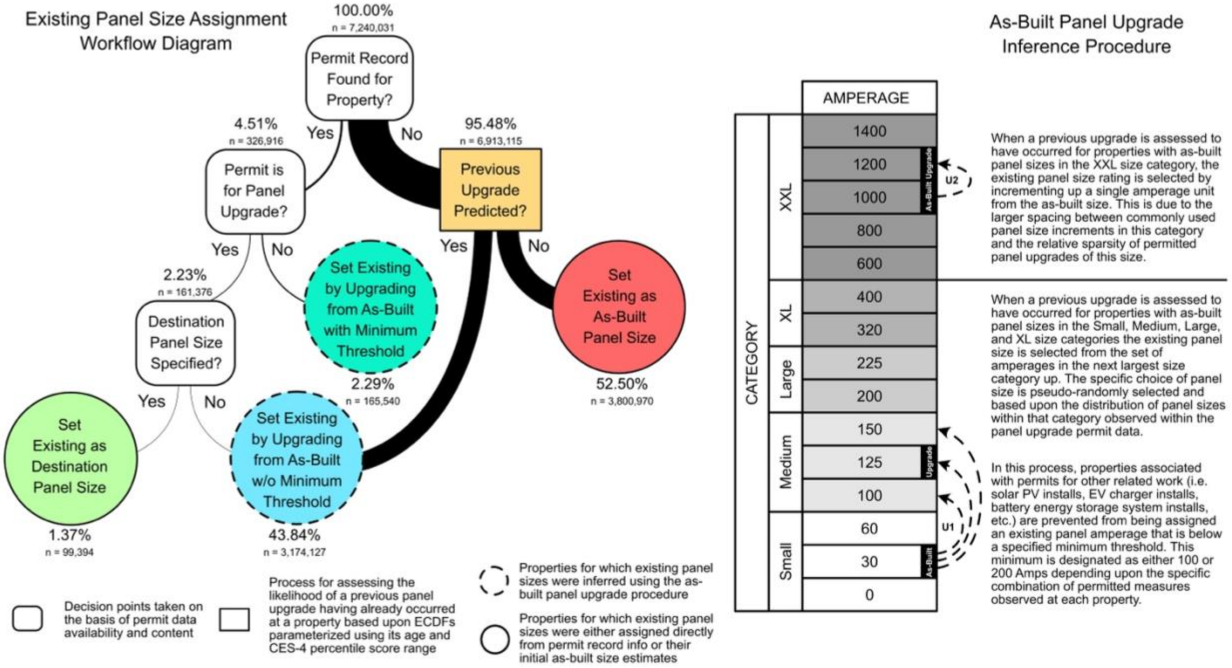
Different municipalities were found to use different schemes for the classification of their permit records. In a minority of cases, these classifications were quite specific, enumerating categories of project type (i.e., “Panel Upgrade,” “EV Charger Installation,” “Solar PV Installation,” etc.). However, in the majority of other municipalities, they were frustratingly generic (i.e., “Electrical” or “Construction”). To augment cases where dedicated fields indicating the presence of a panel upgrade or other related work were missing; permits were classified on the basis of the included “Work Description” field. This is a free-form text field completed by the permit applicant and provides the most detailed information about the scope of the proposed work.

This classification procedure involved tokenizing the work description field’s contents and searching against a list of different keywords and phrases to develop match scores. These scores were then assigned appropriate Boolean flags based on defined thresholds for the following different work categories: [“Main Panel Upgrades”, “Sub-Panel Upgrades”, “PV System Installations”, “Battery Energy Storage System Installations”, “EV Charger Installations”, and “Heat-Pump HVAC System Installations”]. These categories reflect permits that were either explicitly for service panel upgrades or otherwise involved related work, such as for the installation of major new electrical loads, that could otherwise be useful as context for subsequent efforts to estimate existing panel sizes, particularly in cases where the as-built panel size estimate were too small to be considered feasible to support these new electrical loads. Only direct panel upgrade observations, i.e., those which correspond to permit records where the work description indicated that a panel upgrade had occurred and the upgraded panel size was specifically enumerated, were used to parameterize the probability density functions used for the subsequent panel size inference procedure.

Inferring Existing Panel Sizes

As discussed in the overview, the first step in the panel size inference methodology is the assignment of an initial best-estimate of the as-built service panel capacity rating for all properties where the requisite parcel attributes were available. For SF properties, this process involved the development and use of a lookup table that indicated the most likely size of the panel used at the time of construction based upon a property's size (ft^2) and construction vintage year. For MF properties, where there is much less differentiation between the sizes of individual units, only the construction vintage was used. These lookup tables were assembled using information about historical panel sizing requirements specified in historical iterations of the National Electrical Code (NEC) as well as empirical data about the as-built condition of sampled SF homes in various parts of the United States (Pecan Street, 2021; Armstrong, 2021; Davis, 2022; TECH Clean California, 2024).

For properties not associated with direct panel upgrade observations in the permit data, a parametric simulation approach was developed to (1) assess the likelihood of an upgrade occurring since the time of initial construction and (2) infer the most likely existing panel size if a previous upgrade was assessed to have likely occurred. The methodology for assessing the likelihood of previous upgrades is based upon the frequency distribution of properties with directly observed panel upgrade permits relative to the property's age at the time of permit issuance. Alternatively, the methodology for determining the most likely destination panel size when an upgrade was determined to have likely occurred was based on incrementing an upgrade ladder of commonly used panel hardware sizes. Both methods are detailed, for single and multi-family, in *Figures G1* and *G2* below, respectively.

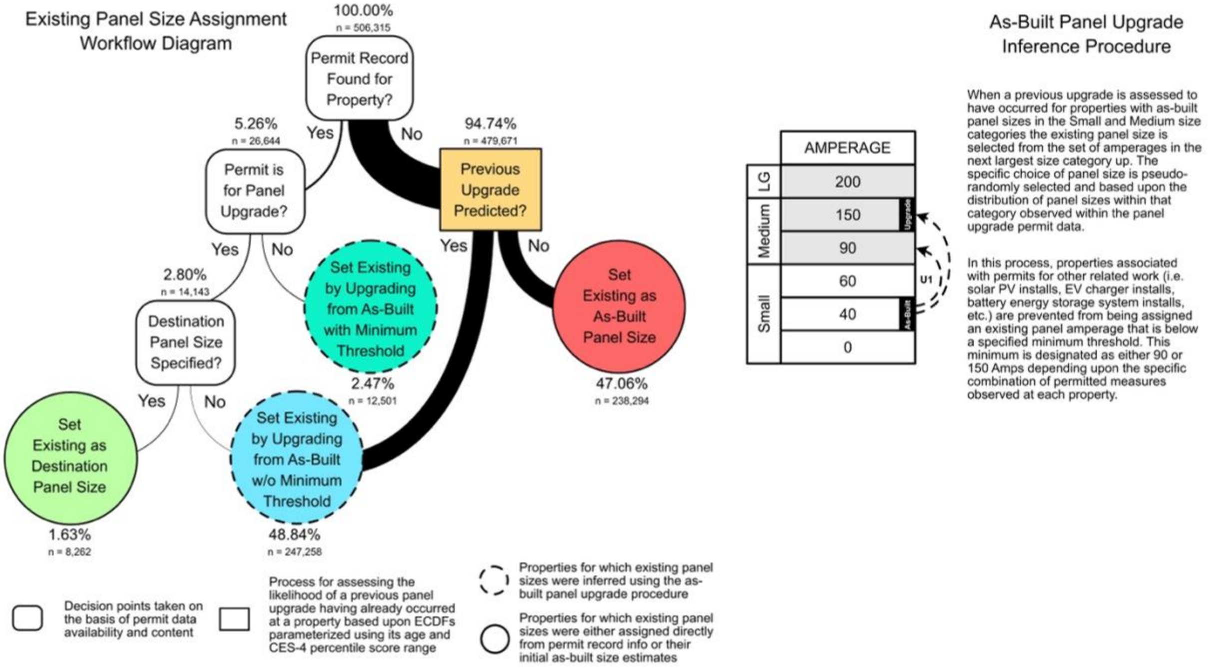


When a previous upgrade is assessed to have occurred for properties with as-built panel sizes in the XXL size category, the existing panel size rating is selected by incrementing up a single amperage unit from the as-built size. This is due to the larger spacing between commonly used panel size increments in this category and the relative sparsity of permitted panel upgrades of this size.

When a previous upgrade is assessed to have occurred for properties with as-built panel sizes in the Small, Medium, Large, and XL size categories the existing panel size is selected from the set of amperages in the next largest size category up. The specific choice of panel size is pseudo-randomly selected and based upon the distribution of panel sizes within that category observed within the panel upgrade permit data.

In this process, properties associated with permits for other related work (i.e. solar PV installs, EV charger installs, battery energy storage system installs, etc.) are prevented from being assigned an existing panel amperage that is below a specified minimum threshold. This minimum is designated as either 100 or 200 Amps depending upon the specific combination of permitted measures observed at each property.

Figure G1. Single-Family property as-built panel size inference workflow diagram



When a previous upgrade is assessed to have occurred for properties with as-built panel sizes in the Small and Medium size categories the existing panel size is selected from the set of amperages in the next largest size category up. The specific choice of panel size is pseudo-randomly selected and based upon the distribution of panel sizes within that category observed within the panel upgrade permit data.

In this process, properties associated with permits for other related work (i.e. solar PV installs, EV charger installs, battery energy storage system installs, etc.) are prevented from being assigned an existing panel amperage that is below a specified minimum threshold. This minimum is designated as either 90 or 150 Amps depending upon the specific combination of permitted measures observed at each property.

Figure G2. Multi-family property as-built panel size inference workflow diagram

Within the workflow diagrams depicted on the left sides of *Figures G1* and *G2*, the weights of the connections between elements reflect the relative proportion of properties involved. Stepping through the workflow: once the set of initial as-built panel size estimates have been assigned to all eligible properties, if an individual property is found to be associated with one or more records in the permit database, then the existing size of its service panel is set as the destination size described in the work permit (green). If this is not known, because it was not specified in the permit's work description, then the existing panel size is inferred from an upgrade routine that is applied using the as-built panel size as the starting point (aqua). If the permit or permits associated with the property were not specifically for a panel upgrade, but rather other related work, then a modified version of this as-built panel upgrade procedure is applied which sets a minimum threshold value for the existing panel size that depends upon the combination of permits observed (turquoise). If no permits were found to be associated with the property, then a binary prediction is made as to whether or not the property is likely to have received a panel upgrade in the past (yellow). If no such previous upgrade is predicted, then the existing panel size is set to the same as the as-built condition (red). Alternatively, if a previous upgrade is predicted, then the same as-built upgrade routine that was used previously is applied (aqua).

On the righthand side of *Figures G1* and *G2* is a graphical illustration of the panel size upgrade ladder that is used for the assignment of existing panel sizes when a previous upgrade is predicted to have occurred. This ladder is composed of the most common panel amperage sizes historically in use. Each panel amperage on the ladder is grouped into one of five corresponding size categories: ["Small," "Medium," "Large," "XL," "XXL"]. This categorization scheme is used to ensure that assessed upgrades do not result in a trivial increase in panel capacities from the as-built condition, as at the lower range of the upgrade ladder the differences between commonly used panel amperages can be small and would likely not be considered a significant enough increase in capacity to warrant the labor and expense associated with a panel upgrade project. According to the implementation of the procedure, for properties with as-built panel sizes in all but the largest (XXL) category, a panel upgrade will always result in an existing panel size that is in the next size category up from that of the as-built condition. The specific choice of the existing panel size for each property is pseudo-randomly assigned, with the relative likelihoods associated with selecting each amperage rating determined based upon their observed distributions within the panel upgrade permit record.

Whether or not a previous panel upgrade has occurred at a given property is predicted by inputting the property's age into an empirical cumulative density function (ECDF) that was fit using data about the ages of properties at the time of observed panel upgrades within the permit data record. This process does not rely upon a single ECDF, but rather 20 different ones that were each fit to a subset of the permitted properties sampled at 5 percentage point increments based upon the CES percentile scores of the tracts in which they are located. This specific number of ECDFs (20) was selected to balance the need to have robust sample sizes within each subset group with the desire to maximally differentiate between upgrade patterns in DAC versus non-DAC regions.