Low-Income Multifamily Housing Characteristics Study

Final Report

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Executive Summary

Low-or-moderate income (LMI) households residing in multifamily housing are a critical segment of Hard-to-Reach (HTR) utility customers. There is a growing body of research on the overall multifamily building stock, however current information on LMI households residing in this housing stock is lacking, especially with respect to electrification challenges. Assessing information specific to LMI households residing in multifamily housing is critical to adoption of decarbonization measures for this market segment. Understanding this sector's demographics is helpful for designing appropriate program delivery mechanisms. Understanding existing building systems and metering configurations are valuable for developing appropriate retrofit solutions using technologies available today and for developing future technologies. Additional details on current housing conditions will help characterize the need for complementary measures and funding.

This study provides information on the scale of barriers and opportunities in low-income multifamily housing to guide technology and program development, which could help expand deployment of efficient electrification and decarbonization technologies in this historically underserved customer segment. The population analysis uses data from the U.S. Census Bureau and Department of Energy to examine LMI households residing in multifamily buildings statewide and in select metropolitan areas.

Based on data analyzed from the 2021 American Community Survey (ACS), the population analysis shows that about a third of LMI households in California reside in multifamily buildings with five or more units; over 90 percent of these households rent their homes; about a quarter live in buildings with 5-9 units and a third live in buildings with 50 or more units; and a third live in buildings constructed before 1970. However, there are regional variations in the size and vintage of multifamily buildings where LMI households reside. Overwhelmingly, these households already are housing cost burdened—spending 30 percent of more of their income on housing costs—underscoring the need to mitigate cost impacts of electrification on utility bills and rents. Apartments where these LMI households live tend to be small—studios or one-bedroom apartments less than 800 square feet—and a substantial share of resident's report issues with insulation and draftiness of their units, particularly in the older building stock. Heating and cooling equipment tends to be unitized while domestic hot water (DHW) systems tend to be centralized in these buildings. Heat pumps represent a small share of existing heating and cooling equipment, and advanced electric technologies like induction stoves are rare.

Findings from the field study suggest that electrical service upgrades will be needed at many multifamily affordable housing buildings. These upgrades likely will be less costly where dedicated, pad-mounted transformers exist. Heating and cooling systems serving common areas tend to differ from those serving apartments—they appear to be newer and more efficient with greater heat pump adoption. Opportunities abound for replacing gas fired DHW with heat pump water heaters (HPWHs), and stakeholders noted that much of their focus in recent efforts has focused on this end use. Existing locations at many building types will be sufficient for upgrading DHW systems, but some building types (e.g., garden-style) may have more limited options. Electric vehicle (EV) charging infrastructure was not observed at any field study properties and solar photovoltaics (PV) were rare, underscoring an equity issue for this market segment. Both are feasible but likely require service upgrades and may require tradeoffs due to limited space available. Newer heat pump technologies that do not require outdoor space is one approach to mitigating the spacing challenges in these buildings. Light emitting diode (LED) technology opportunities still exist in the field study buildings, envelope upgrades appear plenty to help with reducing load demands, and common area facilities represent another opportunity but have the added challenge that the equipment often is leased to the building by a third-party operator. Within apartment units, older buildings and those using gas for heat and cooking are likely to require electrical subpanel upgrades if in-unit electrification occurs. Window types and space limitations pose challenges to certain equipment types, but alternatives technology options are coming to market that could help electrify units. Based on induction stove options currently available and existing electrical capacity in the apartments, cooking electrification will be a challenge where gas stoves exist.

Interviews with stakeholders identified challenges industry faces when electrifying multifamily affordable housing properties, opportunities resulting from emerging technologies and best practices, and technical assistance supports needed by this market segment. Stakeholders underscored electrical infrastructure limitations in these buildings—both on the utility side and within buildings themselves—and the need for programmatic support to make those upgrades. Space considerations are another limiting factor noted by stakeholders with certain often limited by available space in mechanical rooms and utility closets. Stakeholders also noted programmatic challenges including load reduction requirements when electrification adds cooling loads that did not previously exist, and the need to navigate multiple programs with varying eligibility requirements in order to stack incentives and make deep decarbonization projects in multifamily affordable housing financially feasible. Stakeholders also noted building owner concerns that electrification efforts do not have negative impacts on residents, and that the electrified equipment is utilized and maintained properly. Noted emerging technologies that may help move electrification projects along in this space include prefabricated DHW systems and low-power, plug-in heat pumps for heating and cooling loads. Critical to the success of electrification of buildings in this space is comprehensive, free technical assistance for multifamily affordable housing property owners, which do not have the capacity to develop scopes and roadmaps for their portfolio of properties in house.

Based on the population data analysis, field study, and stakeholder interviews, recommendations include the following:

- Technology development:
  - **Continued support for DHW electrification**, which represent a large opportunity in multifamily affordable housing of all building typologies and regions. DHW systems tend to be centralized in this market segment with central plants serving entire buildings or campuses. Innovative approaches like prefabricated HPWH system could help expedite efforts electrifying DHW.
  - **Market demonstration of in-unit heat pumps** to provide the support needed for market adoption of these alternatives for electrifying heating loads of apartments and adding cooling for thermal comfort when more traditional heat pump options are not suitable.
  - **Support additional demonstration of integrated mechanical pods**, another emerging technology that holds potential to reduce costs and increase the pace of deep energy retrofits in the multifamily affordable housing space; additional demonstration is needed to further this technology option in the space and identify the conditions under which it is most applicable for retrofits.

- **Support market innovation by manufacturers of induction cooktops.** Cooking electrification often is the last piece of the electrification puzzle at multifamily affordable housing, and adding induction cooktops often is what triggers an expensive service upgrade. Supporting market innovation of new induction stoves that can operate using standard 120V/20A outlets could alleviate some of the challenges that cooking electrification places on available electrical service in multifamily affordable housing.
- **Incentive new in-unit heat pump clothes dryers that address both space and infrastructure challenges**, like ventless, 120V condensing washer/heat pump clothes dryer combinations. This technology easily could be retrofitted into apartments with existing laundry appliances. However, the price point for this technology is high and program incentives likely would need to cover the incremental cost to incentivize building owners to make this upgrade on behalf of tenants.

- Program development:
    - **Continue to pair electrification with comprehensive energy efficiency measures** (e.g., insulation, air sealing, lighting load reductions) through existing weatherization programs (e.g., Low-Income Weatherization Program (LIWP) and Energy Savings Assistance (ESA) Multifamily Energy Savings) to mitigate potential negative impacts of electrification on customer bills and help avoid costly infrastructure upgrades in some circumstances.
    - **Incentivize electrical infrastructure upgrades** (e.g., service upgrades at the transformer), which pose one of the biggest barriers to full electrification of multifamily affordable housing properties.
    - **Support deployment of solar PV and EV charging infrastructure.** Address equity issues by supporting deployment of more solar photovoltaics (PV) and EV charging infrastructure at multifamily affordable housing properties. While program supports exist for providing solar PV and EV charging infrastructure at multifamily affordable housing, penetration is low and LMI households largely have not realized direct benefits of these technologies.
    - **Conduct additional research on common area laundry facilities.** Common area laundry facilities are common at multifamily affordable housing properties, and these facilities typically involve leased appliances from third-party "route operators." Given the prevalence of route operators in this market segment, and concerns over introducing new equipment (e.g., needing to have service parts available and workforce trained on that equipment), additional research would help to better size this opportunity for the LMI multifamily housing sector in California, better understand the challenges and pain points for route operators deploying new technologies in common area laundry facilities, and determine the best path forward for developing program incentives.
    - **Leverage other survey efforts to refine understanding of this market.** To further develop knowledge of this market sector on a broad basis, other existing research efforts could be leveraged to collect certain data points included in the field study for this project. However, while there are potential efficiencies to gain by leveraging other existing research efforts to collect new information about this target market, there are certain data points collected in this field study (particularly those that require mechanical and electrical engineering expertise) that do not lend themselves to be collected easily or accurately by existing research efforts.

- **Develop additional workforce skills.** Development of trades and skills needed to install and service electrification technologies and alleviate owner and resident concerns over the maintenance and performance of the equipment.
- **Increase technical assistance support**, including support for navigating application processes for existing programs. This is a particular need for nonprofit affordable housing providers which often have capacity issues for supporting these projects.
- **Seek ways to reduce project costs and timelines.** Project timeframes are a major barrier to deep decarbonization and full electrification projects in large multifamily properties. Supporting ways to reduce those timeframes through continued innovation in the technology supports offered may help reduce project costs and timelines
- **Provide support for upfront costs.** Expand incentives to support for upfront costs like engineering and permitting and both soft and hard construction costs, helping projects get under development more quickly.
- **Support streamlining of program requirements and processes.** Multiple energy and housing program incentives need to be stacked to make comprehensive electrification projects pencil out in multifamily affordable housing. If adding new programs or components, make requirements compatible with existing programs.

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Abbreviations and Acronyms

Acronym	Meaning
AC	Air Conditioning
ACS	American Community Survey
AHS	American Housing Survey
AMI	Area Median Income
BUILD	Building Initiative for Low-Emissions Development
CARES	California Alternate Rates for Energy program
CEC	California Energy Commission
CPUC	California Public Utilities Commission
DAC	Disadvantaged Community
DHW	Domestic hot water
DOE	U.S. Department of Energy
EIA	Energy Information Administration
ESA	Energy Savings Assistance program
EV	Electric Vehicles
HCD	California Department of Housing and Community Development
HHS	U.S. Department of Health and Human Services
HHSPG	HHS Poverty Guidelines
HPWH	Heat Pump Water Heater
HTR	Hard-to-Reach
HUD	U.S. Department of Housing and Urban Development
HVAC	Heating, Ventilation, and Air Conditioning

Acronym	Meaning
LADWP	Los Angeles Department of Water and Power
LEAD	Low Income Energy Affordability Data
LED	Light Emitting Diode
LIWP	Low-Income Weatherization Program
LMI	Low- or Moderate-Income
MFES	Multifamily Electric Savings
MSA	Metropolitan Statistical Area
NREL	National Renewable Energy Laboratory
NYCHA	New York City Housing Authority
NYPA	New York Power Authority
NYSERDA	New York State Energy Research and Development Authority
PTAC	Packaged Terminal Air Conditioner
PUF	Public Use File
PUMA	Public Use Microdata Area
PUMS	Public Use Microdata Sample
PV	Photovoltaics
PWHP	Packaged Window Heat Pump
RECS	Residential Energy Consumption Survey
RMI	Rocky Mountain Institute
SMI	State Median Income
SOMAH	Solar on Multifamily Affordable Housing program

Introduction

Based on analysis of a 2021 American Community Survey, nearly a third of California's low-or-moderate-income (LMI) households live in multifamily buildings – over 90 percent of these households are renters and nearly three-fourths are housing cost burdened (i.e., they spend over 30 percent of their income on housing costs including energy bills).[1] Electrifying and deploying advanced electric technologies to this housing stock without negatively impacting housing and energy costs to tenants is critical to reaching the state's equitable climate action goals. Policies and programs tailored to this segment's specific housing characteristics are crucial for achieving fast and scalable building electrification. However, there is insufficient statewide data on the characteristics of low-income multifamily housing. This study will help fill the data gap with analysis of public datasets, input gathered from existing electrification and solar programs, and direct data collection to answer questions that cannot be addressed with currently available data. In addition to a providing general market characterization, this study addresses factors known to be key barriers to electrification in multifamily housing, such as the need for electrical system upgrades (e.g., wiring, circuit panels, service lines), space constraints, and existing water distribution system issues. The study examines the entire low-income multifamily housing market, including subsidized multifamily properties, naturally occurring affordable housing, and market rate multifamily properties with low-income residents.

Background

LMI households residing in multifamily housing are a critical segment of Hard-to-Reach (HTR) utility customers. There is a growing body of research on the overall multifamily building stock, however current information on LMI households residing in this housing stock is lacking, especially with respect to electrification challenges and barriers.

- A 2020 analysis of Housing Equity & Building Decarbonization in California provides estimateson the share of low-income households who live in small or large multifamily buildings, and some additional data on low-income households broken down by housing type (level of energy cost burden, heating fuel cost ratio, number of rent-burdened households by region). However, most of the information about low-income households is not disaggregated by housing type and condition (Rayem 2020).
- The California Energy Commission's (CEC) Clean Energy in Low-Income Multifamily Buildings Action Plan provides limited information on the share of low-income Californians that live in multifamily housing and the number of properties served by the Multifamily Affordable Solar Housing program but does not provide detail on the overall low-income multifamily housing stock or characteristics relevant to building electrification, efficient heating, ventilation, cooling and air conditioning (HVAC), enclosures, and combination systems. (CEC 2018)

[1] Except where noted throughout the report, the term "multifamily buildings" refers to residential buildings with five or more apartment units. The term "LMI households" in this report refer to households with income at or below 250% of the poverty guidelines or 80% of area median income guidelines More information on the approach for defining LMI households is provided in the in the section on Methodology & Approach.

- A 2013 Energy Savings Assistance Program Multifamily Segment Study Report provides detailed information on the statewide low-income multifamily housing stock but is out of date (Cadmus 2013).
- A 2021 report on Accelerating Electrification of California's Multifamily Buildings provides information on the kinds of housing conditions that are important factors for electrification readiness but does not include analysis of the share of low-income multifamily housing with those characteristics (AEA & Stopwaste 2021).
- A 2022 Typology for Decarbonizing U.S. Buildings report and interactive database uses the ResStock model to segment the national residential housing stock by climate zone, wall structure, housing type, year of construction, and thermal energy type and use, but this data set does not identify low-income multifamily buildings as a subset of multifamily buildings (NREL 2022).

Assessing information specific to LMI households residing in multifamily housing is critical to supporting appropriate decarbonization measures for this market segment. Understanding this sector's demographics is helpful for designing appropriate program delivery mechanisms. Determining baseline system and metering configurations is valuable for developing appropriate retrofit solutions using technologies available today and for developing future technologies. Additional details on current housing conditions will help characterize the need for complementary measures and funding.

In the short term, this study provides information on the scale of barriers and opportunities in low-income multifamily housing to guide technology and program development. Data from the study could feed into future modeling analyses that would quantify the savings potential from different technologies.

In the long term, the identification of relevant technologies and program recommendations could help expand deployment of efficient electrification and decarbonization technologies in this historically underserved and HTR segment with sizable energy savings potential.

Objectives

To better understand the opportunities and challenges to electrification measures in the LMI multifamily market segment, and formulate policies and programs specific to multifamily affordable buildings, this project includes the following objectives:

1. Identify the set of desirable housing characteristics to achieve the study's goal of increasing deployment of decarbonization technology solutions like efficient HVAC, enclosures, and combination systems in the LMI multifamily segment. This includes baseline systems, existing electrical service, and additional characteristics relevant to deploying heat pump HVAC, heat pump water heating, mechanical pods, solar, and other technologies.

2. Analyze available data from the U.S. Census Bureau and Department of Energy (DOE). These data sources are discussed in the following section and provide information on the overall market size by building typology and geographic spread of multifamily affordable buildings as well as demographic and basic housing condition factors.

3. Compile additional information from program data and reports identified in interviews with current program administrators, program contractors, and multifamily affordable housing providers, or by the project team. The project team will reach out to current program administrators and multifamily affordable housing stakeholders about the kinds of characteristics they have found to be barriers to or catalysts for these types of installations, and to discuss prospective data sources. Remaining gaps in data will be the target ofthe field study component of the project.
4. Develop an intake form and procedure to test primary data collection to fill gaps in the knowledge base through a field study that will gather data on existing in-unit and whole-building energy equipment, building conditions, and electrical service. The field study will involve a walk-through of common areas as well as 1-4 units per multifamily housing buildings — depending on the unit configurations and previous improvements to the building—to document existing conditions, including electrical panel, HVAC, water heating, appliances, envelope, and space/room configurations. The field study will test the intake form and procedure as a method for filling data gaps and results will augment the characterization of building typologies and other characteristics estimated using publicly available survey data.
5. Process the data into accessible tables and statistics for the Final Report. Findings from the analysis of publicly available data, program data, and field study will be used to identify subgroups and regions of interest, formulate hypotheses on factors needed to electrify this market segment, and lay the groundwork for targeted further study and program development by program administrators.

Methodology & Approach

Literature Review

The project team reviewed program reports and information from income-qualified energy programs serving the multifamily housing market segment in California to develop a baseline understanding of the market and identify information gaps. This information informed both the approach to the analysis of public data and the content of the field study and subsequent analysis. It also helped to guide stakeholder outreach, identifying the most relevant stakeholders and topics of discussion.

Population Data

Several public datasets and tools were considered for analyzing the population of LMI households residing in multifamily buildings in California including the following:

- American Community Survey (ACS)
- Residential Energy Consumption Survey (RECS)
- American Housing Survey (AHS)
- Low-Income Energy Affordability Data (LEAD) analysis tool
- ResStock analysis tool

The project team determined that the ACS, RECS, AHS, and LEAD analysis tool would provide the most useful California-specific information for this market characterization and focused efforts on analyzing those sources. Each is described in further detail below, including limitations of the datasets.

American Community Survey

The ACS is conducted annually by the U.S. Census Bureau. The ACS is a nationally representative survey that provides demographic information on the U.S. population, including a limited set of energy use characteristics of households. The survey has a large sample that allows for state-level and sub-state analyses. The ACS Public Use Microdata Sample (PUMS) file allows researchers to generate customized analyses for specific population segments not available in published summary tables. For this study, the project team utilized the most recent 1-year ACS PUMS file (2021) to define and examine LMI households residing in multifamily buildings in California.[2]

While the ACS is the best source for estimating the number and share of households that are LMI and reside in multifamily buildings, the survey collects only limited information on energy use in homes and physical conditions of housing units. Additionally, unlike the published ACS summary tables that allow for analysis of Census Tracts, towns, and other geographies, the ACS PUMS file allows for limited sub-state geographic analysis— generally counties (whole or partial) or groups of counties, based on the public use microdata areas (PUMAs) defined in the dataset.

Residential Energy Consumption Survey

The RECS is conducted every four or five years by the Energy Information Administration (EIA) at the U.S. DOE. The RECS provides detailed information on household energy characteristics and energy use in the U.S. by combining a household survey with data from energy suppliers. The survey has a nationally representative sample of housing units in the U.S., with the most recent iteration (2020) also allowing for state-level analyses. Like the ACS PUMS, the RECS microdata file allows researchers to generate customized analyses for specific population segments not available in published summary tables. For this study, the project team utilized the 2020 RECS microdata version 2, which was released by EIA in March 2023, to define and examine detailed energy characteristics of California's LMI household population residing in multifamily buildings.[3]

The small sample size of the RECS allows for analysis at the state-level only. Additionally, the small sample size for population segments like LMI households residing in multifamily buildings leads to some concerns over variance in estimates. To reduce the impact of this, analyses based on sample sizes of less than 30 respondents are not included in this report, estimates based on 30 to 100 sample respondents are flagged for readers to view with caution. The RECS microdata also has limitations in how variables for household income and household sizeare made available, which impacts the identification of LMI households in the sample. More information on this limitation is discussed in the section on *Identification of LMI Households in Public Data Sources* below.

[2] For more information about the ACS, see: https://www.census.gov/programs-surveys/acs

[3] For more information about the RECS, see: https://www.eia.gov/consumption/residential/about.php

American Housing Survey

This survey is sponsored by the U.S. Department of Housing and Urban Development (HUD) and is conducted biannually by the U.S. Census Bureau. The AHS includes a nationally representative sample and independent metropolitan area sample and collects detailed information on the size, composition, and quality of the nation's housing stock, including physical condition of homes, energy use characteristics, and information on housing subsidies. Like the ACS PUMS, microdata is made available in the AHS Public Use Files (PUFs) to allow researchers to generate customized analyses for specific population segments not available in published summary tables. [4]

For this study, the project team utilized the 2021 AHS PUFs (both national and independent metropolitan area samples) to define and examine housing, building, and energy characteristics of LMI households residing in multifamily buildings in available metropolitan statistical areas (MSAs) in California. The four MSAs located in California available in the 2021 AHS PUFs, and the corresponding CEC Title 24 climate zones for the primary cities located in each MSA, are listed below:

- Los Angeles-Long Beach-Anaheim MSA (representing CEC climate zones 9, 6, and 8, respectively)
- San Francisco-Oakland-Hayward MSA (representing CEC climate zone 3)
- Riverside-San Bernardino-Ontario MSA (representing CEC climate zone 10)
- San Jose-Sunnyvale-Santa Clara MSA (representing CEC climate zone 4)

While the AHS provides more granular information on the energy characteristics and physical condition of housing units than the ACS, it is less detailed than the RECS. Additionally, the AHS PUFs allow for analysis of select metropolitan areas, not statewide analyses. Like the RECS, the sample size for population segments like LMI households residing in multifamily buildings leads to some concerns over variance in estimates for certain MSAs. To reduce the impact of this, analyses based on sample sizes of less than 30 respondents are not included in this report, and estimates based on 30 to 100 sample respondents are flagged for readers to view with caution.

Low-Income Energy Affordability Data Analysis Tool

The LEAD analysis tool combines estimates from the ACS PUMS file with ACS summary tables published by the Census Bureau to provide more customized population and energy use estimates at finer geographic levels (Census Tracts) than is available using the PUMS file alone. EIA recently updated the LEAD analysis tool to incorporate ACS data from the 2020 ACS PUMS into the mapping tool interface, allowing the project team to examine energy costs and energy burden in LMI multifamily housing units throughout California. In addition, because the LEAD analysis tool provides estimates at the census tract level, it can be combined with information from CalEnviroScreen to look at certain characteristics of the LMI multifamily housing stock for disadvantaged communities (DAC).[5]

While the LEAD analysis tool facilitates certain analyses that the ACS PUMS file alone does not, the LEAD analysis tool provides less flexibility in creating custom analyses for specific population

[4] For more information about the AHS, see: https://www.census.gov/programs-surveys/ahs/about.html

[5] For more information about the LEAD analysis tool, see: https://www.energy.gov/scep/slsc/lead-tool

segments than can be done using the PUMS file directly. In addition, while the LEAD analysis tool's mapping functionality was updated with data from the 2020 ACS PUMS, there are limitations in the ability to download data from the mapping tool for each census tract in the state and combining that with information on the DAC status of census tracts from CalEnviroScreen. As a result, the project team utilized an earlier version of the raw data underlying the LEAD analysis tool (based on 2018 ACS PUMS data) to examine the share of the LMI multifamily housing population located in DAC and non-DAC areas.

Identification of LMI Households in Public Data Sources

One advantage to using the ACS, RECS, and AHS microdata files rather than published summary tables is that the detailed household records available in the microdata files allow researchers to identify and segment analyses for specific population segments, including households whose income and size would qualify them for different income-based energy programs. To do this, the project team first reviewed relevant energy programs operating in California's multifamily sector to determine the relevant income-eligibility guidelines. This includes the following programs:

- Low-Income Weatherization Program (LIWP), which provides comprehensive weatherization services to customers, limits eligibility for multifamily properties that have at least 66 percent of units occupied by households with income at or below 80 percent Area Median Income (AMI).
- Energy Savings Assistance (ESA) Multifamily Energy Savings (MFES) Program (formerly the ESA Common Area Measures Program), which provides in-unit and common area efficiency upgrades, limits eligibility to multifamily properties that have at least 65 percent (deed-restricted) or 80 percent (non-deed restricted) of units occupied by households with income at or below 250 percent of the U.S. Department of Health and Human Services Poverty Guidelines (HHSPG).
- Solar on Multifamily Affordable Housing (SOMAH), which provides financial incentives to support solar installations at multifamily properties, limits eligibility to properties that have at least 80 percent of units occupied by households with income at or below 60 percent AMI.
- California Alternate Rates for Energy Program (CARES), which provides utility bill discounts to customers, limits eligibility to households with income at or below 200 percent HHSPG.

Given the relevance of multiple existing programs to this market segment, the project team used a combination of these income limits— the greater of 250 percent HHSPG and 80 percent AMI relevant to each household record—to segment and define the LMI population.

HHSPG and AMI limits are published each year by HHS and HUD, respectively. AMI estimates vary by county whereas HHSPG is uniform for the entire state. The project team used the 2021 HHSPG and 2021 AMI estimates for defining the LMI population in the 2021 ACS and 2021 AHS. The 2021 HHSPG also were used with the 2020 RECS but State Median Income (SMI) estimates for 2021 were used in place of 2021 AMI estimates because the RECS does not include a geographic identifier that is more precise than the respondent's state.[6] After assigning each household in the microdata files

[6] The 2020 RECS household survey was administered in late-2020 and early-2021. For simplicity and consistency with the other data sources (2021 ACS, 2021 AHS), the project team used the 2021 HHSPG with the 2020 RECS.

the relevant HHSPG and AMI/SMI limits, the project team then compared the household's income to those guidelines to identify households whose income was less than the income limits.

Additional methodological considerations made when defining the LMI population in the public datasets include:

- To assign AMI estimates in the ACS microdata file, the project team mapped the ACS PUMS geographic identifier (Public Use Microdata Areas, or PUMAs) to county boundaries. Where a PUMA encompasses multiple counties, the project team assigned the AMI estimates using the values from the county within the PUMA with the lowest estimates. This was done for simplicity and to be conservative in estimating the number of LMI households statewide.
- To assign AMI estimates in the AHS microdata file, the project team used the AMI estimates for the county within the MSA with the highest values. This was done because of small sample sizes of respondent households marked as LMI within the MSAs. The result is that the size of the LMI household population residing in multifamily buildings in each MSA is slightly overestimated.
- To assign whether a RECS respondent was LMI or not, the project team used the midpoint of the income range available for each household in the RECS microdata file. The income information provided in the RECS microdata file is categorical and top-coded. For the highest income category, the project team assigned income based on the income minimum for the category ($150,000). Household size in the RECS also is top-coded, so for households in the highest category, the project team assigned household size based on the minimum for the category (seven household members). The result is that fewer households in the RECS are categorized as LMI than when using the ACS, which has more precise information on income and household size.

Field Study Data Collection

The project team consulted with multifamily program implementers prior to development of the field study parameters to discuss the value of collecting various data elements not captured by existing surveys and other means. Following those initial consultations, the project team developed the data collection instrument in collaboration with multifamily building technical experts from VEIC and Bright Power. The population surveys reviewed and analyzed as part of the public data analysis for this project (RECS, ACS, AHS) were used as a starting point to frame thinking around key topics and to identify gaps in the knowledge base to target new data collection. Where possible, similar question constructs were used in the study's data collection instrument to facilitate comparison with known population estimates.

Following review of population survey instruments and initial iterations of what information to collect in the field study, the project team consulted with the team from the Market and Technical Evaluation of Multifamily In-Unit Heat Pumps (ETS22SWE0035) to understand the physical characteristics that either allow for, or present challenges to, installation of packaged window heat pump (PWHP) technologies. The project team also consulted with AESC and The Ortiz Group to identify lessons learned from the Market Characterization of Low-Income Single-Family Homes (ET22SWE0022). This feedback was incorporated into the final data collection instrument, which covers the following topics. A copy of the instrument is included in Appendix A: Data Collection Instrument.

- Building characteristics
- Residential unit characteristics
- Heating system details including both residential units and common areas
- Cooling system details including both residential units and common areas
- Thermostat details
- Domestic hot water (DHW) details including barriers for heat pump water heater (HPWH) replacements.
- Cooking appliance details including barriers for induction cooktop replacements
- Details on clothes dryers (both in-unit and common areas, if present) including barriers for heatpump clothes dryer replacements
- Window details including barriers to PWHP technology options
- Electricity service details
- Envelope details
- Affordable housing subsidies/utility allowance details

In designing the data collection instrument and process, the project team prioritized questions that could be answered quickly and inform program design decisions while providing participants with actionable information on their energy use. The result is a data collection instrument that is intended to both answer higher level questions relevant to current and future programs targeting LMI multifamily buildings, and to provide participating buildings with detailed information they can use to make informed decisions on their energy use and systems.

The field study and data collection began in May 2023 and was completed by the end of July 2023. Site visits were conducted by Bright Power who consulted their existing partnerships with multifamily affordable housing property owners and managers in the Bay Area to identify ideal candidates for this study. Bright Power's outreach resulted in data collection from 31 different multifamily affordable housing properties and a total of 50 buildings and 35 apartment units. It is important to note that the properties included in the field study are not a statistically representative sample but rather a convenience sample targeted to test the data collection process and gather information from a cross-section of the LMI multifamily housing market segment to make data-informed hypotheses and recommendations.

The building types vetted for site visits included a mix of low/mid/high-rise and garden style multifamily affordable apartment complexes. The age of individual buildings spans seven decades reaching as far back as 1951 and as recent as 2019 with many of the buildings pre-dating the 2000s. The size of each apartment ranged between 250 and 900 square feet. Most of the apartment complexes visited are fully affordable with deed restrictions and other property-based subsidies, while a few are naturally-occurring affordable housing with mixed-income residents.

Prior to the site visit, representatives from Bright Power contacted each property and gathered easy-to-collect data points from the ownership contact to reduce the time needed for the onsite visit. This included data items like property size, building style, number of buildings at the property, affordability status of the housing, and others. This provided Bright Power with a general understanding of the building and facility type prior to the site visit. It also served as a comparison during the site visit with building staff which helped identify and clarify questions that appeared to be vague or confusing.

To collect data onsite from participating buildings, an engineer from Bright Power conducted a site visit with a property point of contact, usually the property manager or building staff member familiar with the facilities and the site's energy equipment and infrastructure. Site visits averaged two hours, with visits taking longer at multi-building properties where individual buildings were unique. Visits consisted of touring each facility and, where able, a representative apartment unit to assess and gather key characteristics identified on the data collection instrument. Data collected included specific building and unit physical characteristics as well as current electrification configurations to assess building strengths and weaknesses for electrification readiness. Bright Power would identify where current key infrastructure was located (or missing) and identify what would be needed to initiate full building electrification. Photo documentation was gathered to assist in post-visit data validation and analysis.

Stakeholder Outreach

In addition to engaging stakeholders during the field study planning and conceptualizing, the project team engaged stakeholders to incorporate multiple perspectives on the identified opportunities and challenges. Stakeholders included relevant income-qualified energy program implementers AEA and TRC serving the multifamily sector (LIWP, and ESA MFES, respectively), housing organizations (California Housing Partnership, Terner Center for Housing Innovation at UC Berkeley), and project teams within CalNEXT looking at relevant technologies for the multifamily building sector. Discussion topics included:

- Top challenges to electrifying multifamily affordable housing, including physical challenges, programmatic barriers, and how these challenges vary across building typology and other factors.
- Promising best practices/solutions for electrifying this market segment.
- Technical assistance/technology support that is needed to support electrification efforts in multifamily buildings housing LMI residents.

Findings

Population Data Analysis

This section provides initial findings from the analysis of the public data sources. The findings provide important information on the size of the multifamily housing market for LMI residents, building characteristics important to assessing the electrification opportunities and challenges in buildings, and technology areas of interest identified in discussions with the broader VEIC CalNEXT team. The population data analysis results are organized by the following topics.

- Population overview, which provides the size of the California housing market and the share that is LMI by building type.
- Basic housing and building characteristics, including envelope features and issues that could warrant attention when electrifying.
- Basic energy characteristics, including fuels used by end use and bill payment responsibility, which is helpful for understanding how electrification efforts might shift who is responsible for paying bills.

- Heating and cooling usage and equipment, including system type, primary fuel, equipment type, equipment age, and secondary equipment usage.
- Heating and cooling system controls, including type of thermostat, actual temperature control behaviors, and internet access (for potential to deploy smart thermostats).
- DHW including system type, primary fuel, and current storage tank size.
- Cooking appliances including oven type, fuel, and cooktop type.
- In-unit clothes dryers.
- Lighting type and share.

Additional demographic characteristics of LMI households of multifamily buildings are provided in Appendix B: Demographic Analysis. These demographic characteristics are important for understanding who occupies these units and whether special considerations are needed to reach this market segment.

Overview

Based on the most recent ACS data from the U.S. Census Bureau, there are approximately 13.4 million households in California, of which 6.0 million are LMI.[7] Table 1 provides a breakdown of the number of households by LMI status and housing unit type. Nearly a third of LMI households (1.95 million) in California reside in multifamily buildings with five or more apartment units. Table 2 provides the size of the LMI population in four MSAs in California, along with the distribution of those households by housing unit type. A greater share of LMI households living in the Los Angeles-Long Beach-Anaheim MSA reside in multifamily building than the statewide average. The opposite is true of LMI households residing in the Riverside-San Bernardino-Ontario MSA.

Table 1: Statewide Households by LMI Status and Housing Unit Type

Housing Unit Type	LMI Households	Non-LMI Households	All Households
Single family detached	2,697,041	5,109,241	7,806,282
Single family attached	458,553	554,691	1,013,244
Buildings with 2-4 units	617,529	395,899	1,013,428
Buildings with 5+ units	1,953,673	1,181,009	3,134,682
Mobile home/other	319,916	141,519	461,435

[7] As discussed in the Methodology & Approach section above, LMI is defined throughout as having income at or below the greater of 250% HHS Poverty Guidelines or 80% AMI, whichever is higher based on household size.

Housing Unit Type	LMI Households	Non-LMI Households	All Households
Total	6,046,712	7,382,359	13,429,071

Source: 2021 ACS PUMS

Table 2: LMI Households by Housing Unit Type by MSA

Housing Unit Type	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	2,704,326	956,179	980,176	263,001
Single Family Detached	38%	65%	44%	42%
Single Family Attached	7%	5%	10%	7%
Buildings with 2-4 units	11%	4%	12%	9%
Buildings with 5+ units	41%	16%	33%	37%
Mobile Home/Other	2%	9%	2%	4%
Total	100%	100%	100%	100%

Source: 2021 AHS PUF; percentages may not sum to 100% due to rounding.

Basic Housing and Building Characteristics

The term "multifamily buildings" in this study refers to residential buildings with five or more apartment units. However, a 5-unit multifamily building is very different from a 50-unit multifamily building, so it is important to examine the share of different sized multifamily buildings with LMI residents. Table 3 provides a more detailed breakdown of the size of the multifamily buildings in which LMI households reside statewide. Approximately one-third reside in apartment buildings with 50 or more units with the remainder distributed fairly evenly among 5-9 unit apartment buildings, 10-19 unit apartment buildings, and 20-49 unit apartment buildings. Table 4 shows the distribution of LMI households by multifamily building size for each MSA.

Table 3: Statewide LMI Households Residing in Multifamily Building by Number of Units in Structure

Units in Structure	Number of Households	Percent
Buildings with 5-9 units	467,153	24%
Buildings with 10-19 units	401,409	21%
Buildings with 20-49 units	420,430	22%
Buildings with 50+ units	664,681	34%
Total	**1,953,673**	**100%**

Source: 2021 ACS PUMS; percentages may not sum to 100% due to rounding.

Table 4: LMI Households Residing in Multifamily Buildings by Number of Units in Structure by MSA

Units in Structure	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	1,095,619	152,855	309,409	88,368
Buildings with 5-9 Units	21%	25%	24%	20%
Buildings with 10-19 Units	25%	30%	26%	32%
Buildings with 20-49 Units	27%	16%	20%	20%
Buildings with 50+ Units	27%	28%	29%	29%
Total	**100%**	**100%**	**100%**	**100%**

Source: 2021 AHS PUF; percentages may not sum to 100% due to rounding.

Table 5 shows the distribution of LMI households in multifamily buildings by the number of stories or floors in the building for each MSA. Except for the San Francisco-Oakland-Hayward MSA, most of these households reside in multifamily buildings with one or two stories (garden-style, townhome, etc.). In the San Francisco-Oakland-Hayward MSA, these households are more likely to live in multifamily buildings with more stories (mid-rise and high-rise). Stakeholders for this project identified that the opportunities and challenges are similar across low-rise buildings of all types but different from those in mid-rise and high-rise buildings, which are similar to one another. As a result, an implication in Table 5 is that the San Francisco-Oakland-Hayward MSA is more likely to encounter barriers common in mid-rise and high-rise buildings. These include challenges retrofitting with individual heat pumps due to lack of available space to locate outdoor units and line set lengths. Conversely, the other MSAs are more likely to encounter barriers common in low-rise buildings, including a greater share of unitized DHW with limited space available for upsized HPWHs, and existing wall furnaces with no clear place for heat pump equipment.

Table 5: LMI Households Residing in Multifamily Buildings by Stories in Building by MSA

Stories in Building	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	1,095,619	152,855	309,409	88,368
Buildings with 1-2 Stories	62%	79%	34%	60%
Buildings with 3-4 Stories	28%	18%	45%	33%
Buildings with 5+ Stories	10%	2%	21%	7%
Total	**100%**	**100%**	**100%**	**100%**

Source: 2021 AHS PUF; percentages may not sum to 100% due to rounding.

Table 6 shows the vintage of the multifamily buildings in which these LMI households live. Approximately one-third of LMI households residing in multifamily buildings in California live in buildings constructed before 1970, well before building energy codes were introduced in the state, and nearly half live in buildings that were constructed between 1970 and 1999. Figure 1 provides a more detailed look at building vintage by building size, with LMI households residing in very large multifamily buildings (50 or more units) living in buildings that are slightly newer than those of LMI households residing in smaller multifamily buildings. Table 7 shows that the distribution of LMI households residing in multifamily buildings varies considerably by building vintage across the MSAs. For example, LMI households residing in multifamily buildings in the Los Angeles-Long Beach-

Anaheim and San Francisco-Oakland-Hayward MSAs tend to live in older (pre-1970) buildings than the statewide estimates shown in Table 6 and Figure 1. Unless major renovations have taken place, these buildings are likely to have older systems and less efficient construction methods and materials.

Table 6: Statewide LMI Households Residing in Multifamily Buildings by Building Vintage.

Building Vintage	Number of Households	Percent
Built before 1970	660,042	34%
Built 1970-1979	406,343	21%
Built 1980-1989	351,262	18%
Built 1990-1999	179,709	9%
Built 2000-2009	187,101	10%
Built 2010 to present	169,216	9%
Total	**1,953,673**	**100%**

Source: 2021 ACS PUMS; percentages may not sum to 100% due to rounding.

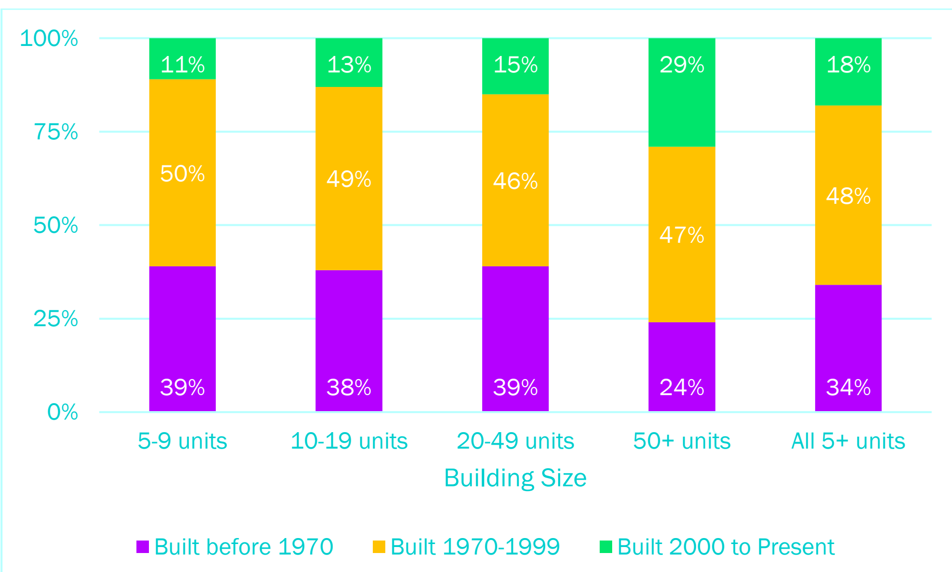


Figure 1: Statewide LMI households residing in multifamily buildings by building size and vintage.

Source: 2021 ACS PUMS; percentages may not sum to 100% due to rounding.

Table 7: LMI Households Residing in Multifamily Buildings by Building Vintage by MSA

Building Vintage	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	1,095,619	152,855	309,409	88,368
Built Before 1970	50%	17%	49%	28%
Built 1970-1999	39%	61%	35%	51%
Built 2000 to Present	10%	23%	15%	21%
Total	**100%**	**100%**	**100%**	**100%**

Source: 2021 AHS PUF; percentages may not sum to 100% due to rounding.

Table 8 shows the number of LMI households residing in multifamily buildings by the size of the apartment units statewide, and Table 9 shows the distribution by MSA. Figure 2 shows the distribution of these households by square footage of the apartment. Statewide, over half of LMI households residing in multifamily buildings live in studio of 1-bedroom apartments and over three-fourths live in apartments that are less than 1,000 square feet.

Table 8: Statewide LMI Households Residing in Multifamily Buildings by Number of Bedrooms in Apartment Unit

Number of Bedrooms	Number of Households	Percent of Households
Studio	319,611	16%
1	759,892	39%
2	733,827	38%
3+	140,343	7%
Total	**1,953,673**	**100%**

Source: 2021 ACS PUMS; percentages may not sum to 100% due to rounding.

Table 9: LMI Households Residing in Multifamily Buildings by Number of Bedrooms in Apartment Unit by MSA

Number of Bedrooms	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	1,095,619	152,855	309,409	88,368
Studio	10%	2%	14%	6%
1	44%	37%	48%	49%
2	42%	50%	30%	37%
3+	4%	10%	8%	8%
Total	100%	100%	100%	100%

Source: 2021 AHS PUF; percentages may not sum to 100% due to rounding.

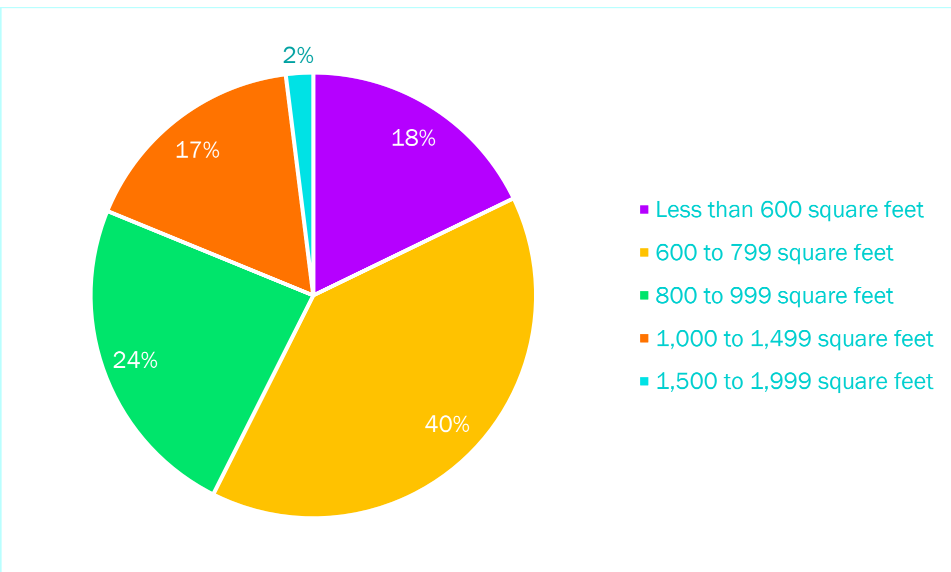


Figure 2: Statewide LMI households residing in multifamily buildings by apartment size.

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Figure 3 shows the share of LMI households residing in multifamily buildings by type of exterior siding materials used on their building. Stucco is most common, with 45 percent of households reporting this siding material, followed by wood and concrete block.

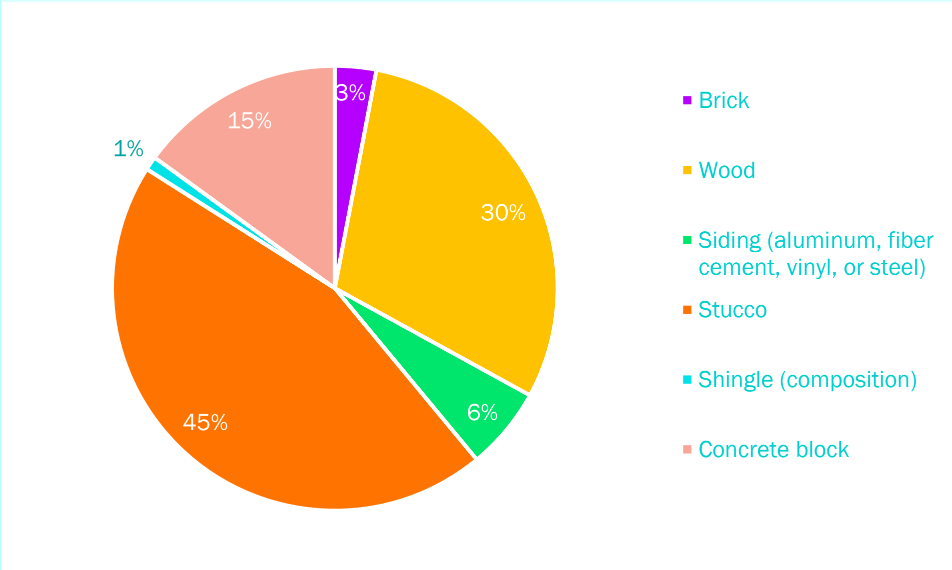


Figure 3: Statewide LMI households residing in multifamily buildings by siding material of building.

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Figure 4 shows the share of LMI households residing in multifamily buildings by building vintage (year built) and whether the windows in their units are mostly original or have been replaced. While households residing in older multifamily buildings are more likely to have had windows replaced, about one-third of households living in buildings constructed before 1970 reported having mostly original windows.

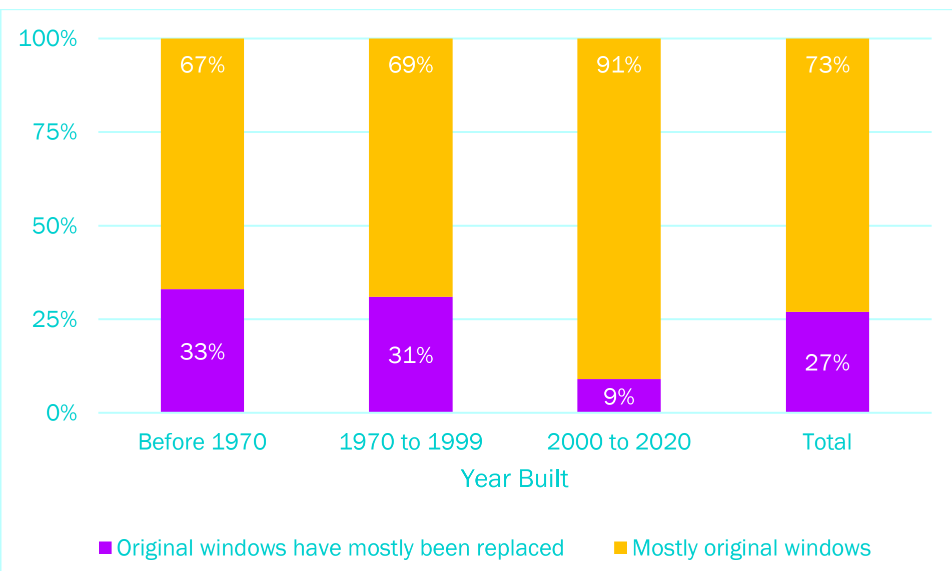


Figure 4: Statewide LMI households residing in multifamily buildings by window replacement status.

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Figure 5 shows the share of LMI households residing in multifamily buildings by building vintage and type of window (single-pane, double-pane, or triple-pane). Regardless of building age, over half of LMI households living in multifamily buildings have single-pane windows. Single-pane windows are most prevalent among households living in buildings constructed before 1970.

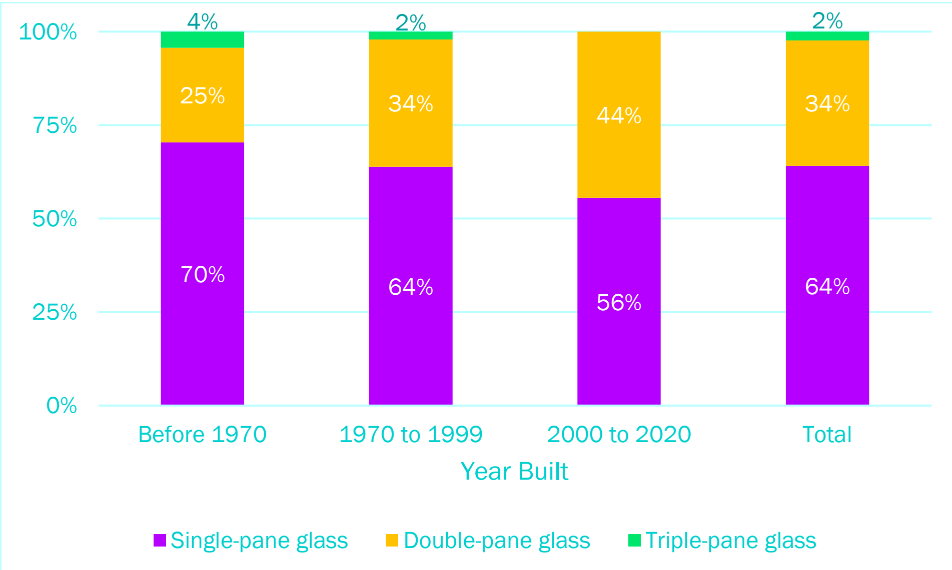


Figure 5: Statewide LMI households residing in multifamily buildings by type of window glass.

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Figure 6 shows the share of LMI households residing in multifamily buildings by the level of insulation reported by the household. [Note: the insulation level is a qualitative assessment made by the respondents.] Approximately 40 percent of all LMI households residing in multifamily buildings, and over half that reside in buildings constructed before 1970, reported having inadequate or no insulation in their homes.

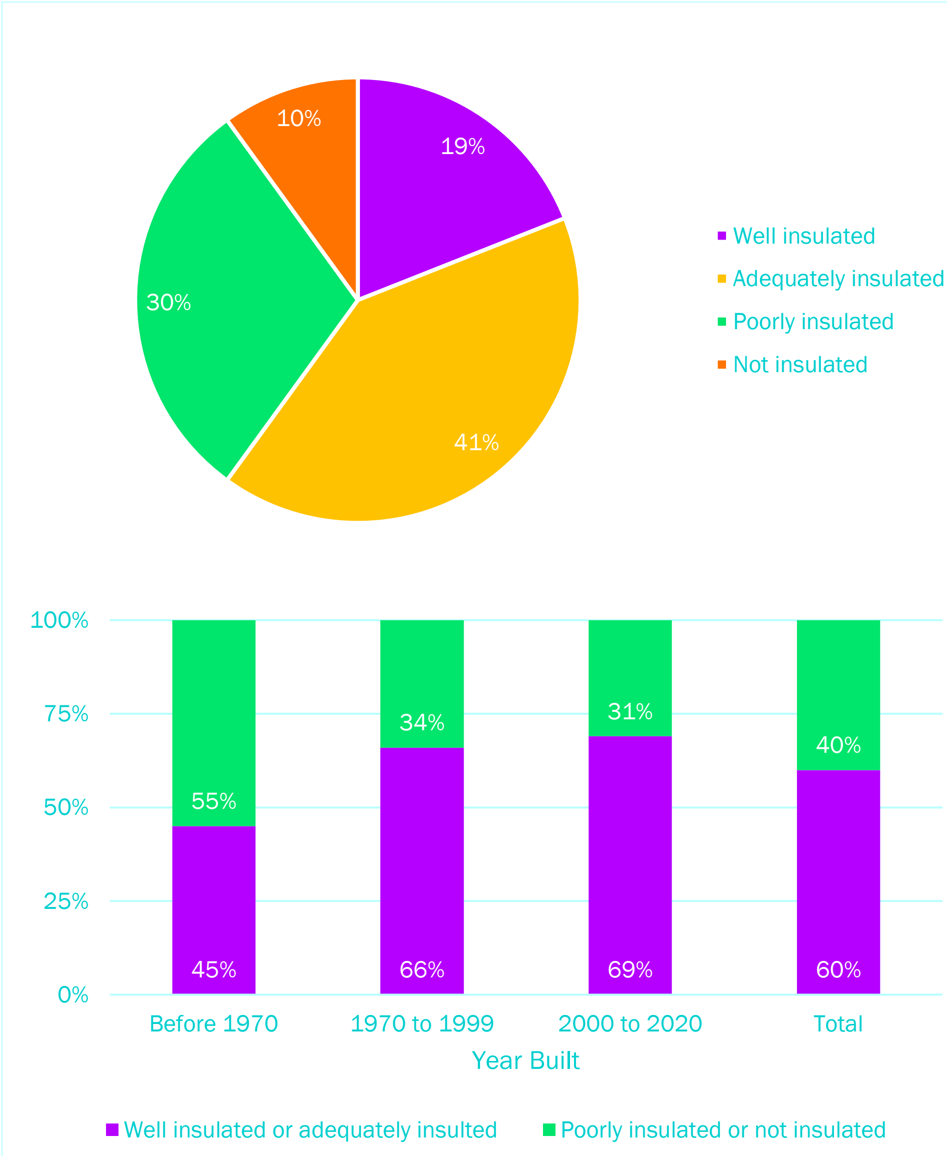


Figure 6: Statewide LMI households residing in multifamily buildings by insulation level of unit (self-reported) and building vintage.

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Figure 7 shows the share of LMI households residing in multifamily buildings that reported having drafty apartments. About one-fourth of these households reported having homes that were drafty most or all the time, and this finding is fairly consistent regardless of building age.

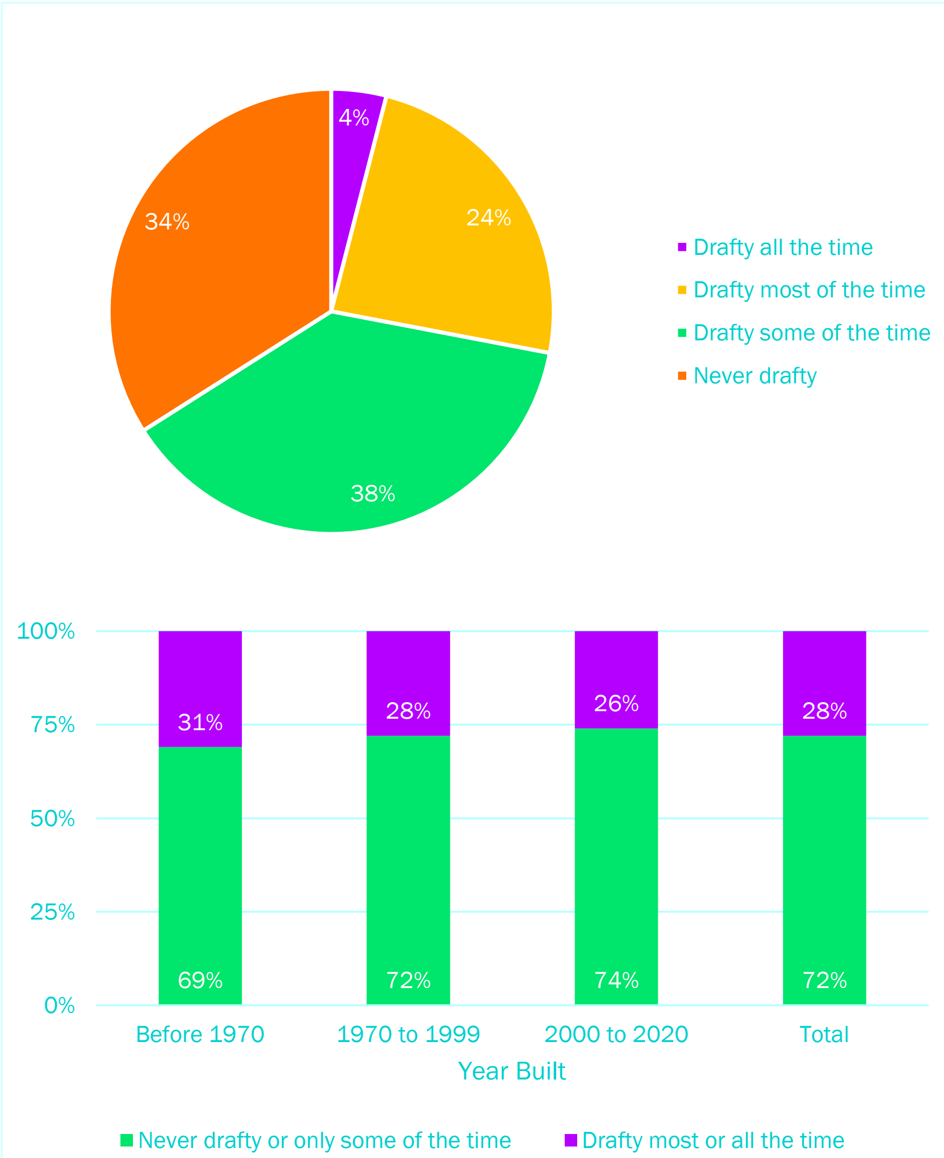


Figure 7: Statewide LMI households residing in multifamily buildings by draftiness of apartment (self-reported) by building vintage.

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Energy Characteristics

Table 10 shows the share of LMI households residing in multifamily buildings using different fuel types in their homes (electricity, natural gas, and propane; other fuel types excluded due to infrequent or non-use) and for which purposes (heating, water heating, cooking). All of these households use electricity for at least one end use and over three-fourths About half of these households use electricity for space heating but only about one-third use electricity for water heating. Natural gas more commonly is used for water heating. Based on the 2020 RECS data analysis, about 20 percent of LMI households residing in multifamily buildings already have all-electric end uses in their apartments. Based on internal discussions with experts and review of California's 2022

Building Energy Efficiency Standards, affordable multifamily housing units that are all-electric today likely vary from 60-amp to over 100-amp service, depending on what end uses are unitized and when the building was constructed. This is supported by findings from AEA & Stopwaste (2021) reviewing electrical infrastructure in multifamily buildings that participated in energy efficiency programs.

Table 10: Statewide LMI Households Residing in Multifamily Buildings by Types of Fuels Used in The Home by End Use.[8]

Fuel Type	Any Use	Heating	Water Heating	Cooking
Electricity	100%	52%	31%	65%
Natural gas	78%	34%	68%	41%
Propane	4%	1%	0%	3%

Source: 2020 RECS

Based on analysis of the 2021 ACS PUMS, nearly all LMI households residing in multifamily buildings are renters (92 percent), and Figure 8 shows that most residents in these buildings are directly responsible for paying their utility bills. Because LMI households residing in multifamily buildings are predominantly renters who pay their energy bills directly but do not own the major energy equipment serving their buildings, there is a split incentive issue in this market segment where building owners under-invest in energy upgrades in the apartment units (such as efficient heat pumps to replace inefficient gas wall furnaces or electric resistance baseboards) because the bill savings from the more efficient equipment does not impact owner-paid utility bills (AEA & Stopwaste 2021).

[8] Values shown in each column are not additive because households might use multiple fuel types for a given end use (e.g., they might have a natural gas range but an electric oven, or they might use primary and secondary heating equipment with different fuel types).

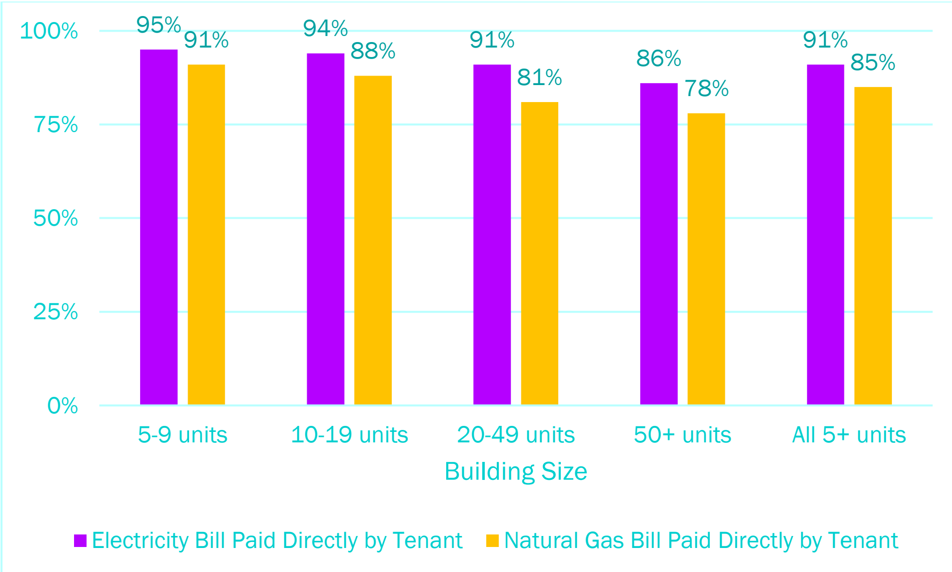


Figure 8: Bill payment responsibility by fuel type and building size for statewide LMI households residing in multifamily buildings (households who reported using the fuel).

Source: 2021 ACS PUMS

Heating and Cooling Systems

Figure 9 shows the share of LMI households residing in multifamily buildings by whether they heat and/or cool their homes. Approximately three-fourths reported heating their homes; note that those reported not heating their homes in the 2020 RECS reference period (winter 2020/2021) reside in a hot-dry climate zone. However, some of the households who reported not heating their homes have heating equipment but did not use during the reference period. Only about seven percent of LMI households residing in multifamily buildings reported not have heating equipment. Subsequent figures and tables showing details on heating and cooling equipment are limited to households that heat and/or cool their homes, as relevant.

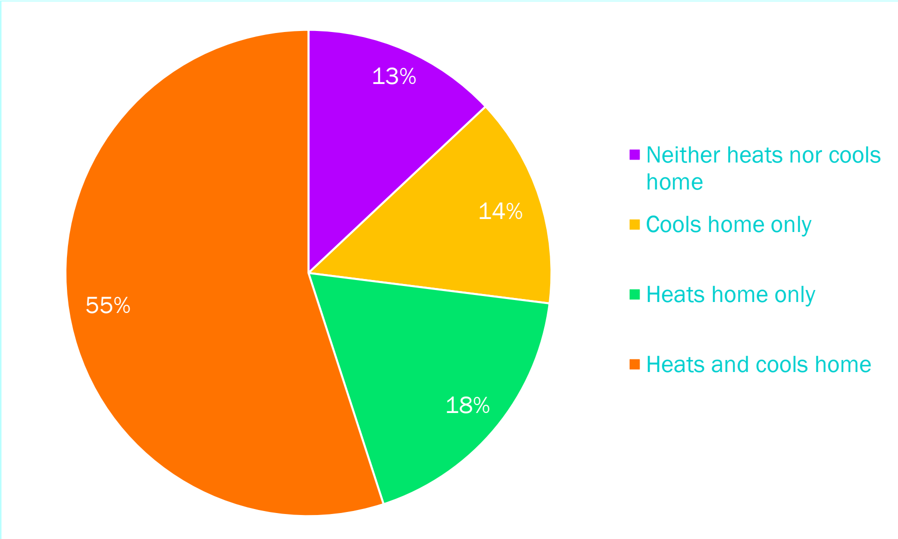


Figure 9: LMI households residing in multifamily buildings by heating and cooling usage.

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Table 11 shows that availability of air conditioning (AC) equipment by LMI households residing in multifamily buildings varies considerably by MSA, as expected given the different climate zones. Nearly all the households living in the Riverside-San Bernardino-Ontario MSA have AC equipment available in their units compared to less than a third living in the San Francisco-Oakland-Hayward MSA. One implication of this regional difference is that converting HVAC equipment to heat pumps in areas that already have AC equipment available is likely to reduce existing cooling loads given the likelihood that newer heat pumps are more efficient than existing AC equipment. In areas where AC usage is less common in this housing segment, converting to heat pumps may add load by introducing cooling where it did not exist previously. While this presents an opportunity for increased thermal comfort of residents, it may need to be paired with energy efficiency and other load reduction measures to limit load and bill impacts.

Table 11: Statewide LMI Households Residing in Multifamily Buildings by Availability of Air Conditioning Equipment by MSA

Air Conditioning	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	1,075,592	152,855	306,305	87,952
Has AC equipment	79%	98%	29%	73%

Air Conditioning	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Does not have AC equipment	21%	2%	71%	27%
Total	**100%**	**100%**	**100%**	**100%**

Source: 2021 AHS PUF; percentages may not sum to 100% due to rounding.

Figure 10 shows the main heating fuel type used by LMI households residing in multifamily buildings who heat their homes, as reported in both the 2020 RECS and 2021 ACS. There is general agreement between the two surveys, with over half of LMI households living in multifamily buildings already using electricity for heat and the remainder mainly using natural gas. Table 12 shows the distribution of LMI households residing in multifamily homes by main heating fuel type by MSA. The distributions resemble the statewide estimates except in the San Jose-Sunnyvale-Santa Clara MSA, where 69 percent of the households use electricity as their main heating fuel and only 30 percent use natural gas.

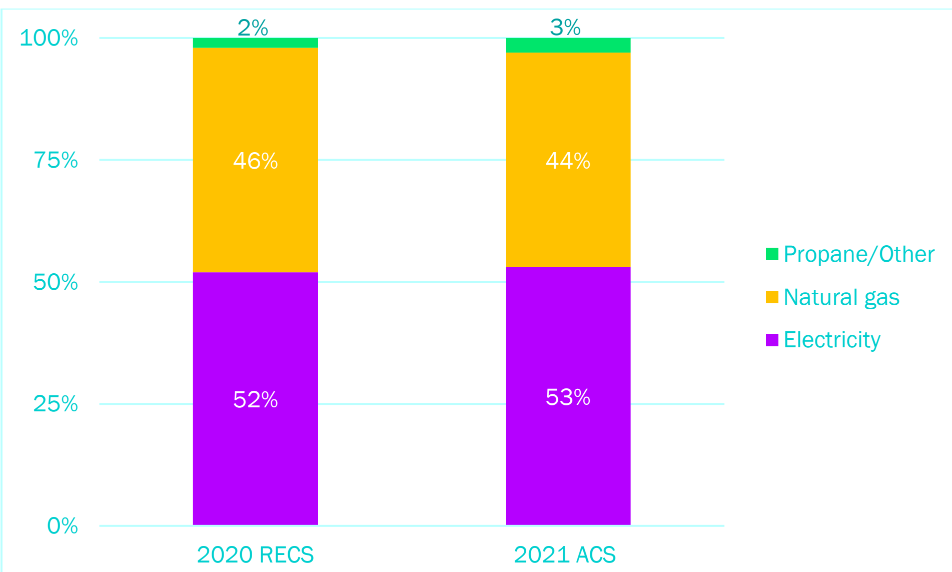


Figure 10: Statewide LMI households residing in multifamily buildings by main heating fuel type (households that report heating their homes).

Source: 2020 RECS, 2021 ACS; percentages may not sum to 100% due to rounding.

Table 12: LMI Households Residing in Multifamily Buildings by Main Heating Fuel Type by MSA (households that report heating their homes)

Fuel Source	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	1,075,592	152,855	306,305	87,952
Electricity	52%	50%	55%	69%
Natural gas	48%	49%	42%	30%
Propane / Other	1%	2%	3%	<1%
Total	**100%**	**100%**	**100%**	**100%**

Source: 2021 AHS PUF; percentages may not sum to 100% due to rounding.

Figure 11 shows a more detailed breakdown of the main heating fuel type used by LMI households in multifamily buildings by size of the buildings, and Figure 12 shows the breakdown by building age. In very large multifamily buildings (50 or more units), electricity is used for heat in nearly two-thirds of the housing units, but in smaller multifamily buildings, natural gas is the predominant heating fuel type. Housing units in newer buildings are more likely to use electricity than natural gas.

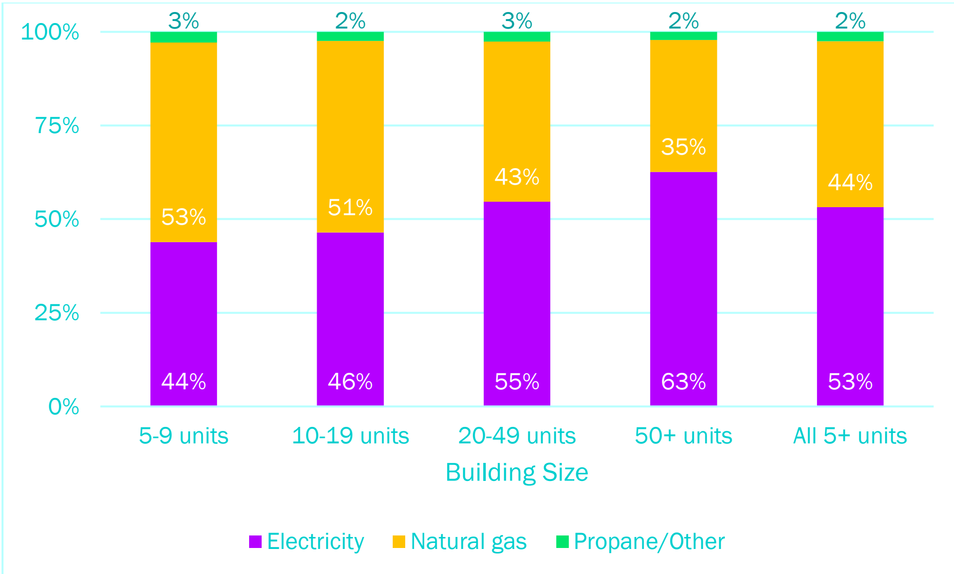


Figure 11: Statewide LMI households residing in multifamily buildings by main heating fuel and building size (households that report heating their homes).

Source: 2021 ACS PUMS; percentages may not sum to 100% due to rounding.

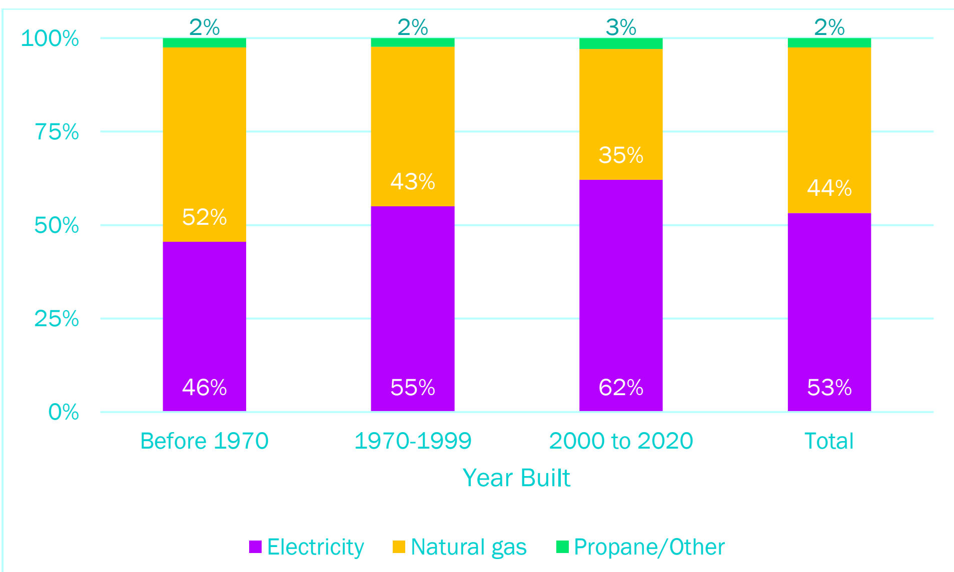


Figure 12: Statewide LMI households residing in multifamily buildings by main heating fuel and building age (households that report heating their homes).

Source: 2021 ACS PUMS; percentages may not sum to 100% due to rounding.

Figure 13 shows the share of LMI households residing in multifamily buildings by whether the heating or cooling system serves multiple units. This is the case for about a quarter of households.

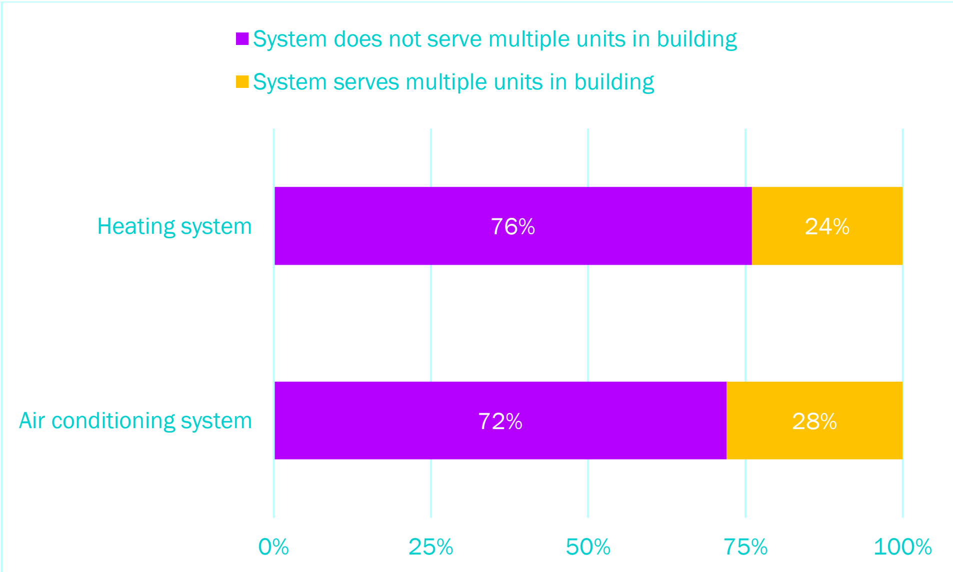


Figure 13: Statewide LMI households residing in multifamily buildings with units served by central heating or air conditioning systems (households that report heating or cooling their homes).

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Figure 14 provides a detailed breakdown of the primary heating equipment used by LMI households in multifamily buildings statewide, and Table 13 shows the distribution by MSA.[9] Statewide, central furnaces are most common with roughly one half of households having this type of equipment. Built-in room heaters that burn natural gas are next most common followed by portable electric heaters. Like the statewide estimates, forced warm air furnaces are most common and heat pumps uncommon in each MSA.

[9] The categories for AC equipment differ in Figure 14 and Table 13 due to differences in data sources.

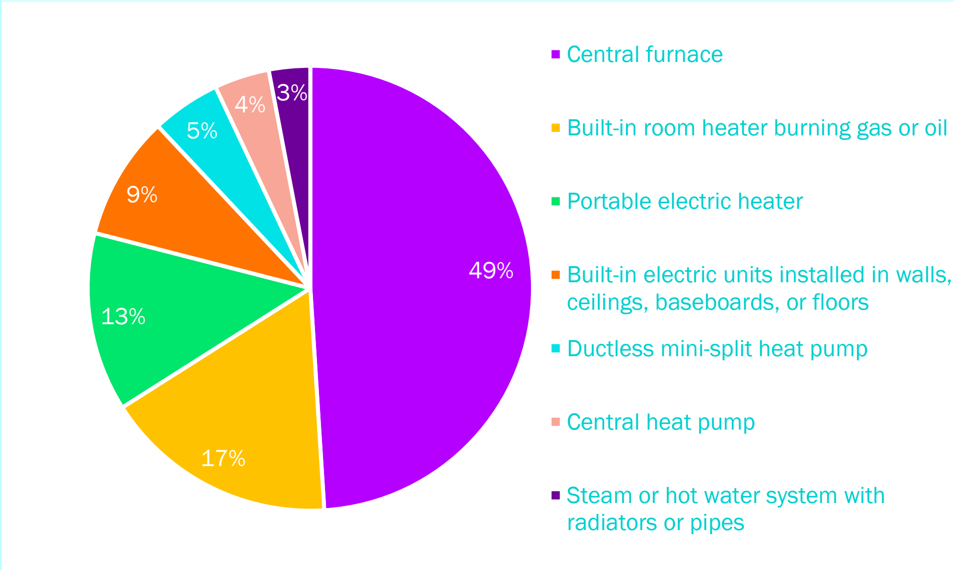


Figure 14: Statewide LMI households residing in multifamily buildings by type of primary heating equipment (households that report heating their homes).

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Table 13: LMI Households Residing in Multifamily Buildings by Type of Primary Heating Equipment (households that report heating their homes)

Primary Heating Equipment	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	1,075,592	152,855	306,305	87,952
Forced warm-air furnace	53%	73%	43%	50%
Floor, wall, other pipeless furnace	28%	15%	24%	24%
Built-in electric baseboard, electric coils	8%	5%	15%	17%
Portable electric heater(s)	6%	2%	3%	1%

Primary Heating Equipment	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Electric heat pump	3%	4%	2%	7%
Steam or hot water system	1%	0%	9%	1%
Other	2%	1%	4%	1%
Total	**100%**	**100%**	**100%**	**100%**

Source: 2021 AHS PUF; percentages may not sum to 100% due to rounding.

Figure 15 provides a detailed breakdown of the primary AC equipment used by LMI households in multifamily buildings statewide, and Table 14 shows the distribution by MSA.[10] Central air conditioners (including central heat pumps) are most common followed by window or wall air conditioners.

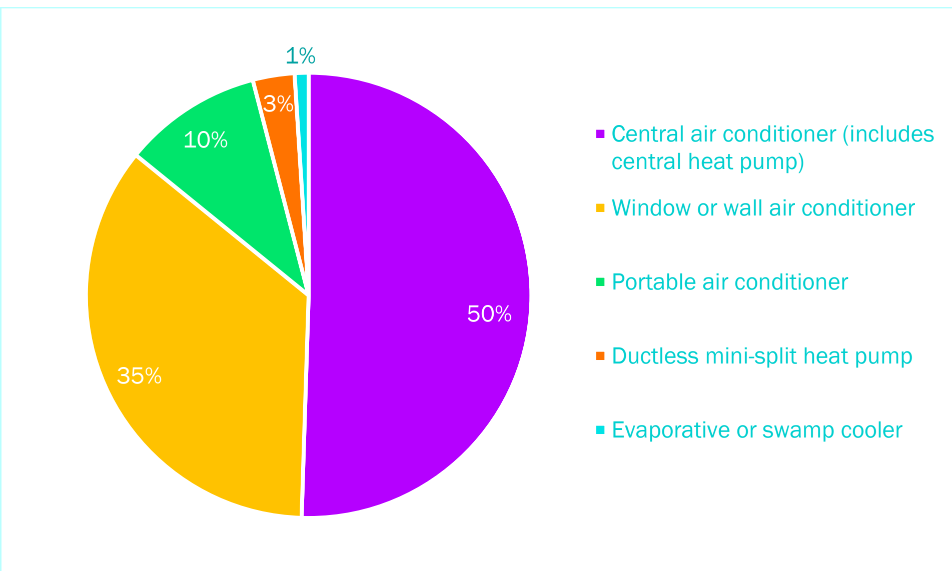


Figure 15: Statewide LMI households residing in multifamily buildings by type of primary air conditioning equipment (households that report cooling their homes).

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

[10] The categories for AC equipment differ in Figure 15 and Table 14 due to differences in data sources.

Table 14: Statewide LMI Households Residing in Multifamily Buildings by Type of Primary Air Conditioning Equipment (households that report having AC equipment)

Primary Air Conditioning Equipment	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	860,227	149,078	91,178	64,886
Electric powered central AC	54%	80%	60%	65%
Room AC	45%	16%	34%	33%
Central AC powered by other fuel source	1%	4%	6%	2%
Total	**100%**	**100%**	**100%**	**100%**

Source: 2021 AHS PUF; percentages may not sum to 100% due to rounding.

Figure 16 shows a distribution of the age of the primary heating and AC equipment usedby LMI households in multifamily buildings. Over half of the primary heating equipment is 15 years or older, while the primary AC equipment tends to be newer than the primary heating equipment.

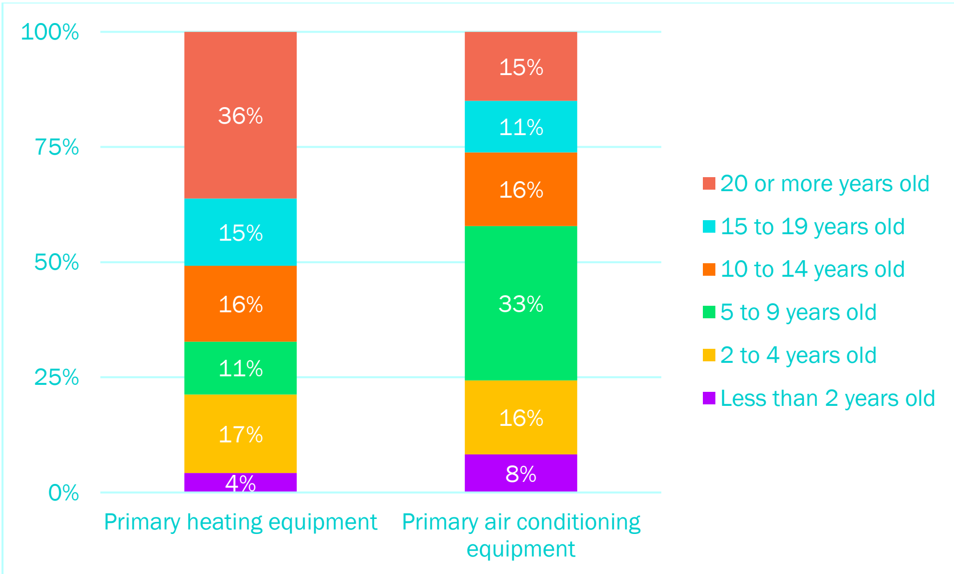


Figure 16: Statewide LMI households residing in multifamily buildings by age of primary heating and cooling equipment (households that heat or cool their homes).

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Figure 17 shows the share of LMI households residing in multifamily buildings who used secondary heating or cooling equipment in their homes. Nearly a third of households used secondary heating equipment but relatively few used secondary cooling equipment.

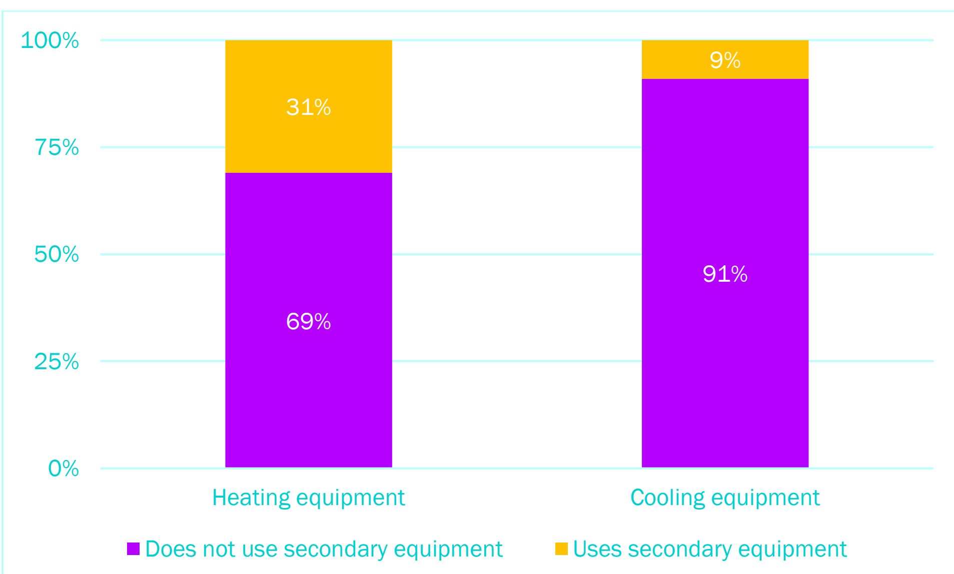


Figure 17: Statewide LMI households residing in multifamily buildings who use secondary heating or air conditioning equipment (households that heat or cool their homes).

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Figure 18 shows a breakdown of the type of secondary heating equipment used by LMI households residing in multifamily buildings. Of those households who used secondary heating equipment, portable electric heaters were the most common type of equipment used. Due to the small sample of households using secondary heating, the estimates shown in Figure 18 should be viewed with caution. The type of secondary AC equipment is not shown due to the very small sample of households reporting use of secondary cooling.

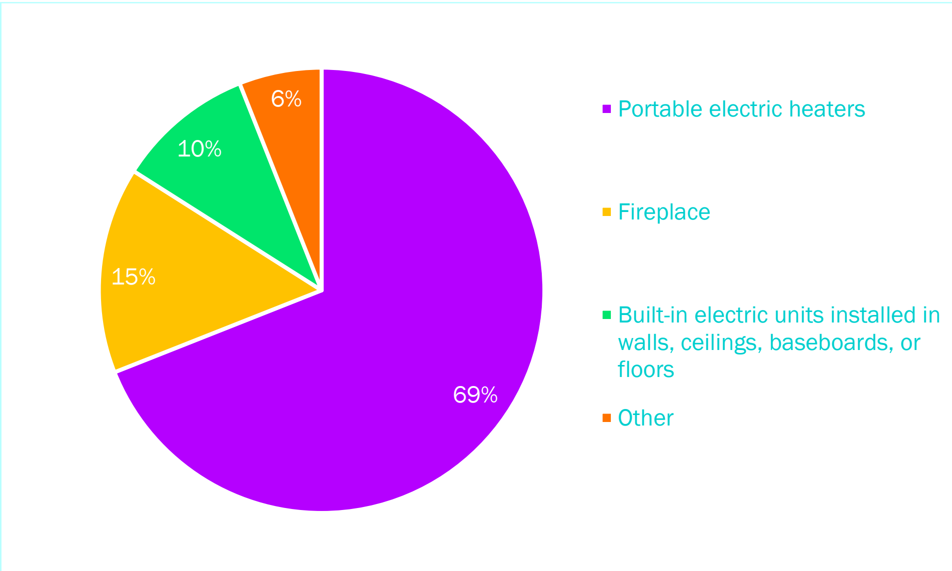


Figure 18: Statewide LMI households residing in multifamily buildings by type of secondary heating equipment used (households using secondary heat).

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Heating and Cooling System Controls

Figure 19 shows the share of LMI households residing in multifamily buildings by type of thermostat. Almost half of these households do not have a thermostat or any kind to control their heating or cooling usage. Of those who do have a thermostat, nearly all have either a manual or standard programmable thermostat. Smart or internet-connected thermostats are seldomly present in these housing units.

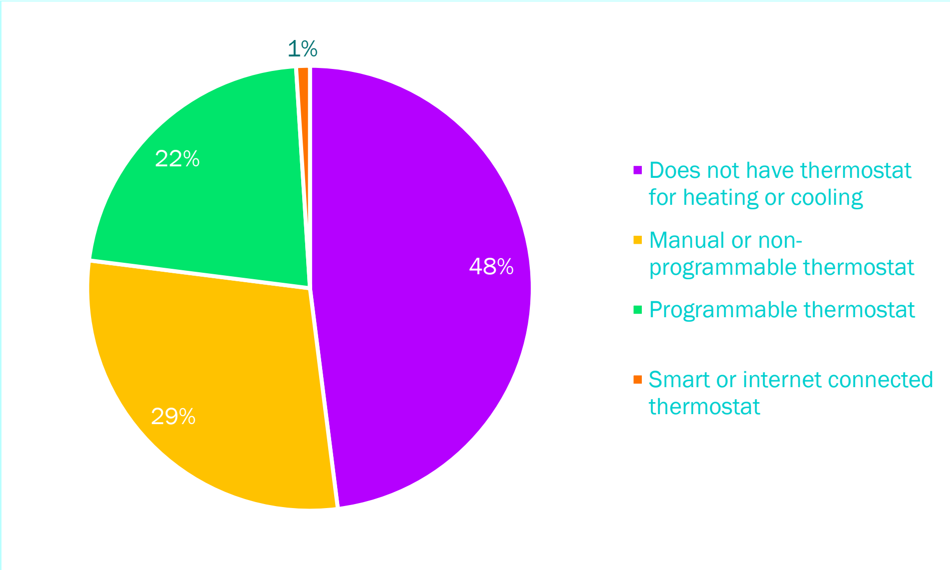


Figure 19: Statewide LMI households residing in multifamily buildings that heat and/or cool their homes by type of thermostat.

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Table 15 provides additional details about the actual method used by LMI households residing in multifamily buildings for controlling their indoor air temperatures by season. Regardless of season, most households either manually adjust their temperature, set one temperature and leave it most of the time, or simply turn the equipment on or off as needed. While about a quarter of households have programmable thermostats, few actually use the programmable features to automatically adjust their indoor air temperatures.

Table 15: Statewide LMI Households Residing in Multifamily Buildings by Actual Method Used to Control Indoor Air Temperature by Season (Households that Heat and/or Cool Their Homes)

Actual Method Used for Controlling Temperature by Season	Winter	Summer
Programmable or smart thermostat automatically adjusts the temperature	5%	4%
Manually adjust the temperature	26%	13%
Set one temperature and leave it most of the time	25%	37%
Turn equipment on or off as needed	30%	32%
Household does not have control over the temperature	13%	14%
Other	2%	0%

Actual Method Used for Controlling Temperature by Season	Winter	Summer
Total	100%	100%

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

High-speed internet access is an important component for smart or internet-connected thermostats, which largely have not been deployed among LMI households residing in multifamily building. Table 16 provides an overview of internet access by these households. About eight out of ten report having high-speed broadband at home, while the rest have internet access but not high-speed access, or no access at all. While this does not necessarily mean that the buildings are not wired for high-speed internet access, or that lack of access is due to financial constraints or other personal choices, it does mean that for about 20 percent of LMI households in multifamily buildings, there is a barrier to using internet-connected devices.

Table 16: LMI Households Residing in Multifamily Buildings by Internet Access at Home.

Internet Access at Home	Number of Households	Percent of Households
Paid access, high-speed/broadband	1,340,009	79%
Paid access, not high-speed/broadband	353,364	8%
Internet access through some other means	63,928	3%
No internet access	196,372	10%
Total	1,953,673	100%

Source: 2021 ACS PUMS; percentages may not sum to 100% due to rounding.

Domestic Hot Water

Figure 20 shows about two-thirds of LMI households reside in multifamily buildings where DHW is supplied centrally to multiple units. Apartment units served by central DHW systems typically do not pay for DHW use directly (i.e., these costs are paid by building owners and built into tenant rents). Whereas central systems serving multiple units with space heating and cooling was the case for only about a quarter of households, central DHW serving multiple units is common.

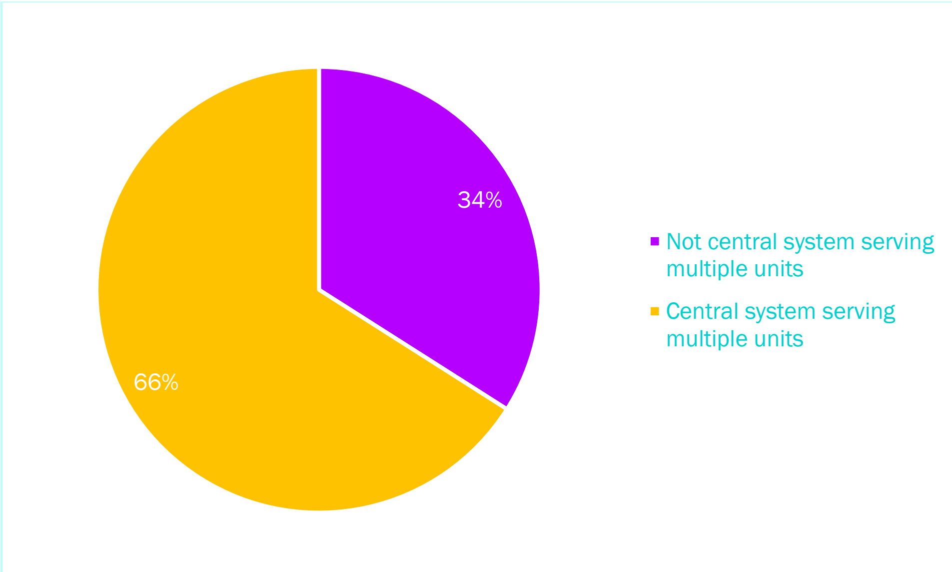


Figure 20: Statewide LMI households residing in multifamily buildings with units served by central DHW systems.

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Figure 21 shows the main fuel for DHW for LMI households residing in multifamily buildings statewide, and Table 17 shows the distribution by MSA. Statewide, natural gas is most common, heating water for about two-thirds of households. While there is some regional variation, natural gas is the most common main fuel for DHW in each MSA.

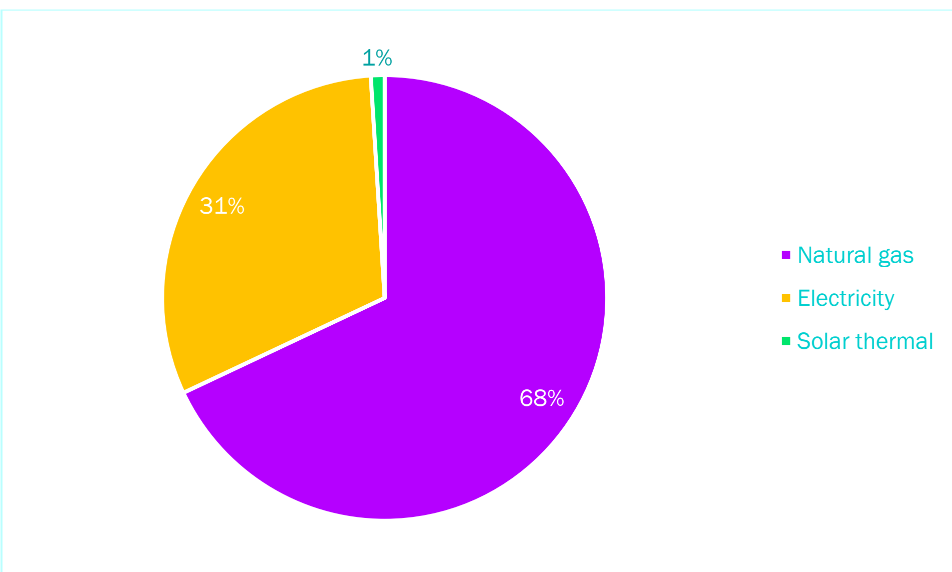


Figure 21: Statewide LMI households residing in multifamily buildings by primary water heating fuel.

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Table 17: LMI Households Residing in Multifamily Buildings by Primary Water Heating Fuel by MSA

Fuel Type	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	1,095,619	152,855	309,409	88,368
Electricity	28%	26%	33%	45%
Natural gas	72%	73%	64%	54%
Other	0%	1%	3%	<1%
Total	100%	100%	100%	100%

Source: 2021 AHS PUF; percentages may not sum to 100% due to rounding.

Figure 22 shows the water heater storage tank size for LMI households residing in multifamily buildings. Most have medium-sized storage tanks or smaller (31- to 49-gallon capacities or less, including tankless on-demand).

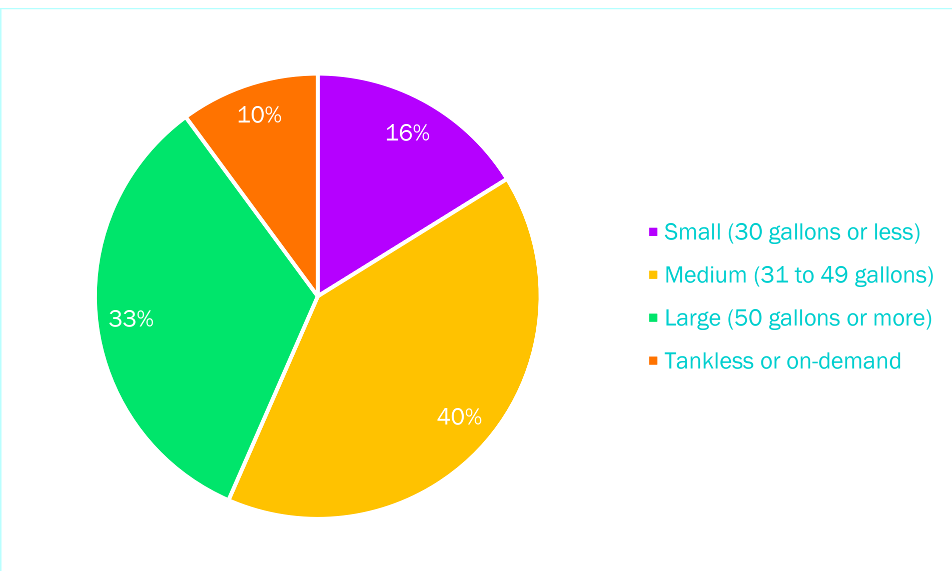


Figure 22: Statewide LMI households residing in multifamily buildings by heater storage tank size.

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Cooking Appliances

Figure 23 shows the type of cooking ovens used by LMI households residing in multifamily buildings statewide, and Figure 24 shows the fuel type used by the range. Most households have a combined range with oven and about half already use electricity as the fuel type.

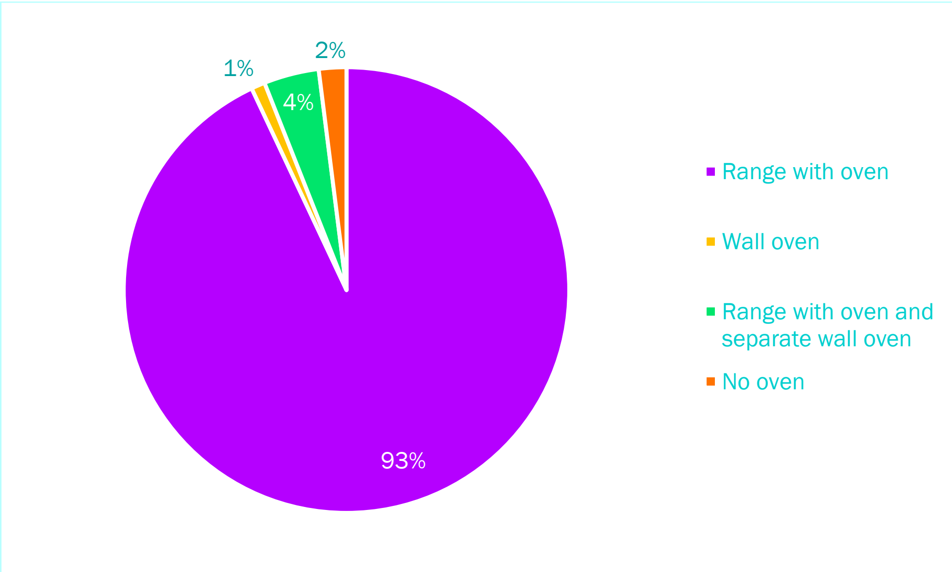


Figure 23: Statewide LMI households residing in multifamily buildings by type of oven.

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

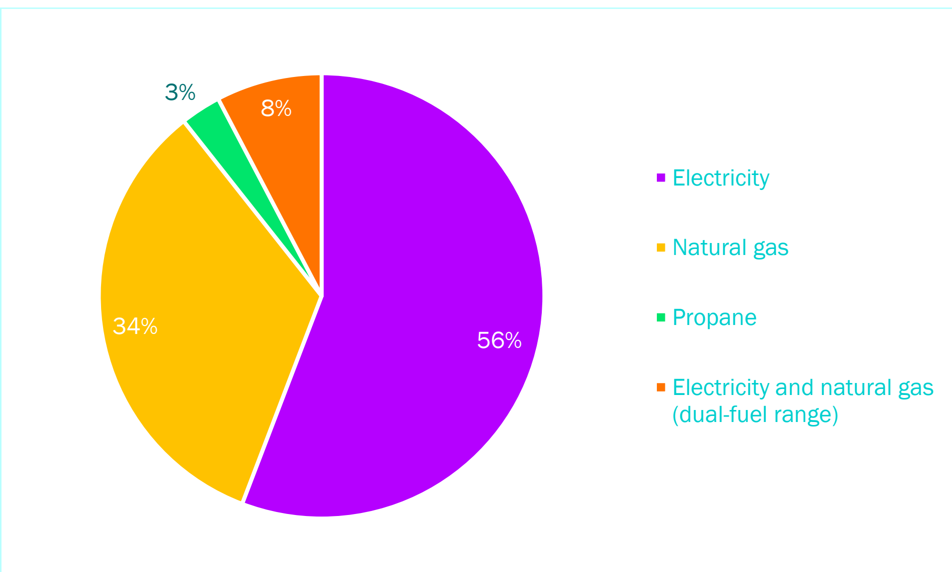


Figure 24: Statewide LMI households residing in multifamily buildings by cooking fuel used by range.

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Figure 25 shows the share of LMI households residing in multifamily buildings by type of cooktop/stove. Electric resistance is most common and is used by about half of the households, and natural gas cooktops/stoves are used by over 40 percent of households. Induction cooktops/stoves, while not common, are about six percent of LMI households residing in multifamily buildings.

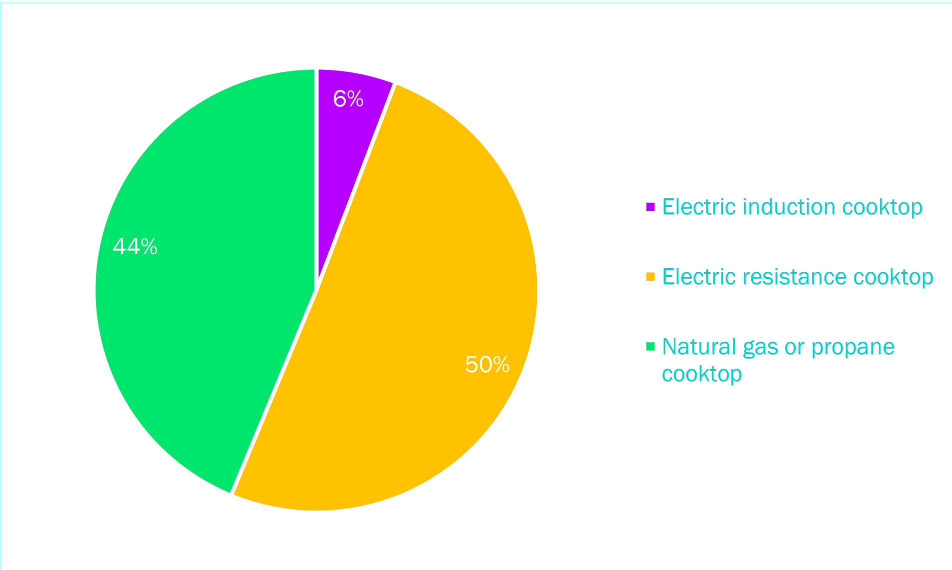


Figure 25: Statewide LMI households residing in multifamily buildings of cooktop used.

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Table 18 shows the distribution of primary cooking fuel used by LMI households residing in multifamily buildings by MSA. Natural gas is most common in the Los Angeles-Long Beach-Anaheim and Riverside-San Bernardino-Ontario MSAs, presenting a greater electrification opportunity than in the San Francisco-Oakland-Hayward and San Jose-Sunnyvale-Santa Clara MSAs, where electricity is the most common primary cooking fuel used by LMI households residing in multifamily buildings.

Table 18: LMI Households Residing in Multifamily Buildings by Primary Cooking Fuel by MSA

Fuel Type	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	1,095,619	152,855	309,409	88,368
Electricity	31%	44%	67%	79%
Natural gas	67%	55%	32%	20%

Fuel Type	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Propane	<1%	<1%	<1%	0%
None	1%	1%	1%	<1%
Total	**100%**	**100%**	**100%**	**100%**

Source: 2021 AHS PUF; percentages may not sum to 100% due to rounding.

Clothes Dryers

Figure 26 shows that about a quarter of LMI households residing in multifamily buildings statewide have in-unit clothes dryers. The age and fuel type of these clothes dryers are not shown due to the small sample of households who have in-unit clothes dryers. Table 19 shows that in-unit clothes dryers are more common in the Riverside-San Bernardino-Ontario than statewide, with about half of LMI households residing in multifamily buildings in this region having an in-unit clothes dryer.

Research by Schaaf and Shah (2018) indicate that over two-thirds of the multifamily housing market is served by common area laundry facilities. While this research was not specific to California or LMI multifamily housing, this estimate is aligned with findings from the field data collection for this study. Schaaf and Shah (2018) also note that appliances in common area laundry facilities in multifamily buildings typically are commercial “family-size” appliances that are leased from “route operators” that install and own the equipment.

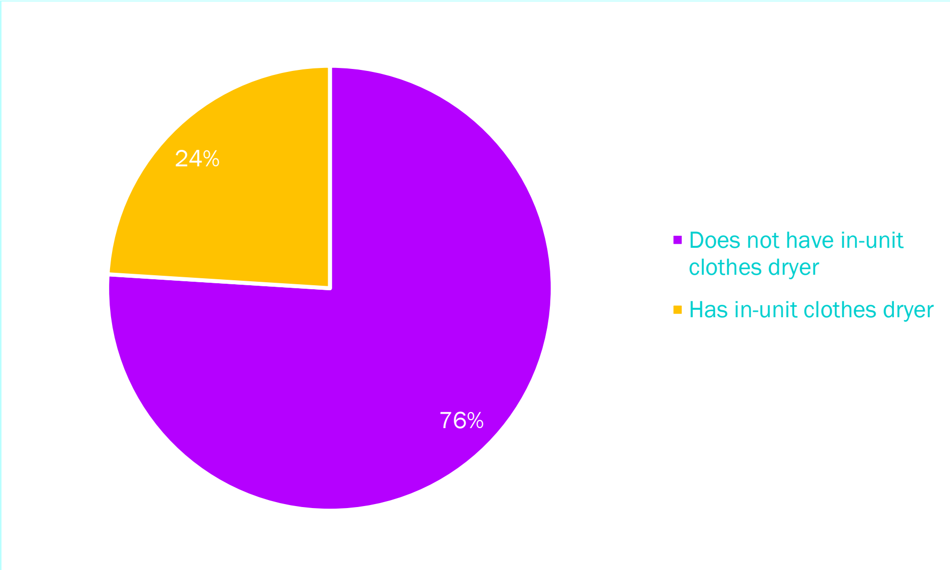


Figure 26: Statewide LMI households residing in multifamily buildings with in-unit clothes dryers.

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Table 19: LMI Households Residing in Multifamily Buildings by In-Unit Clothes Dryers by MSA

	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	1,095,619	152,855	309,409	88,368
No in-unit clothes dryer	73%	52%	71%	63%
Electric powered clothes dryer in-unit	15%	25%	25%	33%
Gas powered clothes dryer in-unit	12%	24%	4%	3%
Total	100%	100%	100%	100%

Source: 2021 AHS PUF; percentages may not sum to 100% due to rounding.

Lighting

Figure 27 shows the type and share of indoor lighting used by LMI households in multifamily buildings. While nearly half of households no longer have any incandescent lighting, about 20 percent still use incandescent bulbs for half or more of their lighting needs. Conversely, while over 40 percent of households use light emitting diodes (LEDs) for half or more of their lighting needs, about a third use no LED bulbs and another quarter only use some LED bulbs.

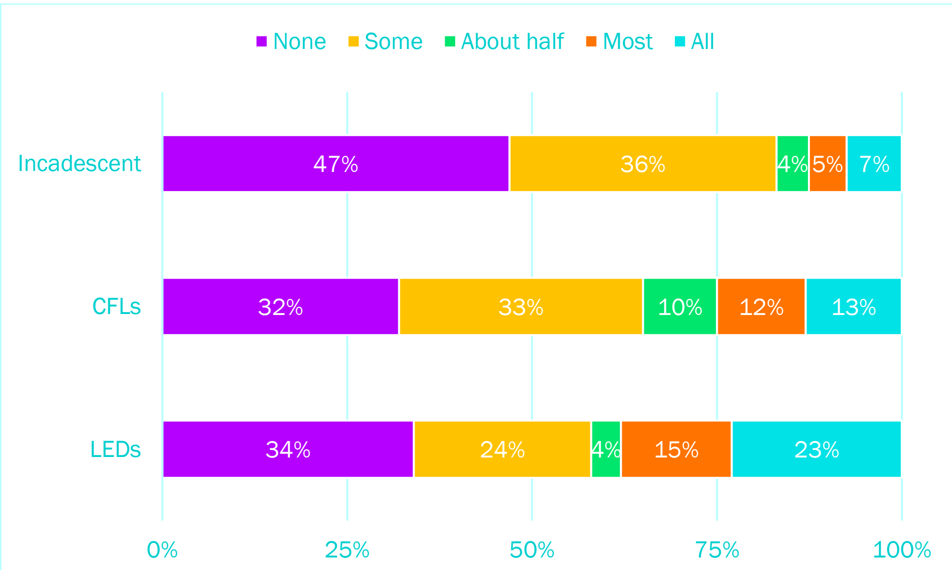


Figure 27: Statewide LMI households residing in multifamily buildings by type and share of indoor lighting.

Source: 2020 RECS; percentages may not sum to 100% due to rounding.

Table 20 shows that five percent or less of LMI households residing in multifamily buildings report having solar PV installed at their buildings in each of the MSAs examined.

Table 20: LMI Residing in Multifamily Buildings that have Solar PV Installed at their Buildings by MSA

	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	1,095,619	152,855	309,409	88,368
Yes (has solar panels)	2%	4%	5%	4%

	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
No (does not have solar panels)	97%	96%	94%	94%
Not reported	1%	0%	1%	2%
Total	100%	100%	100%	100%

Source: 2021 AHS PUF; percentages may not sum to 100% due to rounding.

Field Study Findings

Overview of Properties Visited

As noted in the section on Methodology & Approach above, the properties visited for the field study were a convenience sample developed from existing connections to affordable housing property owners in the Bay Area. The data presented in this section should not be viewed as representative of the population but rather a profile that can be used to help understand the opportunities and challenges to electrification in this building stock. However, Table 21 through Table 23 provide a breakdown of the number and percent of buildings in the field study, and the share of total apartment buildings, by building style, building age, and building size, which can help contextualize the information presented in this section by comparing the field study makeup to the population. Compared to the population of LMI households residing in multifamily buildings in the Bay Area (based on the San Francisco-Oakland-Hayward MSA), the field study properties are comprised of newer units, more units in buildings with 50+ units, and more units in mid-rise buildings. In addition, the buildings visited in the field study primarily are deed-restricted, fully-multifamily affordable housing properties – 80 percent have some type of property-based subsidy posing a restriction on the housing and 91 percent reported being fully affordable with all units limited to LMI households. The buildings typically are set up with direct metering for electricity to individual apartment units, rather than a single master meter for the entire building. A little more than half of the buildings (56 percent) reported having utility allowances in place, indicating residents in those buildings pay for their utilities directly and receive a utility allowance to offset those costs.

Table 21: Number and Percent of Buildings in Sample, and the Percent of Apartments Represented, by Building Age

Building Age	Number of Buildings	Percent of Buildings	Percent of Apartment Units
Built before 1970	12	24	33
Built 1970-1999	21	42	27
Built 2000+	17	34	41
Total	50	100	100

Source: Field Study findings from Project Team; Population Data Analysis findings from Project Team analysis of 2021 AHS PUF

Table 22: Number and Percent of Buildings in Sample, and the Percent of Apartments Represented, by Building Size (Number of Apartment Units)

	Number of Buildings	Percent of Buildings	Percent of Apartment Units
5-9 Units	9	18%	1%
10-19 Units	7	14%	4%
20-49 Units	9	18%	10%
50+ Units	23	46%	85%
Auxiliary/Support Building	2	4%	N/A
Total	50	100%	100%

Source: Field Study findings from Project Team; Population Data Analysis findings from Project Team analysis of 2021 AHS PUF

Table 23: Number and Percent of Buildings in Sample, and the Percent of Apartments Represented, by Building Style

Building Style	Number of Buildings	Percent of Buildings	Percent of Apartment Units
Garden Style	14	28%	7%
Low-Rise (<5 Floors)	13	26%	13%

Building Style	Number of Buildings	Percent of Buildings	Percent of Apartment Units
Mid-Rise (5-9 Floors)	22	44%	74%
High-Rise (10+ Floors)	1	10%	7%
Total	**50**	**100%**	**100%**

Source: Project Team

Field Study Building-Level Summary

The buildings in the field study typically are set up with multiple electric subpanels (32 buildings), however, over a third of the buildings have only one main electric panel. Those with only one main panel tend to be smaller buildings (5-9 units) while multiple subpanels almost always were present in large buildings (50+ units). However, medium-sized buildings had a mix of both multiple subpanels and one main panel. The latter may present a more challenging scenario for electrification since many electrical runs will be required if individual units do any electrification.

Main service amperage was a challenge to locate in ten buildings. In the 40 buildings where main service to the building could be located, 11 have 200A or less and 15 have 400A-800A. The remainder have 1000A or greater main service. Those with low service amperage (200A or less) tend to be smaller buildings (5-9 units) while those with higher service amperage (1000A or more) tend to be large buildings (50+ units). However, medium-sized buildings were a mix of lower and higher service amperages, and older buildings included in the field study tend to have lower main service amperage than newer buildings. When examined on a per-unit basis (i.e., main service amperage to the building divided by the number of units in the building), over 90 percent of the buildings included in the field study have 50A or less main service per unit.

Dedicated, pad-mounted transformers are located at 20 of the buildings and subsurface transformers are located at 10 of the buildings, while the remainder are served by transformers located elsewhere. Where existing electrical service to the building is constrained, it likely will be easier and less costly to upgrade the transformer and service where a pad-mounted, dedicated transformer exists, than with a subsurface transformer that feeds many buildings and city blocks.

Heating is supplied to common areas and/or offices in about two-thirds of the buildings (the remainder typically do not have common areas or offices to heat), and AC cooling is supplied to common/office areas in just under half of the buildings. The HVAC system serving these areas typically is not the same system that serves the apartment units. Heating fuel type is split almost evenly among electricity and natural gas, but unlike in the apartment units (discussed below), the majority of electrically heated systems in common/office areas already are heat pumps not electric resistance. Most of the gas-heated systems supplying common/office areas are 6-20 years old and about one-third have an efficiency less than 90 percent.

Nearly all the buildings (46) have a central or clustered/small central DHW system serving both common areas and apartment units, with a handful that are central plants serving multiple buildings at a property. These central DHW systems overwhelmingly are gas-fired, and over half are less than 90 percent efficient. When looking at the space available in the current location, about three-fourths of the buildings have their DHW systems located in an area that is feasible for replacement by a HPWH. The building configurations also were assessed by the survey team to be more ideal for split HPWH units as opposed to integrated HPWHs. Fuses were present with the building DHW systems in about ten percent of the buildings in the field study.

None of the buildings in the field study have electric vehicle (EV) charging infrastructure onsite for residential use, and only four of the buildings have solar PV. Based on the service amperage and number of apartment units at the buildings in the field study, adding either or both EV charging and solar PV would require utility service upgrades in many cases. Based on review of photo documentation from the field study, rooftops of these buildings appear capable of supporting solar PV, but challenges exist when buildings are located in downtown settings and there is limited outdoor space—tradeoffs may be needed when roof space is limited and the only place to locate outdoor mechanical equipment, or alternative types of equipment (e.g., in-unit heat pumps that do not have outdoor units, like PWHPs) could open up more possibilities.[11] Similarly, buildings located in downtown areas are less likely to have space available for parking, so garden style buildings and other multifamily buildings located on a campus with more outdoor space may present better opportunities for both EV charging opportunities and solar PV.

LED technology is common now in many settings, and program opportunities for lighting are limited, but fewer than half of the buildings in the field study report having over 75 percent of their common area lighting provided by LEDs. Combined with findings on in-unit lighting from the population analysis, there appear to be opportunities to continue targeting LED lighting and related technologies to multifamily affordable buildings. While lighting controls were reported at three-fourths of the buildings, the project team noted that this could be an area deserving of more attention in future research efforts as the share of common areas with lighting controls in place may have been minimal but still counted as having lighting controls.

In-unit clothes washers and clothes dryers are rare in the buildings in the field study, but two-thirds of the buildings have common area laundry facilities available to residents. These facilities often are operated by a leasing company and the clothes dryers typically are gas-fired. The laundry rooms typically have a condensate drain available but do not have 240V plugs and would need electrical upgrades if converting to heat pump dryers.

The most common exterior wall material noted at the buildings in the field study—used in about three-fourths of the buildings—is stucco or stucco in combination with other materials like concrete or brick. Stucco is a poor insulator and while more information on wall construction would be needed to assess the insulation values at the properties it might be safe to assume, based on the common roof insulation material noted (fiberglass insulation), that the wall insulation also is fiberglass. If these assumptions are accurate, it means that the thermal envelopes of the buildings would tend to

[11] The market opportunity for in-unit heat pumps, including PWHPs, is discussed in the Market and Technical Evaluation of Multifamily In-Unit Heat Pumps (ETS22SWE0035), which has not been published at the time of this writing. The final report for that study will be available on the CalNEXT website when published: https://calnext.com/approved-projects/

have low R-values and there would be opportunities to reduce the load in combination with electrification upgrades.

Field Study Apartment-Level Summary

Within the apartment units included in the field study, the electrical subpanels almost always are individual, not shared. Most have a panel capacity rating of 90A or greater; those with lower amperage ratings typically are located in older buildings or use gas heating and cooking equipment. These apartments likely would require panel upgrades if in-unit equipment is electrified. The location of existing subpanels typically was suitable and would not need to be moved if electrification upgrades took place and required a panel upgrade.

The heating systems serving apartment units included in the field study are a mix of unitized equipment (20 units) and central heating systems serving multiple units (15 units). Heating fuel for these units is split almost evenly between gas and electricity, and the most common system type is steam/hot water radiators, followed by electric-resistance baseboards. Heat pumps are uncommon (only observed in one apartment unit) and the systems typically are not ducted. Cooling equipment rarely was observed in the apartments.

Window types observed in the apartments included in the field study are a mix of single-hung/double-hung style windows (about a third) and other types like awning, casement, and slider windows (about two-thirds). The latter may not be compatible with some emerging technologies like PWHPs. In addition, where compatible windows exist, there would need to be an outlet available for the equipment, but this often was not the case in the field study apartment units. This may be more prevalent in milder climates in the state, like the Bay Area where the field study occurred, where existing AC—particularly window AC units that also require a nearby outlet—is less common among LMI households residing in multifamily buildings.

Cooking ranges are predominantly already electric (25 units), only one is induction, and most are five plus years old. For the apartments using gas stoves, electrical upgrades would be needed to support converting to electric ranges currently available since all of these units lack 240V plugs and 50A dedicated breakers. In addition, stakeholders noted that electrifying the range/stove often exceeds the limitations of the main service to the building, requiring a transformer upgrade for the property.

Field Study Electrification Case Studies

CASE STUDY PROPERTY 1

- **Property Overview:** 94-unit, low-rise (less than five floors) complex, built in early-1980s; three buildings at property (two residential, one office); naturally occurring affordable housing with mixed income units
- **Envelope:** stucco exterior, drywall interior, flat roof with fiberglass insulation
- **HVAC:** common area fed by forced air rooftop cooling and natural gas furnace packaged unit, equipment between 6-20 years old, ducted distribution; individual units supplied by through-wall electric packaged terminal air conditioner (PTAC), between 6-20 years old
- **DHW:** central gas-fired water heater located in mechanical room of each residential building feeding individual units, less than five years old, 82 percent efficient; in-unit gas-fired water heater (small tank 30 gallons or less) located in office building, 12 years old, 80 percent efficient

- **Electrical Infrastructure:** pad transformer feeding residential buildings with 600A main breaker amperage, three-phase electrical service
- **Additional Details for Apartment Unit:** individual subpanel, 70A panel capacity; manual/non-programmable thermostat; wired for high-speed internet and WiFi; slider windows; electric range, non-induction cooktop with 240V plug and 50A circuit/outlet

Data and photo documentation collected for Property 1 indicate that there is ample physical space to upgrade the DHW systems serving the residential units to HPWHs, the roof would be capable of supporting solar as well as heat pumps to replace the existing rooftop packaged unit, and the 600A service to the residential buildings should be capable of supporting the upgrade to heat pumps. The attic/roof appears to be accessible and more efficient insulation could be added to reduce the thermal load. Opportunity exists to convert common area laundry from gas-fired clothes dryers to heat pump clothes dryers. Each unit appears to be on its own electrical panel with a 2-pole, 70A breaker. While the window type in the apartments (sliders) is not compatible with newer, in-unit PWHP coming to market, the existing in-unit through-wall PTAC could be replaced with a newer, more efficient packaged terminal heat pump (PTHP). In addition, the cooking range could be upgraded to a more efficient electric model.

Top row, left to right: forced air rooftop packaged unit and available space on flat roof. Second row, left to right: 600A building main breaker and main breaker to units. Third row, left to right: meter bank and central DHW. Fourth row, left to right: gas-fired clothes dryers in common area laundry and existing attic insulation (rotated). Fifth (bottom) row, left to right: apartment unit breaker panel and in-unit electric cooking range.

Figure 28: Photo documentation from case study property 1.

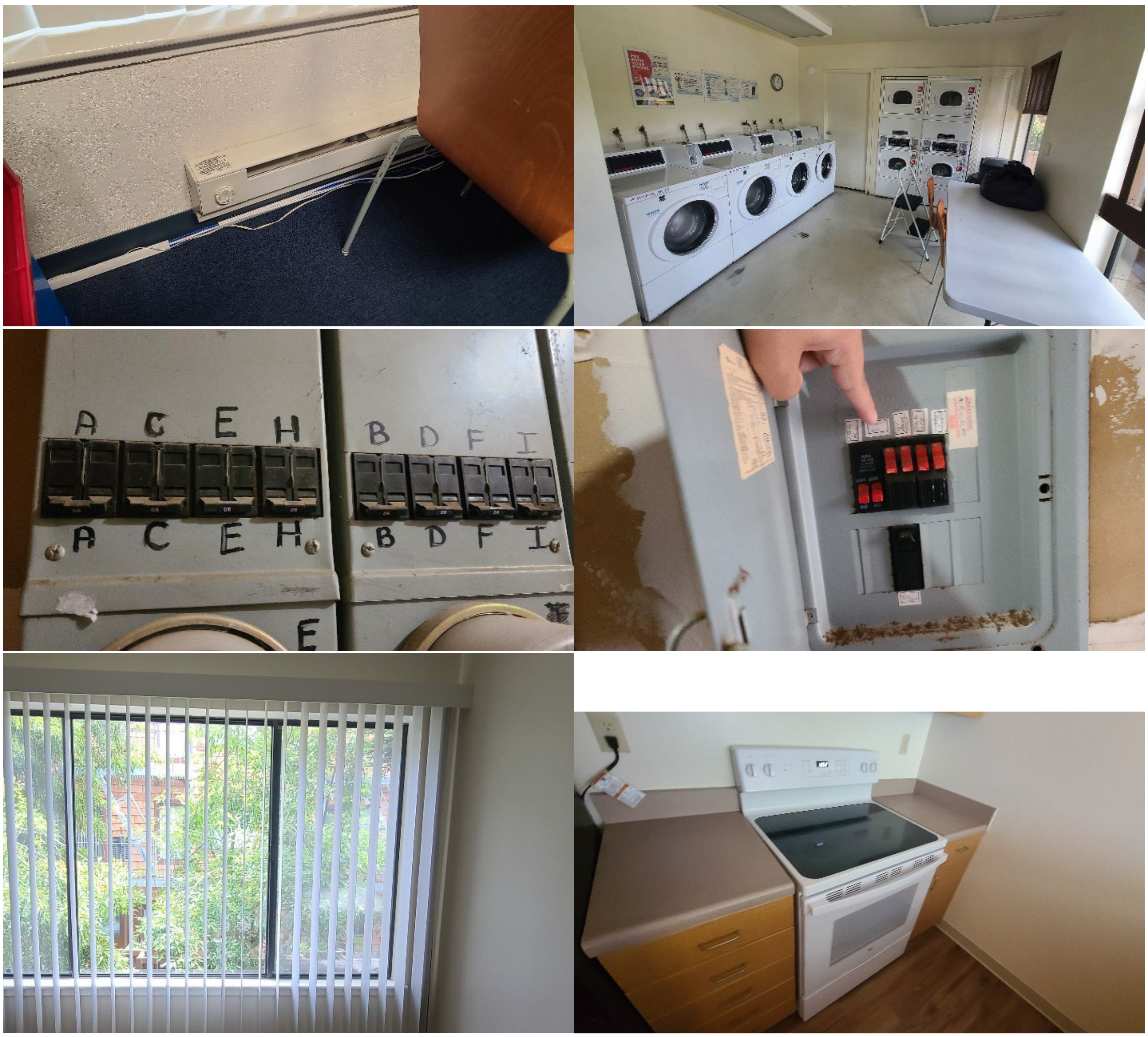
Source: Project Team

CASE STUDY PROPERTY 2

- **Overview:** 45-unit, low-rise (less than five floors) complex, built in late-1970s; three residential buildings at property (two apartment-style, one townhouse-style); deed-restricted affordable housing
- **Envelope:** shingle exterior, drywall interior, flat roof with fiberglass insulation
- **HVAC:** common area in building with leasing office heated with electric resistance baseboards, no AC, equipment between 6-20 years old; gas-fired non-ducted wall furnace located in hallway of apartment-style residential building, no AC, equipment 20+ years old, 70 percent efficient; gas-fired forced air furnace with ducts located in-unit of townhouse-style building, no AC, equipment between 6-20 years old, 80 percent efficient
- **DHW:** central gas-fired water heater located in mechanical/laundry room of each apartment-style residential building, less than five years old, ranging in efficiency from 80 to 97 percent; in-unit gas-fired water heater (medium tank 31-50 gallons), located on porch/balcony of townhouse style residential building, 58 percent efficient
- **Electrical Infrastructure:** pad transformer feeding buildings, unclear total building amperage
- **Additional Details for Apartment Unit:** individual subpanel, 90A panel capacity in apartment-style residential building and 125A panel capacity in townhouse-style residential building;

manual/non-programmable thermostat; wired for high-speed internet and Wi-Fi; slider windows; electric range, non-induction cooktop with 240V plug and 50A circuit/outlet

Data and photo documentation collected for Property 2 indicate that the building design with existing electric-resistance heating in common areas is conducive to replacement with individual heat pumps. In addition, residential units in the apartment-style building are fed by a 90A main breaker with an individual panel that appears to have space for a 40A breaker for a heat pump. However, the total building amperage is unclear, and the windows are not compatible with in-unit PWHP options, so other heat pump types would need to be considered for HVAC if the total building amperage could support it. There is opportunity to reduce thermal load with upgraded insulation, and central laundry could be switched from gas-fired clothes dryers to heat pump clothes dryers.



Top row, left to right: electric resistance heating in leasing office and common area laundry room. Second row, left to right: unit main panel and unit breaker panel. Third (bottom) row, left to right: windows and in-unit electric cooking range.

Figure 29: Photo documentation from case study property 2.

Source: Project Team

CASE STUDY PROPERTY 3

- **Overview:** 250-unit, mid-rise (five to nine floors) complex, built in late-1970s; one building; deed-restricted affordable housing
- **Envelope:** cladding/stucco exterior, drywall interior, flat roof, insulation status unknown
- **HVAC:** common area fed by gas-fired forced air central furnace and central AC located on roof, equipment between 6-20 years old, ducted distribution, 80 percent efficient furnace, unknown AC efficiency; individual units heated by electric resistance baseboards, 20+ years old, no AC
- **DHW:** central gas-fired water heater located in mechanical room feeding common areas and individual units, 20+ years old, 80 percent efficient
- **Electrical Infrastructure:** dedicated pad transformer with 1600A main breaker amperage
- **Additional Details for Apartment Unit:** individual subpanel, 125A panel capacity; manual/non-programmable thermostat; wired for high-speed internet and Wi-Fi; single-hung windows; electric range, non-induction cooktop with 240V plug and 50A circuit/outlet

Data and photo documentation collected for Property 3 indicate that with 1600A main breaker amperage, most electrification upgrades would be possible without a service upgrade. However, since the building has a dedicated pad, upgrading the service would be feasible if needed. The utility room has plenty of physical space for full electrification of heating, cooling, and DHW with potential for a central heat pump. Each apartment unit appears to be served by at least 100A service and could support a heat pump and other electrification upgrades if central electrification was not the best option. The apartment window type (single-hung) is compatible with in-unit PWHP options, and the electric range could be updated to a more efficient option.

Top row, left to right: 1600A main breaker and dedicated transformer pad. Second row, left to right: central DHW and in-unit electric cooking range. Third (bottom) row: common area laundry and meter bank.

Figure 30: Photo documentation from case study property 3.

Source: Project Team

CASE STUDY PROPERTY 4

- **Overview:** 81-unit, low-rise (less than five floors) and mid-rise (five to nine floors) three-building complex, built in mid-2000s; deed-restricted affordable housing
- **Envelope:** stucco exterior, drywall interior, flat roof, insulation status unknown
- **HVAC:** common area fed by gas-fired forced air central furnace and central AC located on roof, equipment between 6-20 years old, ducted distribution, 100 percent efficient furnace, 13 SEER AC efficiency, solar thermal located on roof of one building; individual units heated by gas-fired boiler, 6-20 years old, 81 percent efficient, no AC
- **DHW:** central gas-fired water heater located in boiler room feeding common areas and individual units, 16 years old, 84 percent efficient
- **Electrical Infrastructure:** 2500A main breaker amperage, no transformer at property
- **Additional Details for Apartment Unit:** individual subpanel, 60A or 80A panel capacity based on unit configuration; manual/non-programmable thermostat; wired for high-speed internet and Wi-Fi; slider windows; electric range, non-induction cooktop with 240V plug and 50A circuit/outlet

Data and photo documentation collected for Property 4 indicate that there are limited opportunities for replacing existing heating and cooling with heat pumps because of limited space in the utility room and insufficient roof space due to existing solar thermal. With the building located in a downtown setting, there is insufficient outdoor space to locate equipment outside of the building, and the window type in apartment units (sliders) is not compatible with in-unit PWHP options. However, the property appears to be a good candidate for upgrading existing DHW with HPWHs and, given the service size of both the main and unit breakers, electrification upgrades should not require a service upgrade. The kitchen appears to be modern with no general upgrades needed.

Top row, left to right: central furnace and boiler. Second row, left to right: solar thermal and DHW. Third row, left to right: main breaker and main service. Fourth row, left to right: unit meter bank and electric cooking range. Fifth (bottom) row, left to right: in-unit windows and common area laundry.

Figure 31: Photo documentation from case study property 4.

Source: Project Team

CASE STUDY PROPERTY 5

- **Overview:** 115-unit, garden style five-building complex, built in early -1970s; deed-restricted affordable housing
- **Envelope:** stucco exterior, drywall interior, non-flat roof with fiberglass insulation
- **HVAC:** ductless mini split heat pumps providing heating and cooling to common areas in two of five buildings; individual units heated by electric resistance baseboards, 20+ years old, no AC
- **DHW:** central gas-fired water heater located in boiler room of each building feeding common areas and individual units, ranging from 2 to 20 years in age and 82 to 85 percent efficient

- **Electrical Infrastructure:** shared subsurface transformer, unknown main service amperage
- **Additional Details for Apartment Unit:** individual subpanel, 60A breaker feeding each unit with a 125A rated panel; manual/non-programmable thermostat; wired for high-speed internet and Wi-Fi; slider windows; electric range, non-induction cooktop with 240V plug and 50A circuit/outlet

Data and photo documentation collected for Property 5 indicate that this property would be a good candidate for a split central HPWH. Heat pumps for heating and cooling already have been installed in common areas of two buildings. While the main electrical service could not be located, the project team estimates that it is 400-600A service based on the unit and common area setups with the ability to support a pad-mounted 2-ton heat pump with a 20A double pole breaker. There likely also is space on the roof for solar and the building layout is conducive for electric vehicle chargers.

Top row, left to right: unit main breaker and meter bank. Second row, left to right: heat pump located on outside of building and DHW. Third (bottom) row, left to right: in-unit electric cooking range and unit breaker panel.

Figure 32: Photo documentation from case study property 5.

Source: Project Team

SUMMARY OF CASE STUDY FINDINGS

The two low-rise case study properties (1 and 2) appear capable of full electrification. They generally have space for heat pumps and with the layout of individual main breakers and in-unit panels, the additional load from heat pumps seems plausible. They may need to upgrade the panels in the unit, but the layout of this style of property may facilitate that upgrade without substantial demolition. Locations of existing central gas-fired DHW systems in these two properties appear suitable for replacement by centralized HPWH options, and this is supported by review of additional low-rise buildings included in the field study. However, review of additional low-rise buildings indicates that service upgrades are needed in older properties in this category, especially considering the opportunities for rooftop solar and electric vehicle chargers at this property type. Buildings with pad-mounted and dedicated transformers would be best for any electrical upgrades to service.

The two mid-rise case study properties (3 and 4) appear to be very different in that property 4 appears to be located in a downtown setting and a more traditional high-rise apartment building, while property 3 has more of a low-rise or garden-style layout on a larger scale. The differences between these two properties are significant as buildings like property 4 would only be able to support in-unit window heat pumps whereas buildings like property 3 would have more options for upgrading heating and cooling equipment.

Field Study Process Learnings

The project team took away several learnings from the field study process that could be useful to future studies and building-level data collection efforts in the affordable housing market segment.

In general, site visits and survey questions were designed to be quick, easily understood and have simple answers. However, this was not always the case. There were some instances where questions created misunderstanding for the site managers/owners. For example, questions relating to metering configuration were found to be confusing. When asked whether the site's building is either mastered metered, sub-metered, or individually metered, property staff interpreted the question in one of two ways: what the metering configuration was, or who was the party responsible for paying the utility bill (regardless of meter configuration, since some buildings have individually metered units but the property owner has payment responsibility with the utility). In addition, some of the technical questions (e.g., those related to electrical infrastructure or configuration of HVAC or DHW systems) require on-site review by experienced professionals and cannot be reasonably collected from property managers or on-site staff over the phone.

Additional learnings include:

- Collecting data from the selected sites proved to be moderately challenging. Understanding the pain points for data collection will prove useful for future studies.
- Logistical challenges persisted throughout the field study timeframe, due to perceived administrative burden. Scheduling site visits required time and energy from property staff, particularly property managers/onsite maintenance staff. In some instances, visits needed to be rescheduled, prolonging the data collection time period.
- Some of the property managers/owners were willing to participate in the study but reluctant to commit the staff time necessary to ensure the data collection went smoothly. Some properties had only a few staff available and limited availability making it hard to establish site visits.
- Site visits required property staff to guide Bright Power around the facility in addition to answering building characteristics questions ahead of the onsite collection. However, not every point of contact at each site was knowledgeable on the existing building structure, materials, or its electrification potential. This knowledge gap resulted in some incomplete or inaccurate data collection.
- Some point of contacts spoke English as a second language. Overcoming language barriers was sometimes necessary, particularly if staff were not familiar with the site visit. Having someone on the survey team who can speak multiple languages will be beneficial for future studies.

- Establishing trust with study participants was essential for the project success. Future studies should consider leveraging local community partners to find viable candidates and establish early buy-in.

Stakeholder Outreach and Feedback

The project team engaged stakeholders in the multifamily affordable housing space to incorporate multiple perspectives identifying opportunities and challenges for building electrification and decarbonization. Discussion topics included:

- Top challenges to electrifying multifamily affordable housing including physical challenges, programmatic barriers, and how these challenges vary across building typology and other factors.
- Promising best practices/solutions for electrifying this market segment.
- Technical assistance/technology support that is needed to support electrification efforts in multifamily buildings housing LMI residents.

General observations for multifamily affordable housing offered by stakeholders include the following:

- Mid-rise and high-rise multifamily affordable housing buildings tend to look alike with uniform system configurations (e.g., central DHW), while low-rise multifamily affordable housing have more variability in system configurations, but that variability is similar across different types of low-rise building types (e.g., garden-style apartment buildings and townhomes have similar setups).
- Stakeholders noted that there are no major fundamental physical differences specific to whether an affordable multifamily housing property is subsidized or naturally-occurring, but that there are differences between multifamily affordable housing of either type and market rate multifamily properties.
- Currently, deep, comprehensive decarbonization projects in multifamily affordable housing properties often take two or more years to complete. While costs are a major challenge to these projects, timeframes are equally important.

Stakeholders noted the following challenges to electrifying multifamily affordable buildings:

- Electrical infrastructure limitations, both in terms of utility-side capacity coming into buildings and individual subpanels and wiring in apartment units. Stakeholders noted that panel upgrades add costs to projects and, while utility-side capacity issues are not too common, where present, those issues can prevent projects from moving forward due to the scale of the costs involved.
- Where existing equipment is unitized, small mechanical closets often limit electrification options or require rethinking how or where systems are configured and located. Stakeholders noted that this is a particular challenge for unitized DHW, since HPWH tanks typically are sized up from the existing system to account for slower recovery rate of the HPWH (e.g., a 40-gallon gas-fired hot water tank is replaced by a 60-gallon HPWH), and the free flow of air required for HPWHs to operate correctly adds more spacing requirements. While some 120V HPWH options are marketed as being a one-for-one drop-in units that can replace an existing gas water heater without needing to size up the storage tank, it is unclear whether those

products operate as marketed and it is common for contractors to size up these HPWH units. As a result, HPWHs often do not fit into existing mechanical spaces and sometimes have to be shifted to an outside area, if possible. Spacing challenges are less of a concern when existing equipment is located on an exterior wall; this also makes access easier since work can be done while minimizing access needed to the apartment space.

- Stakeholders noted noise concerns with unitized equipment, particularly HPWHs located inside or right outside of apartment windows.
- Full electrification of apartments is a challenge. Stakeholders noted having completed many electrification projects for individual end uses like DHW or HVAC but that converting gas cooking appliances to electric alternatives often is the last lap, requiring expensive transformer upgrades to bring in more electrical capacity to the building.
- Certain challenges are more common or relevant in specific building typologies. Stakeholders noted the following issues:
    - Wall furnaces in low-rise multifamily buildings. Program implementers noted that there often is no clear place for the new heat pump equipment when the existing equipment is a wall furnace, and replacing wall furnaces with through-wall heat pumps can create building code issues (e.g., a dedicated circuit is required).
    - Retrofitting high-rise properties with unitized heat pumps for heating and cooling can be a challenge due to limited space to locate outdoor units and a need for long line sets between the indoor and outdoor units.

Stakeholders also noted programmatic and organizational challenges for electrifying multifamily affordable housing including:

- While many of the regulatory barriers have been addressed and most programs serving multifamily affordable housing can do electrification, stakeholders noted that the cost-effectiveness requirements can be a challenge in this sector.
- It can be challenging to ensure that electrification efforts do not negatively impact resident bills.
- Upfront costs including engineering costs, permitting, and materials procurement are a hurdle often not covered by programs. Likewise, costs for ancillary measures (e.g., panel upgrades) are not often met by programs but required to move projects forward. The question of who pays for utility-side infrastructure upgrades is a major barrier when those investments are needed. Stakeholders noted the City of Los Angeles, which recently approved plans to cover electric power infrastructure upgrades at fully affordable housing properties being newly constructed (LADWP 2023), and the Comprehensive Affordable Multifamily Retrofits Program funded by the Los Angeles Department of Water and Power (LADWP), which provides incentives to offset costs of utility infrastructure upgrades, as positive developments toward improving utility-side infrastructure needed to electrify multifamily affordable housing.
- There are multiple energy programs operating in this space, but eligibility requirements often are not aligned, and flexibility varies by agency overseeing the programs. Stakeholders noted the Multifamily Finance Super NOFA, which aligns eligibility criteria, scoring, and a single application for four rental housing programs offered by the California Department of Housing

and Community Development (HCD), as a positive example of streamlining program requirements that existing multifamily energy programs could emulate.[12]

- Staff capacity at organizations developing and managing multifamily affordable housing properties is stretched thin, limiting their ability to participate in existing programs even when interested. Program intake and applications are lengthy, and requirements are complicated. Stakeholders noted that technical assistance support is needed, particularly among nonprofit affordable housing owners.
- Incentives through any single program often are insufficient to move projects forward and stacking of program incentives is necessary. Even after combining multiple incentive programs, many buildings have out-of-pocket expenses that make project finances difficult to justify economically.

Electrification and decarbonization opportunities (emerging technologies, best practices, etc.) in multifamily affordable housing noted by stakeholders include the following:

- Prefabricated HPWH systems to electrify DHW – both central systems and unitized. These systems are pre-piped and pre-wired, making them less error prone during installation. Stakeholders noted the movement by industry towards these types of systems, but that there will be some challenges to overcome (e.g., large space requirements, complicated user interfaces that could be improved and made easier for building maintenance staff and tradespeople to use).
- PWHPs and other in-unit heat pumps offer promise where mini splits may not be compatible. Stakeholders noted that while these technologies are expensive right now, they could be good options where low-power, plug-in solutions are needed, and in the case of PWHPs, where cooling is not present yet but needed.
- Efforts to mitigate negative bill impacts on residents and document this through case studies and other research efforts.

Stakeholders provided thoughts on the technical assistance and other supports needed by multifamily affordable housing property owners and developers to electrify their buildings, including:

- Comprehensive, free technical assistance that spans energy audits, scope development, benchmarking, and electrification roadmaps with a focus on portfolios and not just single buildings. Stakeholders noted the technical assistance efforts offered through ESA, the CEC Building Initiative for Low-Emissions Development (BUILD) program, and the TECH Clean California program as examples of successful technical assistance models.
- Continued education and development of trade skills. Stakeholders noted that they are seeing need for better sizing and design training across HVAC contractors, and that there are complexities for plumbers not used to doing electrical work. Even with a move toward more packaged systems reducing the complexities involved with installation, servicing those systems requires skills training and education. Ensuring contractors have the skills necessary to perform the work, whether in-house or through partnerships, is needed to ensure high quality work in this space.

[12] For more information on HCD's Multifamily Finance Super NOFA, see: https://www.hcd.ca.gov/grants-and-funding/supernofa

- Post-completion monitoring support to ensure savings materialize and systems are functioning properly. Stakeholders raised examples of properties where staff turnover and other factors result in systems not working properly, resulting in negative bill impacts to building owners and tenants. Development of processes or tools to help building owners monitor their buildings and portfolios is one way in which stakeholders envision support.

Recommendations

Based on the population data analysis, field study findings, stakeholder discussions, and literature review, the following technology development and program development recommendations are made for supporting electrification efforts in the multifamily affordable housing:

Technology Development Recommendations

- **Continued support for DHW electrification.** Stakeholders noted that much of their focus in multifamily affordable buildings has been on electrifying DHW. Given the predominance of gas-fired centralized boilers, continued support for HPWH technologies is key. Prefabricated, skidded HPWH systems that come pre-piped and pre-wired offer promise and stakeholders noted that the industry is moving in this direction. However, these systems have large space requirements and may not be suitable for all buildings. Gathering more information on prefabricated HPWH systems and building types where they have been successfully integrated could help with program design considerations and streamlining when multifamily affordable housing properties consider this technology. In addition, stakeholders noted that the interfaces of many skidded HPWH systems are complex and not intuitive to building operations staff and contractors. Pushing manufacturers to simplify those interfaces is another way to support the market segment.
- **Market demonstration of in-unit heat pumps.** In-unit heat pumps technologies represent a promising emerging technology for the LMI multifamily housing market segment, and lower cost option when compared to central heat pumps and ductless mini split options. The specific opportunities will vary based on building configuration and other factors; these are the subject of the Market and Technical Evaluation of Multifamily In-Unit Heat Pumps (ETS22SWE0035) and are not discussed at length in this report. However, market demonstration support is needed for market adoption of this class of technologies in California's multifamily affordable buildings.
- **Support additional demonstration of integrated mechanical pods**. Mechanical pods are another emerging technology that holds promise for the multifamily affordable housing sector. By combining heating, cooling, ventilation, DHW, and controls in a simple, efficient design, mechanical pods offer potential to reduce costs and increase the pace of deep energy retrofits in the space. Mechanical pods have been the topic of market demonstration projects by the Rocky Mountain Institute (RMI) and others in multifamily affordable housing in California.[13] Challenges may exist where existing DHW and HVAC are both not centralized

[13] For more information on how RMI and partners have deployed mechanical pods as part of deep energy retrofits in affordable housing in California, see the REALIZE-CA program website: https://rmi.org/our-work/buildings/realize/realize-ca/

or unitized and building configurations need to be rethought. Additional demonstration support is needed to further this technology option for multifamily affordable housing.

- **Support market innovation with induction cooktops.** With most existing cooktops either electric coil or gas stoves, there is opportunity to replace those appliances with induction stoves and achieve savings. When converting from gas, indoor air quality benefits also accrue. However, for buildings with gas stoves, electrical upgrades likely are needed both in the apartment units and at the transformer. Stakeholders noted that support for market innovation by manufacturers (e.g., development of 120V induction stoves)—the focus of a new initiative in New York—is one way to support market development that would not naturally occur and could help alleviate the challenges of replacing gas stoves with induction stoves.[14] If induction stoves were prioritized in program offerings, there would need to be education—and possibly incentives—to ensure residents have the proper cookware (ferrous metal pots and pans).
- **Incentivize new in-unit heat pump clothes dryers that address both space and infrastructure challenges.** About one-quarter of the LMI multifamily housing sector in California has an in-unit clothes dryer. For these apartments, condensing washer/heat pump dryer combinations offer an option to electrify while keeping in mind both space and infrastructure constraints. Ventless, 120V options currently available in the market could easily be retrofitted into apartments with an existing washer and dryer without needing to upgrade the outlet serving the existing appliances. However, the price point for this technology is high compared to stackable laundry appliances or combination appliances with a standard electric dryer. Since the existing appliances most likely are owned by the building not tenants, but utilities are tenant-paid, it is likely that program incentives would need to cover the incremental costs to incentivize building owners to make this upgrade on behalf of tenants.

Program Development Recommendations

- **Continue to pair electrification with comprehensive energy efficiency.** Existing program implementers and affordable housing organizations noted that property owners often express concerns over the impact of electrification efforts on customer bills. Pursuing comprehensive energy efficiency measures (e.g., insulation, air sealing, lighting load reductions) in combination with electrification measures can help to mitigate negative bill impacts on residents, and it can also help to avoid costly infrastructure upgrades in some circumstances.
- **Incentivize electrical infrastructure upgrades.** Electrical infrastructure is one of the biggest barriers to electrification efforts and the electrical infrastructure upgrade costs (service capacity, wiring, etc.) often exceed equipment and appliance costs (AEA & Stopwaste 2021). Particularly in older buildings with less service capacity to support full electrification of HVAC, DHW, cooking, and addition of solar PV and EV charging, electrical infrastructure upgrades are a necessity. Stakeholders noted that who pays for those upgrades is a big challenge for

[14] The Induction Stove Challenge is a partnership between the New York State Energy Research and Development Authority (NYSERDA), New York City Housing Authority (NYCHA), and New York Power Authority (NYPA) that calls for the design and manufacture of new induction stoves that can be installed using standard 120v/20A outlets. More information on the Induction Stove Challenge is available here: https://www.nyserda.ny.gov/About/Newsroom/2023-Announcements/2023-07-24-NYCHA-NYSERDA-and-NYPA-Sign-Agreement-for-the-Induction-Stove-Challenge

affordable housing developers – often, the cost of those upgrades exceeds what they can make work based on their property finances. Providing incentives for service and other infrastructure upgrades is a way to facilitate comprehensive electrification and decarbonization in the multifamily affordable housing segment.

- **Support deployment of solar PV.** Ensuring LMI households have access to the benefits of solar is a key equity consideration, and adding solar PV often is needed to achieve the bill reductions required in certain programs. While solar is a focus area for multifamily affordable housing and is supported by the state's SOMAH program, solar PV still is uncommon in this market segment. The public data analysis indicated that solar PV penetration among multifamily buildings with LMI residents is low. The field study suggests that the roofs of many of these buildings could support solar PV, but that utility service upgrades would be needed if solar were deployed and there are competing end-uses looking at roof space (e.g., outdoor units for heat pumps), particularly in downtown settings. Additional support in this space could help more projects financially feasible.
- **Support deployment of EV charging infrastructure.** Similar to solar PV, access to EV charging infrastructure by LMI households residing in multifamily buildings is a key equity consideration, one which the state has taken up in the Transportation Electrification Framework from the California Public Utilities Commission (CPUC) (2020). Bauer, Hsu, and Lutsey (2021) note that most EVs to-date have been purchased by more affluent households, but over time, as the used car market grows for EVs, they will become more accessible to LMI households. EV charging infrastructure was not observed at any field study properties suggesting that this technology is limited in the multifamily affordable housing space. Ensuring that existing programs like SCE's Charge Ready Program reaches this market segment is one way to help LMI residents in multifamily buildings realize the benefits of EVs. As noted in AEA (2020), infrastructure upgrades required for EV chargers is more cost efficient when done at the same time as solar PV and other systems.
- **Conduct additional research on common area laundry facilities.** Schaaf and Shah (2018) estimate that about two-thirds of multifamily buildings have common area laundry facilities, and findings from this study's field data collection from LMI multifamily buildings in the Bay Area support this. Common area laundry facilities in multifamily buildings typically are owned and operated by third-party "route operators" and leased to buildings. Schaaf and Shah (2018) offer recommendations on ways to incentivize the incremental cost upgrades associated with higher efficiency equipment for common area laundry facilities—including incentives to building owners, route operators, and upstream considerations for manufacturers. One concern of note for route operators is the preference for limiting the variety of appliances they offer (Schaaf and Shah 2018). Given how prevalent route operators are in this market segment, and the challenges associated with introducing new technologies (e.g., having service parts available and workforce trained on those technologies), conducting additional research would help to better size this opportunity for the LMI multifamily housing sector in California, better understand the challenges and pain points for route operators deploying new technologies in common area laundry facilities, and determine the best path forward for developing program incentives.
- **Leverage other survey efforts to refine understanding of this market.** The field study conducted as part of this research is a useful reference for better understanding electrification barriers and opportunities in the LMI multifamily housing sector, but it is not

intended to be generalizable to the population. The data collection was limited to LMI multifamily buildings located in the Bay Area and was fielded using a convenience sample. Conducting additional research efforts with a more representative sample, while applying the learnings from this field study, could help utilities further their understanding of this market sector and develop more targeted programs and offerings. In pursuing future data collection efforts for this market segment, factors that utilities should consider for developing the research design and sampling strategy include building typology, geography, desired precision in the estimates, and sample frame availability. An alternative or additional approach is to leverage other existing research efforts (e.g., the California Energy Commission's Residential Appliance Saturation Survey, or the EIA's RECS, which fielded a multifamily building pilot in 2020) to collect certain data points included in the field study. However, while there are potential efficiencies to gain by leveraging other existing research efforts to collect new information about this target market, those research efforts are intermittent and may not align with the timeframes for developing targeted program offerings, and there are certain data points collected in this field study (particularly those that require mechanical and electrical engineering expertise) that do not lend themselves to be collected easily or accurately by existing research efforts.

- **Develop additional workforce skills.** Stakeholders noted that continued development of workforce skills is critical to ensure projects are completed to high quality standards and that systems are operated as intended, and mitigating bill impacts on residents. New and emerging technologies are requiring workforce skills that cross trades, and even with new prefabricated systems allowing for easier installations, stakeholders noted concerns by building owners about heat pump maintenance. Ensuring that there is adequate workforce to install and service equipment is critical for successful implementation of projects and acceptance of these technologies.
- **Increase technical assistance support.** Stakeholders noted that affordable housing providers need more technical assistance—both in terms of understanding the technologies that are relevant and will work in their buildings, and in navigating the various program incentives and funding opportunities—to develop portfolio-wide roadmaps and priority lists for electrification in their multifamily buildings.
    - Stakeholders noted that is not simply a question of funding—intake and application processes for existing programs are lengthy and complicated, and organizational capacity is limited even when interested. Providing additional technical assistance support to affordable housing providers, particularly nonprofit developers, could help increase the number and pace of electrification projects in this market segment. The technical assistance model provided by AEA through the TECH Clean California program was one approach noted by stakeholders, as was technical assistance that has been provided through the ESA program and CEC BUILD program.
    - Stakeholders also noted that not many consultants are familiar the intricacies of affordable housing properties, and that among those that are familiar, there has been a movement away from providing technical assistance in the space. Stemming that decrease by signaling increased technical assistance support to the affordable housing market segment is one way to increase the pool of consultant organizations who can deliver these services.

- **Seek ways to reduce project costs and timelines.** Program implementers and affordable housing organizations noted that deep decarbonization projects in this market segment often take two or more years and require lining up or stacking incentive funding from multiple programs. There is a need to reduce both project timelines and project costs. Support for continued innovation in technologies may help reduce project costs where existing technologies require significant ancillary upgrades.
- **Provide support for upfront costs.** Program implementers and affordable housing organizations noted that most programs do not include funding support for engineering, permitting, and material supply/procurement (both soft and hard construction costs), posing a barrier for projects particularly when properties have limited capital available. Programs could consider expanding incentives to these areas to help projects with upfront costs and getting under development more quickly.
- **Support streamlining of program requirements and processes.** Stakeholders also noted that more streamlined requirements across programs, including both energy-focused programs and housing programs, could help motivate owners and residents of many affordable housing properties. Within available energy programs, eligibility requirements often differ between programs (e.g., SOMAH and LIWP have different income eligibility requirements), and greater flexibility (through categorical eligibility across programs) could help more affordable housing properties electrify and decarbonize more quickly. Stakeholders noted the Multifamily Finance Super NOFA, which aligns eligibility criteria and scoring for four of the rental housing programs offered by the HCD allowing for a single application and award process, as a positive example of streamlining program requirements that existing multifamily energy programs could emulate.[15] If new offerings or programs are developed, making requirements compatible with requirements of existing programs would be a positive step.

[15] For more information on HCD's Multifamily Finance Super NOFA, see: https://www.hcd.ca.gov/grants-and-funding/supernofa

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Appendix A: Data Collection Instrument

Data Item	Purpose
Building information	
Year built	Comparison with public data and assessing opportunity by typology
Total units	Comparison with public data and assessing opportunity by typology
Number of floors	Comparison with public data and assessing opportunity by typology
Square footage (residential space and residential common areas)	Comparison with public data and assessing opportunity by typology
Configuration (e.g., garden style, high-rise, etc.)	Comparison with public data and assessing opportunity by typology
Is there a main electric panel or multiple subpanels?	Electricity service constraints/pre-electrification needs
Do units have their own subpanels or do units share subpanels?	Electricity service constraints/pre-electrification needs
Amperage of electricity service coming into building	Electricity service constraints/pre-electrification needs
Number of electric meters in building	Electricity service constraints/pre-electrification needs
PV on building	Electrification opportunity/program area of interest
Solar thermal on building	Electrification opportunity/ program area of interest
EV charging at premises for residents	Electrification opportunity/ program area of interest
What is the LED penetration like at the property?	Baseline conditions/remaining opportunities

Data Item	Purpose
Do common areas have lighting controls (e.g., motion sensors, dimmers, etc.)	Lighting controls opportunity/program area of interest
Apartment unit information	
Number of bedrooms	Comparison with public data and assessing opportunity by unit typology
Square footage	Comparison with public data and assessing opportunity by unit typology
Heating system details—residential units	
Does the system serve a single unit, a few units, or an entire building?	Electrification opportunity
Where does the equipment live?	Electrification opportunity
Fuel used for primary heating system supplying residential unit	Electrification opportunity
Type of primary heating system supplying residential units	Electrification opportunity
Secondary/supplemental heating system used for residential units?	Electrification opportunity
Fuel used for secondary heating system supplying residential units (if applicable)	Electrification opportunity
Type of secondary heating system (if applicable)	Electrification opportunity

Data Item	Purpose
Existing ductwork for primary heating system supplying residential units?	Electrification opportunity
(If existing ductwork in need of replacement) Suspected asbestos remediation needed for duct replacement?	Identification of electrification barriers
Efficiency of primary heating system supplying residential units (e.g., AFUE, HSPF)	Electrification opportunity
Age of primary heating system supplying residential units	Electrification opportunity
Heating meter configuration for primary heating system supplying residential units (master, direct, submeter)	Identification of electrification barriers
Electrical service of heating system supplying residential units (voltage/amperage) (if PTAC)	Electrification opportunity
Is there sufficient electrical capacity for heat pump replacement equipment?	Identification of electrification barriers
Does the electrical panel have a dedicated breaker per equipment needed to serve each room/space?	Identification of electrification barriers
Heating system details—common areas (if different from system supplying residential units)	

Data Item	Purpose
Does the system serve a few common areas or an entire building?	Electrification opportunity
Where does the equipment live?	Electrification opportunity
Fuel used for heating system supplying building common areas	Electrification opportunity
Type of heating system supplying building common areas	Electrification opportunity
Existing ductwork for heating system supplying building common areas?	Electrification opportunity
(If existing ductwork in need of replacement) Suspected asbestos remediation needed for duct replacement?	Electrification opportunity
Efficiency of heating system supplying building common areas (e.g., AFUE, HSPF)	Electrification opportunity
Age of heating system supplying building common areas	Electrification opportunity
Electrical service of heating system supplying building common areas (voltage/amperage) (if PTAC)	Electrification opportunity
Is there sufficient electrical capacity for heat pump replacement equipment?	Identification of electrification barriers

Data Item	Purpose
Does the electrical panel have a dedicated breaker per equipment needed to serve each room/space?	Identification of electrification barriers
Air conditioning system details—residential units	
Location (in-unit or central) of cooling system supplying residential units	Electrification opportunity
Type of cooling system supplying residential units	Electrification opportunity
Efficiency of cooling system supplying residential units (e.g., EER, SEER)	Electrification opportunity
Age of cooling system supplying residential units	Electrification opportunity
Air conditioning system details—common areas (if different from residential units)	
Type of cooling system supplying building common areas	Electrification opportunity
Efficiency of cooling system supplying building common areas (e.g., EER, SEER)	Electrification opportunity
Age of cooling system supplying building common areas	Electrification opportunity
Potential HVAC electrification opportunities	

Data Item	Purpose
Is there enough space under the windows and an outlet available for a PTHP?	Electrification opportunity
Is a VRF system an option to provide HVAC for both common area and apartment loads together?	Electrification opportunity
Is there an opportunity to use a heat pump chiller to provide HVAC and DHW?	Electrification opportunity
Is there a reason to remove apartment loads from the central system and move it onto the tenant meter?	Electrification opportunity
Is there a reason to move to unitized HVAC for common areas?	Electrification opportunity
Thermostat type	
Type	Electrification opportunity
Set point	Electrification opportunity
Is building wired for high-speed internet connection capable of Wi-Fi signal in residential units?	Electrification opportunity
DHW details	
Unitized systems or central plant for DHW	Electrification opportunity
Fuel used	Electrification opportunity
Type	Electrification opportunity

Data Item	Purpose
Efficiency	Electrification opportunity
Age	Electrification opportunity
Space constraints for HPWH	Identification of electrification barriers
Ventilation needs for HPWH	Identification of electrification barriers
If central plant, is it one plant per building, one plant feeding multiple buildings, or multiple plants per building?	Feasibility to reconfigure for electrification
If central plant, where is the plant located?	Feasibility to reconfigure for electrification
If central plant, are the tie-ins to each building exposed/known?	Feasibility to reconfigure for electrification
Is there underground piping? Is that piping insulated?	Identification of system issues
Are there balancing valves at the end of the risers?	Electrification opportunity
Is there a recirculation loop? Can it be eliminated?	Electrification opportunity
Is there sufficient panel capacity for electrification? Is the electrical service 3-phase?	Identification of electrification barriers
Is there a 240V, 30A line and circuit available in the installation location? 120V, 15-20A?	Identification of electrification barriers

Data Item	Purpose
Would a load study need to be conducted for electrification potential?	Identification of electrification barriers
If potential HPWH location is the roof, would a structural assessment be needed?	Identification of electrification barriers
Is the DHW distribution piping insulated?	Identification of electrification barriers
Would HPWH equipment noise be a concern?	Identification of electrification barriers
Cooking appliance details	
Fuel used by oven	Electrification opportunity
Age of oven	Electrification opportunity
Fuel used by cooktop/stove	Electrification opportunity
Age of cooktop/stove	Electrification opportunity
Cooktop/stove is induction?	Electrification opportunity
Availability of 240V plug	Identification of electrification barriers
Availability of 50A for cooking range/oven outlet	Identification of electrification barriers
4-wire configuration for cooking range/oven outlet	Identification of electrification barriers
Kitchen hood vented outdoors? (if present)	Electrification opportunity/program area of interest
Clothes dryers—in-unit	
Fuel used	Electrification opportunity

Data Item	Purpose
Age	Electrification opportunity
Efficiency certification (e.g., Energy Star)	Electrification opportunity
Availability of drain for condensate	Identification of electrification barriers
Availability of 240V plug	Identification of electrification barriers
Clothes dryers—common area	
Fuel used	Electrification opportunity
Number of clothes dryers	Electrification opportunity
Age	Electrification opportunity
Efficiency certification (e.g., Energy Star)	Electrification opportunity
Availability of drain for condensate	Identification of electrification barriers
Availability of 240V plug	Identification of electrification barriers
Windows—main living space	
Type (e.g., slider, single-hung, double-hung, awning, casement)	Identification of electrification barriers
Are windows slated for replacement?	Identification of electrification barriers
Is there an outlet located within suitable distance from window for an in-window heat pump installation?	Identification of electrification barriers
Windows—bedroom (if different from main living space)	

Data Item	Purpose
Type (e.g., slider, single-hung, double-hung, awning, casement)	Identification of electrification barriers
Are windows slated for replacement?	Identification of electrification barriers
Is there an outlet located within suitable distance from window for an in-window heat pump installation?	Identification of electrification barriers
Building envelope details	
Exterior wall material	Load reduction possibilities
Interior wall material	Load reduction possibilities
Wall Insulation present?	Load reduction possibilities
Roof insulation present?	Load reduction possibilities
Does the property have flat roofs?	Electrification opportunity/interest of CalNEXT
Type Roof of insulation	Load reduction possibilities
Electricity service	
Meter configurations (master, direct, submeter)	Identification of electrification barriers
Does unit have its own panel/subpanel located within the unit?	Electricity service constraints/pre-electrification needs
Panel capacity	Electricity service constraints/pre-electrification needs
Are there fuse boxes?	Electricity service constraints/pre-electrification needs

Data Item	Purpose
Would the electrical panels in the units need to be relocated during alterations? Under stairs, in a closet, <36" of forward clearance, <30" of side clearance, <78" of height clearance.	Electricity service constraints/pre-electrification needs
Is there more than 3' between gas and electric meter?	Electricity service constraints/pre-electrification needs
Type Roof of insulation	Load reduction possibilities
Affordable housing details	
Fully affordable vs mixed income	Building typology/characterization
Is there a property-based subsidy (e.g., LIHTC) at the building?	Assessing program/regulatory barriers
Are there utility allowances at property?	Assessing program/regulatory barriers
If there are utility allowances at property, what method is used to set the utility allowance?	Assessing program/regulatory barriers

Appendix B: Demographic Analysis

This appendix provides additional demographic analysis of LMI households that reside in multifamily buildings, statewide using 2021 ACS PUMS data and by MSA using 2021 AHS PUF data.

Table 24: Statewide LMI Households Residing in Multifamily Buildings by Poverty Level

Poverty Level	Number of Households	Percent
At or below 100% HHSPG	539,466	28%
101-150% HHSPG	270,102	14%
151-200% HHSPG	267,684	14%
201-250% HHSPG	223,737	11%
251-300% HHSPG	191,606	10%
301-350% HHSPG	144,721	7%
351-400% HHSPG	125,071	6%
Greater than 400% HHSPG	191,286	10%
Total	**1,953,673**	**100%**

Source: 2021 ACS PUMS

Table 25: LMI Households Residing in Multifamily Buildings by Poverty Level by MSA

HHSPG Level	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	1,095,619	152,855	309,409	88,368
At or below 100% HHSPG	28%	27%	23%	30%
101-150% HHSPG	13%	11%	11%	9%

HHSPG Level	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
151-200% HHSPG	14%	12%	11%	9%
201-250% HHSPG	11%	12%	7%	11%
251-300% HHSPG	7%	13%	4%	9%
301-350% HHSPG	9%	9%	8%	8%
351-400% HHSPG	7%	7%	6%	7%
Greater than 400% HHSPG	11%	9%	31%	17%
Total	100%	100%	100%	100%

Source: 2021 AHS PUF

Table 26: Statewide LMI Households Residing in Multifamily Buildings by AMI Level

AMI Level	Number of Households	Percent
At or below 30% AMI	850,235	44%
31-50% AMI	495,229	25%
51-80% AMI	599,998	31%
Greater than 80% AMI	8,211	<1%
Total	1,953,673	100%

Source: 2021 ACS PUMS

Table 27: LMI Households Residing in Multifamily Buildings by AMI Level by MSA

AMI Level	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	1,095,619	152,855	309,409	88,368
At or Below 30% AMI	50%	44%	50%	53%
31-50% AMI	24%	30%	23%	28%
51-80% AMI	26%	26%	27%	19%
Total	**100%**	**100%**	**100%**	**100%**

Source: 2021 AHS PUF

Table 28: Statewide LMI Households Residing in Multifamily Buildings by Housing Tenure (Owner/Renter Status)

Housing Tenure	Number of Households	Percent
Rented	1,803,733	92%
Owned	123,325	6%
Occupied without payment of rent	26,615	1%
Total	**1,953,673**	**100%**

Source: 2021 ACS PUMS

Table 29: LMI Households Residing in Multifamily Buildings by Housing Tenure (Owner/Renter Status) by MSA

Ownership Type	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	1,095,619	152,855	309,409	88,368
Rented	94%	95%	87%	92%
Owned	5%	4%	10%	6%
Occupied without payment of rent	1%	1%	2%	1%
Total	100%	100%	100%	100%

Source: 2021 AHS PUF

Table 30: Statewide LMI Households Residing in Multifamily Buildings by Vulnerable Household Members

Presence of Vulnerable Members in Household	Number of Households	Percent
Young child under six years old	246,021	13%
Household member under 18 years old	550,392	28%
Elderly household member 60 years or older	665,793	34%
Households with any child (under 18 years old) or elderly member (60 years or older)	1,168,537	60%

Source: 2021 ACS PUMS

Table 31: LMI Households Residing in Multifamily Buildings by Vulnerable Household Members by MSA

Ownership Type	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	1,095,619	152,855	309,409	88,368
Young child under six years old	10%	18%	8%	9%
Household member under 18 years old	31%	37%	22%	26%
Elderly household member 60 years or older	30%	27%	43%	35%
Households with any child (under 18 years old) or elderly member (60 years or older)	59%	63%	63%	59%

Source: 2021 AHS PUF

Table 32: Statewide LMI Households Residing in Multifamily Buildings by Household Language

Household Language	Number of Households	Percent
English only	933,718	48%
Spanish	630,499	32%
Other Indo-European languages	136,135	7%

Household Language	Number of Households	Percent
Asian and Pacific Island languages	210,587	11%
Other languages	42,734	2%
Total	**1,953,673**	**100%**

Source: 2021 ACS PUMS

Table 33: Statewide LMI Households Residing in Multifamily Buildings that are Limited English-Speaking Households by Household Language

Household Language	Not Limited English-Speaking Household	Limited English-Speaking Household
English only	100%	0%
Spanish	72%	28%
Other Indo-European languages	60%	40%
Asian and Pacific Island languages	52%	48%
Other languages	72%	28%
Total	**82%**	**18%**

Source: 2021 ACS PUMS

Table 34: Statewide LMI Households Residing in Multifamily Buildings by Race and Ethnicity (Hispanic Origin)

Race of Householder	Non-Hispanic	Hispanic	Total
White only	32%	4%	36%
Black or African American only	11%	<1%	12%
Asian only	14%	<1%	14%

Race of Householder	Non-Hispanic	Hispanic	Total
Alaska Native and/or American Indian	<1%	1%	1%
Native Hawaiian or Pacific Islander alone	<1%	<1%	<1%
Some other race alone	1%	19%	20%
Two or more races	4%	12%	16%
Total	**62%**	**38%**	**100%**

Source: 2021 ACS PUMS

Table 35: Statewide LMI Households Residing in Multifamily Buildings by Housing Burden (Percent of Income Spent on Housing Costs)

Housing Burden	Number of Households	Percent
Not housing cost burdened (housing costs <30% of income)	476,666	24%
Housing cost burdened (housing costs 30-50% of income)	594,764	30%
Extremely housing cost burdened (housing costs >50% of income)	882,243	45%
Total	**1,953,673**	**100%**

Source: 2021 ACS PUMS

Table 36: LMI households Residing in Multifamily Buildings by Housing Cost Burden (Percent of Income Spent on Housing Costs) by MSA

Ownership Type	Los Angeles-Long Beach-Anaheim, CA MSA	Riverside-San Bernardino-Ontario, CA MSA	San Francisco-Oakland-Hayward, CA MSA	San Jose-Sunnyvale-Santa Clara, CA MSA
Total Households	1,095,619	152,855	309,409	88,368
Not housing cost burdened (housing costs <30% of income)	23%	27%	35%	12%
Housing cost burdened (housing costs 30-50% of income)	27%	32%	32%	34%
Extremely housing cost burdened (housing costs >50% of income)	50%	41%	33%	54%
Total	**100%**	**100%**	**100%**	**100%**

Source: 2021 AHS PUF

Table 37: Statewide LMI Households in Multifamily Buildings by AMI Level and Housing Cost Burden (Percent of Income Spent on Housing Costs)

AMI Level	Not Housing Cost Burdened (Housing Costs <30% of Income)	Housing Cost Burdened (Housing Costs 30-50% of Income)	Extremely Housing Cost Burdened (Housing Costs >50% of Income)	Total
At or below 30% AMI	20%	12%	68%	100%
31-50% AMI	15%	39%	46%	100%
51-80% AMI	37%	50%	13%	100%
Greater than 80% AMI	86%	12%	2%	100%
Total	**24%**	**30%**	**45%**	**100%**

Source: 2021 ACS PUMS