Mobile and Manufactured Housing Market Characterization Study

Final Report

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Executive Summary

Manufactured housing is an important source of affordable housing. However, despite lower upfront purchase costs compared to site-built homes, residents of manufactured homes face greater energy insecurity, higher energy costs per square footage, and higher housing cost burdens than residents of other housing types (Kaul and Pang 2022, Bell-Pasht 2023). Codes that regulate the construction and efficiency of manufactured housing lag behind energy efficiency codes implemented for site-built construction, and while there is increasing demand for new, higher efficiency options in manufactured housing, existing homes often are inefficient.

As California pursues decarbonization and electrification goals, retrofitting manufactured housing with energy efficiency and electrification measures presents an opportunity for residents and utilities to save energy and reduce emissions, but gaps exist for understanding the market and technical potential. The purpose of this study is to gain a better understanding of the existing stock of manufactured homes in California, identify barriers and opportunities to electrification and energy efficiency retrofits, and identify where whole-home replacement may be a better option than an electrification retrofit. To address these gaps, this project assessed the characteristics of manufactured housing and residents in California; reviewed existing program offerings, permitting processes, codes and standards regulating existing and new manufactured homes; identified electrification retrofit measure packages; and assessed potential energy savings, bill impacts, peak demand, and greenhouse gas impacts of all-electric retrofit scenarios and high-performance new construction standards. This information was gathered and developed through secondary research, analysis of public datasets, stakeholder interviews, and energy modeling.

Summary of Housing and Household Characteristics

- Three-quarters of manufactured housing in California are located in a hot-dry climate zone (U.S. Census Bureau 2022).
- Most manufactured housing in California is located in mobile home parks, which have over 350,000 individual lots. Most of these mobile home parks are large – over 68 percent have more than 100 individual lots (DHS 2023).
- Most mobile home parks are master-metered, and homes located in the parks typically have less than 100A electrical service (stakeholder discussions).
- More than half of manufactured housing in California was built before 1980, roughly equivalent to the period before federal codes were implemented to regulate the construction standards of manufactured housing (U.S. Census Bureau 2022).
- Residents of manufactured housing in California typically use gas heat or electric resistance heating (U.S. Census Bureau 2022). Air conditioning equipment is common. Ducted systems for heating and cooling are more common in newer units constructed after 2000 (EIA 2023a).
- Gas is used for water heating in over 90 percent of manufactured housing in the state, and water heater storage tanks typically are small or medium in size (less than 50 gallons) (EIA 2023a).

- As a group, residents of manufactured housing are lower income than average. Over 40 percent have income at or below 200 percent of the poverty guidelines, and over half qualify as low-income under the eligibility guidelines for the Family Electric Rate Assistance (FERA) program (U.S. Census Bureau 2022).
- Most residents of manufactured housing own their homes. However, many lease and do not own their land. Manufactured housing residents face higher average energy burdens than residents in single-family detached homes. Nearly 40 percent of residents in manufactured housing are housing cost burdened (spending 30 percent or more of their income on housing costs) (U.S. Census Bureau 2022).

Summary of Barriers and Opportunities for Electrification of Manufactured Housing

- The U.S. Department of Housing and Urban Development (HUD) Code regulating construction of manufactured homes preempts setting more stringent minimum efficiency standards, and updates to the HUD Code have lagged behind energy code efforts relevant to site-built homes.
- Voluntary above-code standards, regional electrification efforts, and anticipated new federal minimum standards are helping to push newly constructed manufactured housing to higher efficiency levels and all-electric models.
- Master metering in mobile home parks creates a complicated split incentive issue even though most manufactured housing residents own their homes. There is a long waiting list for mobile home parks to be converted from master-metering to individually metered lots.
- Efforts have been made to prioritize mobile home parks for utility metering conversion, and this presents an opportunity to target communities with retrofits as utility infrastructure is upgraded.
- Mobile home parks and individual manufactured housing units are aging, and it is challenging to retrofit older homes built before HUD regulations due to structural limitations, minimal insulation, and small compartments for equipment. Electrical service to manufactured homes often is limited to 30A to 100A, electrical panels need upgrading, and electrical wiring often is outdated.
- Energy modeling results and stakeholder discussions indicate that electrification retrofits could be a viable pathway forward for existing housing built to HUD Code standards if structural barriers are not present or have previously been remediated and the homes have been weatherized properly.
- A major barrier to electrifying this market segment is that residents typically have limited income, and the nature of manufactured housing (typically considered personal property not real property) can limit access to low-cost financing to make upgrades to homes.

Key Recommendations and Considerations for Stakeholders

- Revisit measures available to manufactured housing through existing IOU programs and consider whether it is appropriate to use new baselines that are more realistic to the stock of manufactured housing for deciding which measures to include.
- Reclassify IOU programs serving manufactured housing residents as equity-focused programs serving low-income populations and ease cost-effectiveness requirements.
- Increase the pace of converting master-metered mobile home parks to individually metered electric utilities.
- Establish a 200A electrical service minimum standard in the Mobile Home Park Utility Conversion Program to help ease future challenges associated with electrifying manufactured housing in mobile home parks.
- Conduct a field demonstration of panel upgrade alternatives for manufactured housing units that have been converted to 100A service.
- Better coordinate IOU program offerings with statewide low-income weatherization and energy efficiency programs.
- Incentivize high-efficiency new manufactured homes and incorporate early retirement of structurally unsound and inefficient manufactured homes with replacement.
- Utilize the decision model resulting from this research in a pilot to prioritize segments of the market for electrification retrofits and replacement opportunities.
- Refine energy savings estimates and other modeling impacts by working with the WAP or other programs serving this market segment to understand actual energy usage in MMH units. The asset-based prototype modeling conducted for this report assumes average efficiency characteristics across each vintage and standard occupant behavior. It is meant to be illustrative of the potential impacts of electrification and energy efficiency improvements in MMH units and may not reflect actual operating conditions. Using actual energy use data from MMH units treated with comprehensive weatherization measures through the WAP or other programs will help refine the estimated impacts for this market.
- Engage manufactured housing residents through multiple channels and strategies found to be effective by program implementers and others including gaining mobile home park owner/manager buy-in, leveraging partnerships with community-based organizations, providing clear messaging and coordinated program offerings, and supporting the development and use of local workforce.

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Abbreviations and Acronyms

Acronym	Meaning
ACS	American Community Survey
AHS	American Housing Survey
AMI	Area Median Income
ASHP	Air Source Heat Pump
Btu	British Thermal Unit
CA RASS	California Statewide Residential Appliance Saturation Survey
CARE	California Alternate Rates for Energy Program
CFR	Code of Federal Regulations
CPUC	California Public Utilities Commission
CSD	California Department of Community Services and Development
DAC	Disadvantaged Communities
DOE	U.S. Department of Energy
EIA	Energy Information Administration
EISA	Energy Independence and Security Act of 2007
ESMH	ENERGY STAR for Manufactured Homes
EUI	Energy Use Intensity
FERA	Family Electric Rate Assistance Program
GHG	Greenhouse Gas
GWP	Global Warming Potential
HCD	California Department of Housing & Community Development
HHS	U.S. Department of Health and Human Services

Acronym	Meaning
HHSPG	HHS Poverty Guidelines
HPWH	Heat Pump Water Heater
HSC	Health and Safety Code
HTR	Hard-to-Reach
HUD	U.S. Department of Housing and Urban Development
IECC	International Energy Conservation Code
IOU	Investor-Owned Utility
LEAD	Low-Income Energy Affordability Data Tool
LIHEAP	Low-Income Home Energy Assistance Program
LIWP	Low-Income Weatherization Program
MMBtu	Million British Thermal Units
MHP-UCP	Mobile Home Park Utility Conversion Program
MMH	Mobile and Manufactured Homes
MORE	Manufactured Housing Opportunity & Revitalization Program
NEEM	Northwest Energy-Efficient Manufactured Housing
NREL	National Renewable Energy Laboratory
OEHHA	California Office of Environmental Health Hazard Assessment
PG&E	Pacific Gas & Electric
PUMS	Public Use Microdata Sample
RECS	Residential Energy Consumption Survey
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SFD	Single Family Detached Homes

Acronym	Meaning
TBtu	Trillion British Thermal Units
TRM	Technical Reference Manual
Uo	Overall Coefficient of Heat Transmission
WAP	Weatherization Assistance Program
ZERH	Zero Energy Ready Homes
ZERH MH	Zero Energy Ready Homes for Manufactured Housing

Introduction

Manufactured housing is an important source of affordable housing. Upfront costs of manufactured housing are significantly less than site-built housing (Kaul and Pang 2022). Yet residents of manufactured homes experience greater incidence of energy insecurity, higher energy costs per square footage, and higher housing cost burdens than other types of housing (Bell-Pasht 2023). Codes that regulate the construction and efficiency of manufactured housing lag behind energy efficiency codes implemented for site-built construction. While there is increasing demand for new, higher efficiency options in manufactured housing, existing homes often are inefficient. As California pursues decarbonization and electrification goals, this presents an opportunity for utility programs to save energy and reduce emissions by retrofitting existing manufactured housing. However, gaps exist for understanding the market and technical potential of energy efficiency and decarbonization retrofits in existing manufactured housing in California.

To address these gaps, this project assessed the characteristics of manufactured housing and residents in California including distribution by year built, baseline equipment, fuel types, geography/climate zone, ownership status, and affordability challenges. It also examined existing programs, permitting processes, codes and standards, and manufacturer landscape. Barriers to energy efficiency and electrification efforts in this housing stock were identified, as well as opportunities going forward.

Background

Manufactured housing units are regulated by the U.S. Department of Housing and Urban Development (HUD), with regulations first introduced in 1976. Manufactured homes constructed before HUD regulations went into effect commonly are referred to as mobile homes while those constructed in accordance with HUD regulations referred to as manufactured homes. For purposes of this report, mobile and manufactured housing (MMH) are referred to as a single group with differences noted where relevant based on the vintage group (year built).

There are approximately 500 thousand total MMH units in California (440 thousand occupied as primary residences with the remainder unoccupied or secondary/seasonal residences) (U.S. Census Bureau 2022). This represents about three percent of the housing stock statewide. Most of these homes are heated by natural gas (57 percent), followed by electricity (26 percent), propane (nine percent), wood (four percent), other fuels (two percent), or no heating fuel (three percent) (U.S. Census Bureau 2022).[1] Residents of MMH of MMH units are lower income compared to residents in single-family detached homes (U.S. Census Bureau 2022), and MMH units have much higher energy use intensities (EUI) – energy use per square foot– than other building types: in California, EUI of MMH units is estimated to be 40 percent higher than that of single-family detached (SFD) homes (Reyna et al. 2022).

[1] Percentages sum to more than 100% due to rounding. Other heating fuels include fuel oil/kerosene, solar, and “other heating fuels” as defined in the American Community Survey.

The California Public Utilities Commission (CPUC) designates MMH residents as a hard-to-reach (HTR) market segment (CPUC 2020). Existing investor-owned utility (IOU) energy efficiency retrofit programs for MMH in California include measures such as pipe wrapping, brushless fan motor replacement, refrigerant charge adjustment and tune-up, and installation of ENERGY STAR-rated products, including lighting, low-flow showerheads, and aerators. Other statewide programs, like the Energy Savings Assistance (ESA) Program, Weatherization Assistance Program (WAP) and Low-Income Weatherization Program (LIWP) for Farmworker Housing, provide more comprehensive weatherization measures and mechanical equipment. However, these programs are not specific to MMH units and limited to income-qualified residents with different requirements for each program. With the state's increased focus on decarbonization, and technical, economic, and policy barriers to electrification in the MMH market sector, residents in existing MMH units are unlikely to be able to fully contribute to the state's goals without intervention.

Objectives

The purpose of this study is to gain a better understanding of the existing stock of MMH in California, identify barriers and opportunities to electrification and energy efficiency retrofits, and identify when whole-home replacement options may be better investments. This was accomplished by examining public datasets and secondary research characterizing MMH in California, engaging stakeholders to fill in data gaps and identify barriers and opportunities, and conducting energy modeling to demonstrate the impacts of electrification and energy efficiency measures in MMH units segmented by key characteristics of the building stock.

This project helps to identify the characteristics of MMH units where electrification retrofits likely are feasible and the decarbonization and energy efficiency technology solutions relevant for this market sector (e.g., heat pump space conditioning and water heating, recovery ventilation, and solar plus storage). The project also identifies the regulations affecting this market sector and how those regulations fit into the electrification landscape.

Outcomes of this project include:

- Comprehensive information on the MMH sector to fill gaps in existing market studies and provide more targeted details on the housing characteristics of MMH units relevant to electrification technologies.
- Documentation of technical, economic, and policy barriers relevant to decarbonization and energy efficiency programs for the MMH market sector.
- Identification of high priority technologies for MMH units.
- Guidance for program administrators that currently target or are interested in this market sector.
- Potential savings estimates for multiple all-electric package scenarios including whole home replacement.

Methodology & Approach

This project involves two main components intended to lead to the development of program recommendations for the MMH sector:

1. Market Characterization
2. Energy Modeling

Market Characterization

The Market Characterization consisted of four primary components:

- Literature review of existing MMH market studies, technical evaluations, and other published resources to develop a baseline of what is already known about the MMH market in California, including relevant codes and standards and existing energy-related programs.
- Analysis of public data sources to assess the geographic distribution of MMH, Disadvantaged Communities (DAC) versus non-DAC locations, park versus non-park locations, physical characteristics of MMH units, typical energy costs and energy burdens, and tenant demographics and ownership structures. An overview of the public data sources used in this project is included below.
- Outreach and interviews with key stakeholders to confirm our understanding of the MMH market and identify characteristics they have found to be opportunities or barriers for decarbonization and energy efficiency efforts.
- Analysis of additional reports and program information obtained during stakeholder outreach were used to validate or adjust assumptions made for the energy modeling component of the project.

Public Datasets & Resources

The following public datasets and resources were used as part of the market characterization:

- American Community Survey (ACS) data from the U.S. Census Bureau. Both the Public Use Microdata Sample (PUMS) file and Detailed (Summary) Tables were used in this project to examine MMH units statewide and regionally within the state, respectively.[2,3] The primary ACS data used come from the 2021 ACS PUMS to show customized statewide estimates developed by the project team. Published estimates from the five-year 2017-2021 ACS Detailed Tables were combined with other data sources by the project team to show regional estimates for climate zones within California. For analysis of MMH by DAC areas, the published estimates from the five-year 2015-2019 ACS Detailed Tables file were used to align with the vintage of the census tract geographies available in the DAC data file.
- ResStock Analysis Tool created and supported by the National Renewable Energy Laboratory (NREL) provides data and visualizations on energy use and equipment in the residential

[2] More information on the ACS PUMS is available at: https://www.census.gov/programs-surveys/acs/microdata.html

[3] More information on the ACS Detailed Table is available at: https://www.census.gov/programs-surveys/acs/data/data-tables.html

housing stock by state, housing type, climate zone, vintage, and other factors in a customizable way. Metadata from the Typology[4] residential segments December 2022 Update, End Use Load Profile (EULP) 2021.1 Release and End Use Savings Shapes (EUSS) 2022.1 Release were used in this research.[5]

- CalEnviroScreen DACs (version 4.0) census tract file from the California Office of Environmental Health Hazard Assessment (OEHHA) was used in combination with the 2015-2019 ACS Detailed Table data on MMH units by census tract to analyze the size of the MMH market located within DACs.[6]
- Homeland Infrastructure Foundation-Level Data (HILFD) Open Data from the U.S. Department of Homeland Security (DHS) were used to assess mobile home park sizes and locations in California. The HILFD Open Data on mobile home parks were last updated in May 2022.[7]
- Low-Income Energy Affordability Data (LEAD) Tool from the U.S. Department of Energy (DOE). The LEAD Tool provides average energy bill and burden estimates for residential households by state, census tract, housing characteristics, and household demographics. The current version of the LEAD Tool uses data from the 2020 ACS PUMS.[8]
- Residential Energy Consumption Survey (RECS) from the Energy Information Administration (EIA) at the U.S. DOE. The RECS provides detailed energy use characteristics of residential households by state, including heating, cooling, hot water, and appliance equipment types. The 2020 RECS public use microdata were used in this analysis.[9]
- American Housing Survey (AHS) from the U.S. Census Bureau. Data from the 2021 AHS public use file were used to examine energy efficiency improvements made by MMH residents in available metropolitan areas.[10]
- California Statewide Residential Appliance Saturation Survey (CA RASS) from the California Energy Commission (CEC) and DNV. The CA RASS provides detailed estimates of energy equipment and appliances used by MMH residents by IOU service area, climate zone, and other factors. Data from the 2019 CA RASS were used in this analysis.[11]

Stakeholder Engagement

To ensure broad perspectives inform this study and develop a more complete understanding of the MMH market in California, the project team conducted extensive stakeholder engagement. The project team first analyzed the MMH landscape in California to identify relevant stakeholders with demonstrated experience in the state's MMH market. Stakeholders were divided into seven primary industry sectors: state agency, utility, program implementer, manufacturer, manufactured housing

[4] More information on the U.S. Building Typology Segmentation Residential interactive data tool is available at: https://public.tableau.com/app/profile/nrel.buildingstock/viz/USBuildingTypologyResidential/Segments

[5] More information on the ResStock metadata is available at: https://resstock.nrel.gov/datasets

[6] More information on the CalEnviroScreen platform is available at: https://oehha.ca.gov/calenviroscreen

[7] More information on the HILFD Open Data platform is available at: https://hifld-geoplatform.opendata.arcgis.com/

[8] More information on the LEAD Tool is available at: https://www.energy.gov/scep/slsc/lead-tool

[9] More information on the RECS is available at: https://www.eia.gov/consumption/residential/data/2020/

[10] More information on the AHS is available at: https://www.census.gov/programs-surveys/ahs.html

[11] More information on the CA RASS is available at: https://webtools.dnv.com/CA_RASS/Default.aspx

trade organization, mobile home park, and other organizations that have led projects or conducted research for the MMH sector. Next, the project team identified where gaps exist in the available public data and existing research and prioritized stakeholders who could help to fill in those gaps.

Utilizing existing networks, the project team conducted outreach to the targeted stakeholders through emails and phone calls to set up in-depth interviews. Interviews typically lasted one hour, and multiple follow-up attempts were made to reach the targeted stakeholders to ensure their perspectives factored into the research. The project team used the learnings from each interview to inform subsequent interviews and identify whether engagement of other stakeholders not identified at the start would be needed. Questions were tailored to each stakeholder but generally covered the following topics:

- Codes that promote or hinder electrification efforts in MMH.
- Existing programs targeting MMH including electric IOU programs, utility service upgrade programs, and statewide weatherization/energy efficiency and electrification programs.
- Technical and nontechnical barriers and opportunities to electrification and energy efficiency of MMH.
- Outreach strategies used to reach MMH occupants and mobile home parks.

Table 1 shows the stakeholders interviewed during this research and provide an overview of their role within the MMH market in California. In addition to external stakeholders identified below, the project team consulted with internal experts with decades of experience retrofitting MMH units in other locations in order to better understand the barriers and opportunities associated with weatherizing and electrifying MMH units.

Table 1: Interview Status for Targeted Stakeholders[12]

Stakeholder / Stakeholder Group	Type	Role with MMH in California
Synergy Companies	Program Implementer	Implementer of MMH energy efficiency programs in California; perspectives on existing MMH program, experience with opportunities and challenges to efficiency and decarbonization in MMH market sector

[12] The project team also conducted outreach with PG&E staff about their existing energy efficiency program for MMH (Direct Install for Mobile and Manufactured Homes Program) and master meter conversion program for mobile home parks but did not receive a response.

Stakeholder / Stakeholder Group	Type	Role with MMH in California
Staples Energy	Program Implementer	Implementer of MMH energy efficiency programs in California; perspectives on existing MMH program, experience with opportunities and challenges to efficiency and decarbonization in MMH market sector
California Department of Housing and Community Development (HCD)	State Agency	State oversight of MMH including titling, registration, inspection, and enforcement; knowledge of existing opportunities and challenges to efficiency and decarbonization in MMH market sector
California Department of Community Services and Development (CSD)	State Agency	State oversight of WAP and LIWP comprehensive energy efficiency programs for low-income residential housing including MMH units; knowledge of existing opportunities and challenges to efficiency and decarbonization in MMH market sector
CPUC	State Agency	State oversight of utilities including ensuring access to safe, clean, and affordable energy utility services and infrastructure; oversight of master meter conversion program for mobile home parks; knowledge of existing opportunities and challenges to efficiency and decarbonization in MMH market sector
California Energy Commission (CEC)	State Agency	State energy policy and planning agency including regulation of building energy codes; knowledge of existing opportunities and challenges to efficiency and decarbonization in MMH market sector

Stakeholder / Stakeholder Group	Type	Role with MMH in California
The Ortiz Group	Mobile Home Research	CalNEXT partner, experience with MMH opportunities and challenges to efficiency and decarbonization through San Joaquin Valley DAC program
Southern California Edison (SCE)	IOU	Utility-perspective on existing MMH energy efficiency and utility conversion program offerings and feasibility of future offerings
San Diego Gas & Electric (SDG&E)	IOU	Utility-perspective on utility conversion program offerings and feasibility of future offerings
California Manufactured Housing Institute (CMHI)	Trade Organization	MMH trade organization with knowledge of baseline configurations and systems in existing MMH
Clayton	Manufacturer	MMH manufacturer with knowledge of existing units and direction market is going

Stakeholder / Stakeholder Group	Type	Role with MMH in California
Mobile Home Park Managers[13]	Mobile Home Park	Knowledge of existing housing stock, utility infrastructure challenges, uptake of existing programs, and demand for high-efficiency retrofits and new construction
TRC Companies	CalNEXT partner	Partner organization leading the Manufactured Housing Electrification Measure Development Support study (ET23SWE0029)

Source: Project Team

Energy Modeling

The purpose of the energy modeling is to understand the potential energy savings and utility bill impacts of retrofitting existing MMH units with electrification technologies, with and without comprehensive weatherization measures including floor/attic insulation, duct repair and insulation, and air sealing, to identify segments of the existing MMH housing stock best suited for retrofits. It also examines the potential energy savings and utility bill impacts associated with construction of new MMH units built to the updated HUD Code (2022 HUD) as well as more stringent voluntary energy efficiency standards such as ENERGY STAR and Zero Energy Ready Homes (ZERH) to assess the opportunity for whole-home replacement scenarios when retrofitting is not feasible.

Energy modeling for this study included two methods—building stock modeling and prototype modeling. The building stock modeling utilizes the public datasets from NREL's ResStock analysis tool. ResStock incorporates many public and private datasets to generate calibrated energy models representative of a given residential building stock. Using the ResStock analysis tool, NREL annually generates and publishes datasets that include both the housing characteristics assumptions that informed each model and the simulated results. Outputs include annual and timeseries energy and emissions data, as well as end use load profiles and savings shapes.

In the ResStock modeling method, the project team characterized the current state of energy use attributed to MMH in California by vintage bin and climate using NREL's published datasets. Building

[13] The project team received limited feedback from mobile home park owners/managers despite multiple outreach efforts and multiple modes (phone interviews, web meetings, written responses to questions sent in advance) being made available. Continued engagement of this stakeholder group is an important recommendation coming out of this research.

stock level potential savings were also summarized based on the End Use Savings Shapes dataset from ResStock. This dataset includes ten measure packages representing various weatherization and electrification strategies. This study analyzed five upgrade scenarios that were most applicable to this project.

Prototype energy modeling conducted for this study also draws on ResStock by utilizing the average housing characteristic data for each MMH vintage bin to create the prototype models. Prototype models were developed for three vintage bins representative of pre-HUD code homes (<1980), 1976-era HUD Code homes (1980-1999), and 1994-era HUD Code era homes (2000+). Average energy efficiency characteristics for each vintage bin were applied to standard size single- and multi-section MMH models. Energy simulations were run in four Building America climate zones where the majority of MMH in California are located: Hot-Dry, Mixed-Dry, Marine, and Cold. Average statewide utility rates were applied to estimate homeowner energy costs. Two upgrade scenarios were applied to each prototype model to assess savings potential for 'Weatherization + Electrification' and 'Electrification only' upgrade strategies. The prototype models were run using the OpenStudio and EnergyPlus open-source simulation platform.

A more detailed discussion of the energy modeling inputs, assumptions, and processes is provided in Appendix A: Technical Details of Prototype Energy Modeling.

Findings

The following findings are provided based on the literature review, analysis of public datasets and resources, stakeholder outreach, and energy modeling.

Characteristics of Mobile & Manufactured Housing in California

Overview

MMH represent about three percent of the housing units in California. Table 2 shows the breakdown of homes in California by housing unit type. There are roughly 500 thousand total MMH units, of which about 440 thousand are occupied as primary residences.[14]

Table 2: Number of Housing Units/Households in California by Housing Unit Type

Housing Unit Type	All Housing Units (Incl. Unoccupied)		Occupied Housing Units	
	Number	Percent	Number	Percent
Single family detached housing units	8,322,380	57%	7,806,282	58%
Single family attached housing units	1,080,956	7%	1,013,244	8%
Housing units in 2–4-unit buildings	1,120,164	8%	1,013,428	8%
Housing units in 5+ unit buildings	3,467,152	24%	3,134,682	23%
Mobile/manufactured homes	502,024	3%	441,962	3%
Other[15]	19,473	<1%	19,473	<1%
Total	**14,512,149**	**100%**	**13,429,071**	**100%**

Source: 2021 ACS PUMS

[14] Of the 60 thousand unoccupied MMH units in California, 45 percent are for seasonal/recreational use, and about one-quarter were for rent/sale or rented/sold but not occupied yet at the time of the ACS survey. The remaining third were unoccupied for various reasons including foreclosure, repair work, abandoned for demolition, and other reasons.

[15] Other housing units includes "boats, RVs, vans, etc." as reported in the ACS.

Based on analysis of ACS data combined with a list of census tracts designated as DACs by OEHHA, Figure 1 shows that approximately 28 percent of occupied MMH units are located in DACs.[16]

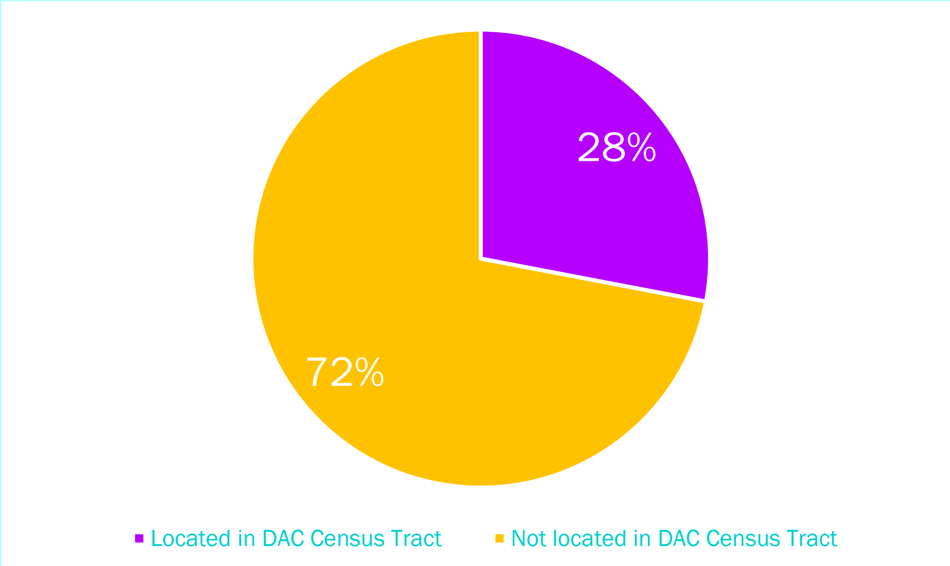

Figure 1: Share of occupied MMH units in California located in DACs.

Source: 2019 5-Year ACS Detailed Table 25032 combined with OEHHA CalEnviroScreen 4.0[17]

For purposes of compliance with HUD building standards for MMH units shipped to California, all of the state is located in HUD's climate zone 2. However, it is useful to consider a more detailed breakdown of the climate zones in California and where most MMH units are located. Figure 2 shows the share of MMH units in the state according to HUD, Building America, IECC, and the California Energy Commission's definitions of climate zones. In later sections of this report showing how energy usage varies and how measure upgrades include consumption, utility costs, peak load, and greenhouse gas emissions, the project team focuses on the Building America climate zones, which who that most MMH units in California are located in a hot-dry climate zone (75 percent of units) or marine climate zone (19 percent of units). A reference map from the California Energy Commission showing its breakdown of climate zones in California is provided in Figure 45 in Appendix C: Additional Information (CEC 2022).

[16] DACs are defined by CalEPA for the purpose of Senate Bill 535. More information on how CalEPA defines census tracts as DACs is available here: https://oehha.ca.gov/calenviroscreen

[17] CalEnviroScreen 4.0 is based on 2010 vintage census tract geographies. To match ACS data using the same vintage of census tract geographies, the 2019 ACS Detailed Table 25032 was used rather than the 2021 ACS, which is based on the 2020 vintage census tract geographies.

Share of MMH Units in California by Climate Zones							
HUD		Building America		IECC		California Energy Commission	
CZ	Share of MMH	CZ	Share of MMH	CZ	Share of MMH	CZ	Share of MMH
2	100%	Marine	19%	2B	1%	1	2%
		Hot-Dry	75%	3B	74%	2	5%
		Cold	2%	3C	17%	3	4%
		Mixed-Dry	4%	4B	4%	4	4%
				4C	1%	5	2%
				5B	2%	6	5%
				6B	<1%	7	3%
						8	6%
						9	6%
						10	17%
						11	8%
						12	12%
						13	7%
						14	5%
						15	7%
						16	6%

Figure 2: Share of MMH units in California by climate zone.[18]

Source: ResStock, 2021 5-Year ACS Detailed Table B25032 combined with California Energy Commission climate zone assignments by zip code

Mobile Home Parks

Most MMH units are in mobile home parks, defined in California as "any area of land or property that has at least two mobile homes *[sic]*, manufactured homes, recreational vehicles, and/or lots that are held out for rent or lease." (HCD 2023) Analysis of HILFD show there are 4,243 mobile home parks in California, in which there is a total of 351,801 MMH units. Los Angeles County has the largest number of mobile home parks (574) followed by San Diego County (345) and San Bernardino County (339). Table 36 in Appendix C: Additional Information provides the number of mobile home parks and units within those parks for each county in California.

Table 3 shows that of the 4,243 mobile home parks, 2,040 are considered small parks with less than 50 homes on site, 940 are considered medium size with between 50 and 100 homes, and 1,263 are considered large parks with over 100 homes on site. Figure 3 shows the geographic distribution of small, medium, and large mobile home parks in California.

[18] Cities indicated in parentheses are representative cities for the climate zone.

Table 3: Number of Mobile Home Parks and Units by Size of Mobile Home Parks in California

Size of Mobile Home Park	Mobile Home Parks		Units in Mobile Home Parks	
	Number	Percent	Number	Percent
Large (>100 units)	1,263	30%	238,081	68%
Medium (51-100 units)	940	22%	66,320	19%
Small (<50 units)	2,040	48%	47,400	13%
Total	**4,243**	**100%**	**351,801**	**100%**

Source: 2022 HIFLD Open Data

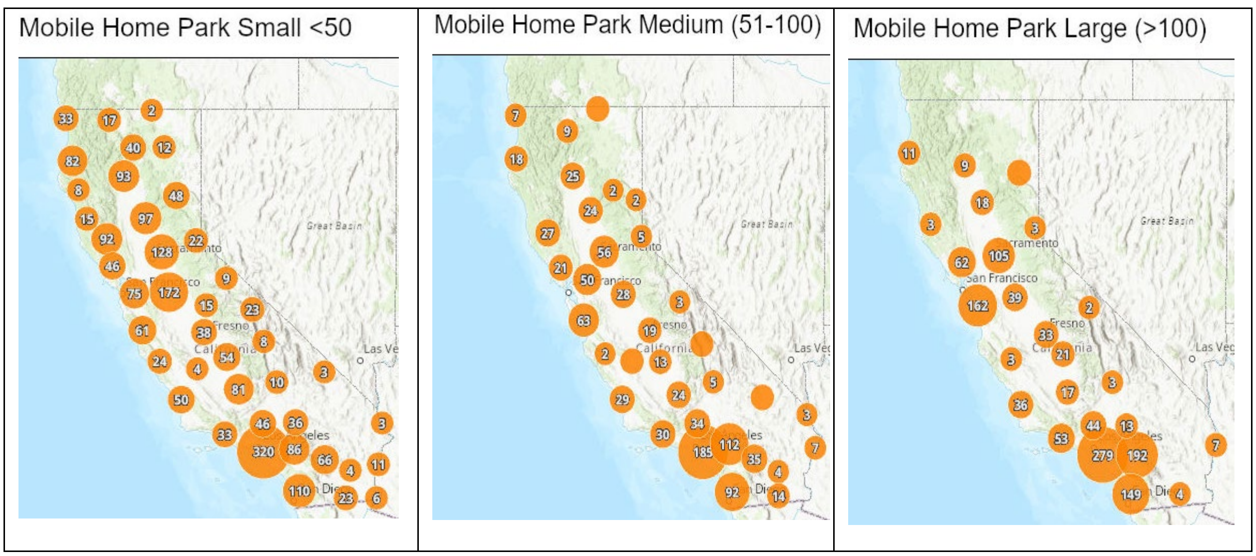

Figure 3: Location of small mobile home parks (less than 50 units).

Source: 2022 HIFLD Open Data; from left to right: small, medium, and large mobile home park locations.

Based on interviews with stakeholders, most mobile home parks have master metered utilities. In correspondence with the CPUC regarding the Mobile Home Park Utility Conversion Program (MHP-UCP), the CPUC noted that 1,987 of the parks in their program, containing 202,893 lots, report having a master meter electric system, and about 88 percent of those spaces report an electric installation before 1980. Table 4 shows the reported electrical service capacity to individual lots in these parks. Most lots have 100 A electrical service or less. The MHP-UCP and other programs relevant to MMH units are discussed more broadly in the section Existing Programs Serving MMH Residents

Table 4: Electrical Service Capacity to Lots in Master Metered Mobile Home Parks Enrolled in MHP-UCP

Reported Amperage to Lots in Master Meter Mobile Home Parks Enrolled in MHP-UCP	Share of Lots
Less than 100A	58%
100A	30%
Greater than 100A	2%
Not reported	10%

Source: Project Team correspondence with CPUC

Housing Characteristics

VINTAGE

Figure 4 shows the breakdown of occupied MMH units in California by building vintage. Over half of occupied MMH units in California were built before 1980, with over one-third built during the 1970s alone (when manufactured housing standards were implemented by the U.S. Department of Housing and Urban Development (HUD)). Among MMH units constructed more recently, a growing share has been built to voluntary higher performance standards. In 2020, approximately 27 percent of new MMH units sold in California were certified to ENERGY STAR specifications (SBRA 2020). While this is a sizeable portion of newly constructed manufactured homes in California, it trails behind the share of ENERGY STAR-certified manufactured homes sold in neighboring Oregon and Nevada, represent makes up approximately half of the new construction market for manufactured housing in those states.

Analysis of the 2021 AHS public use file for the San Jose-Sunnyvale-Santa Clara Metropolitan Statistical Area (MSA) and Riverside-San Bernardino-Ontario MSA indicate that almost 20 percent and 40 percent of MMH residents in those areas, respectively, made home improvements in the last two years to improve their energy efficiency. Due to small sample sizes in the AHS, these upgrades are not broken down by vintage.[19]

[19] Estimates for the Los Angeles-Long Beach-Anaheim MSA and San Francisco-Oakland-Hayward MSA are not provided due to small sample sizes in the 2021 AHS public use microdata.

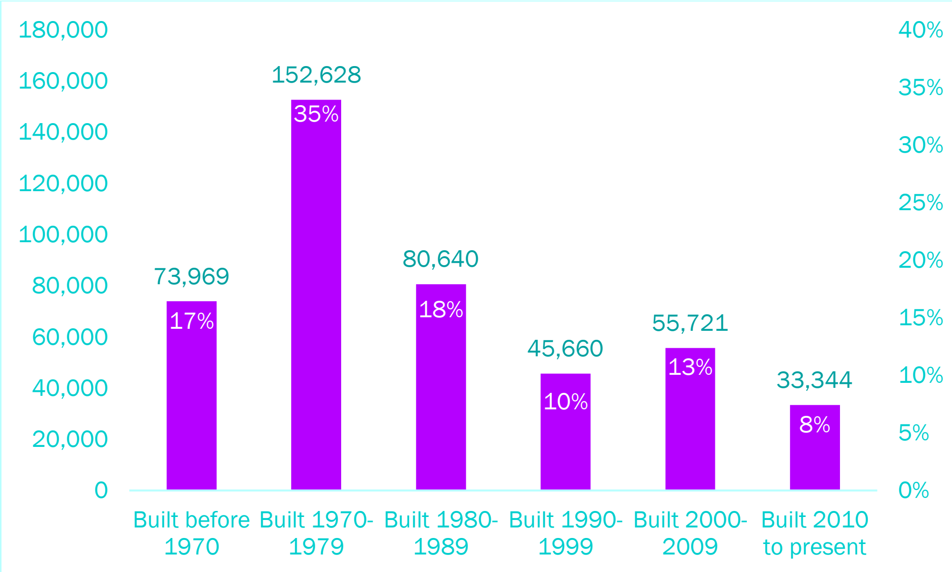

Figure 4: Occupied MMH units in California by year built (vintage).

Source: 2021 ACS PUMS

HOUSING SIZE

Figure 5 shows the distribution of size (square footage) of MMH units statewide. About 41 percent are less than 1,000 square feet in size. Analysis of the 2019 CA RASS data shows that the average size of individually metered MMH units is about 1,300 square feet and relatively consistent across vintage groups (DNV 2021).

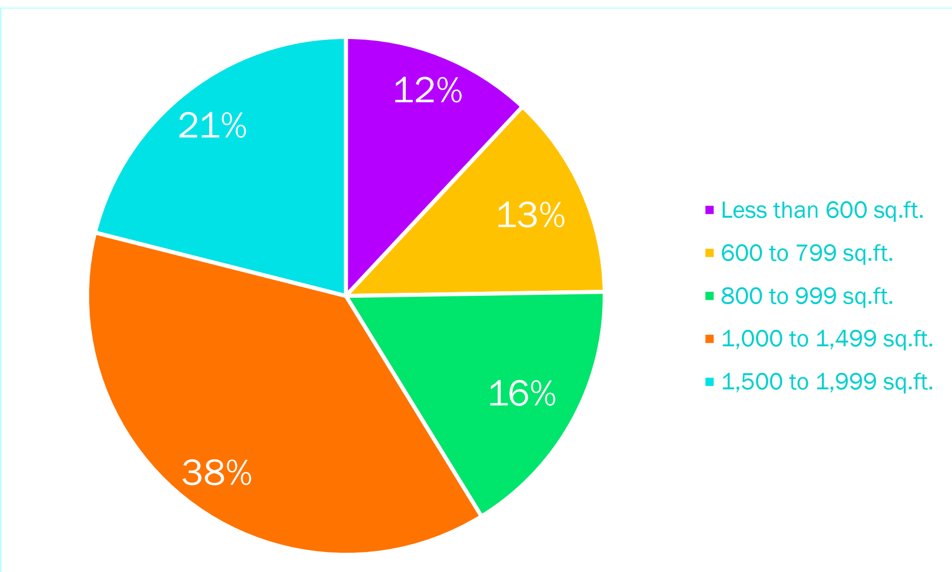

Figure 5: Size of MMH units in California

Source: 2020 RECS public use microdata; reader should exercise caution when viewing these estimates due to small sample size.

HEATING & COOLING

Figure 6 shows the share of MMH units in California by main heating fuel type and compares this distribution to that of occupied SFD homes and all occupied housing units. Utility-provided natural gas is the most common heating fuel in occupied MMH units (57 percent), followed by electricity (26 percent), propane (nine percent), and wood (four percent). Compared to SFD houses, MMH units are less likely to use utility-provided natural gas as the main heating fuel source and more likely to use electricity, propane, and wood for heating.

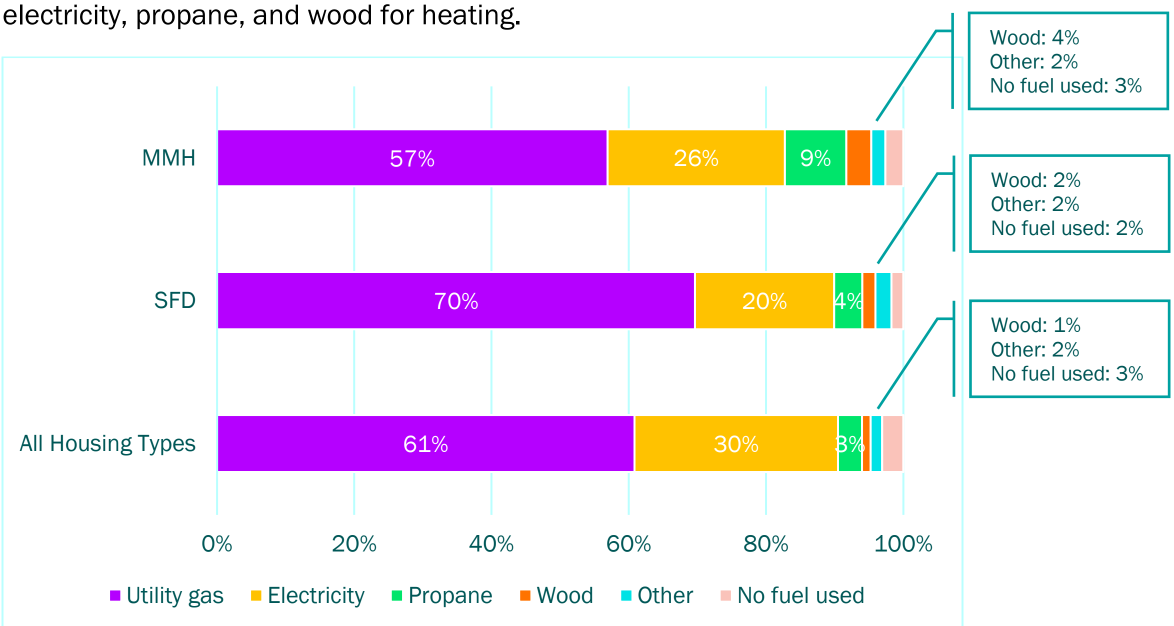

Figure 6: Main heating fuel used in California by housing unit type and climate zone.

Source: 2021 ACS PUMS

Figure 7 shows whether the heating system type is ducted or not ducted for MMH units in California using electricity or natural gas as their main heating fuel. Approximately 79 percent of gas-fired heating systems and 69 percent of electric heating systems in MMH are ducted.

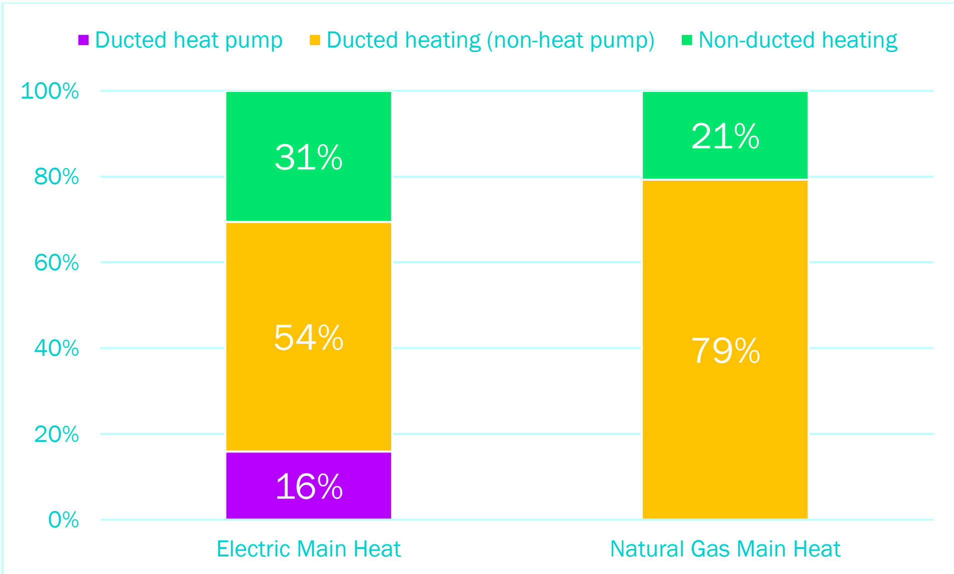

Figure 7: Heating system type of MMH units in California.

Source: 2022 NREL U.S. Building Typology Segmentation Residential

Analysis of the 2020 RECS public use microdata shows that about 79 percent of MMH residents statewide use air conditioning. Figure 8 shows that central air conditioners typically are the primary air conditioning equipment in MMH units. However, analysis of the 2019 CA RASS indicates that about a quarter of MMH residents in individually-metered units use multiple types of air conditioning systems, and that there is regional variability in use of air conditioning in MMH units (with CEC Title 24 Climate Zones 1—Arcata, 5—Santa Maria, and 14—Palmdale having few respondents to the CA RASS reporting use of air conditioning) (DNV 2021).

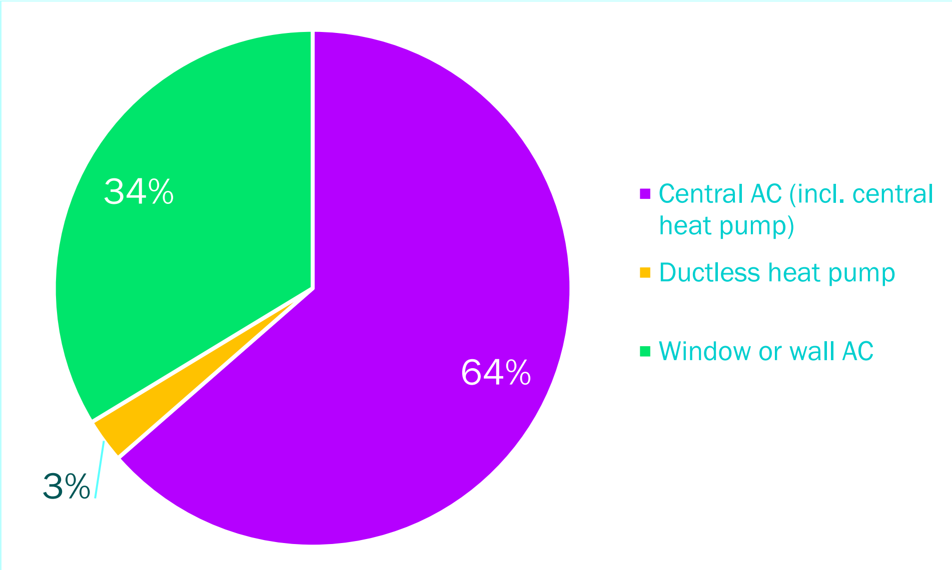

Figure 8: Type of primary air conditioning used by MMH residents.

Source: 2020 RECS public use microdata; reader should exercise caution when viewing these estimates due to small sample size.

Figure 9 shows the share of MMH and SFD units in California with or without ductwork for space conditioning by building vintage. In both MMH and SFD homes, ductwork is almost uniformly present in homes built since 2000, but less likely in homes with older building vintage. This has implications for the type of heat pump equipment that would be suitable in a MMH based on when the unit was built.

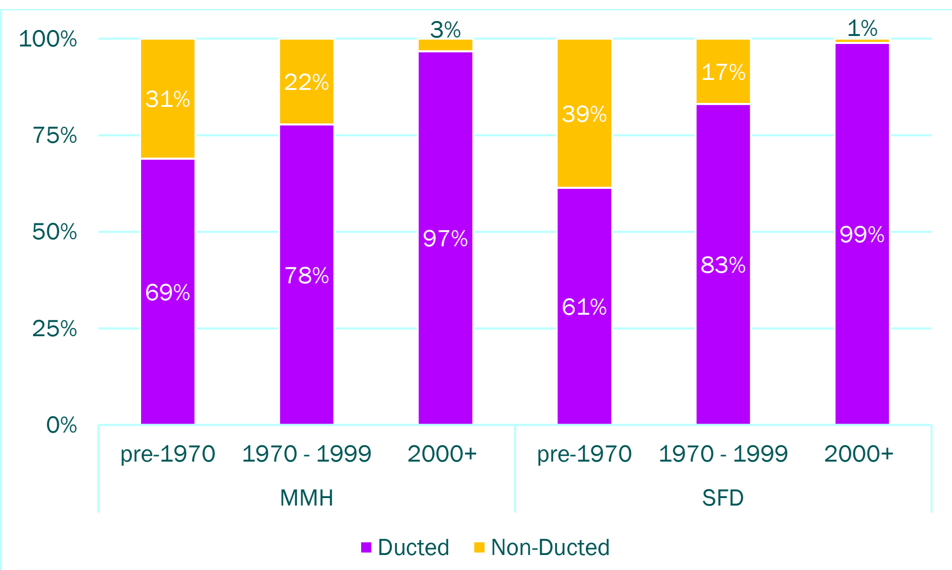

Figure 9: Presence of ducts in MMH and SFD units in California by building vintage.

Source: 2022 NREL ResStock Residential Metadata

DOMESTIC HOT WATER

Analysis of the 2020 RECS public use microdata shows that over 90 percent of MMH residents statewide use natural gas as their main water heating fuel. Most MMH units have small (30 gallons or less) or medium (31-50 gallons) water heater storage tanks, as shown in Figure 10. Analysis of individually-metered MMH units included in the CA RASS indicate that propane is more common in these units (about 20 percent of respondents that reported a water heating fuel), and that there is some regional variability (with CEC Title 24 Climate Zone 16—Blue Canyon being predominantly propane) (DNV 2021).

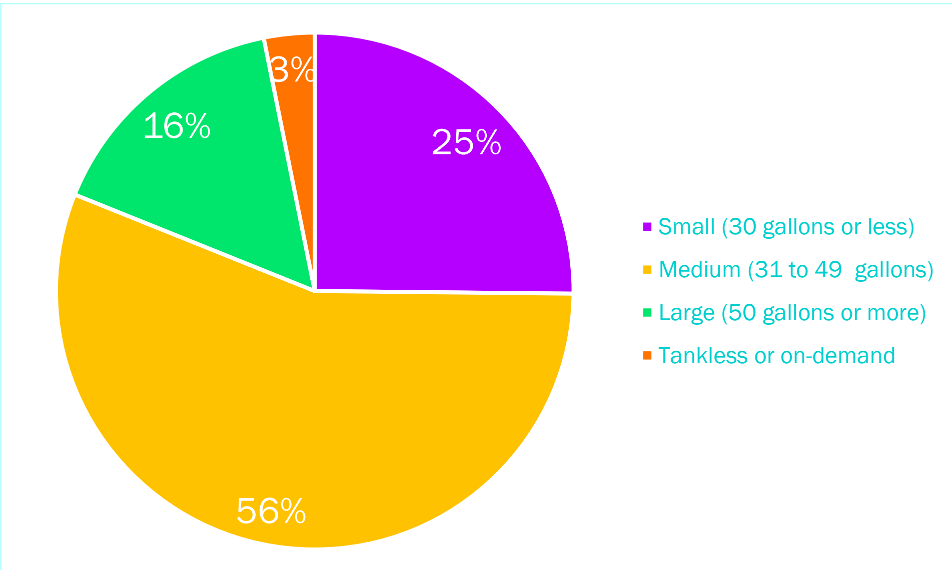

Figure 10: Water heater size in MMH units.

Source: 2020 RECS public use microdata; reader should exercise caution when viewing these estimates due to small sample size.

LAUNDRY

Analysis of the 2020 RECS public use microdata shows that about 83 percent of MMH residents statewide have a clothes dryer at home. About half of the clothes dryers are five to nine years old, and about one-third are ten years or older. Figure 11 shows the fuel type used by these clothes dryers.

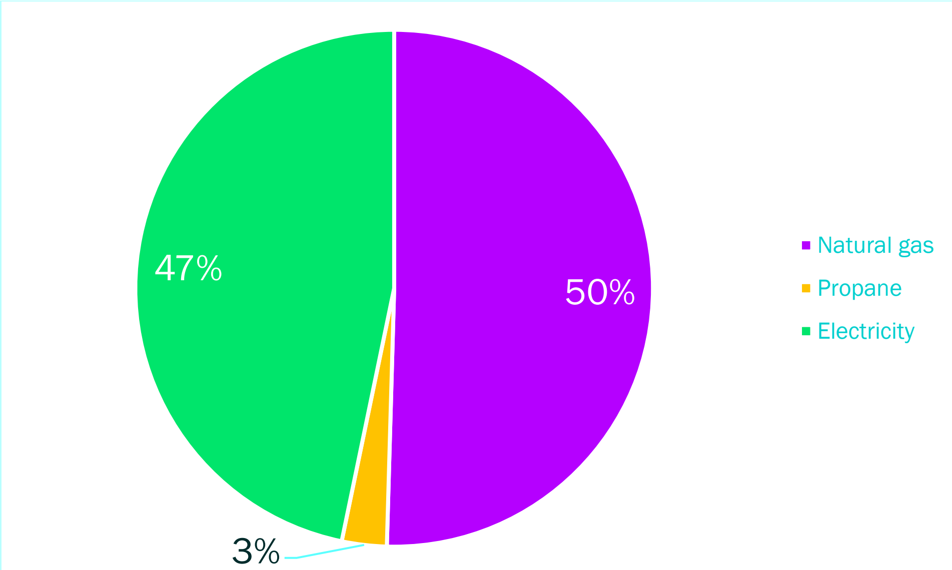

Figure 11: Fuel used by clothes dryers in MMH units.

Source: 2020 RECS public use microdata; reader should exercise caution when viewing these estimates due to small sample size.

COOKING APPLIANCES

Most ranges and ovens in MMH units statewide use natural gas as the cooking fuel. Figure 12 shows that about three-quarters of MMH units use a natural gas range.

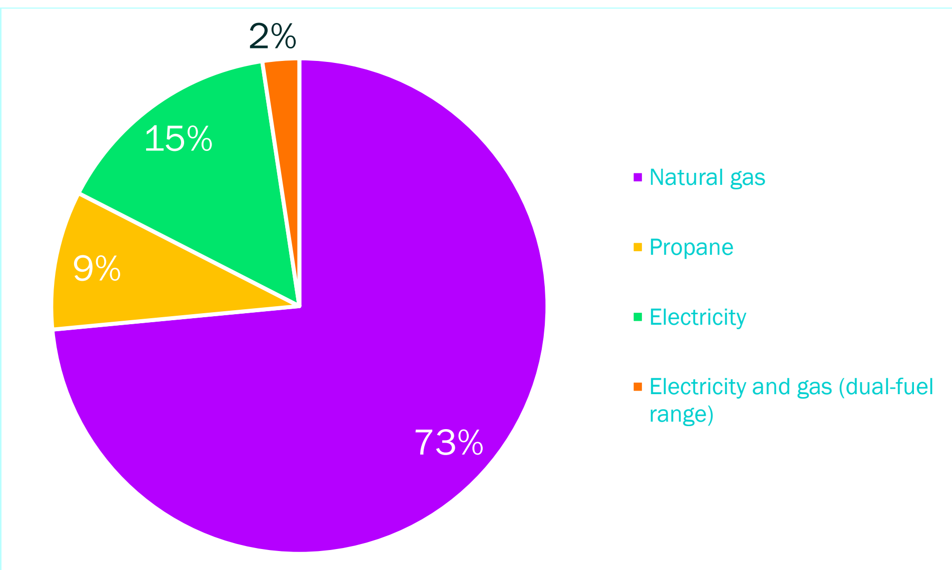

Figure 12: Cooking fuel used by range in MMH units.

Source: 2020 RECS public use microdata; reader should exercise caution when viewing these estimates due to small sample size.

Resident Income Demographics

Households occupying MMH units in California tend to have lower income (adjusted for household size) than households residing in SFD homes and the overall population. Figure 13 shows that 16 percent of California households residing in MMH units have income at or below the U.S. Department of Health and Human Services (HHS) Poverty Guidelines (HHSPG) compared to seven percent of California households residing in SFD homes and 11 percent of all California households. On the opposite end, only about one-quarter of California households residing in MMH units have income greater than 400 percent of HHSPG compared to 59 percent of California households residing in SFD homes. Lower income levels of households residing in MMH may limit the money they have available to invest in improvements to their homes, including energy efficiency and decarbonization measures.

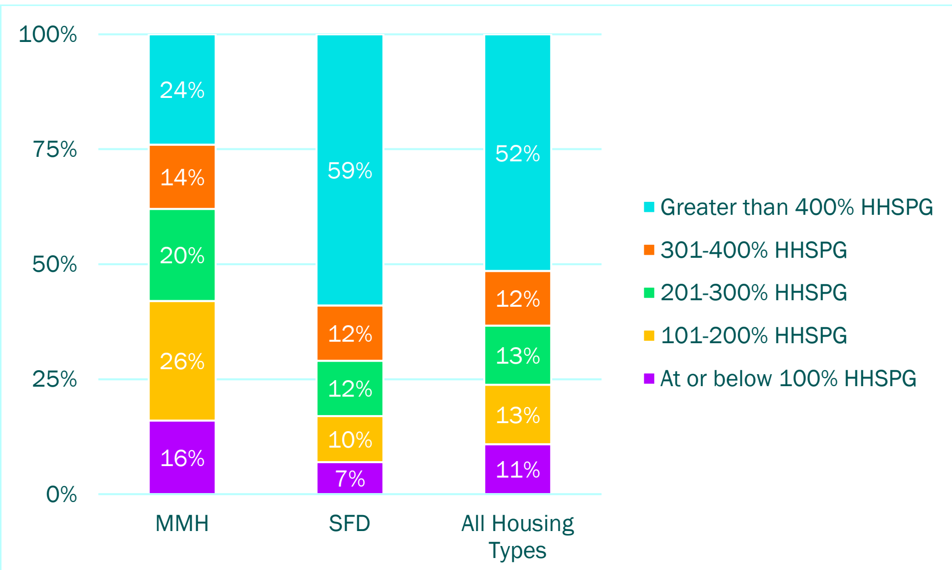

Figure 13: Share of occupied MMH, SFD, and all housing types in California by household poverty level.

Source: 2021 ACS PUMS

Resident Tenure in MMH

Whether a household owns or rents their home can influence their ability to make energy efficiency upgrades and other improvements to their homes. Figure 14 shows the share of occupied MMH, SFD, and all housing types in California by household tenure (owner/renter status). Approximately, three-quarters of households residing in MMH units own their homes, which is slightly less than the share of households residing in SFD homes but higher than the overall share of households in California. Most households residing in MMH own their homes without a mortgage. This may in part reflect the typically lower purchase price of MMH units but also market conditions that make it harder to secure a mortgage for a MMH unit, which typically require that the MMH qualify as real property (land and permanent structure) and not personal property (moveable property) (Bond 2023).

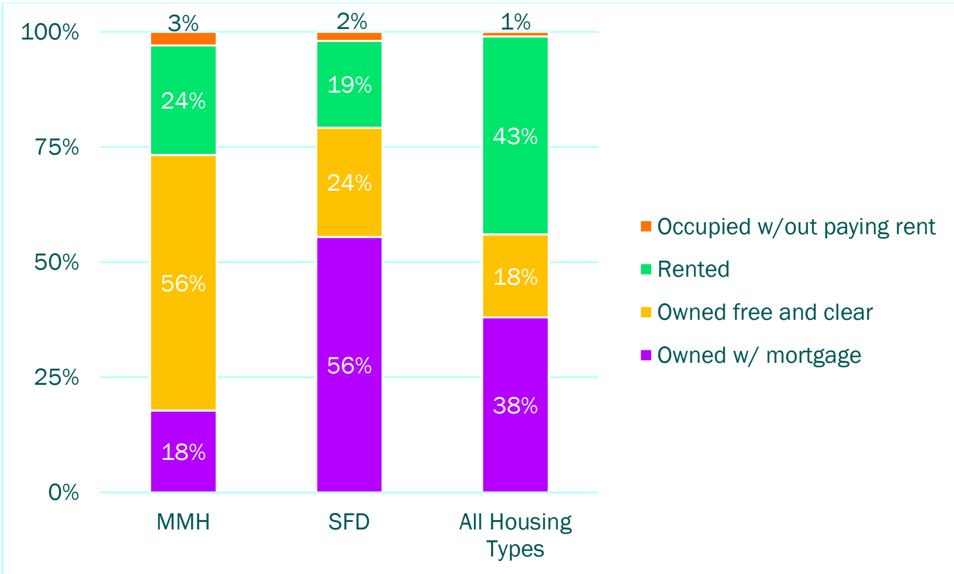

Figure 14: Share of occupied MMH, SFD, and all housing types in California by household tenure.

Source: 2021 ACS PUMS

Most households residing in MMH units in California own their homes. However, mobile home park dynamics can create a complicated split incentive issue for energy efficiency and decarbonization efforts despite many MMH occupants owning their homes. MMH residents often lease their land from mobile home parks, and mobile home parks often have master metered electric and gas utilities with residents paying a set monthly fee. As a result, energy improvement that they make to their homes may not result in a direct financial benefit in the form of bill reductions because the energy savings are shared across all residents in a mobile home park. In addition, utility infrastructure in mobile home parks may be insufficient for electrification upgrades, and park owners maintain control of that infrastructure in master metered parks.

Many MMH residents are elderly with 60 percent of households having at least one member 60 years or older (U.S. Census Bureau 2022). Language, race, and ethnicity demographics of MMH residents are shown in Table 5 and Table 6. Most households residing in MMH units speak English at home or have a member aged 14 years or older that is well or very well. However, 11 percent of MMH households are limited English speaking with most of these households speaking Spanish at home.

Table 5: Share of Households Residing in MMH Units by Household Language and Limited English-Speaking Status

Household Language	Not Limited English-Speaking Household	Limited English-Speaking Household[20]	Total
English only	59%	0%	59%
Spanish	25%	8%	34%
Other Indo-European languages	2%	<1%	2%
Asian and Pacific Island languages	3%	2%	5%
Other languages	<1%*	<1%*	<1%*
Total	89%	11%	100%

Source: 2021 ACS PUMS; *reader should exercise caution when viewing these estimates due to small sample size.

Table 6: Share of Households Residing in MMH Units by Race and Ethnicity (Hispanic Origin)

Race of Householder	Non-Hispanic	Hispanic	Total
White only	51%	5%	55%
Black or African American only	2%	<1%	2%
Asian only	6%	<1%	6%
Alaska Native and/or American Indian	1%	1%	2%
Native Hawaiian or Pacific Islander alone	<1%	<1%	<1%
Some other race alone	<1%	19%	19%
Two or more races	3%	13%	16%
Total	62%	38%	100%

Source: 2021 ACS PUMS

[20] The U.S. Census Bureau defines a household as limited English-speaking if nobody in the household (1) speaks English only or (2) speaks English 'well' or 'very well.'

Housing and Energy Cost Burden in MMH

Figure 15 examines the housing cost burden (i.e., share of income spent on housing costs including energy costs) faced by households residing in MMH units in California as compared to households living in SFD homes and all other housing unit types. About 39 percent of California households residing in MMH Units are housing cost burdened, spending at least 30 percent of their household income on housing and energy, slightly more than the share of California households living in SFD homes that are housing cost burdened.

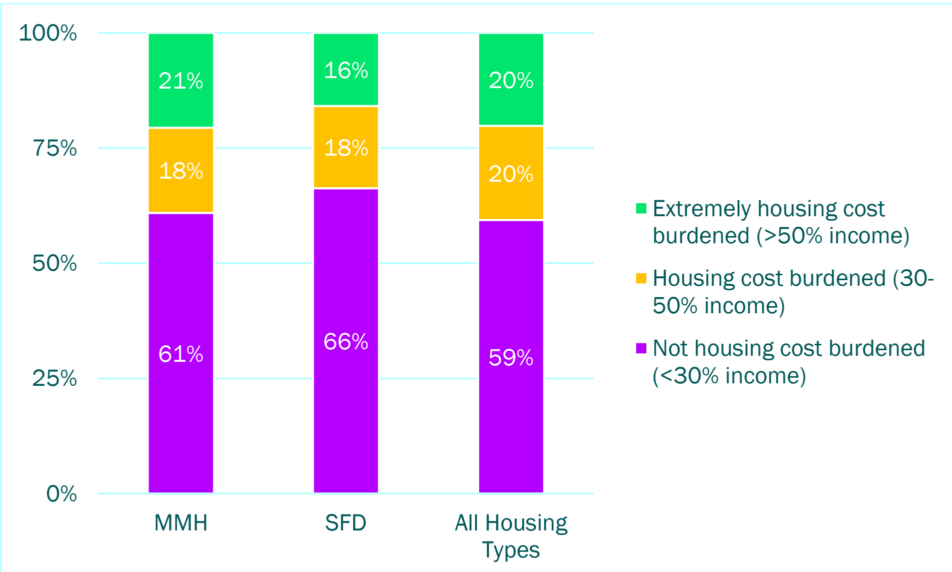

Figure 15: Share of occupied MMH, SFD, and all housing types in California by housing cost burden.

Source: 2021 ACS PUMS

Research indicates that MMH units generally have higher energy burdens (share of income spent on energy costs) compared to other types of housing. A study by the American Council for an Energy-Efficient Economy (ACEEE) found that although the median housing cost burden is similar between MMH and other housing types, the energy burden in MMH units is 39 percent higher causing these households to bear a disproportionate burden of energy costs (Drehobl, Ross and Ayala 2020). The study found that the national median energy burden for MMH units is 5.3 percent with 45 percent of households being highly burdened at six percent or more and 25 percent of households being severely burdened at ten percent or more. In California, while residents in MMH have lower average energy bills than residents in SFD homes, they have higher average energy burdens due to having lower average incomes (DOE n.d.).

Manufactured homes tend to be less efficient compared to site-built homes due to less stringent code requirements included in the 1994 HUD Code. As a result, existing MMH units generally consume more energy per square footage than comparably sized SFD homes, leading to higher energy costs for occupants. When combined with the lower income levels of households living in MMH units, energy cost burdens tended to be higher in these housing units, even when the units are smaller than other housing types and the absolute energy costs are lower.

Existing Programs Serving MMH Residents

Dedicated IOU Energy Efficiency Programs

Existing IOU programs in California targeted to MMH residents offer mostly prescriptive options for energy efficiency upgrades. Apart from Southern California Gas, which offers incentives and financing options for HVAC and water heating equipment upgrades in MMH units, the measures focus on minor upgrades and services at no cost. Table 7 provides an overview of the IOU-funded programs for MMH units.

Table 7: Overview of Existing IOU Energy Efficiency Programs for MMH Residents in California

Utility	Program	Energy Efficiency Measures
PG&E	Direct Install for Mobile and Manufactured Homes Program	• Brushless fan motor replacement • Refrigerant charge adjustment and tune-up • ENERGY STAR-rated products including low-flow showerheads and aerators • Vending machine controllers for common areas
SCE	Mobile Home Upgrade Program[21]	• Light fixtures • Low-flow showerheads • Pipe wrap
SCE	Comprehensive Manufactured Home Program[22]	• Air Conditioning Optimization
SoCal Gas	Manufactured Home Program[23]	• High-efficiency gas furnaces • High-efficiency gas storage water heaters and tankless water heaters • Smart thermostats • Duct test and seal of HVAC systems • Pipe wrap • Low-flow showerheads • Faucet aerators • Free standing ovens • Pool heaters

Source: Project Team

[21] More information on the SCE Manufactured Home Upgrade Program is available here: https://www.sce.com/residential/rebates-savings/manufactured-home-program

[22] More information on the SCE Comprehensive Manufactured Home Program is available here: https://www.synergycompanies.com/utility-program/sce-cmhp

[23] More information on the SoCal Gas Manufactured Home Program is available here: https://www.socalgas.com/save-money-and-energy/rebates-and-incentives/comprehensive-mobilehome-program

Mobile Home Park Utility Conversion Program

The CPUC oversees the MHP-UCP, which helps mobile home parks located in IOU service territories convert from master metering or sub-metering to individually metered utility infrastructure and improve safety, reliability, and capacity of utility infrastructure serving mobile home parks.[24] The MHP-UCP started as a pilot and in 2020 was authorized as a program through 2030. Each IOU implements the MHP-UCP in their service territory. The CPUC lacks the regulatory authority to require municipal owned utilities to participate, although they are encouraged to partner with an IOU when utility services to the park are shared between the two. For electric service, the MHP-UCP currently requires mobile home parks to upgrade to at least 100A to-the-meter (TTM) and behind-the-meter (BTM) infrastructure; proceedings to update the program requirements to 200A TTM and BTM infrastructure are ongoing.[25]

Manufactured Housing Opportunity & Revitalization Program

The HCD oversees the Manufactured Housing Opportunity & Revitalization (MORE) Program which provides an array of opportunities to support mobile home parks and individual units in California.[26] Funds can be directed to help with reconstruction and replacement of mobile home parks, ownership conversion to resident organization, and remediation to fulfill health and safety standards. The program favors mobile home parks that are involved with some resident organization (i.e., nonprofit housing sponsor, local public entity, etc.) although private mobile home park owners and nonprofit organizations can participate under specific circumstances. The program can be used to make energy efficiency upgrades to MMH units including the cost of the equipment and installation, building permits/other fees, services that are related to upgrades (architectural, engineering, inspection, and consulting), and relocation costs. In addition, the MORE Program can be used to fund the replacement of a mobile home unit if the cost to repair a unit exceeds purchasing a new one.

Statewide Income-Qualified Programs

Many MMH residents are lower income and income-eligible for statewide energy efficiency, electrification, and rate discount/bill payment assistance programs. While these programs are not specific to MMH, residents of mobile homes and manufactured housing are able to participate. Table 8 provides an overview of these programs administered by the CPUC and CSD including an estimate of the number and share of MMH residents who are income qualified. It should be noted that for income-qualified households to benefit from the rate discount programs, they must pay their energy bills directly to the utility. In reality, multiple stakeholders noted during interviews that most MMH residents living in mobile home parks have master metered utilities and are unable to participate in these rate discount programs, even when income qualified.

[24] More information on the MHP-UCP is available here: https://www.cpuc.ca.gov/regulatory-services/safety/mhp/mobilehome-park-utility-upgrade-program

[25] More information on proposed changes to the MHP-UCP program are available in CPUC Docket R1804018: https://apps.cpuc.ca.gov/apex/f?p=401:5::::RP,5,RIR,57,RIR

[26] More information on the MORE Program is available here: https://www.hcd.ca.gov/grants-and-funding/programs-active/manufactured-housing-opportunity-and-revitalization-program

Table 8: Overview of Statewide Income-Qualified Energy Efficiency, Electrification, and Rate Discount/Bill Payment Assistance Programs Relevant to MMH Residents in California

Program	Income-Eligibility Threshold	Number of Income-Eligible MMH Residents	Program Overview
Energy Savings Assistance (ESA) (CPUC)[27]	200% HHSPG	186,843 (42%)	Energy efficiency program providing no-cost measures including: • Attic insulation • Energy efficient refrigerators • Energy efficient furnaces • Weatherstripping • Caulking • Low-flow showerheads • Water heater blankets • Door and building envelope repairs to reduce air infiltration
WAP (CSD)[28]	200% HHSPG	186,843 (42%)	Energy efficiency program providing no-cost weatherization and energy efficiency measures including: • Insulation • Air sealing • Window replacement • Repair and replacement of heating, cooling, and hot water systems
LIWP for Farmworker Housing (CSD)[29]	Greater of 80% AMI or 80% SMI	311,112 (70%)	Energy efficiency and electrification program providing no-cost measures including: • Insulation • Central heating and cooling system upgrades • Washers, dryers, refrigerators, and freezers • Lighting upgrades • Water heater replacement • Window replacement • Rooftop solar PV systems

[27] More information on the ESA Program, visit: https://www.cpuc.ca.gov/consumer-support/financial-assistance-savings-and-discounts/energy-savings-assistance

[28] More information on CSD's WAP program is available here: https://www.csd.ca.gov/Pages/Residential-Energy-Efficiency.aspx

[29] More information on CSD's LIWP Farmworker Housing program is available here: https://www.csd.ca.gov/Pages/Farmworker-Housing-Component.aspx

Program	Income-Eligibility Threshold	Number of Income-Eligible MMH Residents	Program Overview
California Alternate Rates for Energy (CARE) Program (CPUC)[30]	200% HHSPG	186,843 (42%)	Rate discount program providing 30-35% discount on electricity bills (20% of customers or electric utilities with less than 100,000 customers) and 20% discount on natural gas bills
Family Electric Rate Assistance (FERA) Program (CPUC)[31]	250% HHSPG	235,295 (53%)	Rate discount program providing 18% discount on electricity bill for customers of SCE, SDG&E, and Pacific Gas & Electric (PG&E)
Low-Income Home Energy Assistance Program (LIHEAP) (CSD)[32]	60% SMI	202,386 (46%)	Energy bill payment assistance program that provides regular and crisis bill payment assistance, weatherization assistance, energy education, and energy budget counseling

Source: Project Team review of program websites, 2021 ACS PUMS

Codes and Standards

The federal laws governing manufactured housing are primarily found in the United States Code, specifically in Title 42.[33] Title 42 of the U.S. Code covers public health and welfare, and it includes several important acts and provisions related to manufactured housing. Minimum standards for all manufactured homes are based on the Manufactured Home Construction and Safety Standards, Title 24 of the Code of Federal Regulations (CFR), and Part 3280 (commonly referred to as the HUD Code).[34] The HUD Code for manufactured housing was first developed in 1976 and construction standards were last updated in 1994. Prior to that time, there were no standards regulating energy efficiency of mobile homes. In addition, the Manufactured Housing Improvement Act (MHIA) of 2000 gave HUD the authority to establish home installation instructions for manufactured homes, including work performed onsite like appliance and utility connections (Kaul and Pang 2022, PD&R 2020).

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[30] More information on CPUC's CARES rate discount program is available here: https://www.cpuc.ca.gov/consumer-support/financial-assistance-savings-and-discounts/california-alternate-rates-for-energy

[31] More information on CPUC's FERA rate discount program is available here:

[32] More information on CSD's LIHEAP program is available here: https://www.csd.ca.gov/pages/liheapprogram.aspx

[33] Title 42, U.S. Code, CHAPTER 70—MANUFACTURED HOME CONSTRUCTION AND SAFETY STANDARDS, http://uscode.house.gov/view.xhtml?path=/prelim@title42/chapter70&edition=prelim

[34] Manufactured Home Construction and Safety Standards (HUD Code) is available at: https://www.ecfr.gov/current/title-24/subtitle-B/chapter-XX/part-3280

Like other energy conservation standards, the DOE is required by the Energy Independence and Security Act of 2007 (EISA) to create efficiency standards for manufactured housing. EISA further directs DOE to base those standards on the current version of the International Energy Conservation Code (IECC). Due to significant industry opposition, an updated version of the HUD Code introduced in 2022, which would have increased the energy efficiency standards for manufactured housing, was blocked and delayed. A new standard for energy efficiency in manufactured housing, based on the 2021 IECC but with less stringent standards for single-section manufactured homes, is expected to go into effect in January 2025. However, until that time, the energy efficiency standard currently in effect for manufactured homes remains the 1994 HUD Code.

- HUD Code sections pertaining to energy efficiency:
- HUD Code Subpart F (Thermal Protection) and Subpart H (Heating, Cooling, and Fuel Burning Systems) include requirements on the following:
    - Envelope insulation and air infiltration:
        - The code requires overall coefficient of heat transmission (Uo) of the manufactured home with an indoor design temperature of 70 F, including internal and external ducts, and excluding infiltration, ventilation, and condensation control, shall not exceed 0.096 British thermal unit (Btu)/(hr.) (sq. ft.) (F) of the manufactured home envelope for HUD Zone 2, which covers all of California.
        - The code states "opaque envelope shall be designed and constructed to limit air infiltration to the living area of the home. Any design, material, method. or combination thereof which accomplishes this goal may be used." It specifically requires "joints not designed to limit air infiltration between wall-to-wall, wall-to-ceiling, and wall-to-floor connections shall be caulked or otherwise sealed".
    - Duct location and insulation:
        - Air supply ducts within floor cavity that are thermally insulated from the rest of the floor cavity shall have a thermal insulation of at least R-4.
    - Space-conditioning and water heating equipment minimum efficiency, installation, and controls:
        - Each gas and oil burning comfort heating appliance must have an Annual Fuel Utilization Efficiency of no less than that specified in 10 CFR part 430, Energy Conservation Program for Consumer Products: Test Procedures for Furnaces/Boilers, Vented Home Heating Equipment, and Pool Heaters.
        - Each automatic storage water heater must comply with the efficiency requirements of 10 CFR part 430, Energy Conservation Program for Consumer Products: Energy Conservation Standards for Water Heaters.

        - All automatic electric storage water heaters installed in manufactured homes shall have a standby loss not exceeding 43 watts/meter2 (4 watts/ft2) of tank surface area.
        - All gas and oil-fired automatic storage water heaters shall meet minimum recovery efficiency, E, and standby loss, S.
    - Each space heating, cooling, or combination heating and cooling system shall be provided with at least one readily adjustable automatic control for regulation of living space temperature.
    - All oil-fired heating equipment must conform to Liquid Fuel-burning Heating Appliances for Manufactured Homes and Recreational Vehicles, UL 307A–1995, with 1997 revisions, and be installed in accordance with Standard for the Installation of Oil Burning Equipment, NFPA 31–01 (incorporated by reference, see § 3280.4).
- Ventilation systems
    - The venting as required by § 3280.707(b) shall be accomplished by one or more of the methods given.
    - Mechanical ventilation which exhausts directly to the outside atmosphere from the living space of a home shall be equipped with an automatic or manual damper. Operating controls shall be provided such that mechanical ventilation can be separately operated without directly energizing other energy consuming devices.

Additional regulations and standards for manufactured housing, mobile homes, and mobile home parks in California are primarily governed by the Health and Safety Code (HSC) Division 13, Part 2, which includes provisions on registration, titling, construction standards, and health and safety requirements.[35]

California's Building Energy Efficiency Standards (Title 24 of the California Code of Regulations) are not directly applicable to mobile homes and manufactured housing due to federal preemption of the HUD Code.[36] However, insofar as the Building Energy Efficiency Standards impact market availability of different technologies and contractor skills for residential buildings, it may have an indirect impact on what energy efficiency and energy technologies are installed in MMH that have been retrofitted.

Voluntary Above Code Standards

While federal preemption prevents HCD from setting a more stringent energy efficiency baseline requirement for manufactured homes in California, homeowners and mobile home parks can voluntarily retrofit existing MMH units, or have new MMH units constructed, to higher energy

[35] HSC Division 13, Part 2 is available at: http://leginfo.legislature.ca.gov/faces/codes_displayexpandedbranch.xhtml?tocCode=HSC&division=13.&title=&part=2.&chapter=&article=

[36] 2022 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, Title 24, Part 6, is available at: https://www.energy.ca.gov/sites/default/files/2022-08/CEC-400-2022-010_CMF.pdf

efficiency levels than is required in the HUD Code. For new MMH, there are two national programs that provide more stringent energy efficiency standards than the HUD Code:

- **ENERGY STAR for Manufactured Homes (ESMH) Program**: The ESMH program released a more string program requirement in 2023 (ESMH v3), but due to the 2022 HUD Code implementation delay, ESMH v2 remains in effect. ESMH v3 is expected to go into effect in January 2024.[37]

- **Zero Energy Ready Homes for Manufactured Housing (ZERH MH) Program**: The ZERH MH program was newly developed for 2023 in support of the 45L New Energy Efficient Home tax credits. The current standard, ZERH MH v1, is a pilot program that will be in effect at least through 2023. The revised 45L provides a $5,000 tax credit to builders for most home certified to ZERH standards. DOE will review stakeholder comments and feedback on the v1 pilot program to inform development of the v2 standard.[38]

In addition to the national voluntary programs, the **Northwest Energy-Efficient Manufactured Housing (NEEM) Program** engages with factories to build on and exceed the standards used in ESMH.[39]

Stakeholder Outreach Findings

The following section discusses barriers and opportunities identified by stakeholders for completing electrification and energy efficiency retrofits and new construction in the MMH sector. The barriers and opportunities are organized by topic area, and not all barriers have corresponding opportunities.

Barriers

- Codes and Standards
    - **Preemption by federal HUD Code and lagging updates:** As noted in the Codes and Standards section, the HUD Code governs the minimum efficiency standards for manufactured homes. The HUD Code was introduced in 1976 and last updated in 1994. Attempts to increase the minimum energy efficiency standards in the code have been blocked and delayed. Stakeholders noted that federal preemption by the HUD Code prevent HCD from implementing California's Building Energy Efficiency Standards or other more stringent energy efficiency requirements as the minimum efficiency standards for manufactured homes in California.

- Utility Metering Infrastructure
    - **Split incentives for master metered mobile home parks**: Stakeholders noted that most mobile home parks still have master metered utilities, with estimates ranging by service territory from half to over 85 percent of parks. In master metered mobile home parks, utility costs are a passthrough from park owners to residents, often are included in a "slip fee" that does not vary with usage. As a result, stakeholders noted that residents who improve

[37] More information on the ESMH certification is available here: https://www.energystar.gov/partner_resources/residential_new/homes_prog_reqs/manufactured_national_page

[38] More information on the ZERH MH certification is available here: https://www.energy.gov/eere/buildings/zerh-manufactured-homes

[39] More information on the NEEM certification is available here: https://www.neemhomes.com/neem-plus

the efficiency of their homes do not realize the full benefit of those savings because they are shared across all park residents when utilities are master metered and not sub-metered by park owners.

  - **Measuring energy savings in master metered mobile home parks**: Stakeholders noted that master metering in mobile home parks makes it challenging to claim energy savings for retrofits. A deemed savings approach is needed, but many deemed measures have become dropped from IOU programs because they are no longer considered cost-effective. One measure noted by stakeholders was sealing of duct leaks, where actual leakage observed in the field vary substantially from the assumed baseline, but because a deemed savings approach is used, it does not meet program requirements.
  - **Waitlist for utility conversion upgrades**: Stakeholders noted the high demand for the MHP-UCP. At the current conversion rate, CPUC anticipates that the waitlist of parks will not be fully converted until 2055.
- Building Stock
  - **Aging parks and building stock**: Multiple stakeholders discussed that it is challenging to retrofit any mobile or manufactured home built prior to the mid-1990s due to structural limitations, minimal insulation, and small compartments available to electrify HVAC. General state of the homes and construction quality also were noted as barriers.
- Physical Constraints
  - **Limited space between units in mobile home parks**: Stakeholders noted that minimum spacing requirements between MMH units (6 feet) as a barrier to retrofitting these homes, and they noted that many mobile home parks have setbacks between units that are smaller than the minimum. The limited space between units in mobile home parks poses a barrier to machinery access for trenching and installing electric service upgrades, and the resulting labor adds large costs to projects. Additional access and cost issues arise when outdoor space is needed for storage due to limited availability of indoor space.
  - **Indoor space constraints**: Stakeholders noted that there is limited space available inside MMH units. This is particularly challenging for retrofitting domestic hot water—existing utility closets tend to be very small and unable to fit heat pump water heater (HPWH) storage tanks. For heating and cooling, there often is minimal space to add ventilation.
  - **Poor insulation and hard-to-access ductwork**: Stakeholders noted that MMH units often are poorly insulated and duct leakage rates can be as high as 40 percent. The ductwork and crossovers can be poorly constructed. Remediating thermal envelope issues can be challenging because of the limited cavity space to add insulation and cost prohibitive.
- Electrical Infrastructure
  - **Service capacity limits**: Stakeholders reported that the typical electrical service to lots in mobile home parks was 30A to 100A, and that the MHP-UCP only requires mobile home parks to upgrade to 100A service when converting from master metering, making it harder to fully electrify existing MMH units or replace old units with new, all-electric MMH units that

require 200A. Stakeholders also noted that when electrifying whole parks, transformer upgrades may be needed.

  - **Panel upgrades**: In addition to upgrading electrical service from the utility, stakeholders noted that MMH units will need to upgrade to a 200A panel inside the home when electrifying heating, DHW, clothes dryers, and cooking appliances. They discussed that in older MMH units, the type of framing construction makes it difficult to make panel upgrades and add circuits.
  - **Condition of electrical infrastructure**: Stakeholders noted that in a pilot program for electrification of homes in DACs, they commonly found outdated electrical systems in MMH units and about one-third of MMH units had electrical issues. Copper electrical wires are common in pre-HUD Code vintage homes.

- Socioeconomic Challenges
  - **Limited income and entry-level homes**: Stakeholders noted that MMH residents often face affordability challenges to retrofitting their homes. Many reside in MMH units that were "entry level" in their construction quality at the time they were built and do not have the income available to make improvements.
  - **Farmworkers**: Stakeholders also noted that in agricultural areas, many MMH residents are farmworkers who are low-income, move often, and do not prioritize energy efficiency upgrades.
  - **Financing**: Access to capital often is limited for MMH residents. For MMH to qualify for mortgage and other traditional lending instruments available for real property, the homes must be affixed permanently to land owned by the homeowner (Kaul and Pang 2022). However, many MMH residents lease their land from mobile home parks and their homes are considered personal property. Stakeholders noted that personal property loans (often referred to as chattel loans) have higher interest rates and shorter repayment terms, and that this complicates access to capital for homeowners to make investments in their homes.
- Existing Programs
  - **Utility rates**: Stakeholders noted that low-income residents living in master metered mobile home parks cannot qualify for rate discount programs like CARE or FERA because the meter is ineligible for the rate. Converting these parks to direct metering can open these rates to residents and make electrification efforts more affordable.
  - **Cost-effectiveness requirements**: Cost-effectiveness requirements have limited the services they can offer through existing IOU programs. Stakeholders noted duct sealing as a measure that was eliminated for this reason.
  - **Fragmented program offerings**: Stakeholders noted that there are multiple programs operating in this market sector, from IOU offerings to statewide programs. They discussed challenges with confusion and lack of trust with residents when program offerings are not coordinated.

- **Marketing and outreach**: For MMH units located in mobile home parks, program marketing must typically go through park owners who act as gatekeepers. Stakeholders noted that it can be difficult to get into parks with one utility estimating that 35-40 percent of mobile home parks have not opened their doors to the programs. One of the challenges discussed by stakeholders is that park owners do not financially benefit from many of the programs and there is risk that residents will not be happy with the programs if the work is not done properly.
- **Permitting issues and delays**: To retrofit MMH units, permits must be obtained from one of the two regional HCD permitting offices. Stakeholders noted that there can be long processing timeframes resulting in project delays.

Opportunities

- Codes and Standards
  - **Voluntary above-code efficiency standards**: Stakeholder discussed opportunities for homeowners and mobile home parks to voluntary retrofit existing MMH units, or have new MMH units constructed, to high efficiency levels than is required in the HUD Code. Some manufacturers were noted as having already voluntarily adopted the ENERGY STAR or DOE ZERH standards for manufactured homes.
  - **Regional electrification codes**: Stakeholders noted that local or regional electrification codes, like bans on new gas infrastructure connections, will require fully electrified MMH units and mobile home parks within their jurisdictions in the future.
  - **New federal standards go into effect in 2025**: Stakeholders noted that while the 1994 HUD Code remains in effect today, a new minimum standard for energy efficiency in manufactured housing is expected to go into effect in January 2025. This will require newly constructed MMH units and retrofit standards to meet a higher efficiency level, even if voluntary programs are not adopted.
- Utility Metering Infrastructure
  - **Priority mobile home parks**: As part of the planning process for the Mobile Home Park Utility Conversion Program, the CPUC creates a priority list of master metered mobile home parks for the IOUs to convert to direct metering. The priority list is based on risk assessment including electric capacity, installation dates of gas systems, leak history of gas systems, proximity to areas of high temperatures, if they have been affected by natural disasters, and if the park is located in a DAC area. This presents an opportunity to focus efforts on locations already prioritized for utility conversion upgrades.
  - **Electrical service upgrades**: By converting metering to individual lots, it transfers ownership of the electrical infrastructure in parks to the electric utilities. Stakeholders noted that this transfer in ownership reduces the liability mobile home parks face while improving electrical capacity. Stakeholders also noted that the incremental cost of upgrading electrical service to 200A instead of the 100A is small relative to the cost already incurred for construction and trenching. CPUC is exploring whether 200A service should be the minimum standard.

- Building Stock
    - **Target high potential electrification opportunities**: Stakeholders noted the value in targeting MMH residents who use propane for heating or DHW with electrification retrofits, and that newer gas heated MMH units with a moderate insulation and air sealing in the building envelope as easier wins for minimizing the energy bill impact (or reducing bills) through electrification.
- Existing Programs
    - **Marketing and outreach**: Stakeholders noted that leveraging community organizations is key to reaching mobile home parks in DAC or low-income areas. They also mentioned that packaged solutions across programs are important so that residents are not confused about offerings. Forms of outreach that stakeholders have found effective with residents of mobile home parks include community meetings and leveraging utility data to inform residents of the potential bill reductions they could achieve.
    - **Local workforce**: Supporting development of local workforce capacity is another way stakeholders noted building trust with MMH residents.
- New Construction Initiatives
    - **Whole home replacement**: Stakeholders noted that in some cases, replacing existing homes—particularly older, pre-HUD Code homes—is more cost-effective than retrofitting the home.
    - **Market demand**: Stakeholders noted that there is increasing demand for new, high efficiency MMH units. With available federal incentives, stakeholders noted that manufacturers who voluntarily adopt new efficiency standards like ESMH or ZERH MH can achieve cost parity with standard efficiency models.[40] This will help to maintain the affordability of MMH units sold while pushing the market to be more efficient.

Energy Modeling

MMH located in the northern and mountainous areas of the state have EUIs (energy use per square foot) that are approximately 30 higher, on average, than MMH located in other areas of the state. Figure 16 shows the average end use intensities of MMH throughout the state based on NREL's ResStock model. The number of housing units are represented by the size of the circles in the chart (large circles means more housing units) and the color of the circles represents the end use intensities (green circles indicate lower end use intensities, red circles indicate higher end use intensities).

[40] Clayton is offering its "eBuilt" manufactured homes, which is compliant with ZERH MH and the anticipated 2025 HUD Code, at the same price as its standard efficiency model. The eBuilt model is solar-ready and includes heat pump HVAC, hybrid heat pump water heater, smart thermostats, ENERGY STAR appliances, LED lighting, high efficiency windows and insulation, member sealing, and whole house fans. More information on the eBuilt model is available here: https://www.claytonbuilt.com/ebuilt/

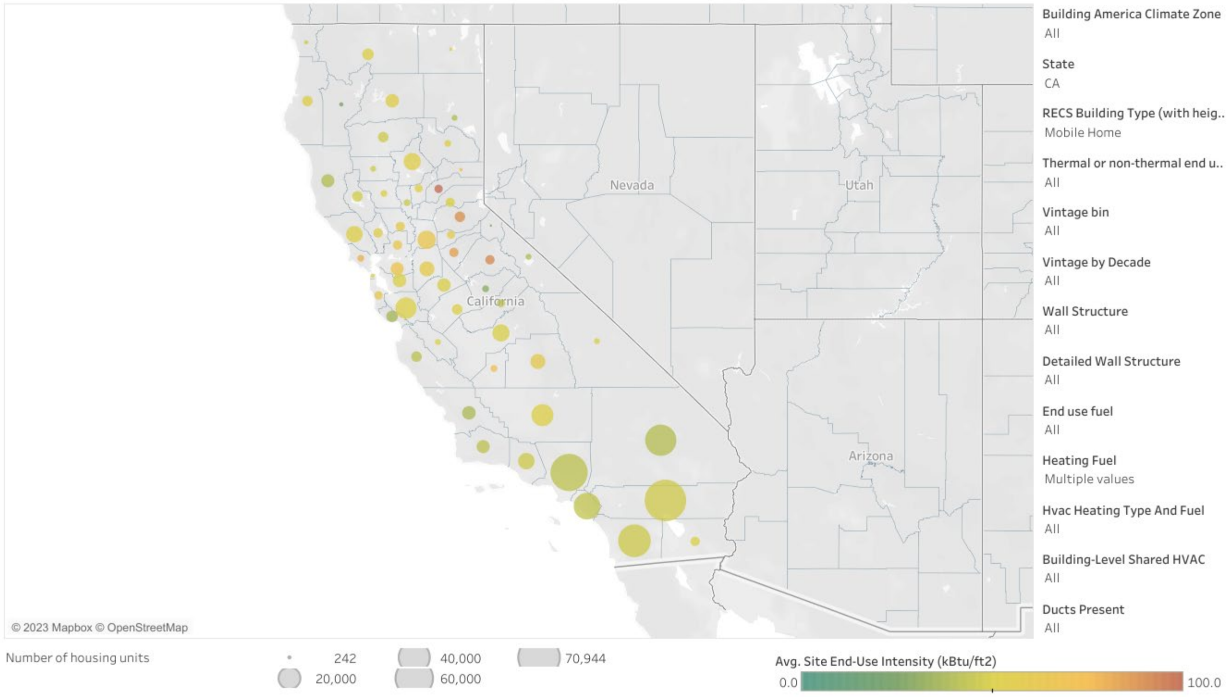

Figure 16: Map of end use intensities of MMH in California.

Source: NREL ResStock

Analysis of NREL's ResStock shows that existing MMH units in California account for over 27 trillion Btu (TBtu) of energy use each year. While this total is a small percentage of all single-family housing (approximately five percent, when combining energy use of MMH units with that SFD homes), MMH units have a much higher EUI, or energy use per square foot of building area, than SFD housing. Across all climate zones, the EUI of MMH units is about 40 percent higher than SFD homes. Figure 17 shows that in Hot and Mixed-Dry climates, where most MMH units in California are located, the EUI of MMH units is roughly 30 percent higher than SFD homes. In Cold climate zones, EUI is nearly 60 percent higher in MMH units.

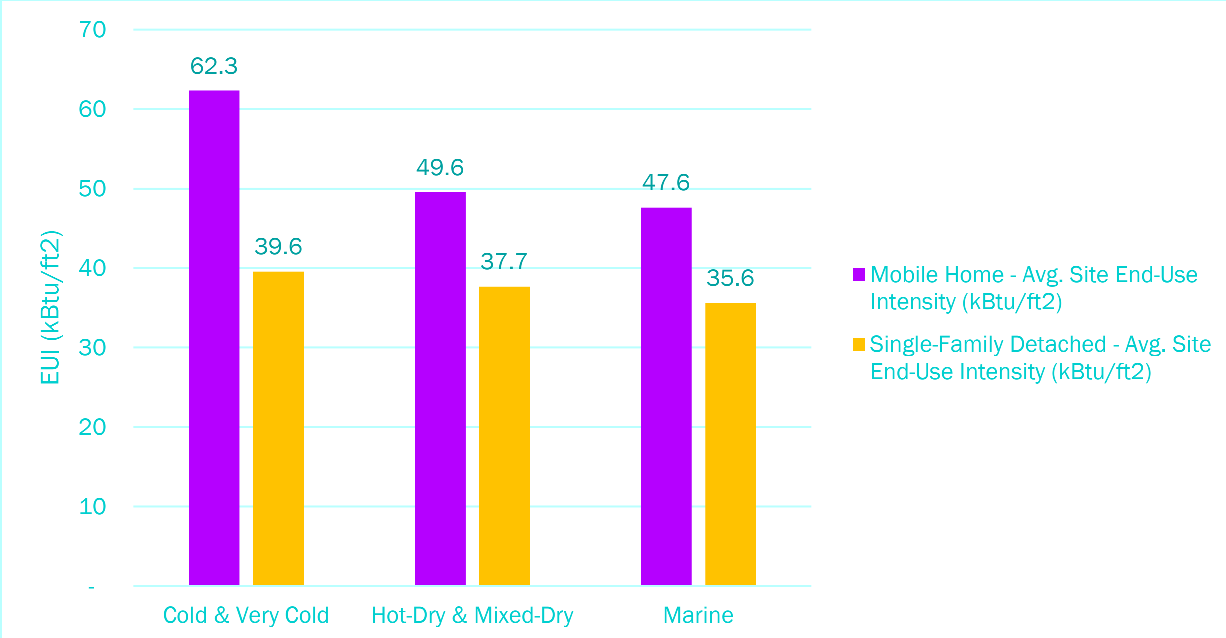

Figure 17: Average energy use intensity for MMH and SFD homes across Building America Climate Zones.

Source: NREL ResStock

The majority of MMH units in California were built before 1980. This vintage group represents the period prior to initial implementation of the HUD Code regulating the construction of manufactured homes and setting energy conservation standards (1976). Not surprisingly, this vintage group has the highest aggregate energy use and highest EUI. Figure 18 shows average annual energy use and share of MMH units by vintage based on modeling from NREL's ResStock. Figure 19 shows aggregate energy use and number of MMH units by vintage based on modeling from NREL's ResStock.

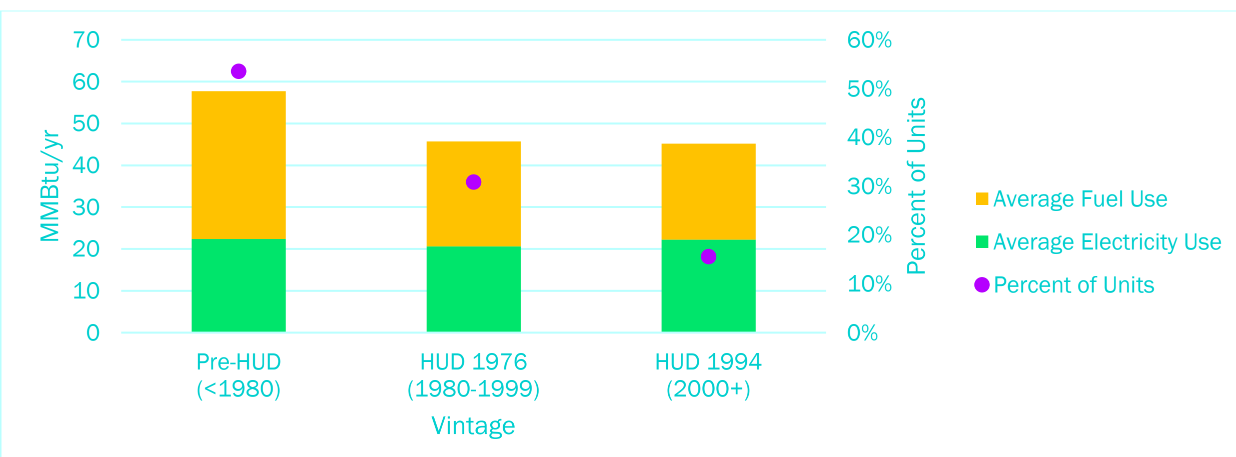

Figure 18: Average annual energy consumption (MMBtu) and percent of MMH units by vintage.

Source: NREL ResStock

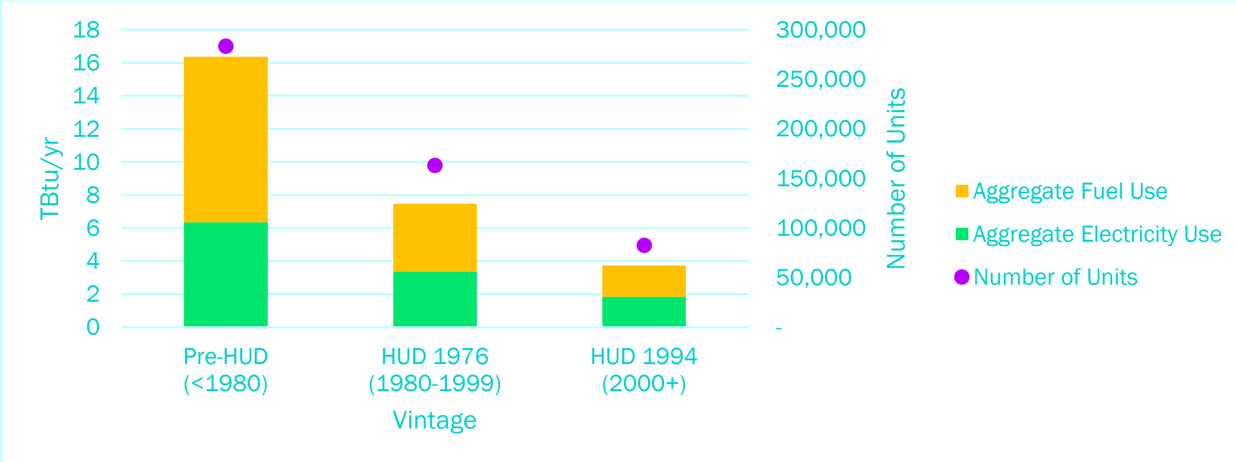

Figure 19: Aggregate annual energy consumption (TBtu) and number of MMH units by vintage.

Source: NREL ResStock

Figure 20, based on NREL's End Use Savings Shape data, provides an illustrative example of the energy reduction that can be realized from upgrading the existing MMH building stock in California. Five possible upgrade scenarios are shown here representing the 'high efficiency' option packages. A 17 percent reduction in energy usage can be realized from upgrading the building enclosure, or thermal envelope. Close to a 60 percent reduction in site energy usage is possible with a high efficiency, whole home electrification package. These scenarios represent total technical savings potential.

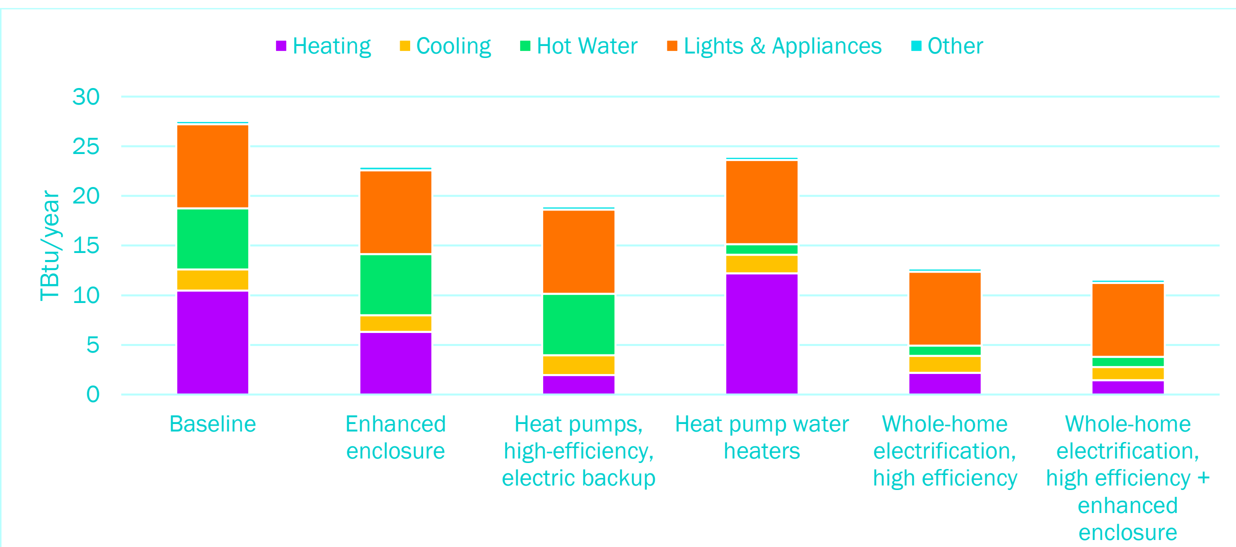

Figure 20: Total annual energy consumption for baseline and upgrade packages for existing manufactured homes in California.

Source: NREL ResStock

Prototype Model Results

Existing statewide energy consumption for MMH in California shown above was derived from ResStock building stock model data. The following section provides results from prototype modeling of electrification retrofit and all-electric new construction scenarios.

As discussed in detail in Appendix A: Technical Details of Prototype Energy Modeling, two upgrade scenarios were run for electrification retrofit scenarios:

- Electrification Only – this includes replacement of all equipment, appliances, and lighting along with duct sealing and moderate air sealing measures from caulking and foaming.
- Electrification + Weatherization – In addition the electrification measures, this scenario includes ceiling and floor insulation, window replacement, and more significant air leakage reduction assumptions.

Both the 'Electrification Only' and 'Electrification + Weatherization' retrofit scenarios were applied to the 1976 HUD vintage baseline, whereas only the 'Electrification Only' scenario was applied to the 1994 HUD vintage homes.

In addition to the two electrification retrofit scenarios applied to existing baseline housing vintages, four 'above code' all-electric new construction scenarios were modeled:

1. 2022 HUD Code – specifications based on the proposed 2022 update of the HUD Code for manufactured homes.
2. ES-MH v3 – specifications based on the ENERGY STAR program certification for manufactured housing (version 3), meeting minimum specifications for an all-electric home under this program.
3. ZERH-MH v1 (minimum specifications) – specifications based on the Zero Energy Ready Home Program certification for manufactured housing (version 1), meeting minimum specifications for an all-electric home under this program.
4. ZERH-MH v1 (target specifications) – specifications based on the Zero Energy Ready Home Program certification for manufactured housing (version 1) for an all-electric home but with high-performance equipment.

Equipment and other specifications for each scenario are provided in Table 18 through Table 23 in Appendix A: Technical Details of Prototype Energy Modeling.

ENERGY USE IMPACTS

Figure 21 through Figure 24 provide the estimated annual consumption (in million British thermal units, or MMBtus) of the prototype models by vintage (pre-HUD, 1976 HUD, and 1994 HUD), unit configuration (single-section versus multi-section) and main heating fuel type (natural gas versus electricity). For most scenarios, heating dominates the end use energy consumption. The exception is in the 1994 HUD vintage in the Marine and Hot-Dry climates.

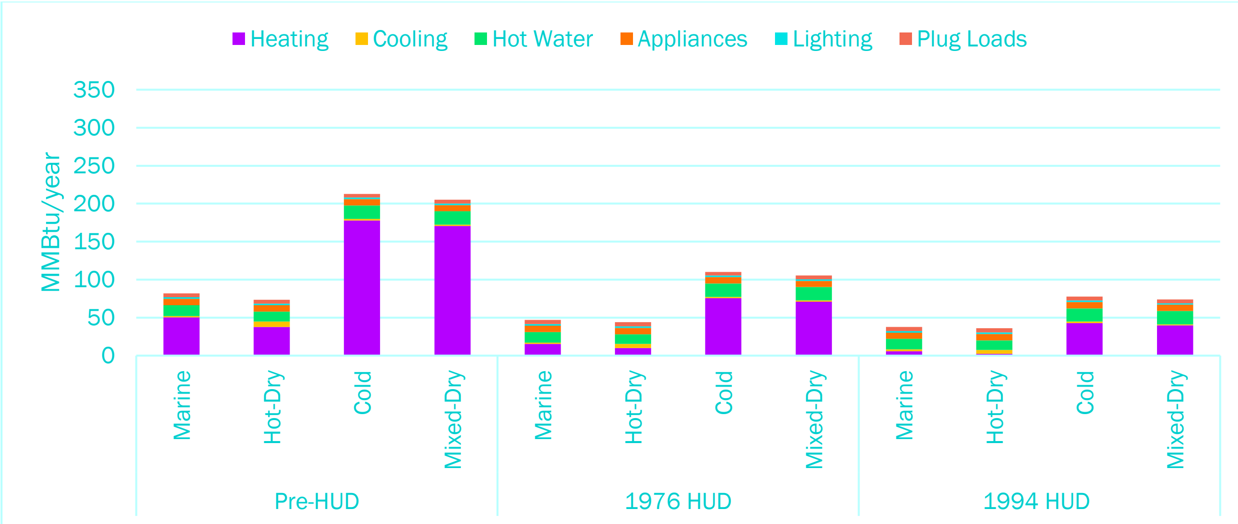

Figure 21: Modeled annual energy consumption for single-section units using gas heat.

Source: Project Team

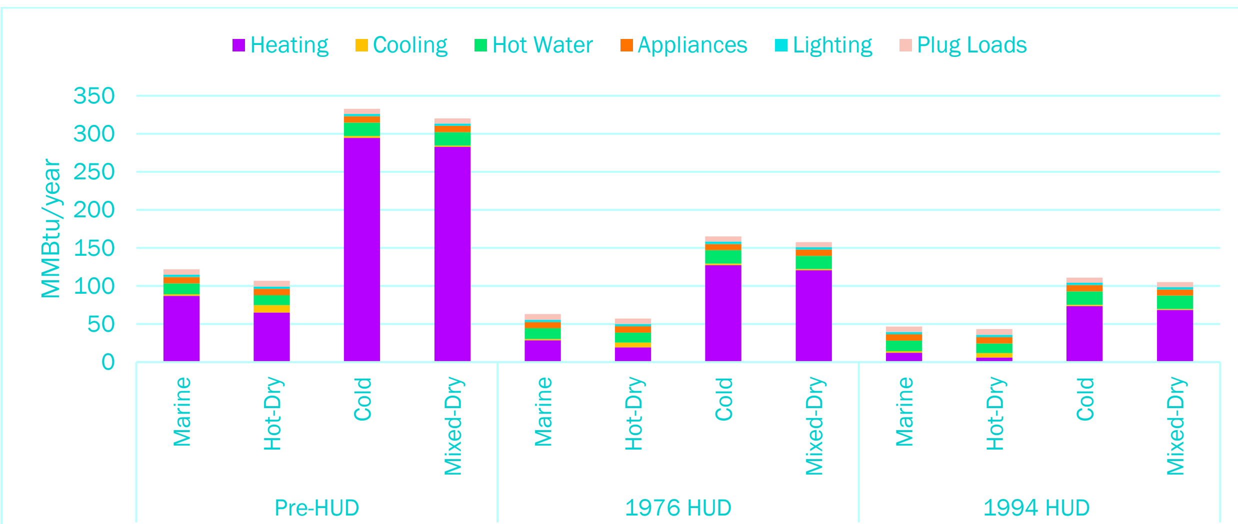

Figure 22: Modeled annual energy consumption for multi-section units using gas heat.

Source: Project Team

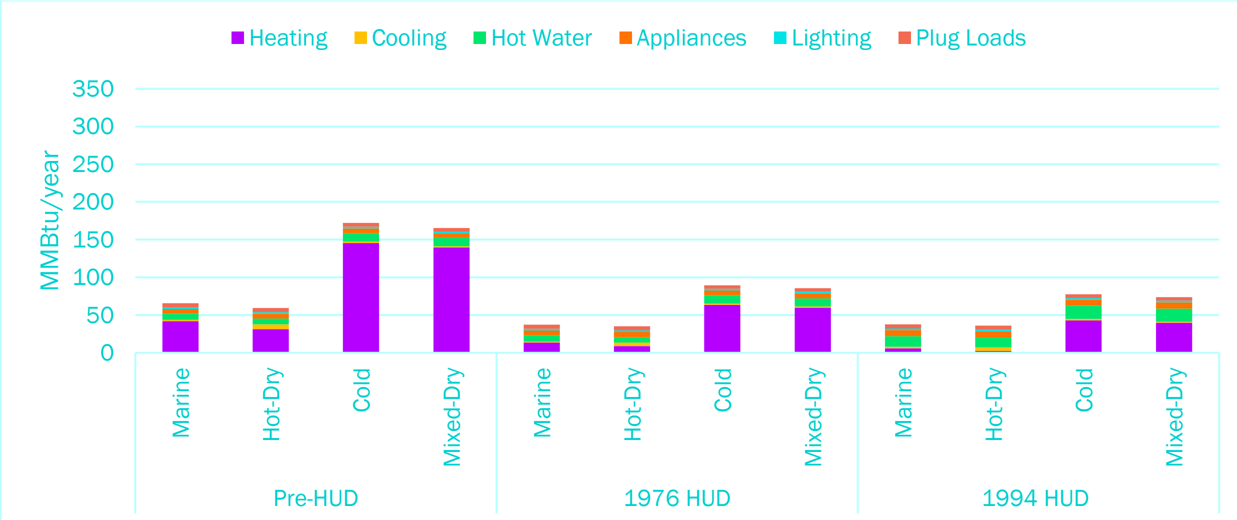

Figure 23: Modeled annual energy consumption for single-section units using electric heat.

Source: Project Team

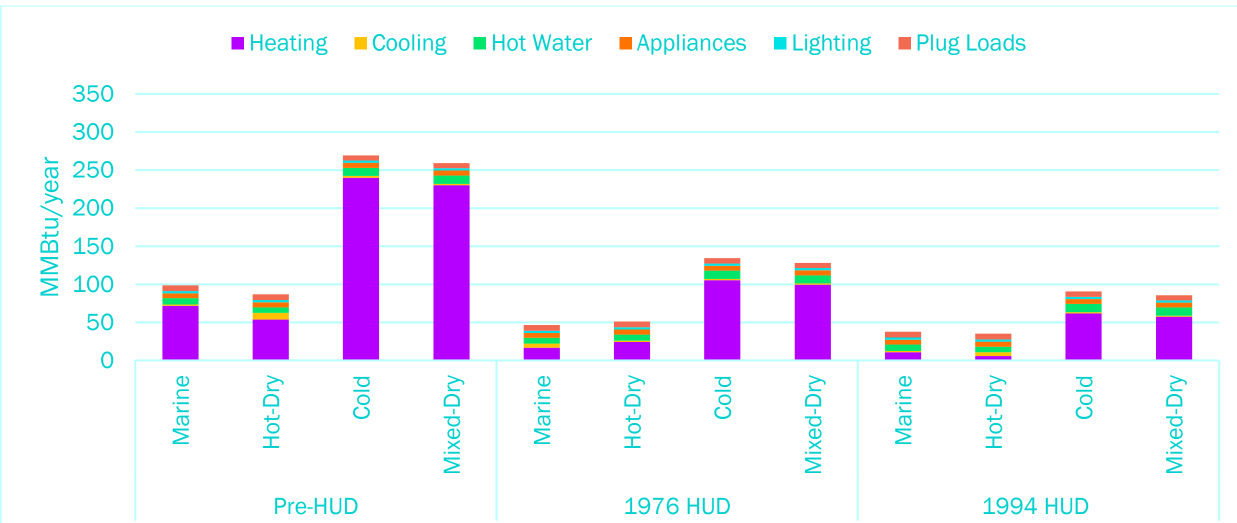

Figure 24: Modeled annual energy consumption for multi-section units using electric heat.

Source: Project Team

An important caveat of prototype modeling highlighted above is the very high consumption estimates of electrically heated MMH units in cold climates. As noted in the section on Limitations of Prototype Modeling, the prototype modeling assumes typical weather data and standard operating assumptions, but these assumptions do not always match reality. This will need to be taken into consideration when evaluating upgrade measures and associated savings, with validation using actual consumption data for a representative sample of MMH units.

Figure 25 shows the estimated annual energy consumption for each single-section prototype model home efficiency scenario in the Hot-Dry Climate, and Figure 26 shows the same for each multi-section prototype model home. On average, the electrification retrofit upgrade scenarios result in approximately 50 percent energy consumption savings over the 1976 and 1994 HUD baselines, and new construction replacement scenarios result in 20 to 50 percent energy consumption savings. Additional details on the modeled used of all-electric replacement scenarios for other climate zones are provided in the Supplemental Results: Modeled Energy Consumption.

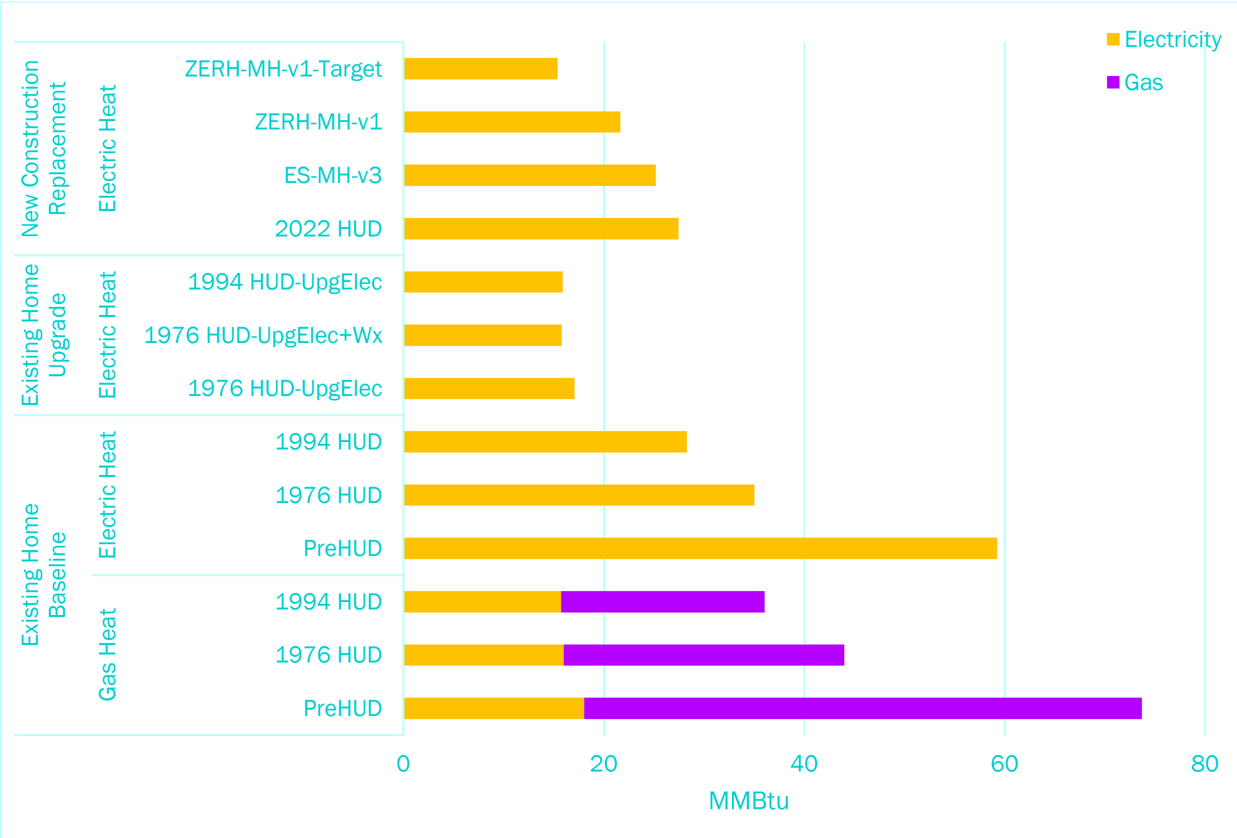

Figure 25: Modeled annual energy consumption for single-section units, Hot-Dry climate zone only, for existing baseline, electrification retrofit, and all-electric new construction scenarios.

Source: Project Team

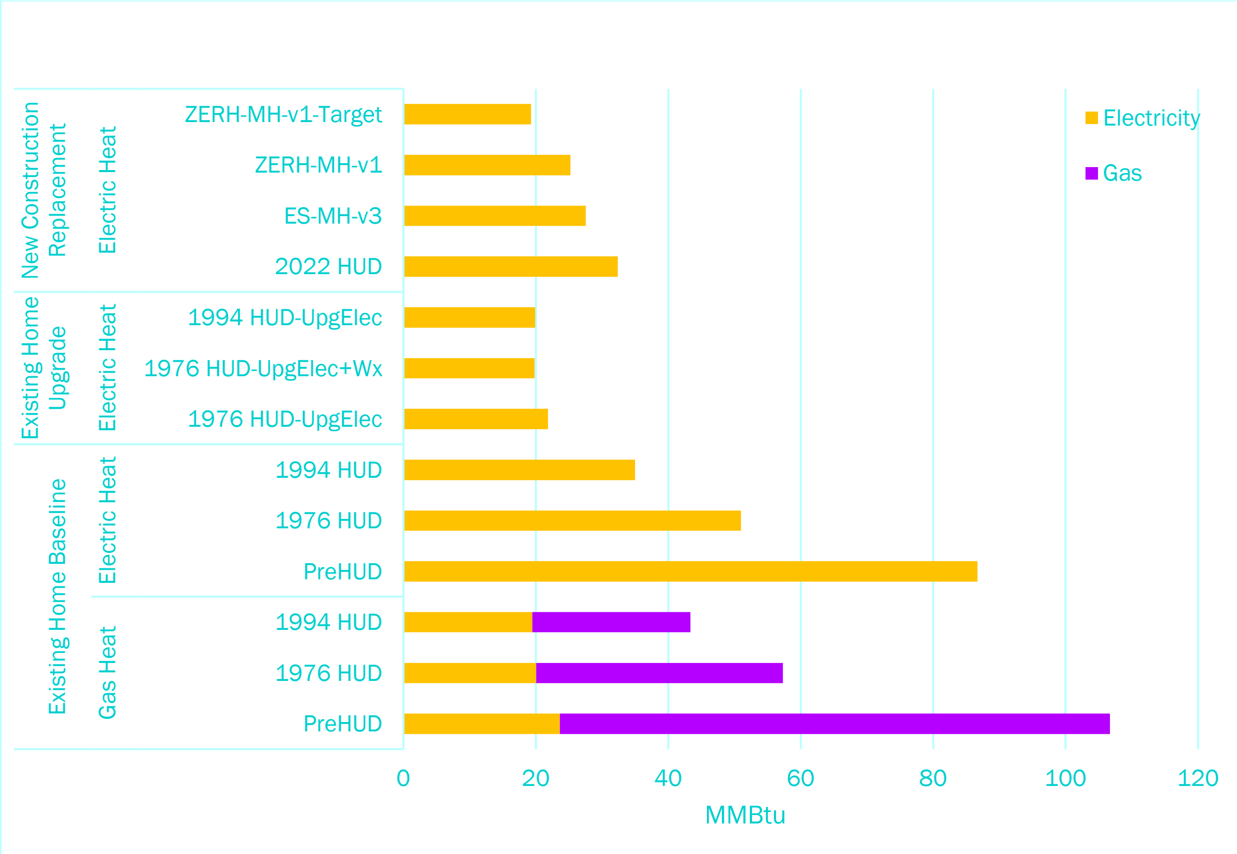

Figure 26: Modeled annual energy consumption for multi-section units, Hot-Dry climate zone only, for existing baseline, electrification retrofit, and all-electric new construction scenarios.

Table 9 shows the percent change in site energy consumption of the two upgrade and four new construction replacement scenarios over baseline conditions, for the Hot-Dry climate zone only (where most MMH units are located in California). For single-section homes in the Hot-Dry climate zone, modeled energy use savings ranges from three percent to 79 percent. For the new construction replacement scenarios, a level of savings comparable to the 'Electrification + Weatherization' retrofit scenario is only reached in the ZERH-MH-v1-Target scenario where a higher level of efficiency is seen in both the envelope and all systems and appliances. A similar range of energy use savings is observed in the other climate zones for single-section homes. Likewise, savings results for multi-section homes in a Hot-Dry climate are comparable to those presented below and not shown separately.

Table 9: Modeled Energy Consumption Impacts (Percent Decrease or Increase) for Single-Section Units, Electrification Retrofit Upgrade and Replacement Scenarios over Baseline Conditions in Hot-Dry Climate.

	Existing Home Upgrade Electric Heat		New Construction Replacement Electric Heat			
Baseline Condition	Electrification Only	Electrification + Wx	2022 HUD	ENERGY STAR MH-v3	ZERH-MH-v1	ZERH-MH-v1-Target
Replacement Scenarios						
Pre-HUD Gas Heat	n/a		-63%	-66%	-71%	-79%
Pre-HUD Electric Heat			-54%	-57%	-63%	-74%
Upgrade and Replacement Scenarios						
1976 HUD Gas Heat	-61%	-64%	-38%	-43%	-51%	-65%
1976 HUD Electric Heat	-51%	-55%	-22%	-28%	-38%	-56%
1994 HUD Gas Heat	-56%	n/a	-24%	-30%	-40%	-57%
1994 HUD Electric Heat	-44%	n/a	-3%	-11%	-23%	-46%

Source: Project Team

UTILITY BILL IMPACTS

As noted in the Methodology section, prototype modeling has limitations in that it assumes thermostat setpoints are met 100 percent of the time by equipment, equipment is operating as designed year around, and 'typical occupancy' assumptions for residents. This can produce unreasonably high estimates as is seen in the case of the pre-HUD vintage homes in cold climates. For this reason, estimated utility bill impacts, which were estimated applying statewide electricity and natural gas costs from EIA for 2022 to the modeled energy usage for each scenario, are presented as percent savings in Table 10 through Table 13 below rather than absolute dollar savings. Negative values (highlighted green) represent decreases in utility bills, and positive values (highlighted in red) represent increases in utility bills.

With the exception of the 'Electrification Only' upgrade scenario for multi-section, gas heated homes in the Cold and Mixed-Dry climate zones, all upgrade scenarios realized energy cost savings. Modeled annual energy cost savings ranged from three percent to nearly 30 percent for gas heated homes and to just under 60 percent for electrically heated homes under the 'Electrification Only' scenario. For multi-section, gas heated homes under the 'Electrification Only' scenario, modeling results project a cost increase between four percent and 11 percent, underscoring the importance of combining electrification measures with weatherization measures for achieving utility cost savings.

Table 10: Modeled Utility Bill Impacts (Percent Decrease or Increase) for 'Electrification Only' Retrofit Scenario over 1976 HUD and 1994 HUD Vintage Groups, Single-Section Units.

Baseline Heating Fuel	1976 HUD Vintage				1994 HUD Vintage			
	Marine	Hot-Dry	Cold	Mixed-Dry	Marine	Hot-Dry	Cold	Mixed-Dry
Gas	-22%	-27%	-3%	-4%	-20%	-25%	-4%	-5%
Electric	-54%	-51%	-57%	-57%	-47%	-44%	-53%	-53%

Source: Project Team

Table 11: Modeled Utility Bill Impacts (Percent Decrease or Increase) for 'Electrification Only' Retrofit Scenario over 1976 HUD and 1994 HUD Vintage Groups, Multi-Section Units

Baseline Heating Fuel	1976 HUD Vintage				1994 HUD Vintage			
	Marine	Hot-Dry	Cold	Mixed-Dry	Marine	Hot-Dry	Cold	Mixed-Dry
Gas	-23%	-27%	11%	11%	-18%	-23%	5%	4%
Electric	-53%	-57%	-52%	-52%	-47%	-43%	-51%	-51%

Source: Project Team

Table 12: Modeled Utility Bill Impacts (Percent Decrease or Increase) for 'Electrification + Weatherization' Retrofit Scenario over 1976 HUD Vintage Group, Single-Section Units

Baseline Heating Fuel	1976 HUD Vintage			
	Marine	Hot-Dry	Cold	Mixed-Dry
Gas	-27%	-33%	-25%	-26%
Electric	-58%	-55%	-67%	-67%

Source: Project Team

Table 13: Modeled Utility Bill Impacts (Percent Decrease or Increase) for 'Electrification + Weatherization' Retrofit Scenario over 1976 HUD Vintage Group, Multi-Section Units

	1976 HUD Vintage			
Baseline Heating Fuel	Marine	Hot-Dry	Cold	Mixed-Dry
Gas	-29%	-34%	-23%	-24%
Electric	-57%	-61%	-67%	-67%

Source: Project Team

Figure 27 shows the estimated annual energy costs for each single-section prototype model home efficiency scenario in the Hot-Dry climate only. On average, the upgrade scenarios result in approximately 35 percent energy cost savings over the 1976 and 1994 HUD baselines. New construction replacement scenarios result in three percent energy cost increase to 30 percent energy cost savings. With respect to scenarios with energy cost increases, it is important to remember that the fuel heat prototype home assumes natural gas. While the majority of homes are heated with natural gas, approximately 15 percent use other delivered fuels such as propane or fuel oil that have higher energy costs than gas. The 2022 HUD and ES-MHv3 replacement scenarios result in slightly higher energy costs due to the higher costs of electricity. Savings are realized in the ZERH scenarios where high efficiency heat pump equipment is assumed.

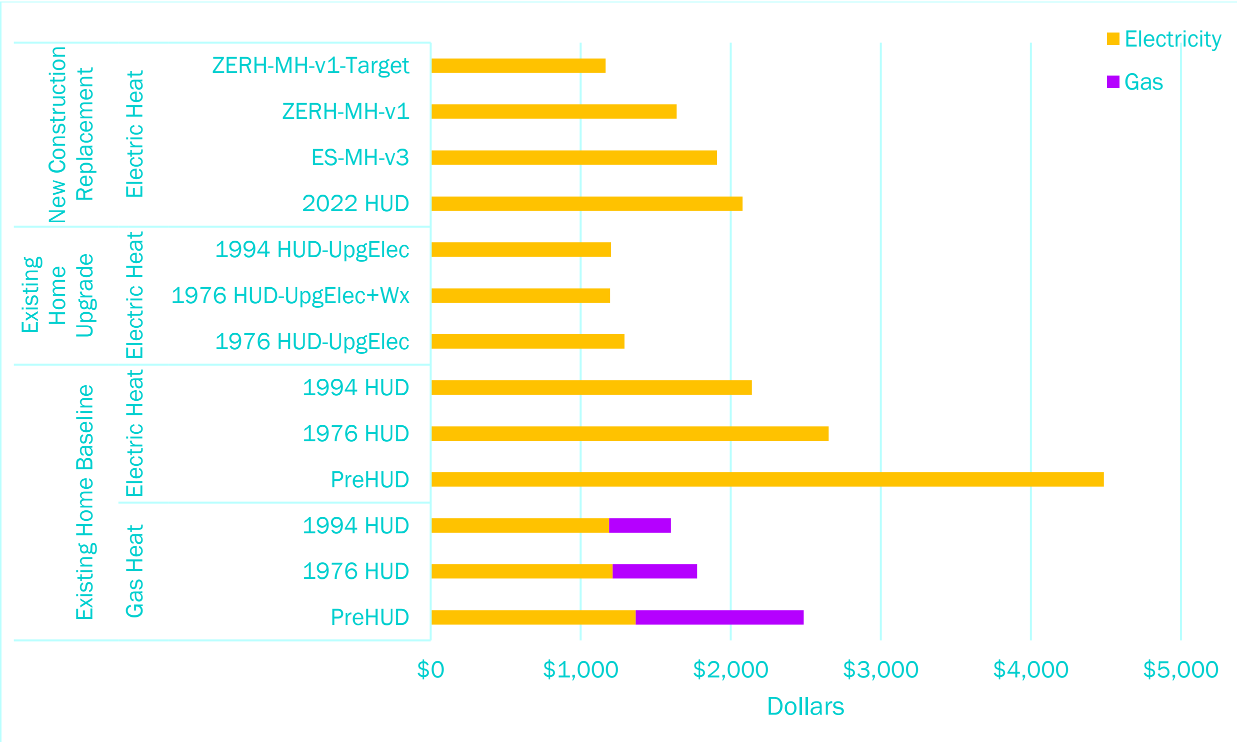

Figure 27: Modeled annual utility bill costs for single-section units, Hot-Dry climate zone only, for existing baseline, electrification retrofit, and all-electric new construction scenarios.

Source: Project Team

Table 14 shows the percent utility bill savings of the two upgrade and four new construction replacement scenarios over baseline conditions, for the Hot-Dry climate only. Negative values (highlighted green) represent decreases in utility bills in the retrofit or new construction replacement scenario compared to baseline scenario, and positive values (highlighted in red) represent utility bill increases. Modeled utility bill impacts in the Hot-Dry climate zone range from a 74 percent decrease to 30 percent increase, and a similar pattern is observed in other climate zones. Like Table 9, Table 14 shows that for the new construction replacement scenarios, a level of savings comparable to the 'Electrification + Weatherization' scenarios is only reached in the ZERH-MH-v1-Target scenario where a higher level of efficiency is seen in both the envelope and all systems and appliances. However, in the case of the 2022 HUD and ES-MH new construction replacement scenarios, where only nominal thermal shell improvements for single family homes are required, bill increases are seen for an all-electric home over gas baseline. These results highlight the importance of including high efficiency heat pump technologies in all upgrade and new construction when electrification in a key goal. Savings results for multi-section homes in a Hot-Dry climate are comparable to those presented below and not shown separately.

Table 14: Modeled Utility Bill Impacts (Percent Decrease or Increase) for Electrification Retrofit Upgrade and Replacement Scenarios over Baseline Conditions in Hot-Dry Climate.

	Existing Home Upgrade Electric Heat		New Construction Replacement Electric Heat			
Baseline Condition	Electrification Only	Electrification + Wx	2022 HUD	ENERGY STAR MH-v3	ZERH-MH-v1	ZERH-MH-v1-Target
Replacement Scenarios						
Pre-HUD Gas Heat	n/a		-16%	-23%	-34%	-53%
Pre-HUD Electric Heat			-54%	-57%	-63%	-74%
Upgrade and Replacement Scenarios						
1976 HUD Gas Heat	-27%	-33%	17%	7%	-8%	-34%
1976 HUD Electric Heat	-51%	-55%	-22%	-28%	-38%	-56%
1994 HUD Gas Heat	-25%	n/a	30%	19%	2%	-27%
1994 HUD Electric Heat	-44%	n/a	-3%	-11%	-23%	-46%

Source: Project Team

PEAK LOAD IMPACTS ON ELECTRICITY

Figure 28 shows the modeled summer and winter peak electricity demand for single-section units in a Hot-Dry climate, and Figure 29 shows the same for multi-section units. These figures, which just show results for the Hot-Dry climate (where the majority of MMH units are located in California), are meant to be illustrative. Results for each of the major climate zones are presented in Table 29 and Table 30 in Appendix B: Supplemental Modeling Results.

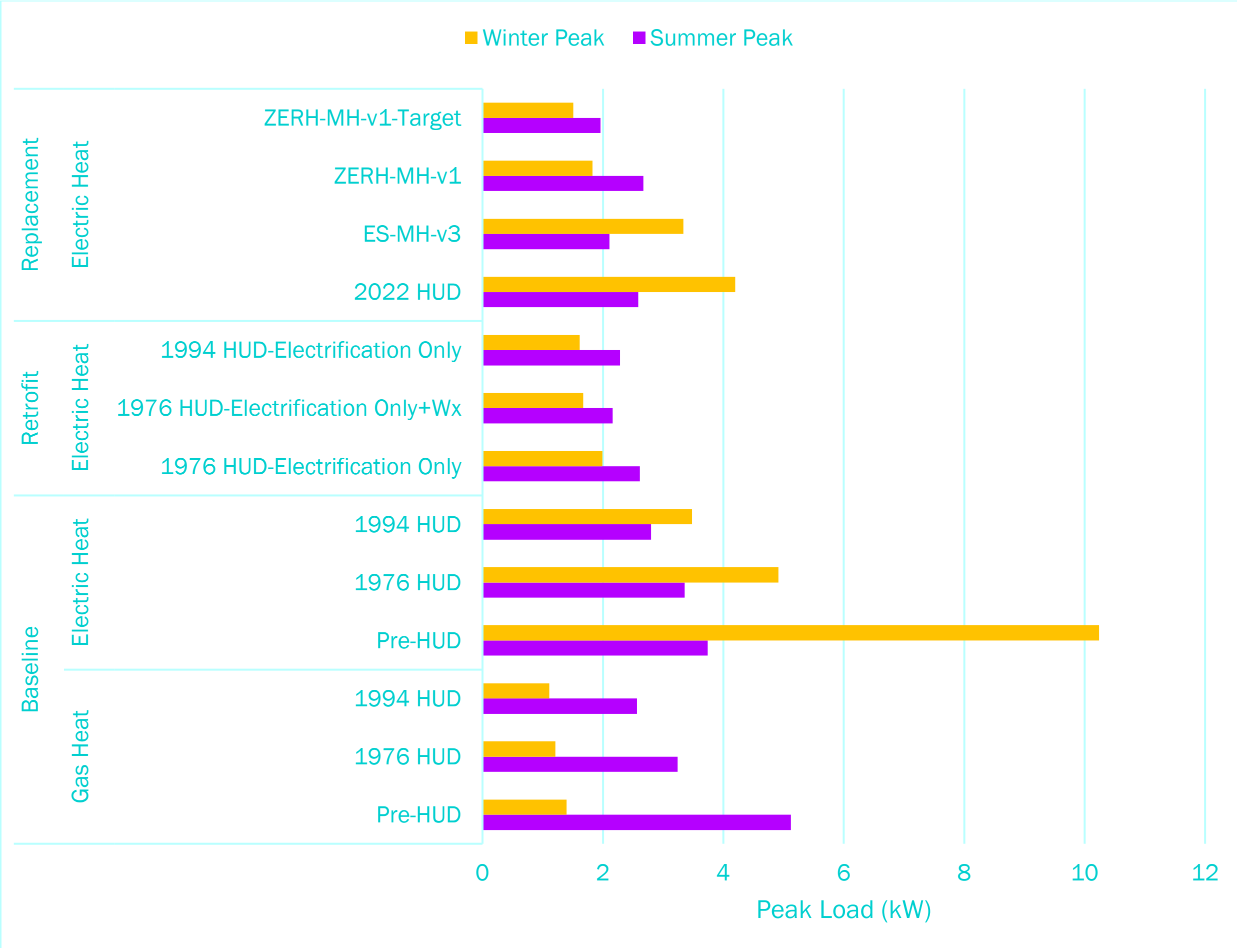

Figure 28: Modeled summer and winter peak electric load (kW) for single-section units, Hot-Dry climate zone only, existing baseline, electrification retrofit, and all-electric new construction scenarios.

Source: Project Team

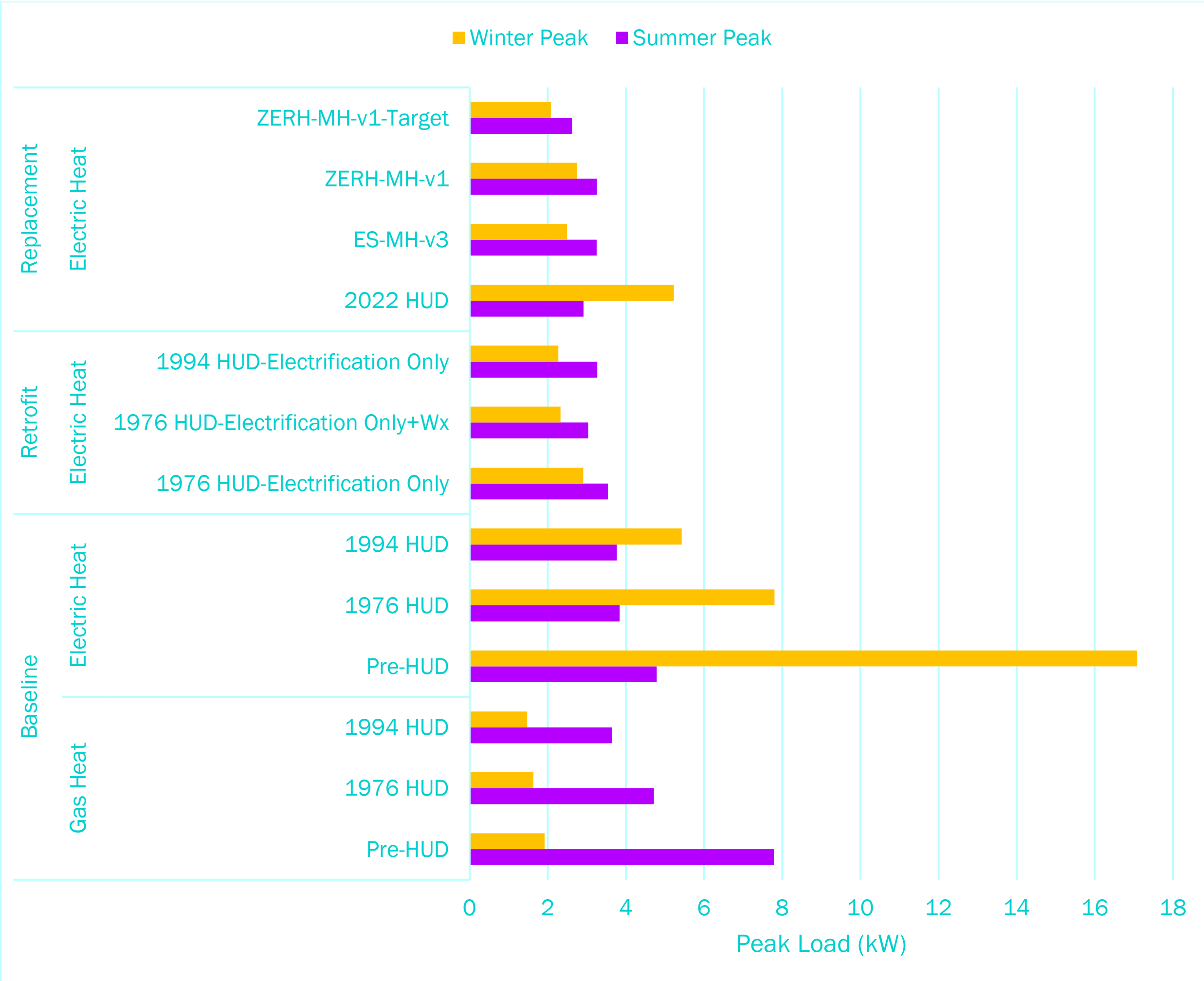

Figure 29: Modeled summer and winter peak electric load (kW) for multi-section units, Hot-Dry climate zone only, existing baseline, electrification retrofit, and all-electric new construction scenarios.

Source: Project Team

Table 15 shows summer peak electric demand impacts of the electrification retrofit upgrade and replacement scenarios compared to relevant existing baselines for the scenarios, and Table 16 shows the same for winter peak electric demand. Negative values (highlighted green) represent decreases in peak load under the retrofit scenario compared to the baseline, and positive values (highlighted in red) represent increases in peak load.

Table 15: Modeled Impact on Summer Peak Electric Load (Percent Decrease or Increase) for Electrification Retrofit and All-Electric New Construction Relative to Existing Baseline Modeling Scenarios.

		Single-Section				Multi-Section			
		Marine	Hot-Dry	Cold	Mixed-Dry	Marine	Hot-Dry	Cold	Mixed-Dry
Replacement Scenarios									
Elec heat	ZERH target / Pre-HUD	-61%	-48%	-86%	-88%	-71%	-45%	-87%	-89%
Gas heat	ZERH target / Pre-HUD	-57%	-62%	-15%	-27%	-65%	-66%	4%	-13%
Retrofit Upgrade Scenarios									
Elec heat	Electrification Only / 1976 HUD	-35%	-22%	-50%	-58%	-40%	-8%	-40%	-53%
	Electrification + Wx / 1976 HUD	-38%	-36%	-67%	-70%	-44%	-21%	-62%	-71%
	Electrification Only / 1994 HUD	-29%	-18%	-54%	-54%	-31%	-13%	-42%	-51%
Gas heat	Electrification Only / 1976 HUD	-27%	-19%	84%	42%	-37%	-25%	174%	96%
	Electrification + Wx / 1976 HUD	-30%	-33%	22%	3%	-41%	-36%	73%	22%
	Electrification Only / 1994 HUD	-16%	-11%	33%	5%	-22%	-10%	93%	32%

Source: Project Team

Table 16: Modeled Impact on Winter Peak Electric Load (Percent Decrease or Increase) for Electrification Retrofit and All-Electric New Construction Relative to Existing Baseline Modeling Scenarios.

		Single-Section				Multi-Section			
		Marine	Hot-Dry	Cold	Mixed-Dry	Marine	Hot-Dry	Cold	Mixed-Dry
Replacement Scenarios									
Elec heat	ZERH target / Pre-HUD	-76%	-85%	-74%	-80%	-79%	-88%	-62%	-71%
Gas heat	ZERH target / Pre-HUD	188%	8%	347%	253%	207%	8%	379%	324%
Retrofit Upgrade Scenarios									

		Single-Section				Multi-Section			
		Marine	Hot-Dry	Cold	Mixed-Dry	Marine	Hot-Dry	Cold	Mixed-Dry
Elec heat	Electrification Only / 1976 HUD	-44%	-60%	-24%	-25%	-49%	-63%	-23%	-28%
	Electrification + Wx / 1976 HUD	-52%	-66%	-45%	-48%	-57%	-70%	-46%	-48%
	Electrification Only / 1994 HUD	-40%	-54%	-22%	-27%	-39%	-58%	-19%	-24%
Gas heat	Electrification Only / 1976 HUD	294%	64%	891%	763%	337%	78%	1073%	928%
	Electrification + Wx / 1976 HUD	240%	38%	621%	495%	271%	42%	725%	635%
	Electrification Only / 1994 HUD	230%	45%	719%	570%	276%	54%	878%	714%

Source: Project Team

GREENHOUSE GAS IMPACTS

Figure 30 and Figure 31 compare the marginal greenhouse gas (GHG) emissions, measured in carbon dioxide-equivalent (CO2e), for single-section and multi-section MMH units located in a Hot-Dry climate zone, where the majority of MMH units in California are situated. Additional details for all climate zones are provided in the Supplemental Results: Greenhouse Gas Impacts.

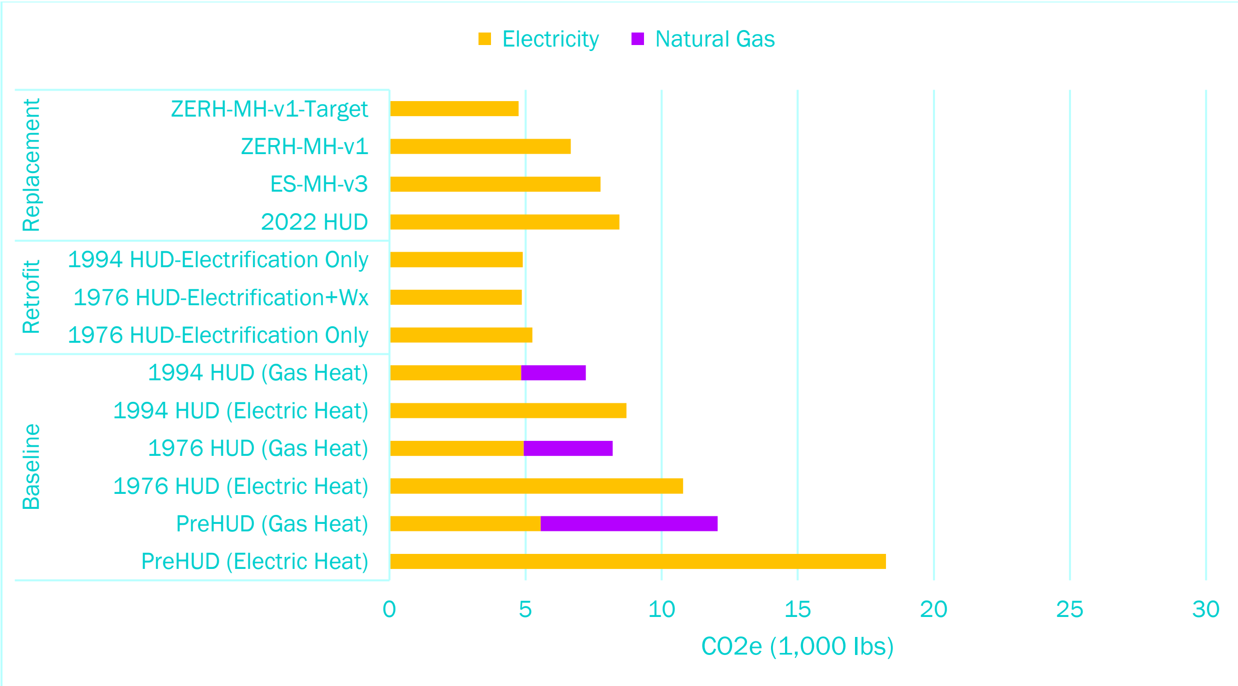

Figure 30: Estimated greenhouse gas emissions for single-section units, Hot-Dry climate zone only, for existing baseline, electrification retrofit, and all-electric new construction modeling scenarios.

Source: Project Team

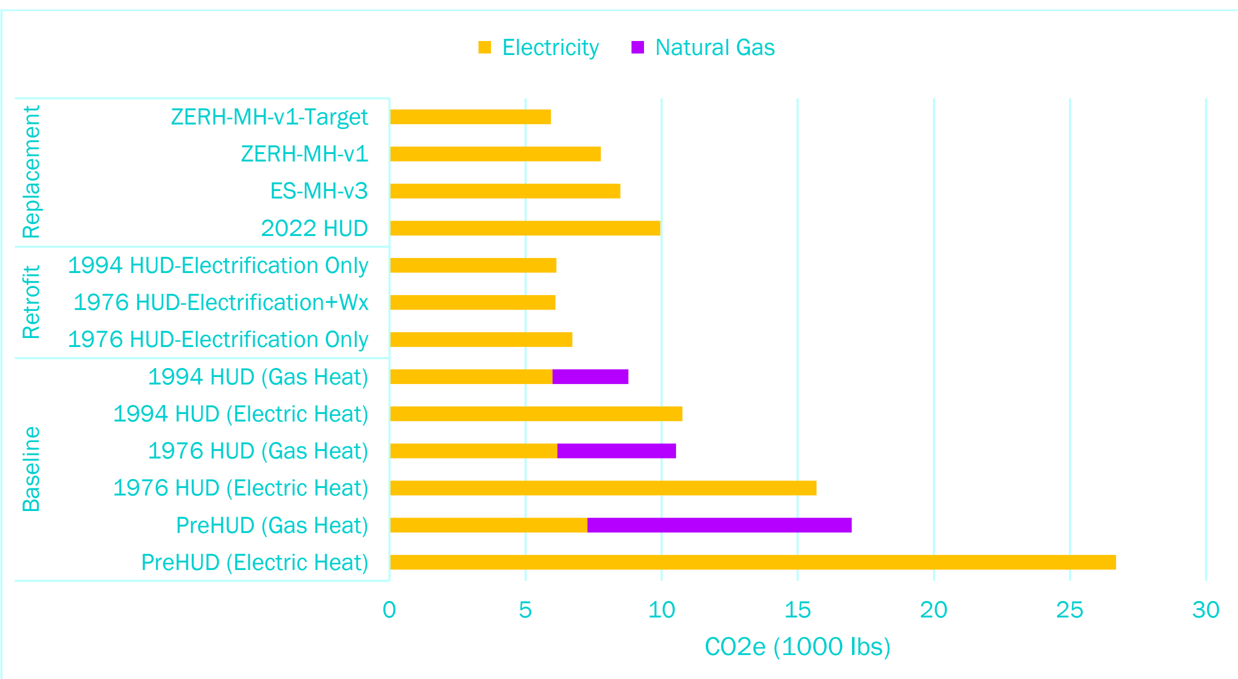

Figure 31: Estimated greenhouse gas emissions for multi-section units, Hot-Dry climate zone only, for existing baseline, electrification retrofit, and all-electric new construction modeling scenarios.

Source: Project Team

Electrification Retrofit and Whole-Home Replacement Decision Model

Figure 32 and Figure 33 provide a decision model framework for stakeholders interested in targeting electrification retrofits and/or whole-home replacement opportunities for the existing stock of MMH units. For some portions of the existing housing stock (e.g., homes constructed prior to implementation of the initial 1976 HUD Code), electrification retrofits are not recommended due to likely structural challenges and limited ability to pair electrification with cost-effective weatherization. The goal of this framework is to help stakeholders understand where to prioritize electrification retrofit efforts versus replacing existing housing stock with above code all-electric new manufactured homes.

The decision model presented below is informed by outcomes of current programs targeting this space with other measures, stakeholder perspective, and modeling results that apply measure packages to different segments of the housing stock. The decision model is broken down into two pieces: one piece that discusses utility-side to-the-meter consideration and another that discusses behind-the-meter considerations for individual homes.

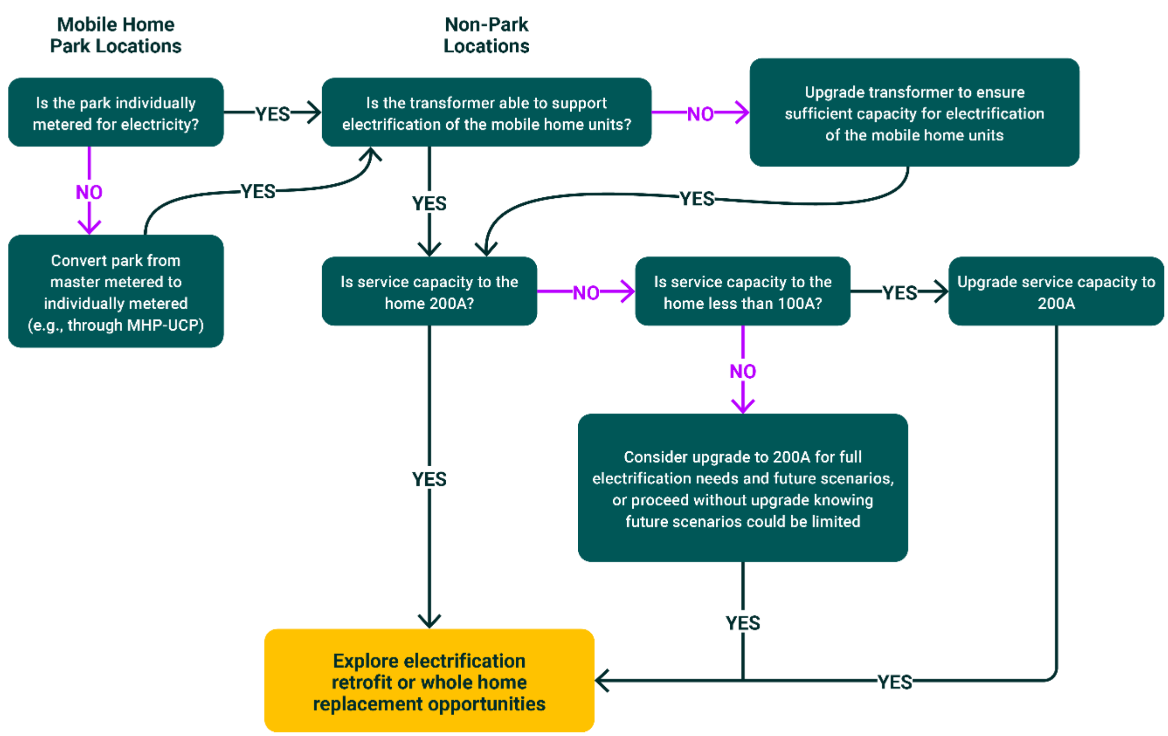

Figure 32: Process model to prepare for to-the-meter (TTM) electrification retrofit and replacement opportunities.

Source: Project Team

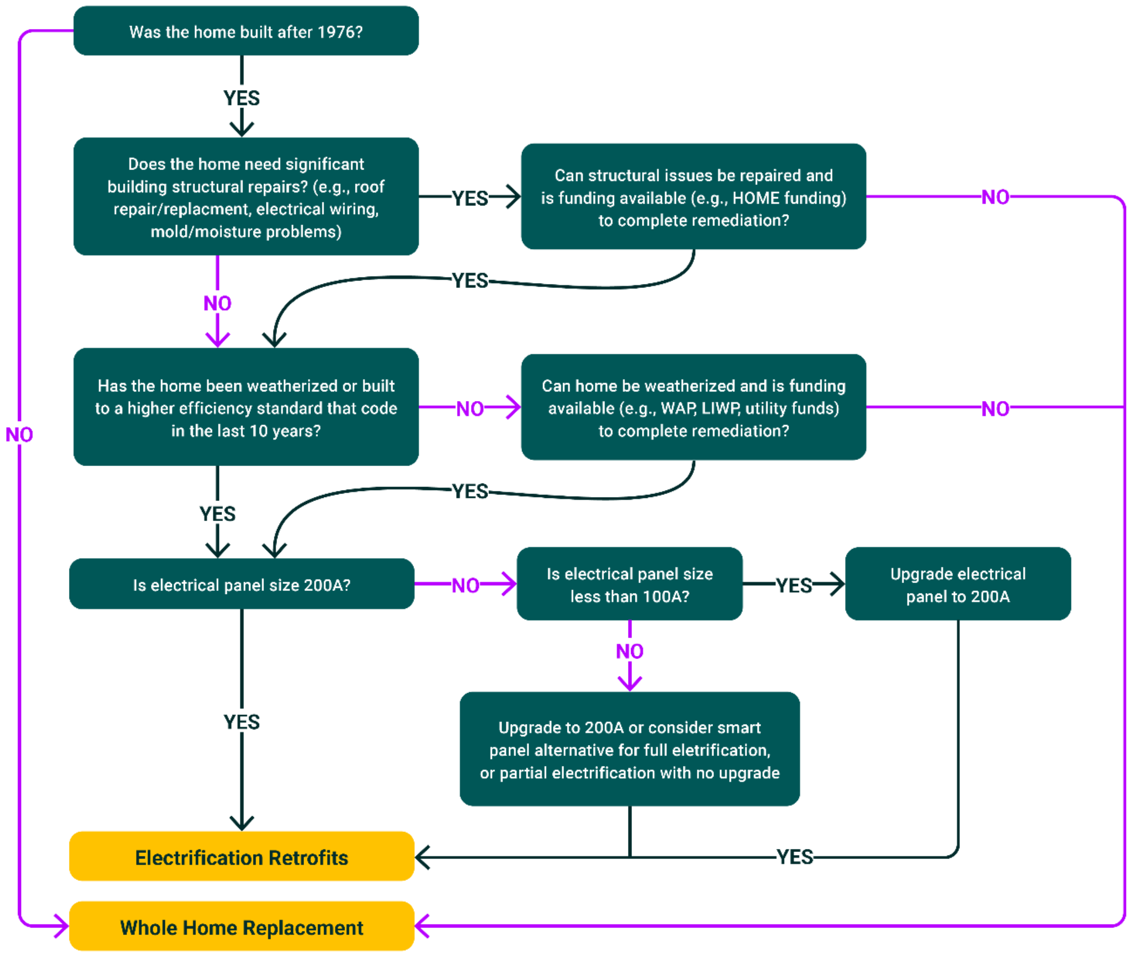

Figure 33: Process model to prepare for behind-the-meter (BTM) electrification retrofit and replacement opportunities.

Source: Project Team

Additional considerations that do not directly factor into the process models above but could be important factors for the success of a comprehensive electrification retrofit and replacement program include the following:

- Delivered heating fuels and electric resistance: while energy modeling indicates that utility bill impacts of electrification retrofits are likely to be beneficial under most scenarios, actual impacts will vary based on specific usage of residents and actual differences in fuel costs. Residents who use propane or electric resistance heating are more likely to experience a beneficial utility bill impact compared to those using natural gas as their existing heating fuel, where understanding actual consumption, differences in fuel costs, and, in the case of master metered mobile home parks, how utilities currently are passed through to residents are more important considerations for a program to consider.

- Remote areas: MMH units located in remote areas of the state (e.g., mountainous areas) may be more difficult and expensive to retrofit due to lack of workforce, materials, limited electrical infrastructure, and other factors. Likewise, challenges with transporting new homes to these areas may make whole-home replacement costs higher. A program may need to consider allowing higher costs in certain areas to serve the MMH population equitably.
- Park dynamics: where land is leased, motivations of mobile home park owners, not just residents, need to be accounted for when considering electrification retrofits or whole home replacement. While residents may still own their homes, they may not have full authority to electrify or replace their home. Gaining buy-in from mobile home park owners is an important step for implementing a successful program.

Program Recommendations

The following program recommendations are made based on findings from the market characterization and energy modeling.

- **Revisit measures available to MMH units through IOU programs.** Stakeholders noted that MMH units often have lower actual baseline efficiencies than assumed, and screening measures based on more realistic baseline efficiencies in the housing sector would make those measures more cost-effective and feasible to implement in existing programs. Energy efficiency and electrification measures noted by internal experts as opportunities for MMH units include:
  - Ducted ASHP to replace gas furnaces and ductless minis-split or other emerging heat pump options where ducts do not already exist.
  - 110v HPWH options to offer flexibility to MMH units with a constrained panel.
  - Small storage tank options for HPWHs that can fit into existing utility closets while still meeting resident needs; options developed abroad could be the focus of an emerging technology research or pilot effort.
  - Ventilation including whole house fans and energy recovery ventilation (ERV) as an indoor air quality (IAQ) measure.
  - Insulation in floor/attic (when access allows). Wall insulation likely is cost-prohibitive and not recommended.
  - Duct repair and sealing.
  - Other air sealing.
  - Efficient electric cooking appliances.
- **Reclassify programs serving MMH residents as equity-focused programs serving HTR and low-income populations.** Stakeholders noted that cost-effectiveness requirements are a challenge in programs targeting MMH units, and reclassifying as serving HTR and low-income populations would ease the cost-effectiveness requirements. The CPUC considers MMH residents as HTR, and analysis of Census data shows that most residents living in MMH units have lower incomes

(e.g., 53 percent are income-eligible for the FERA rate discount, and 70 percent have incomes that are less than 80 percent AMI or 80 percent SMI, the income requirements used in the LIWP Farmworker Housing program). Given the challenges stakeholders expressed in serving MMH units, particularly those in mobile home parks, IOUs could seek to reclassify existing MMH programs offerings as targeted to low-income and HTR communities and seek easing of the cost-effectiveness requirements that prevent certain measures from being included in existing programs.

- **Increase the pace of master meter mobile home park conversions.** Master metering in mobile home parks presents an obstacle to electrification efforts. CPUC could propose increasing the pace at which these communities are converted to direct metering will expedite addressing the split incentive issues residents face when considering energy efficiency and electrification measures and potentially open rate discounts to income-qualified residents living in those communities.
- **Establish the 200A electrical service minimum standard for MHP-UCP.** CPUC is considering updating the Mobile Home Park Utility Conversion Program to require 200A electrical service with proceedings underway. Establishing this requirement would help ease future challenges associated with electrifying MMH units in mobile home parks. Delaying this decision and implementation will result in lost opportunities, or the need to deploy potentially expensive technologies, to fully electrify MMH in parks that upgrade to 100A service.
- **Conduct a field demonstration of panel upgrade alternatives in MMH units.** Most MMH units have 30A to 100A service and panel capacity. For locations where upgrading the service and panels to 200A is not feasible, smart panel and other panel upgrades alternatives could present an opportunity to help MMH residents electrify if allowable by HCD. For this technology type to work in the MMH sector, additional research and demonstration is needed.
- **Better program coordination.** Stakeholders noted that there are numerous program offerings available to MMH residents and mobile home parks, and this can cause confusion. Better coordination between MMH-specific energy efficiency offerings by IOUs, utility metering conversion programs, and statewide income-qualified programs can help prioritize investments and achieve maximum savings for residents. There is opportunity for an IOU program administrator to act as a coordinator and facilitator across programs.
- **Incentivize high efficiency new manufactured homes.** While stakeholders indicated that incentives from DOE are pushing manufacturers of new manufactured homes to adopt voluntary energy efficiency standards that are more stringent than HUD Code, providing additional incentives could help push the market in this direction more quickly and make high efficiency new homes more affordable to purchase.
- **Incorporate whole-home replacement of old, structurally unsound MMH units into new programs.** Stakeholders noted that whole-home replacement can be more cost-effective in certain situations (e.g., older, pre-1976 HUD Code homes with little to no insulation and limited cavities to add it; and poor general housing quality with structural limitations). The manufactured home replacement program model from the Energy Trust of Oregon and Oregon

Housing and Community Services could serve as a starting point for incentivizing whole-home replacement.[41]

- **Utilize the decision model in a pilot** to prioritize segments of the market for electrification retrofits and replacement opportunities. If utilities consider implementing electrification retrofit and/or whole-home replacement programs, the decision model developed in this report provides a framework for prioritizing segments of the manufactured housing landscape for each pathway. This could be useful in a pilot for identifying opportunities that are well-suited to each pathway, and the model could be refined as pilot learnings are developed.
- **Refine energy savings estimates by working with the WAP program to understand actual energy usage in MMH units**. While the asset-based prototype energy modeling completed for this study provides a useful starting point for assessing the potential energy savings, utility bill impacts, and greenhouse gas impacts of electrification retrofit and replacement scenarios, it is meant to be illustrative of the potential impacts of electrification and energy efficiency improvements in MMH units and may not reflect actual operating conditions. A better approximation of savings could be developed by calibrating the results with actual energy usage data for a representative sample of MMH units in California. This is particularly true of less populated climate zones in the state (i.e., cold and mixed-dry) where small samples underlying the prototype modeling assumption could have a disproportionate impact on the modeling results. If utilities consider implementing electrification retrofit and/or whole-home replacement programs, the project team recommends working with CSD, local WAP agencies, and other stakeholders to better understand actual energy usage in this housing sector in order to refine savings estimates from this study. It is also important to consider that potential energy savings may be offset by an ability to maintain safe and comfortable temperatures in upgraded or replacement homes.
- Program administrators should engage MMH residents in DAC and HTR communities through multiple channels and strategies:
    - Gaining buy-in from park owners and on-site managers.
        - As noted in the Stakeholder Engagement section, mobile home park owners and managers were a difficult stakeholder group to engage in this project, but they play a vital role in programs reaching residents. Continued engagement with this stakeholder group is needed to ensure that programs are designed and implemented in a way that aligns with park procedures and dynamics.
        - One path to engage mobile home park owners and managers is through existing programs like the MHP-UCP, which has successfully engaged many of the mobile home parks in California, and demonstrating the value of existing and future programs to both residents and park owners.

[41] The Energy Trust of Oregon and Oregon Housing and Community Services have partnered to provide incentives for the early replacement of old, inefficient. Incentives are available to residents who replace an MMH unit constructed before 1995 with an ENERGY STAR or NEEM+ manufactured home. More information on this program is available here: https://www.energytrust.org/residential/manufactured-home-replacement/

- Leveraging partnerships with trust community-based organizations.
- Providing clear messaging and coordinated program offerings.
- Utilizing local workforce and supporting development of needed skills by members in these communities.

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Appendix A: Technical Details of Prototype Energy Modeling

Energy use data for California's mobile and manufactured housing stock was obtained from NREL's ResStock building energy tool. ResStock runs energy simulations using a statistical model of housing characteristics. Housing characteristics are obtained through a number of public datasets including the RECS, ACS, and AHS surveys, in addition to other attribute-specific datasets.[42]

The project team utilized ResStock metadata (2022.1 Release) to characterize energy use in existing MMH units by various factors such as vintage and climate type. In addition to existing building energy, NREL also released a set of End Use Savings Shapes based on several upgrade scenarios including whole building electrification.[43]

The ResStock metadata also were utilized to inform characteristics of prototype energy models. Prototype models are used in this analysis to represent the average existing energy consumption and potential savings by home size, vintage group, and climate zone.

Prototype modeling applies average or common construction and energy efficiency characteristics to a single energy model. This model can then be run in various climates to estimate pre- and post-energy consumption that inform the savings potential attributed to energy conservation measures. While this type of modeling is very common, it has limitations in that it assumes, for example, heating and cooling setpoints are always met and equipment is operating as designed. In reality, this often is not the case. It is well documented that low-income homeowners, and residents of manufactured housing specifically, are more likely to operate their homes in ways that reduce energy costs such as not maintaining healthy indoor air temperatures. A recent brief by the American Council on an Energy-Efficient Economy (Bell-Pasht 2023), summarizing energy insecurity data from the 2020 RECS, reports that occupants of manufactured homes are more than twice as likely to operate their homes at unhealthy temperatures than residents of single-family housing. The results of the prototype modeling below should be viewed in this light – that the energy consumption and costs are potential values were the home to be operated as designed.

While the HUD Code has regulated the construction of manufactured housing since 1976, the code does not prescribe assembly insulation values. Rather, HUD Code establishes a maximum Uo by climate zone. California falls within the HUD Climate Zone 2 which requires a maximum Uo of 0.096. Existing prototype energy modeling of manufactured housing was reviewed for common representative efficiency inputs (PNNL 2014, Pigg et al. 2021). However, final inputs for existing home efficiency characteristics relied heavily on the ResStock dataset which is a calibrated building stock model and is more likely to represent actual existing conditions. Table 17 provides an overview of the attributes on which the prototype energy modeling varied. Vintage group is a best fit alignment between effective HUD code periods and vintage bins present in the ResStock database.

[42] More information on the ResStock methodology is available here: https://www.nrel.gov/docs/fy22osti/83063.pdf

[43] More information on the End Use Savings Shapes is available here: https://oedi-data-lake.s3.amazonaws.com/nrel-pds-building-stock/end-use-load-profiles-for-us-building-stock/2022/EUSS_ResRound1_Technical_Documentation.pdf

Table 17: Attributes of MMH Units that Vary in Prototype Energy Modeling

Attribute	Variations
Home size	Single-section: 924 square feet (14x66) Multi-section: 1,568 square feet (28x56)
Vintage group	Pre-HUD Code (constructed <1940-1979) 1976 HUD Code (constructed 1980-1999) 1994 HUD Code (constructed 2000+)
Climate zone	Marine (San Jose) Hot-Dry (Riverside) Cold (Truckee Tahoe) Mixed-Dry (Lake Tahoe)
Fuel type	Natural gas, electricity

Source: Project Team

Table 18 provides input assumptions for the three prototype home vintage groups. Thermal envelope assumptions are based on ResStock weighted average value by vintage group. All floors are assumed to be 2x6 framing. Pre-HUD and 1976 HUD walls are assumed to be 2x4 framing, 1994 HUD walls are assumed to be 2x6 framing. Single-section ceiling truss height is assumed to be 18 feet for single-section units and 30 feet for multi-section units (PNNL 2014). All homes assume 12 percent window to wall ratio on all sides. Heating and cooling system assumptions are based on the most common occurrence of the variable type. Heating and cooling setpoints are 72- and 75-degrees Fahrenheit, respectively, with no setback temperatures in place. Water heating and appliance assumptions are based on default assumptions derived from the ANSI/RESNET/ICC 301 Standard, which assume 2006-era efficiency levels as implemented in the OS-HPXML workflow.[44] Ventilation is assumed to be kitchen and bath exhaust fans based on the 2010 Building American House Simulation Protocol (BAHSP).[45] No whole home mechanical ventilation is assumed. Efficient lighting assumptions are based on overall ResStock average. Efficiency levels did not vary significantly by vintage group, likely assuming natural replacement over time.

Table 18: Prototype Modeling Input Assumptions by Vintage Group

	Vintage Group Vintage Years	Pre-HUD <1980	1976 HUD 1980-1999	1994 HUD 2000+
Thermal Shell	Floors	R-0	R-11	R-19
	Ceiling	R-18	R-25	R-32
	Walls	R-0	R-12	R-15
	Windows (U/SHGC)	1.16/0.76	0.76/.67	0.52/0.60

44 More information on the ANSI/RESNET/ICC 301 Standard is available here: https://codes.iccsafe.org/content/RESNET3012019P1

45 More information on the BAHSP is available here: https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/house_simulation.pdf

	Vintage Group Vintage Years	Pre-HUD <1980	1976 HUD 1980-1999	1994 HUD 2000+
	Air Leakage	20 ACH50	12 ACH50	9 ACH50
Systems	Heating Type / Fuel	Forced hot air furnace / Natural Gas, Electric		
	Heating Efficiency	80 AFUE (gas), 100% efficient (electric)		
	Cooling System	Central Air		
	Cooling Efficiency	13 SEER		
	Duct Systems	20%, R-4	20%, R-4	20%, R-8
	Hot Water Type / Fuel	Storage tank / Natural Gas, Electric		
	Hot Water EF/RE	0.59/0.76 (gas), 0.92/0.98 (electric)		
	Ventilation	Kitchen and bath exhaust		
Lights & Appliances	Lighting	33% CFL, 45% LED		
	Clothes Washer	400 kWh/year rated		
	Clothes Dryer	3.01 CEF (Natural Gas, Electric)		
	Dishwasher	467 kWh/year rated		
	Refrigerator	673 kWh/year rated		
	Cooking Range/Oven	Natural Gas, Electric (non-induction)		
	Miscellaneous Electric Loads	Calculated per ANSI/RESNET/ICC 301-2019[46]		

Source: Project Team

For determining equipment size, the modeling software allows users to auto-size the equipment or provide specific input parameters, but not both. For the pre-HUD, 1976 HUD, and 1994 HUD baselines, heating and cooling equipment were auto-sized to meet the specific thermal needs of the model units. However, for analysis of peak load impacts for these housing vintages, the project team ran a second model and capped the heating and cooling equipment size (75 thousand Btu/hour for heating load and 30 thousand Btu/hour for cooling load) given that auto-sizing resulted in unreasonably large heating and cooling equipment sizes for some model units.

It is important to note that while average and 'most common' values were utilized for prototype modeling to estimate baseline energy usage and potential savings, there is a high level of variation across homes represented in the ResStock building model. For example, Figure 34 through Figure 38 show the distribution of efficiency levels from the primary assemblies and systems of MMH units in the ResStock metadata.

[46] ANSI/RESNET/ICC-301-2019 is available here: https://codes.iccsafe.org/content/RESNET3012019P1

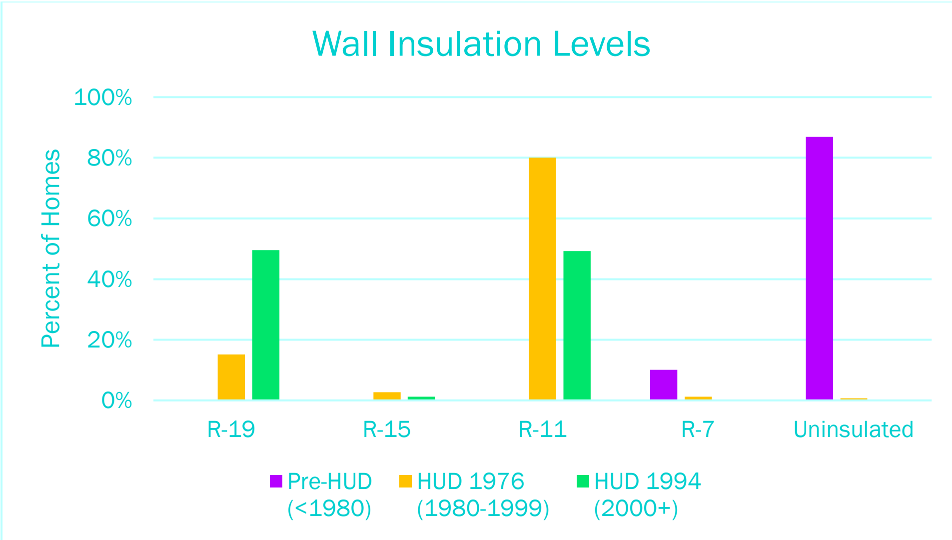

Figure 34: Distribution of wall insulation levels in MMH units by vintage group.

Source: ResStock metadata

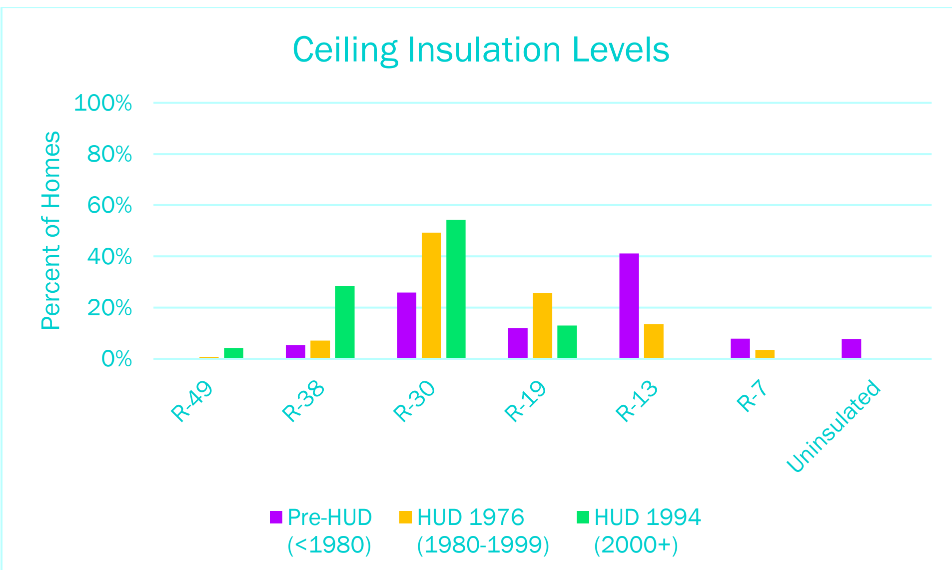

Figure 35: Distribution of ceiling insulation levels in MMH units by vintage group.

Source: ResStock metadata

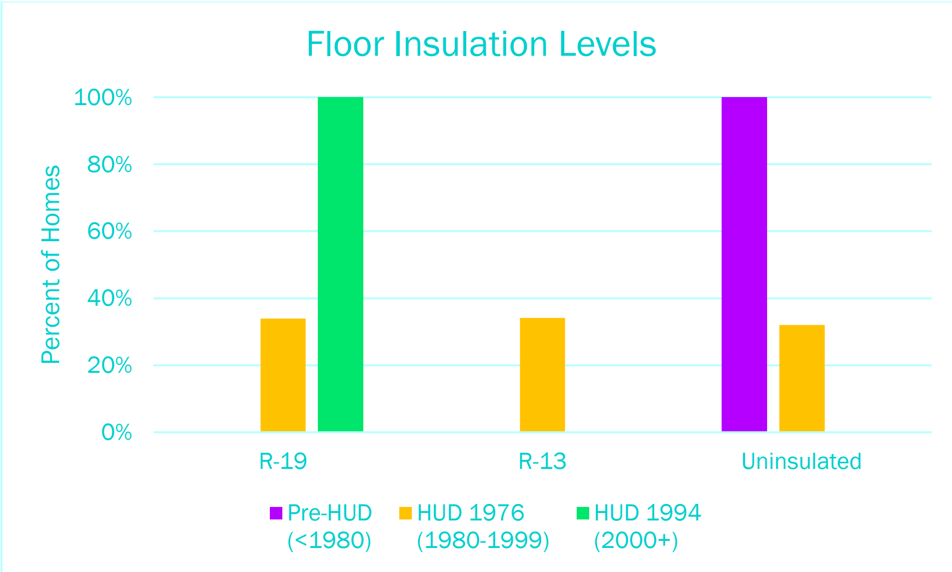

Figure 36: Distribution of floor insulation levels in MMH units by vintage group.

Source: ResStock metadata

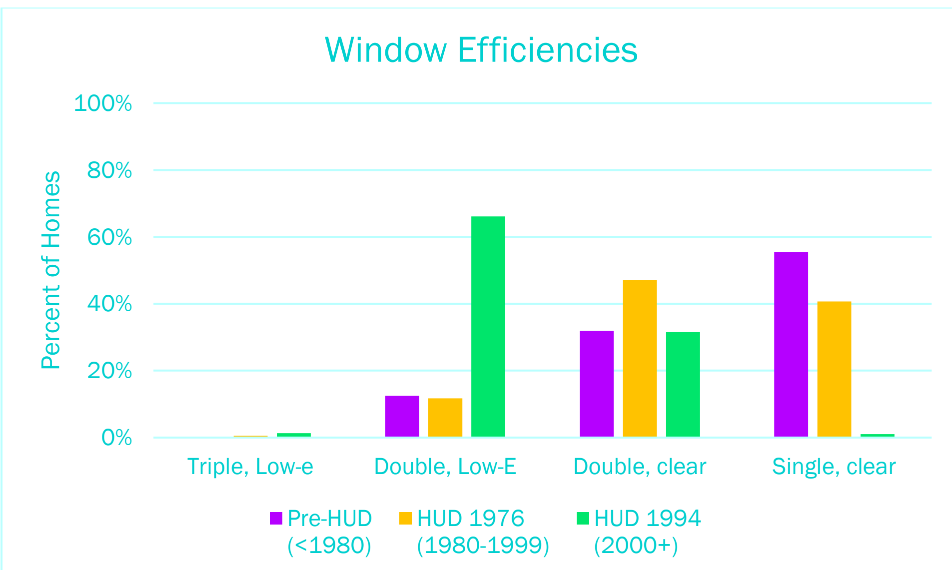

Figure 37: Distribution of window efficiency levels in MMH units by vintage group.

Source: ResStock metadata

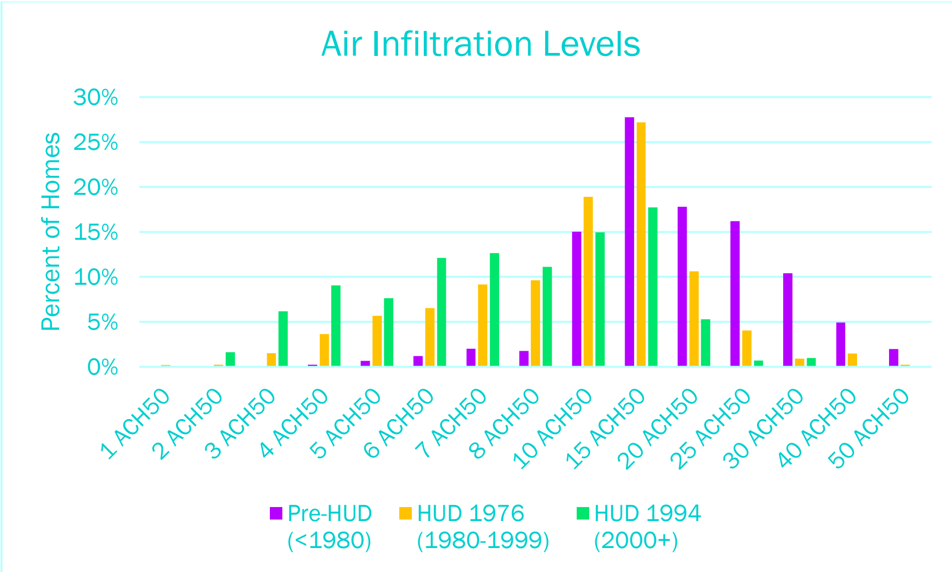

Figure 38: Distribution of air infiltration levels in MMH by vintage group.

Source: ResStock metadata

Prototype Upgrade Measures and Model Inputs

Parameters for Electrification Retrofit Modeling Scenarios

The primary measures assessed in this modeling are electrification measures. These include air source heat pumps (ASHP) to replace existing heating and cooling systems, heat pump water heaters (HWPH), balanced ventilation, 100 percent light emitting diode (LED) lighting, and all appliances meeting the most recent ENERGY STAR criteria. Mechanical system efficiency levels were drawn from the California Technical Reference Manual (TRM) for each measure.

In addition to electrification measures, the project team also considered weatherization upgrades including floor and ceiling insulation, high efficiency windows, and air and duct leakage reduction. Wall insulation is not considered as the quality of mobile and manufactured housing generally prevents the addition of insulation in the wall cavity and continuous insulation would be cost prohibitive. Windows may also be excluded from future weatherization scenarios for cost reasons. Based on national evaluations of the WAP program, wall insulation is not a common measure for MMH units and window replacement is infrequent (Blasnik et al. 2014). Base air leakage reduction assumptions are based on no insulation measures and only caulking and foaming measures (15 percent reduction). A deeper air leakage reduction scenario (40 percent reduction) is associated with weatherization work and is based on Vermont data from pre- and post-weatherized homes.[47]

Table 19 provides efficiency values assumed for the upgrade scenarios. Floor and ceiling insulation measures generally assume filling the available cavity space. A value of ‘None’ in the thermal shell section of the table indicates the ‘Electrification only’ scenario.

[47] Data shared by the Vermont Office of Economic Opportunity (OEO).

Table 19: Assumed Efficiency Values for Upgrade Scenarios in Prototype Modeling

	Vintage Group Vintage Years	Pre-HUD <1980	1976 HUD 1980-1999	1994 HUD 2000+
Thermal Shell	Walls	None	None	None
	Floors	None, R-19	None, R-19	None
	Ceiling	None, R-30	None, R-30	None
	Window (type)	None	None	None
	Windows (U/SHGC)	n/a	n/a	n/a
	Air Leakage	15% (17 ACH50), 40% (12 ACH50)	`15% (14 ACH50), 40% (10 ACH50)	15% (9 ACH50), 40% (6 ACH50)
Systems	Heating Type / Fuel	ASHP / Electric		
	Heating Efficiency	10 HPSF (CA eTRM)		
	Cooling System	ASHP / Electric		
	Cooling Efficiency	20 SEER (CA eTRM)		
	Duct Systems	6%, R-8		
	Hot Water Type / Fuel	HPWP / Electric		
	Hot Water EF/RE (120V)	3.75 UEF (CA eTRM)		
	Ventilation	Balanced Heat Recovery 86% SRE (CA eTRM)		
Lights & Appliances	Lighting	100% LED		
	Clothes Washer	ENERGY STAR (IMEF ≥ 2.06)		
	Clothes Dryer	ENERGY STAR (3.8 CEF)		
	Dishwasher	ENERGY STAR (270 kWh/year)		
	Refrigerator	ENERGY STAR (10% <Federal Minimum, 606 kWh)		
	Cooking Range/Oven	Induction		
	Miscellaneous Electrical Loads	Calculated per ANSI/RESNET/ICC 301-2019[48]		

Source: Project Team

Parameters for Above Code All-Electric New Construction Modeling Scenarios

Table 20 and Table 21 show, first the minimum base requirements of 2022 HUD, ES-MH and ZERH-MH, followed by the selection of additional EE points to fulfill the requirements of ES-MH for multi-section homes and all ZERH-MH homes. Table 22 shows the assumed modeling inputs based on the minimum requirements plus additional EE points. Table 23 represents a target scenario that goes beyond the minimum requirements ZERH-MH to incorporate high efficiency electric systems for hot water and ventilation, in addition to heating/cooling. If a MMH replacement program is developed based on one of the above code voluntary programs discussed here, a recommended next step would be to do a detailed cost benefit analysis in conjunction with partner factories to determine

[48] ANSI/RESNET/ICC-301-2019 is available here: https://codes.iccsafe.org/content/RESNET3012019P1

whether a higher efficiency thermal shell, based on the Uo <= 0.049 Additional EE Point option, is feasible.

Table 20: Base Efficiency Minimum Requirements for All-Electric Replacement Scenarios.

		2022 HUD		ENERGY STAR MH v3		ZERH MH v1
		Single	Multi	Single	Multi	All homes
Thermal Shell	Walls	R-13	R-21			
	Floors	R-19		R-22		
	Ceiling	R-22	R-30	R-33		
	Windows (U)	0.50	0.30			
	Windows (SHGC)	0.60	0.25			
	Doors (U)	0.40				
	Air Leakage	Visual Inspection				
Systems	Heating	NR (Federal minimum standard)				
	Cooling	NR (Federal minimum standard)				
	Thermostat	Manual		Programmable		
	Hot Water	NR (Federal minimum standard)				
	Ventilation (1)	Minimum fan efficacy as per 2021 IECC				ENERGY STAR exhaust fans
	Duct Leakage	4 CFM25/100sf* (not tested)				* (10% tested)
	Duct Insulation	Covered by floor insulation*		*R-8 all areas other than floor		
Other	Lighting	NR (Federal minimum standard)				
	Appliances	NR (Federal minimum standard)				
	Additional EE points	0	0	0	10	18

Source: Project Team; NR = no requirement; * indicates repeated requirement.

Table 21: Additional Energy Efficiency Points Requirements and Assumptions for Modeling Inputs for Replacement Scenarios.[49]

Optional EE Requirement	Points (Zone 2)	ENERGY STAR (multi-section)	ZERH (all homes)
Mandatory Requirements			
All requirements in Exhibit 1	2.5	X	X
Optional Envelope Improvements			
Coefficient of heat transmission (Uo)≤0.049	9.5		
Optional Heating and Cooling Equipment			
Heat pump ≥ 7.5 HSPF2 / 14.3 SEER2	13.5	X	X
Gas / propane Furnace ≥ 90 AFUE.	2.5		
Gas / propane Furnace ≥ 95 AFUE.	3.5		
Gas / Propane Furnace ≥ 96 AFUE.	4.0		
Optional Water Heater Equipment			
Gas / Propane Water Heater ≥ 0.93 UEF.	3.5		

[49] The ENERGY STAR multi-section points scenario exceeds the minimum requirement because this report assumes all electric end-uses in the new homes/replacement scenarios.

Heat pump water heater ≥ 2.20 UEF	With electric furnace, electric strip, or electric baseboard primary space heating.	5.5		
Heat pump water heater ≥ 3.30 UEF		7.0		
Heat pump water heater ≥ 2.20 UEF	With all other primary space heating systems.	10.0		
Heat pump water heater ≥ 3.30 UEF		13.0		
Optional Lighting, Appliances, & Water Fixtures				
LED lighting installed in all permanently installed fixtures		0.5		X
Bathroom faucets ≤ 1.5 gallons per minute (gpm) and showerheads ≤ 2.0 gpm.		0.5		X
ENERGY STAR certified refrigerator and dishwasher		0.5		X
ENERGY STAR certified clothes washer		0.5		X
Points Summary				
Total Points Required			10	18
Points Selected			16	18

Source: Project Team

Table 22: Modeled Inputs Reflecting Base Efficiency Minimum Requirements and Additional Energy Efficiency Points for Replacement Scenarios.[50]

		2022 HUD		ENERGY STAR MH v3		ZERH MH v1
		Single	Multi	Single	Multi	All homes
Thermal Shell	Walls	R-13	R-21			
	Floor	R-19		R-22		
	Ceiling	R-22	R-30	R-33		
	Windows (U)	0.50	0.30			
	Windows (SHGC)	0.60	0.25			
	Doors (U)	0.40				
	Air Leakage	8 ACH50		6 ACH50		4 ACH50
Systems	Heating	Electric Furnace (100% Eff)			**ASHP 7.5 HSPF2**	
	Cooling	Fed Min Std CAC (13.4 SEER2)			**ASHP 14.3 SEER2**	
	Thermostat	Manual		Programmable		
	Hot Water	Electric tank (0.92 UEF)				
	Ventilation	Minimum fan efficacy as per 2021 IECC				ENERGY STAR exhaust fans
	Duct Leakage	6 CFM25/100sf[51]				4 CFM25/100sf
	Duct Insulation	Covered by floor insulation*		*R-8 all areas other than floor		
Other	Lighting	100% CFL[52]				**100% LED**
	Appliances	Federal Minimum				**ENERGY STAR**

[50] Because this report is looking at electrification, heat pumps were modeled in all new construction scenarios at the federal minimum standard where not required by an above code voluntary program and at the same efficiency as the retrofit scenarios (using inputs from the California TRM) where required by an above code voluntary program.

[51] Estimated duct leakage used slightly higher than 2021 IECC requirement without testing.

[52] Proxy for minimum federal standard lighting efficiency.

		2022 HUD		ENERGY STAR MH v3		ZERH MH v1
		Single	Multi	Single	Multi	All homes
	Water fixtures	Standard				**Low flow**

Source: Project Team

Table 23: Modeled Inputs Reflecting High Efficiency ZERH Target Specification.

		ZERH MH v1 Target Specification
Thermal Shell	Walls	R-21
	Floor	R-22
	Ceiling	R-33
	Windows (U)	0.030
	Windows (SHGC)	0.025
	Doors (U)	0.40
	Air Leakage	4 ACH50
Systems	Heating	ASHP 10 HSPF (8.5 HSPF2)[53]
	Cooling	ASHP 20 SEER (19 SEER2)[53]
	Thermostat	Programable
	Hot Water	HPWH 3.75 UEF
	Ventilation (1)	HRV 0.86 SRE
	Duct Leakage	4 CFM25/100sf
	Duct Insulation	Under floor insulation, R-8
Other	Lighting	100% LED
	Appliances	ENERGY STAR
	Water fixtures	Low flow

Source: Project Team

Limitations of Prototype Modeling

Prototype modeling has limitations in that it assumes thermostat setpoints are met 100 percent of the time by equipment, equipment is operating as designed year around, and 'typical occupancy' assumptions for residents. In reality, these assumptions do not always hold, especially among MMH residents who are more likely to leave their homes at unhealthy temperatures than residents of other housing types due to high bills, equipment failure, or utility disconnections (Bell-Pasht 2023). This can produce unreasonably high estimates as is seen in the case of the pre-HUD vintage homes in cold climates. This will need to be taken into considering when evaluating upgrade measures and associated savings.

The 2020 RECS consumption and expenditure data provides insight into the actual consumption and costs experienced by residents, but there were no sample units located in the cold and mix-dry climates in California for the MMH housing type. Table 24 below shows how the unweighted average, minimum, and maximum energy consumption estimates compare between the prototype energy

[53] HSPF/HSPF2 and SEER/SEER2 conversions for reference only, HSPF and SEER ratings from the California TRM were used in modeling scenarios.

models created based on ResStock characteristics data, RECS data for MMH residents in California, and ResStock individual building models for MMH in California.

The Hot-Dry climate, in which the majority of MMH are located and for which the most sampled data is known from RECS, are closely aligned. The biggest disparity is seen in the cold and hot-dry climates, for which there is no RECS sample data for California. The RECS values for those two climate areas presented below in Table 24 are from cold and hot-dry climates in other states (filtered to include only IECC climate zones 4 and 5, which occur in California). The very low energy shown in the ResStock model represents old vintage, poorly insulated homes that are being operated at unhealthy and potentially unsafe temperatures.

Table 24: Comparison of Unweighted Energy Consumption Estimates from Prototype Modeling, RECS, and ResStock

	Prototype Models			RECS			ResStock		
Climate	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Cold	152.4	62.7	322.8	71.7	21.7	144.0	76.5	18.1	198.0
Hot-Dry	54.7	28.3	106.7	54.4	17.3	125.2	56.3	12.3	600.9
Marine	59.5	29.6	122.0	43.1	23.8	60.2	51.6	16.4	152.6
Mixed-Dry	145.9	59.6	320.1	76.9	18.3	214.8	96.5	8.4	320.5

Source: Project Team modeling, 2020 RECS public use microdata file, ResStock

Inputs Used in Estimating Energy Cost Impacts

Energy costs and savings were calculated using the U.S. EIA 2022 statewide average retail price of electricity and natural gas. Table 25 shows the statewide average costs as well as 2022 average price of electricity for the CA Electric IOU's. The electric IOU costs show the range of electric costs that exist by region and climate, which can vary by 50% or more. When considering utility costs, many MMH located in parks are master metered and may fall under a different rate structure than the average retail rate applicable to a stand-alone residence.

Table 25: 2022 Statewide Electricity and Natural Gas Cost Estimates, and 2022 Electricity Cost Estimates for IOUs.

Entity	Electricity (dollars/kWh)	Natural Gas (dollars/ccf)
Statewide Average	$0.2584	$2.015
Pacific Gas & Electric Co.	$0.3098	
San Diego Gas & Electric Co	$0.3792	
Southern California Edison Co	$0.2462	

Source: EIA 2023b (electricity), EIA 2023c (natural gas)

Inputs Used in Estimating Greenhouse Gas Impacts

Greenhouse gas (GHG) emissions impacts for all modeling scenarios were calculated using marginal (non-baseload) carbon dioxide-equivalent (CO2e) emissions factors from EPA's 2023 GHG Emissions Factor Hub. The following tables provide the global warming potential (GWP) values and emissions factors used to calculate a common CO2e factor in pounds of emissions per MMBtu of energy, which was then applied to modeled gas and electricity consumption for all scenarios.

Table 26: 100-Year Global Warming Potential Values.

Gas	100-Year GWP
CH_4	25
N_2O	298

Source: EPA 2023

Table 27: Natural Gas CO2e Factors.

Fuel Type	CO_2 Factor	CH_4 Factor	N_2O Factor	CO2e Factor
	(kg CO_2 per MMBtu)	(g CH_4 per MMBtu)	(g N_2O per MMBtu)	(lb per MMBtu)
Natural Gas	53.06	1.0	0.10	116.85

Source: EPA 2023

Table 28: Electricity CO2e Factors.

eGRID Subregion Name	Non-Baseload Emission Factors			
	CO_2 Factor	CH_4 Factor	N_2O Factor	CO2e Factor
	(lb/MWh)	(lb/MWh)	(lb/MWh)	(lb / MMBtu)
CAMX (WECC California)	1,047.5	0.049	0.006	307.9

Source: EPA 2023

Appendix B: Supplemental Modeling Results

Supplemental Results: Modeled Energy Consumption

The following figures provide additional details on the modeled energy use for above code all-electric new construction standards modeled for the whole-home replacement scenarios. Modeling results are shown separately by climate zone and scenario for single-section units and multi-section units.

Figure 39: Modeled annual consumption for single-section units based on above code new construction scenarios.

Source: Project Team

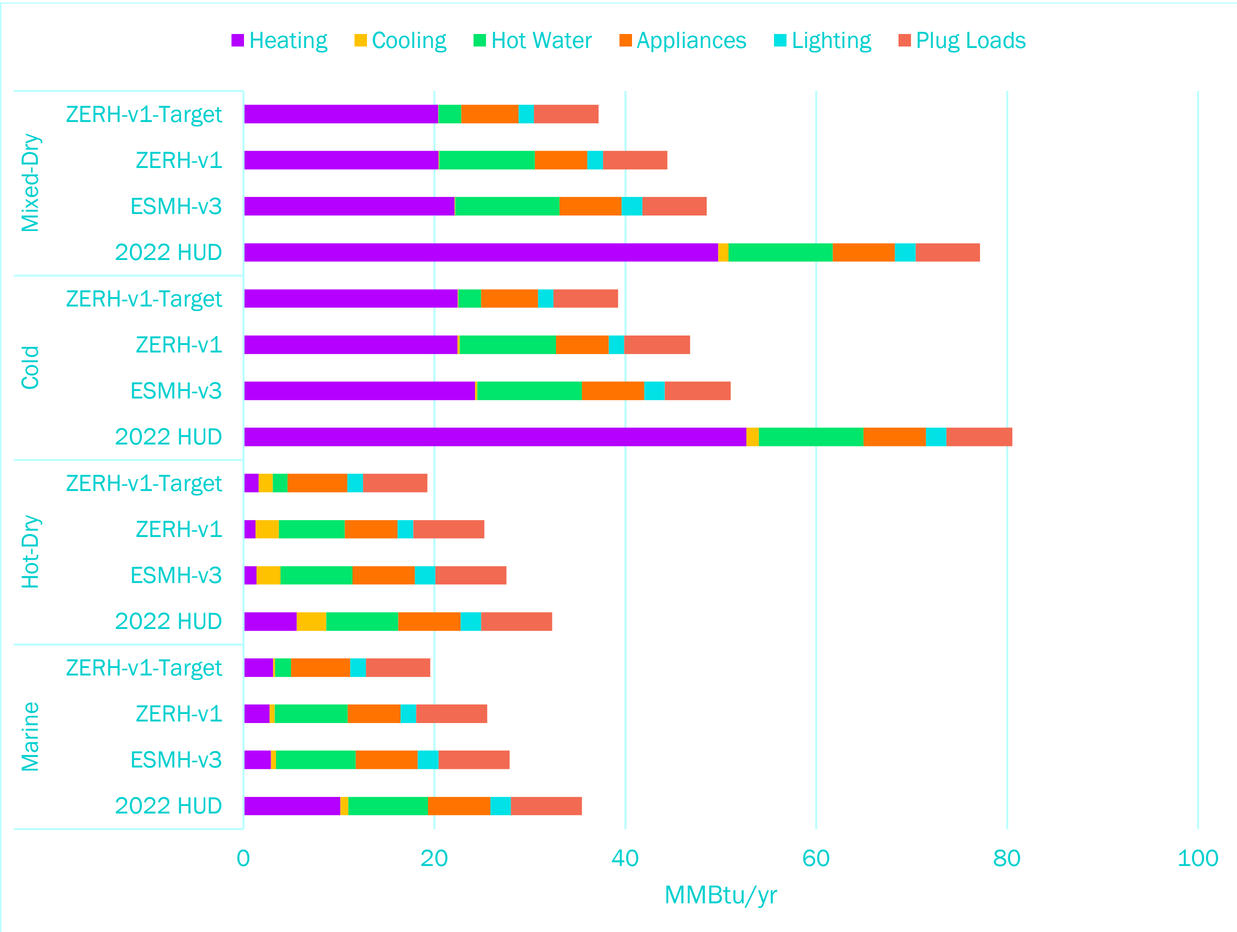

Figure 40: Modeled annual consumption for multi-section units based on above code new construction scenarios.

Source: Project Team

Supplemental Results: Estimated Energy Costs

The following figures provide additional details on estimated energy cost impacts from the modeled energy consumption for baseline existing units by vintage group.

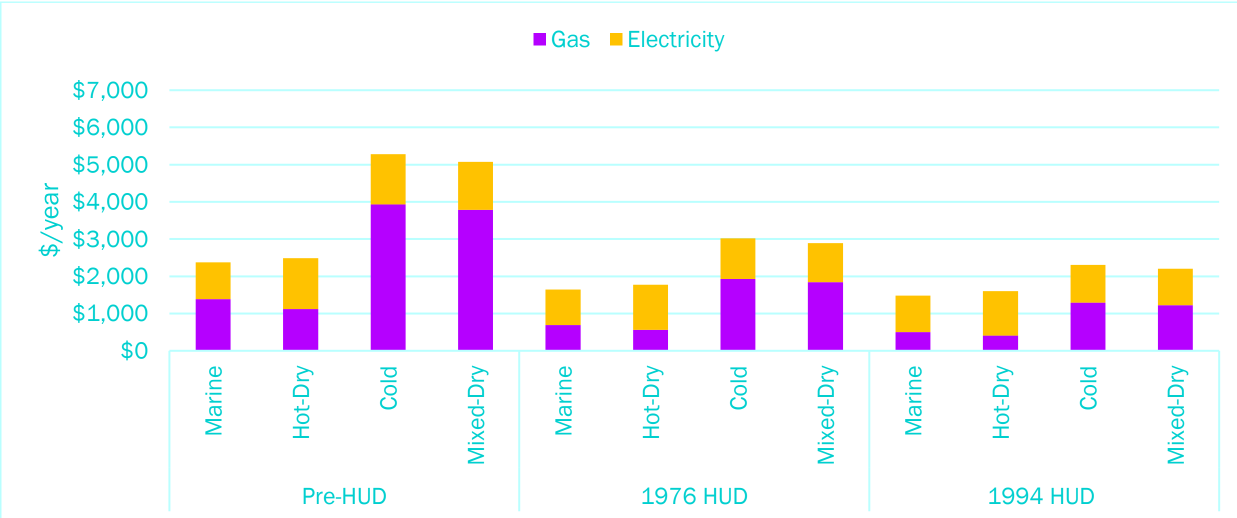

Figure 41: Modeled annual utility costs by fuel type for single-section units using gas heat.

Source: Project Team

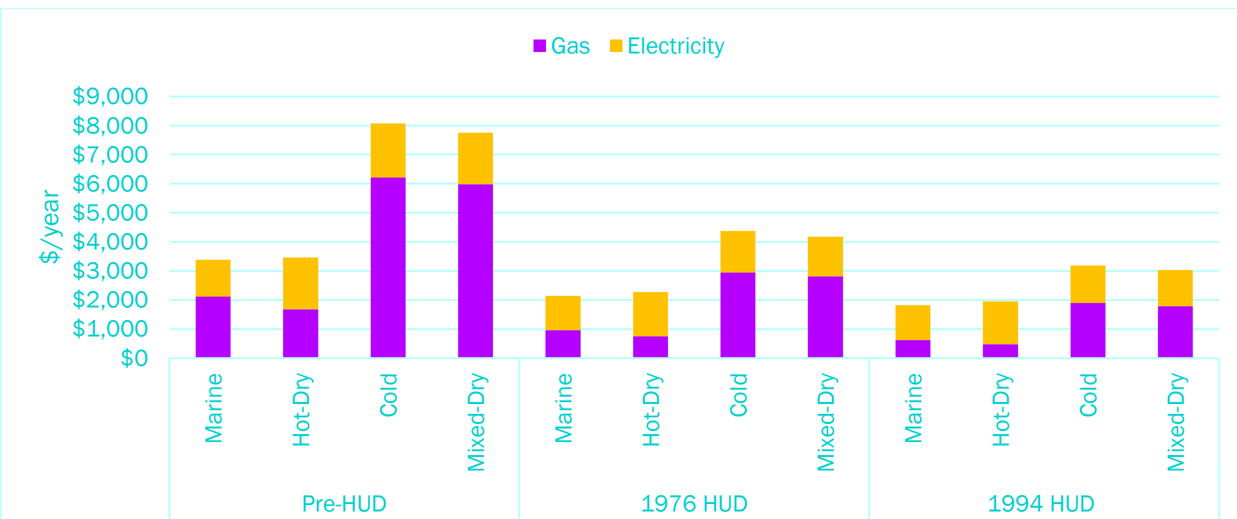

Figure 42: Modeled annual utility costs by fuel type for multi-section units using gas heat.

Source: Project Team

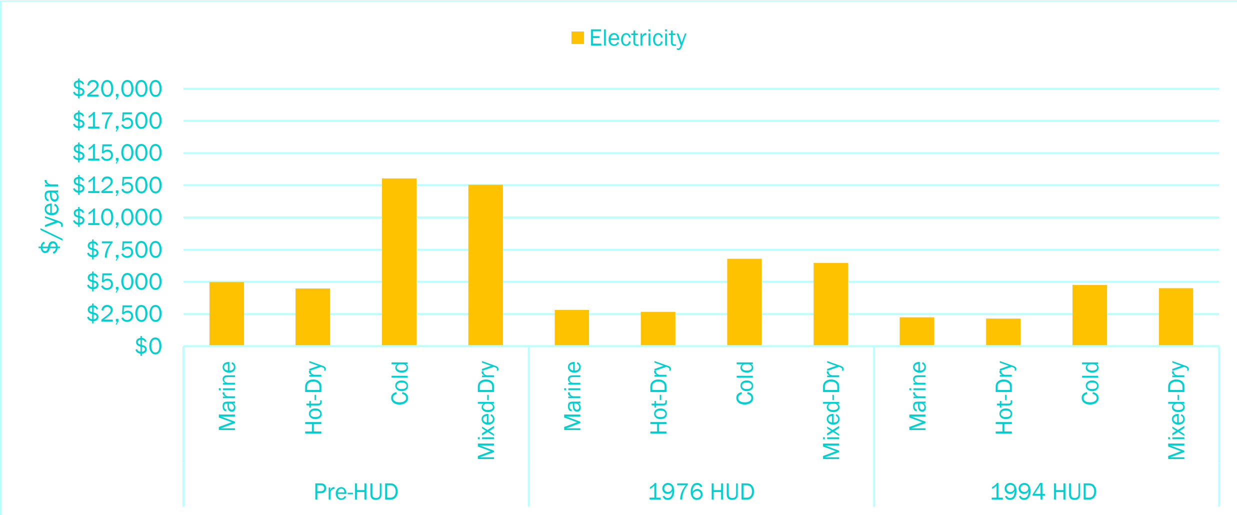

Figure 43: Modeled annual utility costs by fuel type for single-section units using electric heat.

Source: Project Team

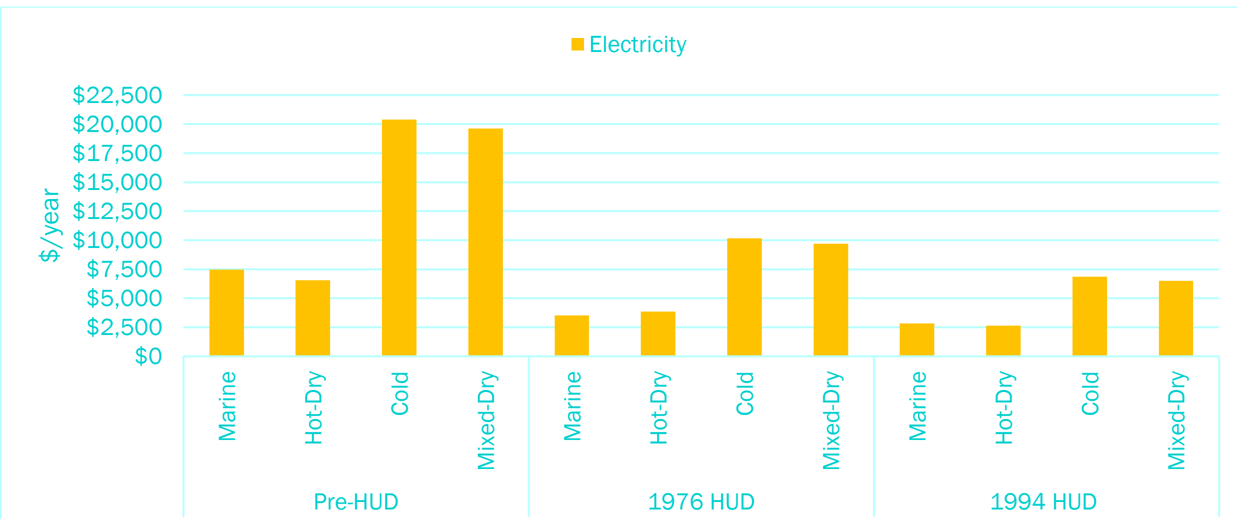

Figure 44: Modeled annual utility costs by fuel type for multi-section units using electric heat.

Source: Project Team

Supplemental Results: Peak Load Impacts

The following tables provide additional details on modeled summer and winter peak load for existing baseline, electrification retrofit, and all-electric replacement modeling scenarios.

Table 29: Modeled Summer Peak Load (kW) for Existing Baseline, Electrification Retrofit, and All-Electric Replacement Modeling Scenarios.

		Single-Section Units				Multi-Section Units			
		Marine	Hot-Dry	Cold	Mixed-Dry	Marine	Hot-Dry	Cold	Mixed-Dry
Gas Heat	Pre-HUD Baseline	3.0	5.1	2.0	1.6	4.3	7.8	2.6	2.0
Gas Heat	1976 HUD Baseline	2.0	3.2	1.7	1.4	2.7	4.7	2.1	1.8
Gas Heat	1994 HUD Baseline	1.8	2.6	1.5	1.3	2.3	3.6	1.9	1.6
Electric Heat	Pre-HUD Baseline	3.3	3.7	12.3	9.8	5.3	4.8	20.4	15.9
Electric Heat	1976 HUD Baseline	2.3	3.4	6.1	4.7	2.9	3.8	9.8	7.3
Electric Heat	1994 HUD Baseline	2.1	2.8	4.4	3.0	2.6	3.8	6.4	4.3
Electric Heat	1976 HUD Electrification Only Retrofit Upgrade	1.5	2.6	3.1	2.0	1.7	3.5	5.9	3.4
Electric Heat	1976 HUD Electrification + Weatherization Retrofit Upgrade	1.4	2.2	2.0	1.4	1.6	3.0	3.7	2.1
Electric Heat	1994 HUD Electrification Only Retrofit Upgrade	1.5	2.3	2.0	1.4	1.8	3.3	3.7	2.1
Electric Heat	2022 HUD	2.0	2.6	4.3	3.1	2.1	2.9	5.7	4.0
Electric Heat	ENERGY STAR MH v3	1.7	2.1	3.8	2.6	2.2	3.2	3.4	2.4
Electric Heat	ZERH MH v1 (minimum spec)	1.9	2.7	2.4	1.7	2.2	3.3	3.3	2.2
Electric Heat	ZERH MH v1 (target spec)	1.3	2.0	1.7	1.2	1.5	2.6	2.7	1.8

Source: Project Team

Table 30: Modeled Winter Peak Load (kW) for Existing Baseline, Electrification Retrofit, and All-Electric Replacement Modeling Scenarios.

		Single-Section Units				Multi-Section Units			
		Marine	Hot-Dry	Cold	Mixed-Dry	Marine	Hot-Dry	Cold	Mixed-Dry
Gas Heat	Pre-HUD Baseline	0.8	1.4	1.4	1.2	1.0	1.9	1.9	1.7
	1976 HUD Baseline	0.7	1.2	1.0	0.9	0.9	1.6	1.4	1.2
	1994 HUD Baseline	0.7	1.1	0.9	0.8	0.9	1.5	1.2	1.1
Electric Heat	Pre-HUD Baseline	9.5	10.2	23.9	20.5	15.0	17.1	24.4	24.1
	1976 HUD Baseline	5.2	4.9	13.4	10.4	7.9	7.8	21.1	17.0
	1994 HUD Baseline	4.0	3.5	9.6	7.6	5.5	5.4	14.5	11.4
	1976 HUD Electrification Only Retrofit Upgrade	2.9	2.0	10.1	7.9	4.0	2.9	16.2	12.3
	1976 HUD Electrification + Weatherization Retrofit Upgrade	2.5	1.7	7.4	5.4	3.4	2.3	11.4	8.8
	1994 HUD Electrification Only Retrofit Upgrade	2.4	1.6	7.5	5.6	3.4	2.3	11.8	8.7
	2022 HUD	4.4	4.2	8.9	7.7	5.5	5.2	12.1	10.3
	ENERGY STAR MH v3	3.6	3.3	7.3	6.6	3.3	2.5	10.6	7.8
	ZERH MH v1 (minimum spec)	2.2	1.8	6.7	4.7	3.1	2.7	9.9	7.4
	ZERH MH v1 (target spec)	2.3	1.5	6.1	4.2	3.1	2.1	9.3	7.0

Source: Project Team

Supplemental Results: Greenhouse Gas Impacts

The following tables provide additional details on estimated greenhouse gas impacts for existing baseline, electrification retrofit, and all-electric replacement modeling scenarios.

Table 31: Estimated Greenhouse Gas Emissions for Pre-HUD Vintage Modeling Scenarios.

Scenario			CO2e (lb)		
Heating Fuel	Climate	Size	Electricity	Natural Gas	Total
Electric Heat	Cold	Multi	82,930	-	82,930
		Single	52,960	-	52,960
	Hot-Dry	Multi	26,692	-	26,692
		Single	18,243	-	18,243
	Marine	Multi	30,340	-	30,340
		Single	20,254	-	20,254
	Mixed-Dry	Multi	79,726	-	79,726
		Single	50,950	-	50,950
Gas Heat	Cold	Multi	7,567	36,019	43,586
		Single	5,501	22,798	28,299
	Hot-Dry	Multi	7,276	9,708	16,984
		Single	5,552	6,504	12,056
	Marine	Multi	5,147	12,306	17,453
		Single	4,019	8,070	12,089
	Mixed-Dry	Multi	7,195	34,676	41,871
		Single	5,230	21,974	27,204

Source: Project Team

Table 32: Estimated Greenhouse Gas Emissions for 1976 HUD Vintage Modeling Scenarios.

Scenario			CO2e (lb)		
Heating Fuel	Climate	Size	Electricity	Natural Gas	Total
Electric Heat	Cold	Multi	41,312	-	41,312
		Single	27,616	-	27,616
	Hot-Dry	Multi	15,690	-	15,690
		Single	10,787	-	10,787
	Marine	Multi	14,309	-	14,309
		Single	11,477	-	11,477
	Mixed-Dry	Multi	39,414	-	39,414
		Single	26,351	-	26,351
Gas Heat	Cold	Multi	5,804	17,095	22,899
		Single	4,435	11,190	15,625
	Hot-Dry	Multi	6,168	4,357	10,525
		Single	4,927	3,270	8,198
	Marine	Multi	4,781	5,563	10,345
		Single	3,898	4,007	7,904

Scenario			CO2e (lb)		
Heating Fuel	**Climate**	**Size**	**Electricity**	**Natural Gas**	**Total**
	Mixed-Dry	Multi	5,572	16,305	21,877
		Single	4,251	10,692	14,943

Source: Project Team

Table 33: Estimated Greenhouse Gas Emissions for 1994 HUD Vintage Modeling Scenarios.

Scenario			CO2e (lb)		
Heating Fuel	**Climate**	**Size**	**Electricity**	**Natural Gas**	**Total**
Electric Heat	Cold	Multi	27,863	-	27,863
		Single	19,319	-	19,319
	Hot-Dry	Multi	10,766	-	10,766
		Single	8,704	-	8,704
	Marine	Multi	11,574	-	11,574
		Single	9,129	-	9,129
	Mixed-Dry	Multi	26,377	-	26,377
		Single	18,340	-	18,340
Gas Heat	Cold	Multi	5,269	10,985	16,254
		Single	4,129	7,500	11,629
	Hot-Dry	Multi	5,993	2,788	8,781
		Single	4,840	2,375	7,216
	Marine	Multi	4,850	3,631	8,480
		Single	3,998	2,901	6,899
	Mixed-Dry	Multi	5,068	10,381	15,448
		Single	3,959	7,123	11,083

Source: Project Team

Table 34: Estimated Greenhouse Gas Emissions for Electrification Retrofit Modeling Scenarios.

Scenario			CO2e (lb)		
Retrofit Scenario	**Climate**	**Size**	**Electricity**	**Natural Gas**	**Total**
1976 HUD Electrification Only	Cold	Multi	19,689	-	19,689
		Single	11,965	-	11,965
	Hot-Dry	Multi	6,720	-	6,720
		Single	5,253	-	5,253
	Marine	Multi	6,717	-	6,717
		Single	5,234	-	5,234
	Mixed-Dry	Multi	18,930	-	18,930
		Single	11,328	-	11,328
1976 HUD Electrification + Weatherization	Cold	Multi	13,695	-	13,695
		Single	9,162	-	9,162
	Hot-Dry	Multi	6,094	-	6,094

Scenario			CO2e (lb)		
Retrofit Scenario	Climate	Size	Electricity	Natural Gas	Total
		Single	4,862	-	4,862
	Marine	Multi	6,137	-	6,137
		Single	4,871	-	4,871
	Mixed-Dry	Multi	12,946	-	12,946
		Single	8,670	-	8,670
1994 HUD Electrification Only	Cold	Multi	13,620	-	13,620
		Single	9,052	-	9,052
	Hot-Dry	Multi	6,133	-	6,133
		Single	4,892	-	4,892
	Marine	Multi	6,078	-	6,078
		Single	4,834	-	4,834
	Mixed-Dry	Multi	12,854	-	12,854
		Single	8,541	-	8,541

Source: Project Team

Table 35: Estimated Greenhouse Gas Emissions for All-Electric Replacement Modeling Scenarios.

Scenario			CO2e (lb)		
Replacement Scenario	Climate	Size	Electricity	Natural Gas	Total
2022 HUD	Cold	Multi	24,795	-	24,795
		Single	18,149	-	18,149
	Hot-Dry	Multi	9,958	-	9,958
		Single	8,449	-	8,449
	Marine	Multi	10,914	-	10,914
		Single	8,893	-	8,893
	Mixed-Dry	Multi	23,754	-	23,754
		Single	17,256	-	17,256
ENERGY STAR-MH v3	Cold	Multi	15,714	-	15,714
		Single	16,093	-	16,093
	Hot-Dry	Multi	8,483	-	8,483
		Single	7,759	-	7,759
	Marine	Multi	8,581	-	8,581
		Single	8,249	-	8,249
	Mixed-Dry	Multi	14,939	-	14,939
		Single	15,474	-	15,474
ZERH-MH v1 (minimum spec)	Cold	Multi	14,403	-	14,403
		Single	10,407	-	10,407
	Hot-Dry	Multi	7,766	-	7,766
		Single	6,663	-	6,663
	Marine	Multi	7,859	-	7,859

Scenario			CO2e (lb)		
Replacement Scenario	Climate	Size	Electricity	Natural Gas	Total
		Single	6,709	-	6,709
	Mixed-Dry	Multi	13,674	-	13,674
		Single	9,942	-	9,942
ZERH-MH v1 (target spec)	Cold	Multi	12,079	-	12,079
		Single	8,234	-	8,234
	Hot-Dry	Multi	5,933	-	5,933
		Single	4,740	-	4,740
	Marine	Multi	6,021	-	6,021
		Single	4,768	-	4,768
	Mixed-Dry	Multi	11,450	-	11,450
		Single	7,852	-	7,852

Source: Project Team

Appendix C: Additional Information

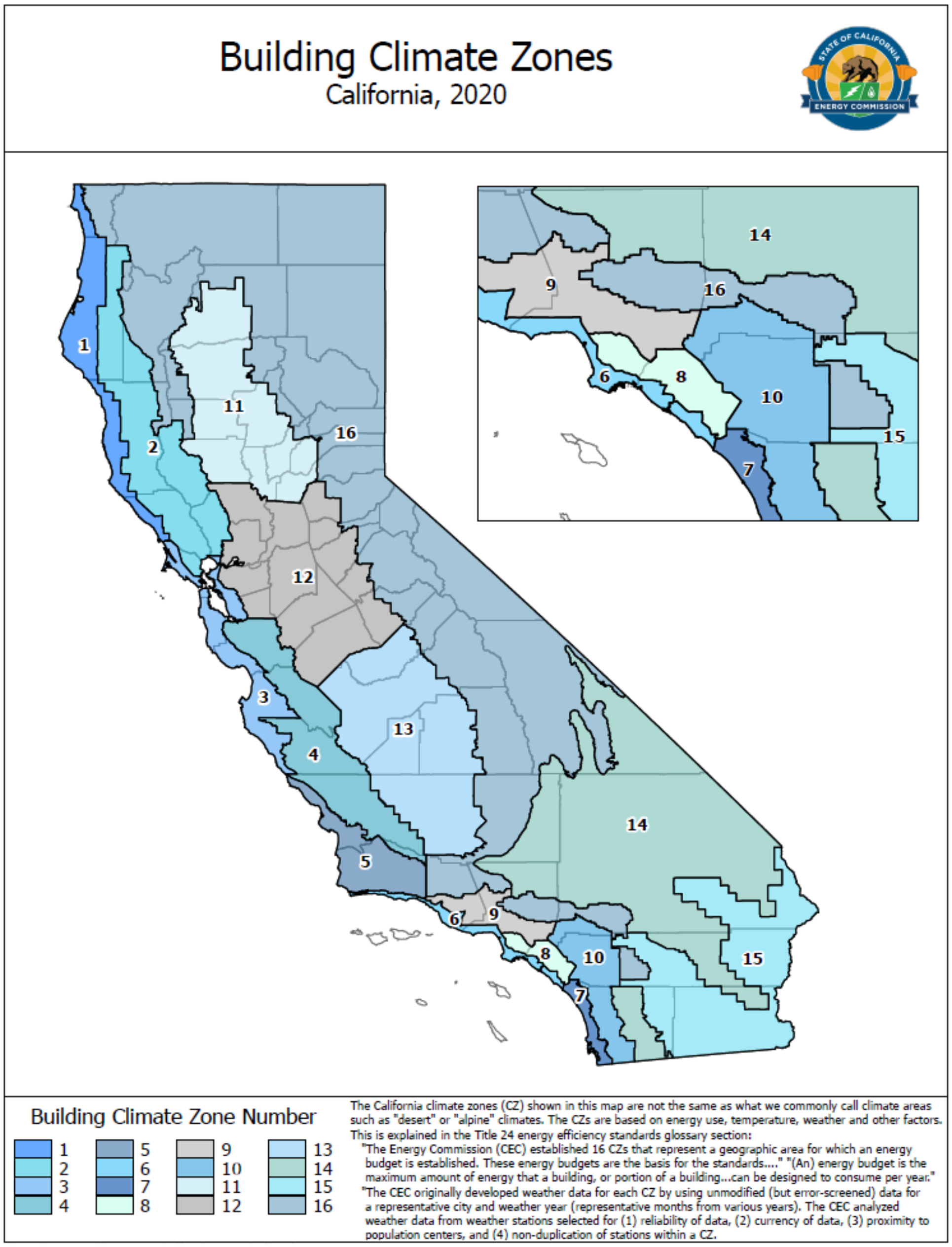

Figure 45: Reference map of California building climate zones.

Source: California Energy Commission (2022)

Table 36: Number of Mobile Home Parks and Lots within Mobile Home Parks in California by County

County	Number of Mobile Home Parks	Number of Lots in Mobile Home Parks
Los Angeles	574	46,901
San Diego	345	37,682
San Bernardino	339	30,737
Riverside	333	33,779
Orange	202	28,191
Kern	170	9,709
Sacramento	100	11,914
Santa Clara	98	17,613
Stanislaus	98	5,778
Butte	94	5,302
San Joaquin	94	5,697
Ventura	93	10,178
Sonoma	88	8,115
San Luis Obispo	86	6,222
Shasta	84	4,113
Fresno	80	6,894
Lake	79	2,471
Santa Cruz	76	5,809
Tulare	73	4,395
Monterey	70	3,814
Humboldt	68	2,719

County	Number of Mobile Home Parks	Number of Lots in Mobile Home Parks
Contra Costa	62	6,009
Santa Barbara	60	6,652
Imperial	57	2,647
Alameda	56	6,229
Mendocino	55	2,118
El Dorado	53	2,950
Placer	43	3,300
Siskiyou	41	1,160
Del Norte	40	1,154
Solano	36	3,517
Merced	35	2,499
Napa	34	3,722
Plumas	34	588
Tehama	34	1,293
Yolo	34	2,819
Inyo	33	1,210
Tuolumne	30	1,715
Nevada	27	1,937
Yuba	25	951
San Mateo	19	2,537
Sutter	19	1,080
Amador	18	1,078

County	Number of Mobile Home Parks	Number of Lots in Mobile Home Parks
Mono	17	343
Calaveras	16	865
Lassen	16	593
Trinity	16	267
Kings	15	1,070
Madera	15	879
Glenn	14	344
Colusa	12	257
Mariposa	10	322
Marin	8	1,159
San Benito	7	279
Modoc	3	64
Sierra	2	61
Alpine	1	30
Klamath	1	12
La Paz	1	58
Total	**4,243**	**351,801**

Source: 2022 HIFLD Open Data