Manufactured Housing Electrification Measure Development Support

Final Report

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Disclaimer

Executive Summary

Background

In California, escalating housing costs have driven a greater reliance on affordable manufactured housing, particularly in wildfire-prone areas. However, these homes have historically been excluded from California efficiency rebate programs. While the Title 24 building code does not apply to manufactured housing, the industry operates under HUD code standards that do not emphasize resilience or efficiency. Despite federal preemption preventing stringent energy efficiency standards, homeowners and mobile home parks can opt for higher efficiency levels through national programs like ENERGY STAR® for Manufactured Homes (ESMH) and Zero Energy Ready Homes for Manufactured Housing (ZERH MH). These programs offer options for energy-efficient features and significant utility bill savings. Additionally, the Northwest Energy-Efficient Manufactured Housing (NEEM) program works to exceed ENERGY STAR standards, driving adoption among manufacturers and retailers. However, upfront costs have hindered the adoption of heat pumps, leading to reliance on energy-intensive electric resistance heaters, and contributing to higher homeownership costs.

Objectives

The project's objective was to support the development of an electronic Technical Reference Manual (eTRM) measure package[1] for the electrification of newly constructed manufactured housing in California. A complementary project was proposed by Vermont Energy Investment Corporation (VEIC) to complete a market assessment of electrification in manufactured housing (ET23SWE0017 Mobile and Manufactured Housing Market Characterization Study) (McGrath, Badger, & et al., 2023). In conjunction with the VEIC project, the project aims to drive the adoption of more energy-efficient manufactured housing through well-designed incentive measures for the California manufactured housing market. The TRC project team included the ESMH program and the NEEM program for the development of an all-electric manufactured home measure package. The ZERH program is currently a pilot initiative and as such was not included.

Methodology

The project team conducted energy savings and incremental cost collection analyses, and collected insights from manufacturer and stakeholder interviews.

For the energy savings analysis, the project team established base case assumptions from a review of applicable codes and VEIC's market characterization study. The specifications used included envelope improvements from ENERGY STAR and NEEM programs, induction cooktop, heating, ventilation, and air conditioning (HVAC), and domestic hot water (DHW) measures from existing California deemed measure package offerings. The project team used DEER EnergyPlus prototypes to model savings from envelope improvements and HVAC measures. The project team calculated DHW savings using an hourly spreadsheet-based DEER Water Heater Calculator. For induction

[1] eTRM Measure Package: Formally known as workpapers. Measure packages establish eligibility, energy savings, and cost effectiveness for deemed energy efficiency measures for California Programs. They are hosted on the California Electronic Technical Reference Manual (eTRM), which is designated as the energy efficiency information data source of record for California.

cooktop savings, the project team collected savings from eTRM for gas, electric, and induction cooking technology.

The project team obtained the incremental costs for heat pump HVAC, heat pump water heaters, and induction cooking from the CPUC-approved workpapers and online data collection from retailers.

For stakeholder interviews, the project team conducted interviews with manufacturers and industry stakeholders to confirm the market penetration of measure packages, incremental costs, and other challenges associated with introducing heat pumps in manufactured housing.

Findings

Energy Efficiency Upgrades: Upgrading the envelope and using higher efficiency heat pump HVAC, DHW, and cooking equipment in newly constructed manufactured housing in California can yield significant energy savings.

Incremental Costs: The incremental cost for heat pump HVAC ranges from $336 to $1,542 compared to air conditioner and gas furnace HVAC equipment, and from $836 to $2,042 compared to air conditioner and electric resistance HVAC equipment. Similarly, the incremental cost for HPWH ranges from $1,210 to $2,089 compared to gas water heaters, and from $1,236 to $2,115 compared to electric resistance water heaters. The incremental cost for induction cooktops is $666 compared to natural gas cooktops and $1,003 compared to electric resistance cooktops.

Stakeholder Insights: Approximately 27 to 30 percent of newly manufactured homes purchased in California are ENERGY STAR certified. About 50 percent of new homes use natural gas for heating, water heating, cooking, and clothes, and electricity is used for the other half. Cost competitiveness is crucial for high-efficiency homes to succeed in the market. Barriers such as outdated HUD codes, infrastructure limitations, and affordability issues all hinder the widespread adoption of heat pumps. Educating stakeholders about the benefits of heat pumps and addressing logistical challenges are essential for promoting their use in manufactured homes.

Recommendations

Develop an electronic Technical Reference Manual (eTRM) measure package for the electrification of newly constructed manufactured housing in California.

To ensure the successful placement of heat pump technologies in manufactured homes, it is recommended that manufacturers not only consider the optimal locations within floor plans for such technologies but also undertake necessary envelope upgrades to guarantee their efficiency.

The 45L tax credit has played a role in pushing the manufactured housing market towards electrification. The drawback of the tax credit is that it primarily goes to corporations leaving little incentive for the local retailers to install heat pumps and create more efficient homes. There is also no guarantee that the tax credit will be passed along to the customer. The recommendation is to offer incentives at the retailer level that would benefit the all-electric housing market.

Stakeholders noted that engaging community organizations is a crucial strategy for accessing mobile home parks in disadvantaged communities and low-income areas. Stakeholders highlighted community meetings and utility data analyses as effective outreach methods, both of which can enable residents to better understand the potential bill reduction benefits. Stakeholders also

suggested the development of local workforce capacity to build trust with manufactured home residents.

To encourage the voluntary adoption of new manufactured home construction to higher efficiency levels than those mandated by the HUD Code, we recommend increasing awareness among homeowners and mobile home parks through educational efforts on the benefits of such homes. We recommend implementing outreach programs that highlight the advantages of ENERGY STAR and NEEM standards, emphasizing energy efficiency, cost savings, and environmental impact.

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. As the development of new measure packages progresses, it is imperative to closely monitor and integrate the impending energy efficiency standards set to take effect in January 2025 for manufactured housing.

In response to the anticipated shift towards fully electrified manufactured housing units and mobile home parks due to a few local or regional electrification codes, we recommend proactively engaging with relevant stakeholders, including policymakers, manufacturers, and residents. Develop educational initiatives to inform stakeholders about the upcoming electrification requirements and the benefits of fully electrified MMH units. Additionally, establish a collaborative framework to address potential challenges associated with this transition. Doing so will help ensure a smooth and well-coordinated implementation of electrification measures within the affected jurisdictions.

As part of the planning process for the Mobile Home Park Utility Conversion Program (MHP-UCP), the CPUC created a priority list of master metered mobile home parks for the investor-owned utilities (IOUs) to convert to direct metering. This presents an opportunity to focus on locations already prioritized for utility conversion upgrades.

Abbreviations and Acronyms

Acronym	Meaning
ACS PUMS	American Community Survey Public Use Microdata Sample
AFUE	Annual Fuel Utilization Efficiency
CalTF	California Technical Forum
COP	Coefficient of Performance
CPUC	California Public Utilities Commission
CZ	Climate Zone
DAC	Disadvantaged Communities
DEER	The Database for Energy Efficient Resources
DHW	Domestic Hot Water
DOE	Department of Energy
DXGF	Direct Expansion Cooling Systems and Gas Furnaces for Heating
EER	Energy Efficiency Ratio
EPA	U.S. Environmental Protection Agency
ESMH	ENERGY STAR for Manufactured Homes
eTRM	electronic Technical Reference Manual
EUI	Energy Use Intensity
HCD	Housing & Community Development
HUD	U.S. Department of Housing and Urban Development
HVAC	Heating, Ventilation, and Air Conditioning

Acronym	Meaning
IOUs	Investor-owned utilities
MHP-UCP	Mobile Home Park Utility Conversion Program
MMH	Mobile and Manufactured Homes
NEEM	Northwest Energy Efficient Manufactured
OEHHA	Office of Environmental Health Hazard Assessment
SEER	Seasonal Energy Efficiency Ratio
SHGC	Solar Heat Gain Coefficient
The U.S.	The United States
UEC	Unit Energy Consumption
UES	Unit Energy Savings
VEIC	Vermont Energy Investment Corporation
ZERH MH	Zero Energy Ready Homes for Manufactured Housing

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Introduction

With rising housing costs in California, the prevalence of affordable manufactured housing has been growing. Especially in areas affected by recent wildfires, manufactured housing is a way for many homeowners to get back in a home much faster and more affordably, compared with site-built homes. For years, manufactured homes have been excluded from California efficiency rebate programs, but with the number of manufactured homes growing every year, there is an increasing need to ensure the units going into the market are efficient all-electric units.

Currently, the Title 24 building code does not apply to manufactured housing in California. Instead, the manufactured housing industry operates under the federal U.S. Department of Housing and Urban Development (HUD) code standards that were adopted in 1994 and are not highly focused on resiliency or significant energy savings. HUD code revisions in 1994 increased energy efficiency requirements and established standards for wind resistance, thermal capacity, and roof load requirements. HUD code stipulates that the home must be designed and constructed to conform to one of the three thermal load zones based on the geographical location (California is Thermal Zone 2). Within each Thermal Zone, the customer has the choice of selecting the fuel type (gas or electricity) for their heating, ventilation, and air conditioning (HVAC) and domestic hot water (DHW) equipment. The all-electric option from the HUD code is an electric resistance water heater and a central air conditioner with an electric forced air furnace.

For newly manufactured homes, two national programs provide more stringent energy efficiency standards than the HUD Code:

ENERGY STAR® for Manufactured Homes (ESMH) Program: Manufactured homes produced on or after June 1, 2020, must be certified to ENERGY STAR Version 2 program requirements. This program has three options that the homeowners can choose from — Envelope-Only Package, High-Efficiency Furnace Package, and Electric Heat Pump Package. Each of these options offers energy-efficient features, including effective insulation, tight construction, high-efficiency windows, and efficient heating/cooling equipment. Independently inspected to meet the U.S. Environmental Protection Agency (EPA) guidelines, these homes provide lower ownership costs by significantly reducing energy consumption for heating, cooling, and water heating, resulting in substantial utility bill savings. Additionally, properly installed energy-efficient improvements enhance comfort, offering better protection against external elements. Choosing an ENERGY STAR-qualified manufactured home not only benefits homeowners financially but also contributes to a cleaner environment by reducing air pollution and promoting sustainability for present and future generations.[2] ENERGY STAR has released Version 3 for manufactured homes built on or after January 1, 2024.
Zero Energy Ready Homes for Manufactured Housing (ZERH MH) Program: The U.S. Department of Energy's (DOE) ZERH MH program was newly developed for 2023.[3] The current standard, ZERH MH

[2] More information on the ESMH certification is available here:

https://www.energystar.gov/partner_resources/residential_new/homes_prog_reqs/manufactured_national_page

[3] https://www.energy.gov/eere/buildings/doe-zero-energy-ready-home-zerh-manufactured-homes

v1, is a pilot program that will be in effect at least through 2023. The revised 45L section in the Inflation Reduction Act (IRA) provides a $5,000 tax credit to builders for most homes certified to ZERH standards. DOE will review stakeholder comments and feedback on the v1 pilot program to inform the development of the v2 standard.

In addition to the national voluntary programs, the Northwest Energy-Efficient Manufactured Housing (NEEM) (NEEA, 2023) program engages with factories to build on and exceed the standards used in ESMH.[4] The NEEM program, a key player in this domain, has transitioned from incentivizing manufacturers to driving greater adoption among retailers and home buyers. This shift aligns with the industry's evolving landscape, where retailer sales capacity and consumer demand provide additional motivation for manufacturers to adopt NEEM specifications. NEEM is one of two organizations recognized by the EPA ENERGY STAR program as a Quality Assurance Provider and is able to certify that manufactured homes are built to qualify for the ENERGY STAR. More than half of new manufactured home buyers in the Northwest choose homes with NEEM ENERGY STAR certification. According to data from Northwest Energy Works, the NEEM program administrator, in the first half of 2023, 43,893 homes had been shipped nationally. 12,573 (28.6 percent) of these homes were ENERGY STAR certified. Of these totals, California received 1,618 homes in total, with 468 (28.9 percent) of them being ENERGY STAR certified and 60 (3.7 percent) being NEEM 1.1 certified.

Heat pumps are up to three times more efficient than electric resistance heaters. However, the up-front costs of electric resistance heaters are less than those of heat pumps. Because there are no additional incentives for installing heat pumps in HUD-mandated homes, customers generally install electric resistance heaters for HVAC and DHW equipment. Electric resistance heaters are energy intensive, adding avoidable strain to grid operations without offering load flexibility. Energy is one of the major contributors to homeownership costs and high energy costs create a pronounced financial burden on households that have modest incomes.

The development of an all-electric manufactured home measure package allows for a more streamlined inclusion of manufactured housing in utility rebate programs.

Objectives

The project's objective is to support the development of an electronic Technical Reference Manual (eTRM) measure package[5] for the electrification of newly constructed manufactured housing in California. The expected outcomes of this project include energy modeling results, savings estimates, incremental cost collection, and manufacturer (and other stakeholder) interview results. The findings in this report include supporting documentation for a measure package for the electrification of newly constructed manufactured housing in California. The outcomes of this project will support the

[4] More information on the NEEM certification is available here: https://www.neemhomes.com/

[5] eTRM Measure Package: Formally known as workpapers. Measure packages establish eligibility, energy savings, and cost effectiveness for deemed energy efficiency measures for California Programs. They are hosted on the California Electronic Technical Reference Manual (eTRM), which is designated as the energy efficiency information data source of record for California.

adoption of more energy-efficient newly constructed manufactured housing with well-designed incentive measures for the California market.

Methodology and Approach

The methodology for developing measures, baselines, and energy savings are as follows:

1. Establish baseline assumptions for materials, efficiencies, equipment types, and fuel types from applicable code requirements (HUD, federal code, California Title 20 code), market characterization from VEIC's study, and stakeholder interviews.
2. Establish measure case assumptions:
    a. Envelope improvements from ENERGY STAR and NEEM program requirements,
    b. Induction cooktop, HVAC, and DHW measures from existing California deemed measure package offerings.
3. Calculate energy savings based on participation in ENERGY STAR or NEEM programs plus efficient HVAC and/or DHW equipment and induction:
    a. Envelope improvements and HVAC measure savings modeled using DEER EnergyPlus prototypes,
    b. DHW measures savings modeled using an hourly spreadsheet-based DEER Water Heater Calculator,
    c. Induction cooktop measure savings estimated based on the electronic Technical Reference Manual (eTRM) measure saving values for gas, electric, and induction cooking technology.

The following sections provide details of each of the methods and approaches.

Building Code Analysis for Baseline and Measure Case Determination

The Project Team conducted a literature review to determine the base case and measure package characteristics, including HUD code standard (Housing and Urban Development Department, 2021), ENERGY STAR program requirements (ENERGY STAR, 2023), NEEM program requirements (NEEM, 2023), California Title 20 appliance code, and the Federal Code of Regulations. The Project Team followed the HUD code standard to define the specifications for base case packages, including fuel type, envelope R-value/U-value requirements, HVAC system type and efficiency, and DHW system type and efficiency. For the measure case packages, the project team used the ENERGY STAR and NEEM program requirements to obtain all-electric specifications with better envelope performance and improved HVAC, DHW, and cooking system efficiencies in alignment with current eTRM measure packages.

Energy Savings Analysis

The project team employed a two-fold approach — by using energy modeling for HVAC and building envelope, and the DEER water heater calculator for DHW savings — to align with methodologies used in the California Public Utilities Commission (CPUC)-approved workpapers and to significantly reduce the number of modeled permutations required in the analysis. We incorporated induction cooking savings from eTRM measure saving values. We did not calculate energy savings associated with any other efficient appliances, such as laundry appliances in manufactured homes.

To estimate the potential energy savings of the heat pump HVAC systems from the ENERGY STAR and NEEM certification programs over the HUD code, the Project Team used existing DEER prototypes for mixed-fuel and all-electric double-wide manufactured homes and made the necessary updates to model the insulation requirements for the HUD code base case. For the measure cases, the Project Team revised the DEER prototypes to reflect ENERGY STAR- and NEEM-certified insulation requirements based on the specifications obtained from the Building Code Analysis. This modeling effort included both standard resistance heating technologies and heat pumps of varying above-code efficiencies across all 16 California climate zones (CZs).

Finally, the Project Team created an energy savings summary sheet that combined the envelope and HVAC energy consumption from the DEER prototype energy models, DHW energy consumption from the DEER water heater calculator, and cooktop energy consumption from the eTRM to calculate the total energy savings from installing heat pump technologies and induction cooktops within the ENERGY STAR and NEEM certification programs compared to the HUD code.

Incremental Cost Collection

The Project Team obtained the incremental cost for heat pump HVAC, heat pump water heater, and induction cooking from the CPUC-approved workpapers and online data collection from retailers.

HVAC

If the preferred fuel choice for space heating is natural gas, then the base case HVAC equipment is an air conditioner (Seasonal Energy Efficiency Ratio 2 (SEER2=14.3) and a natural gas furnace (80 percent Annual Fuel Utilization Efficiency (AFUE)). Conversely, if the fuel choice for space heating is electric, then the base case HVAC equipment is an air conditioner (SEER2=14.3) and an electric resistance furnace (98 percent AFUE). We obtained the base case cost data for a combination of air conditioners and gas furnace HVAC equipment from the SWHC045-03 Heat Pump HVAC, Residential, Fuel Substitution workpaper. We also gathered cost information for a combination of air conditioner and electric resistance furnace HVAC equipment by collecting online data from various retailers, including Home Depot, Lowes, Grainger, Menards, and Supply.com.

Water Heating

For gas water heaters, we obtained the base case cost data for a 40-gallon gas water heater from the SWWH025-06 Heat Pump Water Heater, Residential, Fuel Substitution workpaper and the cost for a 50-gallon electric water heater from the SWWH014-05 Heat Pump Water Heater, Residential workpaper.

For heat pump water heater options, choices include 40-gallon, 50-gallon, or 65-gallon heat pump water heaters. The DEER water heater calculator provides three different uniform energy factor (UEF) values for each of these heat pump water heaters.

Cooking

If the preferred fuel choice for cooking is natural gas, the corresponding base case equipment is a gas range. Conversely, if the fuel choice for cooking is electric, the base case equipment is an electric resistance cooktop. The measure case is an induction cooktop. We obtained the base case cost data for a natural gas cooktop from the SWAP015-03 Induction Cooking with or without Electric Range, Residential workpaper and the cost for an electric resistance cooktop from the SWAP013-03 Cooking Appliances, Residential, Fuel Substitution workpaper. For the induction cooktop measure case, we used the cost data from the SWAP015-03 Induction Cooking with or without Electric Range, Residential workpaper.

Stakeholder Engagement

The project team conducted interviews with manufacturers and industry stakeholders to confirm market penetration of measure packages, incremental costs, and other challenges associated with introducing heat pumps in manufactured housing. The overall objectives of the industry stakeholder interviews included the following:

- Confirm current market penetration of various measure packages and preferred appliance/equipment choices.
- Determine associated incremental costs.
- Identify any existing hurdles to including heat pumps in manufactured homes.

The project team developed an initial interview guide for manufactured housing fabricators (Appendix A: Interview Design), following the guide's outlined objectives. As we gained more information during the stakeholder interview process, we modified the guide to allow the interview team to explore additional topics and areas of interest with the different types of stakeholders. We interviewed various industry stakeholders, including manufactured housing fabricators and certification agencies. The project team conducted five interviews in total, each lasting 45 minutes to an hour.

The project team also coordinated with VEIC. A complementary project was proposed by VEIC to complete a market assessment of electrification in manufactured housing (ET23SWE0017 Mobile and Manufactured Housing Market Characterization Study). We leveraged the findings from VEIC's market characterization study for our base case measure case specification development. This project and the VEIC project can be considered as two essential components of a comprehensive strategy to support manufactured housing electrification. Throughout the project, the Project Team shared data, preliminary results, and stakeholder feedback outside of the regular prescribed CalNEXT reporting process.

Findings

The following sections describe the relevant market characterization findings summarized from VEIC's study, specifications of technologies included in the base case and measure case packages, and the interview results gathered from industry stakeholders.

Market Characterization

The Project Team summarized the market characterization findings from the VEIC Mobile and Manufactured Housing Market Characterization Study (ET22SWE0017).

Mobile and manufactured homes (MMHs) represent three percent of the housing units in California (2021 American Community Survey Public Use Microdata Sample (ACS PUMS)). We estimate that 28 percent of occupied MMHs are located in disadvantaged communities (DACs) based on the tool (CalEnviroScreen 4.0) developed by the Office of Environmental Health Hazard Assessment (OEHHA).

By analyzing the ACS PUMS data, the VEIC team found that the main heating fuel type of the units in California is utility-provided natural gas (57 percent), followed by electricity (26 percent), and other fuel types (17 percent). Approximately 79 percent of gas-fired heating systems and 69 percent of electric heating systems in MMHs are ducted (2022 National Renewable Energy Laboratory (NREL) U.S. Building Typology Segmentation Residential). It also showed that central air conditioners are the typical primary air conditioning equipment (64 percent) in MMH units (2020 Residential Energy Consumption Survey (RECS) public use microdata). The 2022 NREL ResStock Residential Metadata also indicates that ductwork is present in almost all MMH homes (97 percent) built since 2000.

For the DHW system, 2020 RECS data shows that over 90 percent of the MMH residents statewide use natural gas as the primary water heating source. Eighty-one percent of the MMH units have small or medium water heater storage tanks (less than 50 gallons). The data also indicates that 73 percent of the ranges and ovens in MMH units statewide use natural gas as the cooking fuel, while 15 percent use electricity.

Since manufactured homes are regulated by the less stringent 1994 HUD code requirements, they tend to be less efficient than site-built homes. Thus, manufactured homes usually consume more energy per square footage than comparable single-family detached homes. VEIC's study also shows that MMH units generally have a higher energy burden compared to other types of housing. About 39 percent of California MMH households are cost-burdened, spending 30–50 percent of their household income on housing and energy (2021 ACS PUMS).

Most MMH units are located in mobile home parks. Most mobile home parks have master metered utilities based on VEIC's stakeholder interviews. Based on the Mobile Home Park Utility Conversion Program (MHP-UCP), 88 percent of the lots in master metered mobile home parks enrolled in the MHP-UCP have electrical service capacity that is less than or equal to 100-amp.

Measure Specifications

The ENERGY STAR certification addresses air sealing, properly installed insulation, and high-performance windows to deliver reduced maintenance costs and lower energy bills. The ENERGY STAR program requirements include either the Electric Heat Pump Package, the High-Efficiency

Furnace Package, or the Envelope-Only (EO) Package. We developed the ENERGY STAR measure package specification based on the Electric Heat Pump Package.

The NEEM program helped develop and currently certifies the ENERGY STAR standard for manufactured homes in the Northwest. Some of these homes will be shipped to California. The NEEM team works with manufactured home builders in the Northwest, looking for cost-effective ways to improve the quality, durability, and energy efficiency of manufactured homes. The latest NEEM 2.0 certification (also known as NEEM+) incorporates an advanced set of specifications to take a unit beyond the NEEM/ENERGY STAR certification.

DEER Prototypes

DEER provides estimates of the energy savings potential for energy-efficient technologies in residential and nonresidential applications. This database includes prototype models representative of various types of new and existing buildings with different energy systems. The Project Team has modified DEER prototypes (double-wide with an area of 2,484 ft^2) to develop the base case and measure case models. Specifically, the direct expansion cooling systems and gas furnaces for heating (DXGF)-New set of DEER prototype models were adapted.

Base Case Characteristics

For the first base case, HUD-1, the project team replaced the gas furnace in the DXGF-New model with electric resistance heating to simulate a fully electric manufactured home. In the second base case, HUD-2, the Project Team used the gas furnace as the heating system but increased the furnace efficiency from the default efficiency of 72 to 80 percent, representing a mixed fuel option of electric cooling and gas heating. In both base cases, we configured the cooling system performance to 13.4 SEER2 and 10.6 Energy Efficiency Ratio 2 (EER2). For the DHW system, stakeholders indicated that when the preferred fuel for water heating is natural gas, the prominent choice is a 40-gallon gas water heater with a medium draw pattern and a recovery efficiency of 0.64. Conversely, if the chosen fuel for water heating is electric, the optimal choice shifts to a 50-gallon water heater with a medium draw pattern and a recovery efficiency of 0.92. Therefore, we set the DHW in HUD-1 to be a 50-gallon electric resistance water heater with a thermal efficiency of 0.92 and a 40-gallon gas storage water heater with a thermal efficiency of 0.64 for HUD-2. HUD-1 assumed an electric cooktop with a nominal efficiency of 74 percent, while HUD-2 assumed a natural gas cooktop with an efficiency of 39.9 percent. We also updated the ceiling, floor, and wall insulation values to align with HUD code standards, setting the window's U-value and solar heat gain coefficient (SHGC) to 0.34 and 0.33, respectively. We maintained all other values as per the default settings in the DXGF DEER prototype. Table 1 highlights the key model parameters for the HUD-1 and HUD-2 base cases.

Table 1: Key Model Parameters for HUD Base Cases

Code requirements	HUD-1	HUD-2
All-Electric	Yes	No
Ceiling Insulation	R-22	R-22
Floor Insulation	R-22	R-22
Wall Insulation	R-11	R-11
Window U-value/SHGC	0.34/0.33	0.34/0.33
Ducts, crossover	R-4	R-4
Heating system	Electric Furnace 0.98 AFUE	Natural Gas Furnace 0.8 AFUE
Cooling system	Central AC; 13.4 SEER2, 10.6 EER2	Central AC; 13.4 SEER2, 10.6 EER2
DHW System	50 Gallon, **Electric Storage**, 0.92 Recovery Efficiency	40 Gallon, **Gas Storage**, 0.64 Recovery Efficiency
Cooking Range/Oven	Electric	Gas

Measure Case Characteristics

For this study, the project team defined measure packages based on the ENERGY STAR 2.1 certification requirements, along with NEEM1.1 and NEEM2.0 certification programs. Each set was implemented in eight distinct HVAC system efficiency levels, and nine different DHW system efficiency levels, culminating in a total of 216 measure packages for each CZ. These measure packages all feature DX for cooling and heat pumps for heating as the primary cooling and heating source, a heat pump water heater as the primary DHW system, and induction cooking.

Table 2 lists the key parameters we set for the measure cases to comply with the respective certification programs.

Table 2: Key Parameters for Various Measure Cases

Data	ENERGY STAR	NEEM1.1	NEEM2.0
All-Electric	Yes	Yes	Yes
Ceiling Insulation	R-33	R-40	R-44
Floor Insulation	R-22	R-33	R-33
Wall Insulation	R-11	R-21	R-21
Window U-value/SHGC	0.34/0.33	0.34/0.33	0.25/0.34
Ducts, crossover	R-8	R-8	R-8
Heating and Cooling System	DX cooling and heat pump heating with eight efficiency measures offering tiers of Heating Seasonal Performance Factor 2 (HSPF2) and SEER2 (See Table 5 for details)	DX cooling and heat pump heating with eight efficiency measures offering tiers of HSPF2 and SEER2 (See Table 5 for details)	DX cooling and heat pump heating with eight efficiency measures offering tiers of HSPF2 and SEER2 (See Table 5 for details)
DHW System	Heat pump water heater with nine efficiency measures offering tiers of UEF (see Table 4 for details)	Heat pump water heater with nine efficiency measures offering tiers of UEF (see Table 4 for details)	Heat pump water heater with nine efficiency measures offering tiers of UEF (see Table 4 for details)
Cooking Range/Oven	Induction	Induction	Induction

ENVELOPE AND HVAC

To model the envelope and HVAC in the measure cases, the project team used the HP-New DEER prototype as our foundation, and made several adjustments to the HP-New root file, which represents newly manufactured homes equipped with DX for cooling systems and heat pumps for heating:

- For the ENERGY STAR criteria, we adjusted the R-values for the ceiling, floor, and walls to R-33, R-22, and R-11, respectively. We set the windows' U-value and SHGC to 0.34 and 0.33. Furthermore, we increased the insulation R-value for the heat pump duct from R-4 to R-8.

- For NEEM1.1, we enhanced the ceiling, floor, and wall R-values to R-40, R-33, and R-21, respectively, and maintained the windows' U-value and SHGC at 0.34 and 0.33. We also raised the insulation R-value for the heat pump duct to R-8.
- Under NEEM2.0, we further improved the ceiling, floor, and wall R-values to R-44, R-33, and R-21. We also reduced the windows' U-value to 0.25 while keeping the SHGC at 0.34. We set the heat pump duct's insulation R-value again at R-8.

From these models, we created eight measures offering tiers for each ENERGY STAR, NEEM1.1, and NEEM2.0 compliant model, varying the heat pump efficiencies. The first measure offering tier includes an air source heat pump with a SEER value of 14 and 8 HSPF, with subsequent measures featuring higher performance ratings, as detailed in Table 3.

Table 3: HVAC Measure Offering Tiers

Measure Offering Tier	SEER2	HSPF2
Tier 0	13.4	6.7
Tier 1	14.3	7.2
Tier 2	15.2	7.7
Tier 3	16	8.0
Tier 4	16.9	8.1
Tier 5	17.8	8.1
Tier 6	18.7	8.5
Tier 7	19.6	8.9

To accurately model the heat pump's performance in EnergyPlus software, we converted the SEER2 and HSPF2[6] values to coefficient of performance (COP) values for cooling and heating. We did these conversions based on the DEER prototype SEER-rated AC-HP measure package. In line with the DEER SEER-rated heat pump cases file, we also adjusted the motor efficiency and supply fan total efficiency. Table 4 lists the relationship between COP values and SEER2 and HSPF2 values.

[6] Performance metrics like SEER and HSPF can't be directly inputted in EnergyPlus. We calculated SEER and HSPF values from SEER2 and HSPF2 and chose the cooling and heating COP corresponding to those values from the DEER prototype crosswalk table here: https://github.com/sound-data/DEER-Prototypes-EnergyPlus/blob/main/residential%20measures/SWHC049-03%20SEER%20Rated%20AC%20HP/SWHC049-03%20SEER%20Rated%20AC%20HP_DMo/cases/DMo%260%26rDXHP%26New%26dxHP_equip.csv.

Table 4: Cooling COP and Heating COP for EnergyPlus Software

Performance Rating	Cooling COP	Motor Efficiency	Supply Fan Total Efficiency	Heating COP
HSPF2 6.7, SEER2 13.4	3.23	0.24	0.12	2.34
HSPF2 7.2, SEER2 14.3	3.58	0.24	0.12	2.49
HSPF2 7.7, SEER2 15.2	3.58	0.24	0.12	2.64
HSPF2 8.0, SEER2 16	3.58	0.5	0.25	2.75
HSPF2 8.1, SEER2 16.9	3.58	0.5	0.25	2.79
HSPF2 8.1, SEER2 17.8	3.72	0.5	0.25	2.79
HSPF2 8.5, SEER2 18.7	3.82	0.5	0.25	2.92
HSPF2 8.9, SEER2 19.6	3.94	0.5	0.25	3.09

DHW-DEER WATER HEATER CALCULATOR

The annual unit energy savings (UES) of the measure case heat pump water heater are available in the 2023 version of DEER. We derived the annual unit energy consumption (UEC) values using the DEER water heater energy use calculator v5.1, a macro-enabled Excel workbook developed by consultants of the CPUC Energy Division to standardize the inputs and savings calculations for water heating measures. The residential hot water load profiles were adopted from California Building Energy Code Compliance (CBECC)-Res 2019/2021 for application in the DEER Water Heater Calculator. Further, the simulation tool uses the technology definitions to determine the hot water energy use for each CZ and DMo building type that is part of the standard DEER applicability parameters. The usage of electric resistance heating during peak usage events was modeled, using a residential NREL field performance study and CBECC-derived draw profile. Heat pump mode is disabled whenever the ambient dry bulb air temperature is outside of the predetermined minimum and maximum cut-off temperatures, as defined for each DEER TechID. If the hourly draw is more than 50 percent of the heat pump water heater tank volume, then 10 percent of the total water heater capacity is met by electric resistance heating.

The calculator includes a range of water heaters — gas storage, gas instantaneous, electric storage, electric instantaneous, and heat pump water heaters. The HUD code does not dictate the water heater capacity and recovery efficiency but provides an option for the fuel type — gas or electric. The Project Team chose the base case equipment type based on feedback from Northwest Energy Works, which had advised that when the preferred fuel for water heating is natural gas, the prominent choice is a 40-gallon gas water heater with a medium draw pattern and a recovery efficiency of 0.64. Conversely, if the chosen fuel for water heating is electric, the prominent choice shifts to a 50-gallon water heater with a medium draw pattern and a recovery efficiency of 0.92. We

also selected the measure case heat pump based on the feedback obtained from the stakeholder engagement that suggested manufactured homes install either a 40-gallon, 50-gallon, or 65-gallon heat pump water heater. Each of these heat pump water heaters has three different efficiency options — 3.30 UEF, 3.50 UEF, and 3.75 UEF resulting in nine total DHW efficiency levels. The calculator simulated energy savings for these nine heat pump options with both gas storage and electric resistance storage water heaters in the base cases.

Table 5 below shows the characteristics of the measure case heat pump water heaters and the assumed baselines.

Table 5: DEER Water Heater Calculator Inputs

Measure Case Storage Capacity (Gallons)	Measure Case UEF of Heat Pump Water Heater	Base Case Equipment Type	Corresponding HUD Code
<45	3.30	40 Gallon, **Gas Storage**, 0.64 Recovery Efficiency	HUD-2
<45	3.50	40 Gallon, **Gas Storage**, 0.64 Recovery Efficiency	HUD-2
<45	3.75	40 Gallon, **Gas Storage**, 0.64 Recovery Efficiency	HUD-2
≥45 to ≤55	3.30	40 Gallon, **Gas Storage**, 0.64 Recovery Efficiency	HUD-2
≥45 to ≤55	3.50	40 Gallon, **Gas Storage**, 0.64 Recovery Efficiency	HUD-2
≥45 to ≤55	3.75	40 Gallon, **Gas Storage**, 0.64 Recovery Efficiency	HUD-2
>55 to ≤75	3.30	40 Gallon, **Gas Storage**, 0.64 Recovery Efficiency	HUD-2
>55 to ≤75	3.50	40 Gallon, **Gas Storage**, 0.64 Recovery Efficiency	HUD-2
>55 to ≤75	3.75	40 Gallon, **Gas Storage**, 0.64 Recovery Efficiency	HUD-2

Measure Case Storage Capacity (Gallons)	Measure Case UEF of Heat Pump Water Heater	Base Case Equipment Type	Corresponding HUD Code
<45	3.30	50 Gallon, **Electric Storage**, 0.92 Recovery Efficiency	HUD-1
<45	3.50	50 Gallon, **Electric Storage**, 0.92 Recovery Efficiency	HUD-1
<45	3.75	50 Gallon, **Electric Storage**, 0.92 Recovery Efficiency	HUD-1
≥45 to ≤55	3.30	50 Gallon, **Electric Storage**, 0.92 Recovery Efficiency	HUD-1
≥45 to ≤55	3.50	50 Gallon, **Electric Storage**, 0.92 Recovery Efficiency	HUD-1
≥45 to ≤55	3.75	50 Gallon, **Electric Storage**, 0.92 Recovery Efficiency	HUD-1
>55 to ≤75	3.30	50 Gallon, **Electric Storage**, 0.92 Recovery Efficiency	HUD-1
>55 to ≤75	3.50	50 Gallon, **Electric Storage**, 0.92 Recovery Efficiency	HUD-1
>55 to ≤75	3.75	50 Gallon, **Electric Storage**, 0.92 Recovery Efficiency	HUD-1

COOKING

If the preferred fuel choice for cooking is natural gas, then the base case equipment is a gas range. Conversely, if the fuel choice for cooking is electric, then the base case equipment is an electric resistance cooktop. The measure case was an induction cooktop while the all-electric baseline (HUD-1) was configured with an electric resistance cooktop and the mixed fuel baseline (HUD-2) was equipped with a gas range during the modeling process. According to the eTRM energy saving measure data for a gas range, electric cooktop, and induction cooktop, we set the efficiency to 39.9 percent, 74 percent, and 84 percent, respectively. The estimated yearly energy use of selected cooking technologies is 5.74 therms per year for the natural gas range, 102 kWh per year for the electric cooktop, and 90 kWh per year for the induction cooktop. We extracted the UES values for the electric cooking appliances from SWAP013-02 Cooking Appliances, Residential, Fuel Substitution, and SWAP015-03 Induction Cooking with or without Electric Range, Residential workpapers.

Measure Savings Analysis

The project team summarized the number of measures and number of runs in total below:

- Modeled the heat pump HVAC measures, encompassing eight distinct efficiency tiers across all sixteen California CZs.
- Modeled the heat pump water heater measures, comprised of nine tiers, based on storage tank capacity and UEF values across all sixteen California CZs.
- Modeled both HVAC and water heater measures for three certification programs (ENERGY STAR, NEEM1.1, and NEEM2.0), resulting in a total of 216 simulations for each of the sixteen California CZs.

DHW systems installed in conditioned spaces can have interactive effects, with HVAC systems that increase or decrease both heating and cooling loads. This analysis did not model DHW systems in EnergyPlus to align the calculation methodology for DHW with currently approved eTRM measure packages. Therefore, we didn't include the interactive effects between DHW and HVAC systems in this analysis. This approach is similar to the approach approved in the SWWB008 All-Electric Homes, Residential, New Construction measure package work paper, which includes DHW and HVAC offerings for new construction single-family homes and multifamily dwelling units.

In the findings, the project team used a graphical representation to focus on a curated selection of key graphs. We designed this carefully chosen subset to encapsulate the most crucial insights and trends within the data, providing a visual narrative that enhances clarity and accessibility. By distilling the extensive set of 3,456 simulation results into a smaller representative group, we aim to offer a comprehensive yet focused overview, providing stakeholders with a quick insight into the essential aspects of our analysis.

Total kWh Savings for Heat Pump HVAC Measure

Scenario 1:

Table 6 and Figure 1 below illustrate the cumulative kWh savings achieved by the heat pump HVAC measure. It covers savings generated by all three certification programs when using Tier 0 HVAC equipment in all CZs. Tier 0 HVAC equipment has an efficiency rating of 13.4 SEER2 and 6.7 HSPF2. These savings are derived from enhancements in envelope efficiency beyond the HUD code, along with the modeling of a code minimum heat pump HVAC equipment, as opposed to a code minimum electric resistance furnace (HUD-1). The negative savings trend observed in CZs 1, 2, and 16 can be associated with their colder climate, which results in higher energy use for defrost and crankcase heaters. For the defrost and crankcase heaters, we aligned the assumptions with the current DEER measures. Cold Climate Heat Pumps (CCHP) could be one way to provide better performance in these colder CZs. However, given that CCHPs would require different assumptions and performance curves that the project team did not have access to during this analysis, this may be a good opportunity for future research.

Table 6: HVAC Savings with Tier 0 HVAC Equipment Compared to HUD-1 Base Case

Climate Zones	ESTARHP.Tier 0	NEEM1.1.Tier 0	NEEM2.0.Tier 0
CZ01	(1,150)	(364)	74
CZ02	(290)	1,051	1,559
CZ03	1,089	1,837	1,995
CZ04	830	1,679	1,894
CZ05	247	1,276	1,594
CZ06	1,323	1,736	1,689
CZ07	1,144	1,548	1,505
CZ08	1,241	1,789	1,792
CZ09	1,241	1,898	1,864
CZ10	1,392	2,578	2,868
CZ11	1,433	3,130	3,616
CZ12	1,433	2,960	3,402
CZ13	1,521	3,023	3,414
CZ14	2,757	4,512	5,053
CZ15	1,860	3,494	3,807
CZ16	(749)	1,394	2,009

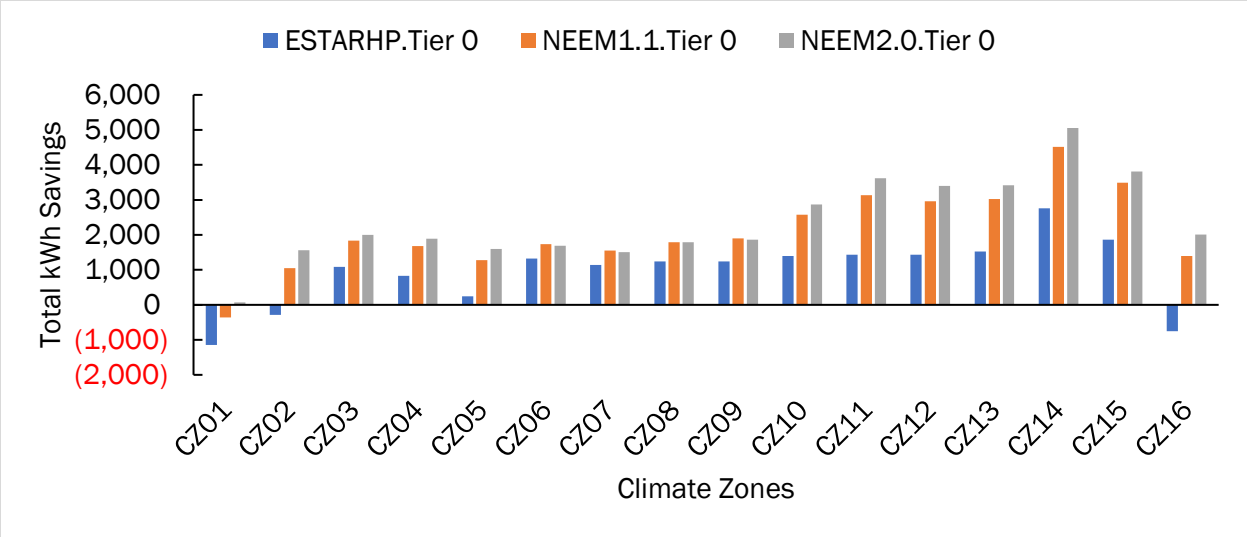

Figure 1: HVAC Savings with Tier 0 HVAC Equipment Compared to HUD-1 Base Case

Scenario 2

Table 7 and Figure 2 illustrate the cumulative kWh savings achieved by the heat pump HVAC measure across all three certification programs when using Tier 7 HVAC equipment in all CZs. Tier 7 HVAC equipment has an efficiency rating of 19.6 SEER2 and 8.9 HSPF2. These savings are derived from enhancements in envelope efficiency beyond the HUD code, along with the modeling of a higher efficiency heat pump equipment in contrast to a code minimum electric resistance furnace (HUD-1).

Table 7: HVAC Savings with Tier 7 HVAC Equipment Compared to HUD-1 Base Case

Climate Zones	ESTARHP.Tier 7	NEEM1.1.Tier 7	NEEM2.0.Tier 7
CZ01	(931)	(261)	163
CZ02	308	1,427	1,880
CZ03	1,644	2,216	2,353
CZ04	1,398	2,069	2,255
CZ05	765	1,602	1,891
CZ06	2,055	2,359	2,324
CZ07	1,833	2,130	2,098

Climate Zones	ESTARHP.Tier 7	NEEM1.1.Tier 7	NEEM2.0.Tier 7
CZ08	2,023	2,432	2,436
CZ09	2,463	2,952	2,926
CZ10	2,570	3,505	3,756
CZ11	3,293	4,634	5,038
CZ12	2,908	4,100	4,468
CZ13	3,499	4,662	4,980
CZ14	4,964	6,298	6,728
CZ15	4,635	5,869	6,109
CZ16	615	2,465	3,032

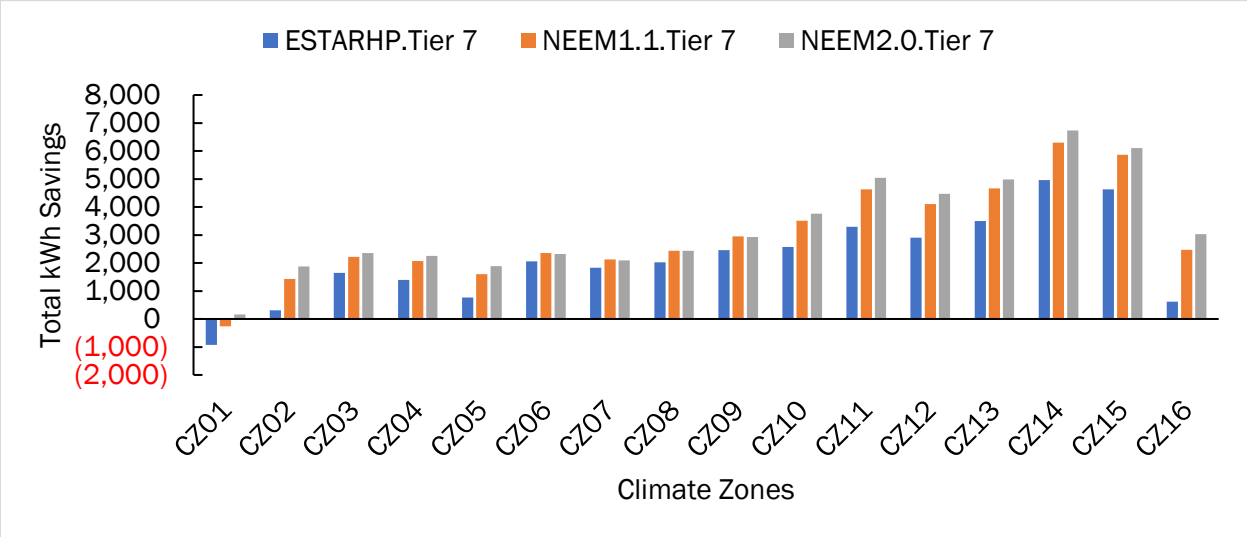

Figure 2: HVAC Savings with Tier 7 HVAC Equipment Compared to HUD-1 Base Case

Total kWh Savings for Heat Pump Water Heater Measure

To illustrate the impact of CZs on heat pump water heater consumption, the project team chose CZ 1 and CZ 13.

CZ 1 is the area along the North Pacific coast. The northern coastal region is a moist and cool climate that represents the coolest climate in California. Heating usage characterizes this CZ, with

very minor cooling needs. Heat pump water heaters can leverage relatively mild and consistent temperatures, making them an efficient option in coastal CZs.

CZ 13 is the southern area of California's Central Valley. Winters can be harshly cold, and summers are hot and humid with lots of sunshine, making energy consumption high in this region. Significant heating and considerable cooling are required in this CZ. There is an interesting inverse effect with heat pump water heaters in the hot-humid CZ. Although the cooling and dehumidification benefits and higher UEFs of a heat pump water heater would be more advantageous in a hot-humid climate, the incoming water temperature tends to be higher, meaning that less water heating is required. Lower loads equate with less energy savings compared with the same base case as illustrated in Figure 3 below.

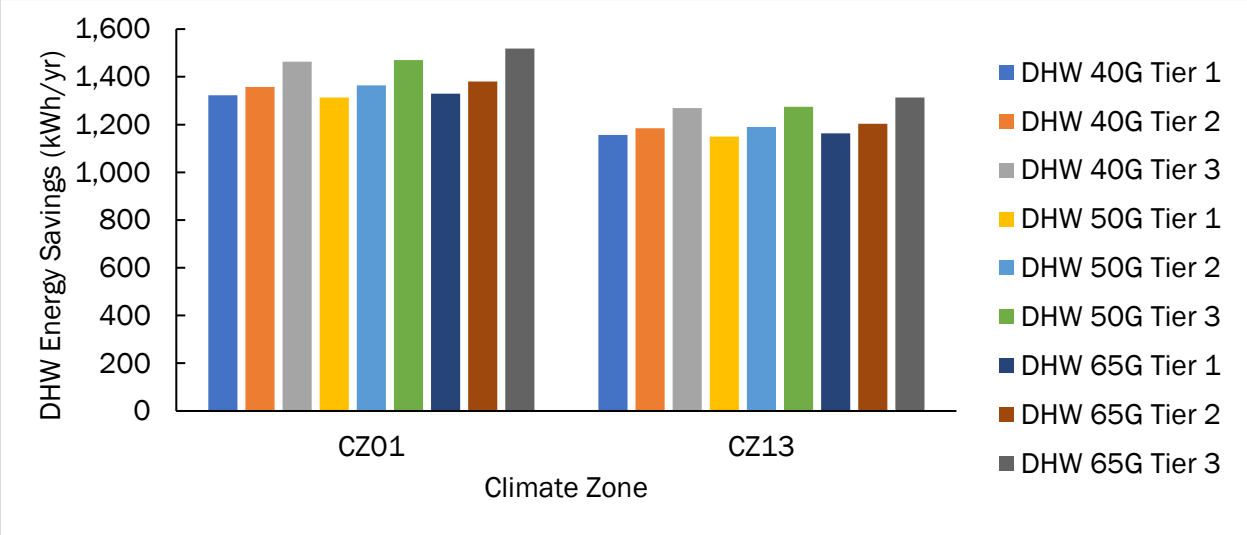

Figure 3: DHW Savings for CZ01 and CZ13 Compared to HUD-1

Efficiency Comparison of Total kWh Savings

In this section, the project team first looked at the total kWh savings generated by the combination of an ENERGY STAR building envelope and Tier 0 HVAC efficiency and heat pump water heater with 3.3 UEF efficiency and induction cooking. They then compared the results with a combination of NEEM 2.0 building envelope and Tier 7 HVAC efficiency and heat pump water heater with 3.75 UEF efficiency and induction cooking (Figure 4).

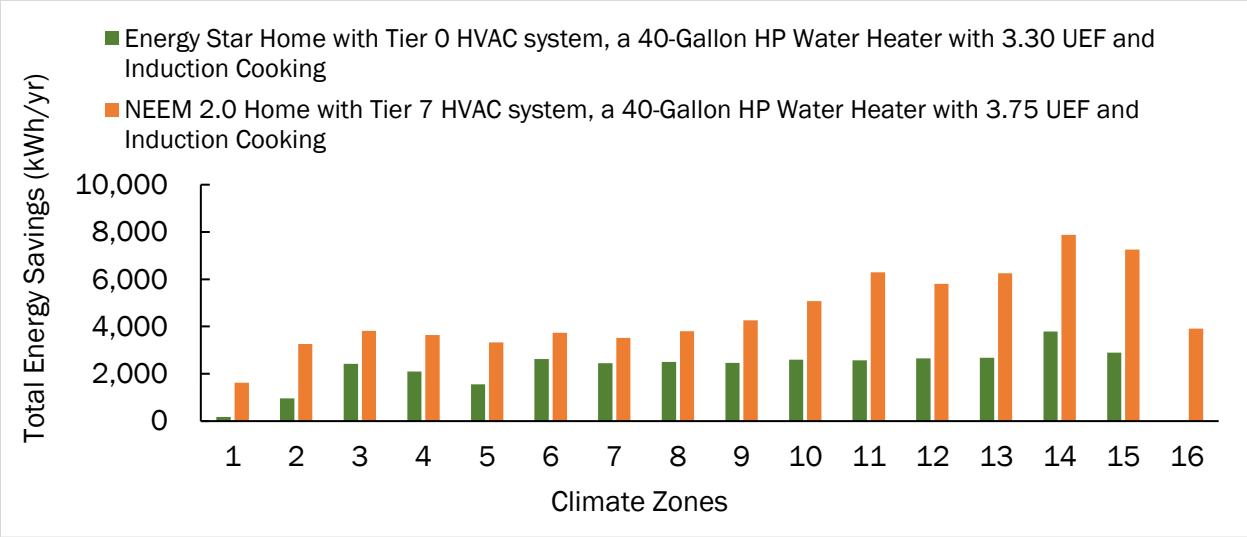

Figure 4: Total Energy Savings for Example ENERGY STAR and NEEM2.0 Homes

Distribution of Energy Savings Between Heat Pump HVAC and Envelope and Heat Pump Water Heater Measures

For Scenario 1, the project team selected CZ 14 for illustration purposes. This area is comprised of medium to high desert and is influenced by the neighboring cold CZ 16 and the subtropical CZ 15. Winters are very cold, and summers are hot and dry. There are large diurnal swings in temperature. Large amounts of both heating and cooling are required in this CZ. As depicted in Figure 5 below, the heat pump HVAC and envelope measure combination contribute to 73 percent of the total savings, while the heat pump water heater constitutes the remaining 27 percent, compared with the HUD-1 base case. This distribution is the result of the extreme cooling needs in the CZ, which leads to a higher contribution from the heat pump HVAC and envelope combination measure to the overall savings.

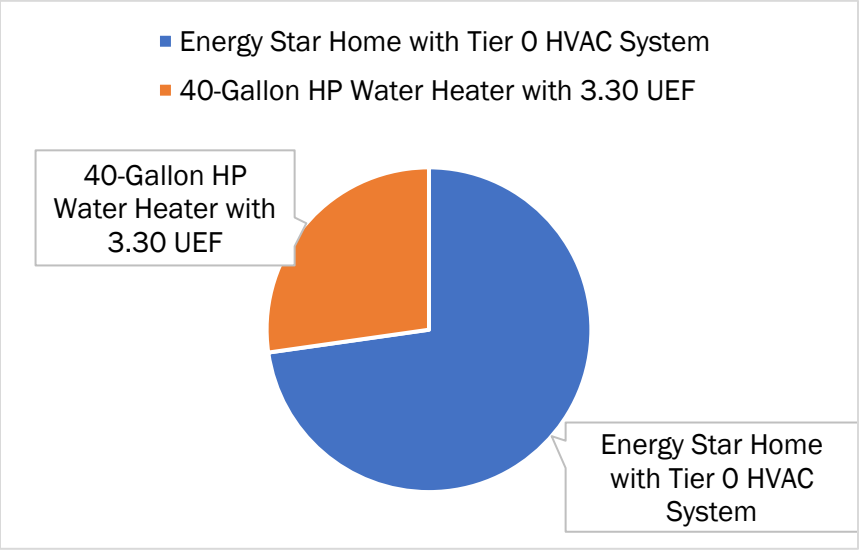

Figure 5: Total Energy Savings Distribution in CZ14 Compared to HUD-1

Compared to the HUD-2 base case, the heat pump HVAC and envelope measure combination contribute to 65 percent of the total savings, while the heat pump water heater constitutes the remaining 35 percent (Figure 6).

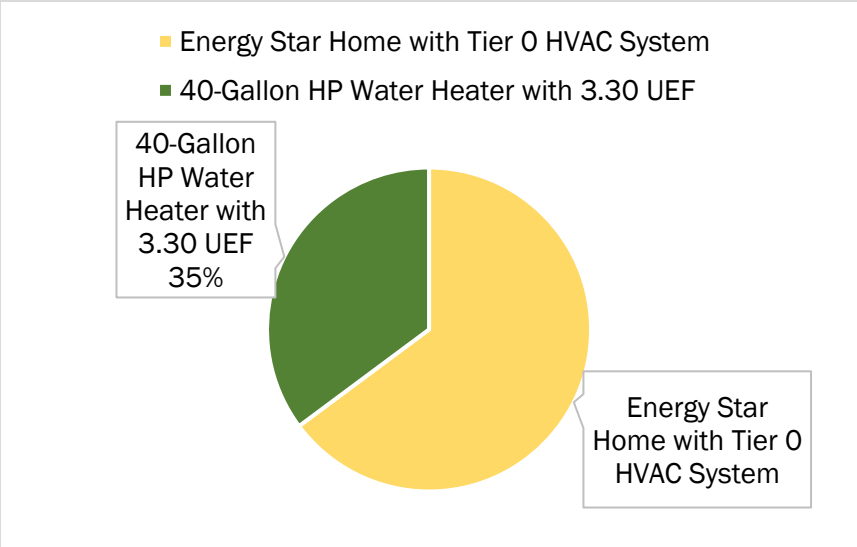

Figure 6: Total Energy Savings Distribution in CZ14 Compared to HUD-2

For Scenario 2, we selected Climate Zone 4 for illustration purposes. This area encompasses the Central Coast Region. This zone is comprised of numerous microclimates throughout central California. Seasons are well defined with mildly cool winters and hot, dry summers. Heating dominates this climate zone, with moderate cooling needs. As shown in Figure 7 below, the combination of heat pump HVAC and envelope measures contributes to 39 percent of the total savings, with the heat pump water heater constituting the remaining 61 percent, compared with the HUD-1 base case. This distribution is driven by the moderate cooling needs in the climate zone, leading to a higher contribution from the heat pump water heater measure to the overall savings. In contrast, the scenario is opposite in Climate Zone 14 for the same modeled measures.

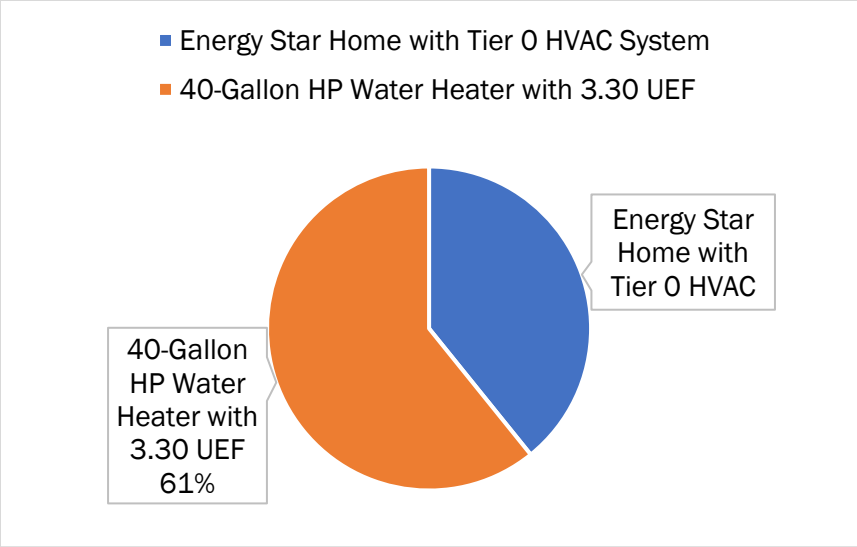

Figure 7: Total Energy Savings Distribution in CZ4 Compared to HUD-1

We noted a similar observation in comparing results from CZ 4 to CZ 14 against the HUD-2 base case. The heat pump HVAC and envelope measure combination contributes to 41 percent of the total savings, while the heat pump water heater constitutes the remaining 59 percent (Figure 8).

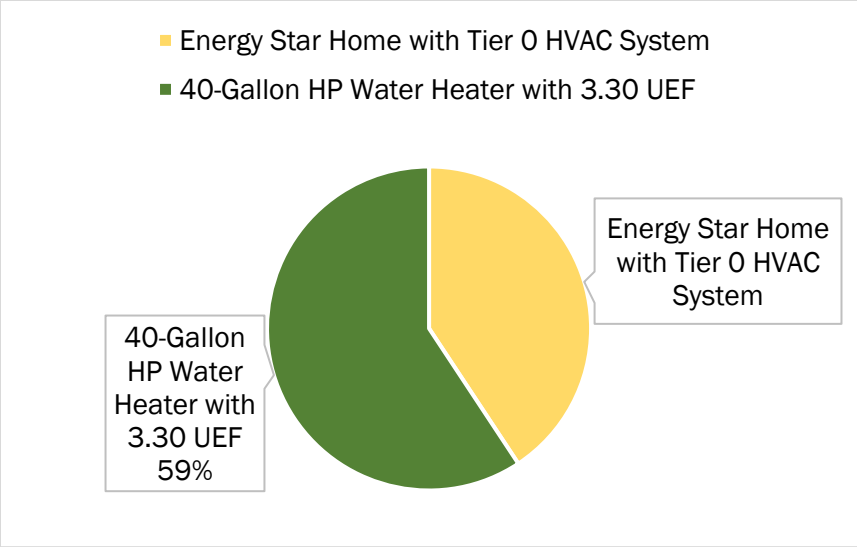

Figure 8: Total Energy Savings Distribution in CZ4 Compared to HUD-2

Please refer to Appendix B: Energy Saving Results for All Measure Cases for the detailed description of the energy analysis spreadsheet, including energy savings results for all measure cases.

Incremental Cost Collection

HVAC

Table 8 and Table 9 illustrate the base case cost for an air conditioner with a gas furnace and an electric resistance furnace, respectively, along with the measure case costs of heat pump HVAC equipment based on different efficiencies.

Table 8: Air Conditioner and Gas Furnace HVAC Equipment versus Heat Pump HVAC Costs

Base Case System Type	Measure Case Heat Pump Efficiency	Base Case Costs (A)	Measure Case Costs (B)	Incremental Costs (B-A)
Residential SEER2-rated split/packaged air conditioner (SEER2 14.3) with gas furnace (AFUE 80%)	SEER2 ≥ 13.4	$1,858	$1,704	($154)
	SEER2 ≥ 14.3	$1,858	$1,947	$89
	SEER2 ≥ 15.2	$1,858	$2,194	$336
	SEER2 ≥ 16	$1,858	$2,435	$577
	SEER2 ≥ 16.9	$1,858	$2,676	$818
	SEER2 ≥ 17.8	$1,858	$2,918	$1,059
	SEER2 ≥ 18.7	$1,858	$3,159	$1,301
	SEER2 ≥ 19.6	$1,858	$3,400	$1,542

Table 9: Air Conditioner and Electric Resistance Furnace HVAC Equipment versus Heat Pump HVAC Costs

Base Case System Type	Measure Case Heat Pump Efficiency	Base Case Costs (A)	Measure Case Costs (B)	Incremental Costs (B-A)
Residential SEER2-rated split/packaged air conditioner (SEER2 14.3) with electric resistance furnace (AFUE 98%)	SEER2 ≥ 15.2	$1,358	$2,194	$836
	SEER2 ≥ 16	$1,358	$2,435	$1,077
	SEER2 ≥ 16.9	$1,358	$2,676	$1,318
	SEER2 ≥ 17.8	$1,358	$2,918	$1,559
	SEER2 ≥ 18.7	$1,358	$3,159	$1,801

Base Case System Type	Measure Case Heat Pump Efficiency	Base Case Costs (A)	Measure Case Costs (B)	Incremental Costs (B-A)
	SEER2 ≥ 19.6	$1,358	$3,400	$2,042
	SEER2 ≥ 15.2	$1,358	$2,194	$836
	SEER2 ≥ 16	$1,358	$2,435	$1,077

WATER HEATING

Table 10 and Table 11 illustrate the base case cost for a gas and an electric resistance water heater, respectively, along with the measure case costs of heat pump water heaters based on tank capacity and different UEF values.

Table 10: Gas Water Heater versus Heat Pump Water Heater Costs

Heat Pump Water Heater Storage Capacity (gallons)	Heat Pump Water Heater Efficiency (UEF)	Total Gas Water Heater Costs (A)	Total Heat Pump Water Heater Costs (B)	Incremental Costs (B-A)
<45	3.30	$1,207	$2,417	$1,210
<45	3.50	$1,207	$2,417	$1,210
<45	3.75	$1,207	$2,463	$1,256
≥45 to ≤55	3.30	$1,207	$2,492	$1,285
≥45 to ≤55	3.50	$1,207	$2,492	$1,285
≥45 to ≤55	3.75	$1,207	$2,579	$1,372
>55 to ≤75	3.30	$1,207	$2,961	$1,754
>55 to ≤75	3.50	$1,207	$3,042	$1,836
>55 to ≤75	3.75	$1,207	$3,296	$2,089

Table 11: Electric Resistance Water Heater vs Heat Pump Water Heater Costs

Heat Pump Water Heater Storage Capacity (gallons)	Heat Pump Water Heater Efficiency (UEF)	Total Electric Resistance Water Heater Costs (A)	Total Heat Pump Water Heater Costs (B)	Incremental Costs (B-A)
<45	3.30	$1,181	$2,417	$1,236
<45	3.50	$1,181	$2,417	$1,236
<45	3.75	$1,181	$2,463	$1,282
≥45 to ≤55	3.30	$1,181	$2,492	$1,311
≥45 to ≤55	3.50	$1,181	$2,492	$1,311
≥45 to ≤55	3.75	$1,181	$2,579	$1,398
>55 to ≤75	3.30	$1,181	$2,961	$1,780
>55 to ≤75	3.50	$1,181	$3,042	$1,862
>55 to ≤75	3.75	$1,181	$3,296	$2,115

COOKING

Table 12 and Table 13 summarize the base case cost for a natural gas cooktop and an electric resistance cooktop, respectively, along with the measure case costs of the induction cooktop.

Table 12: Natural Gas Cooktop versus Induction Cooktop Costs

Base Case Cooktop	Measure Case Cooktop	Base Case Costs (A)	Measure Case Costs (B)	Incremental Costs (B-A)
Natural Gas Cooktop	Induction Cooktop	$1,651	$2,317	$666

Table 13: Electric Resistance Cooktop versus Induction Cooktop Costs

Base Case Cooktop	Measure Case Cooktop	Base Case Costs (A)	Measure Case Costs (B)	Incremental Costs (B-A)
Electric Resistance Cooktop	Induction Cooktop	$1,314	$2,317	$1,003

Stakeholder Engagement

The project team developed a topic guide to facilitate gathering feedback from manufacturers and industry stakeholders to meet the project's research objectives. Table 14 presents the research themes that the project team focused on during the interviews.

Table 14: Interview Research Themes

Research Objective	Research Themes
Confirm current market penetration of various measure packages	What percentage of manufactured housing is standard versus high efficiency? What types of space heating and cooling systems are installed in manufactured housing? What types of water heating systems are installed in manufactured housing?
Determine associated incremental costs	What are the upfront costs associated with installing standard natural gas or electric resistance versus heat pumps?
Identify any additional existing barriers to installing and operating heat pumps in manufactured housing units	What are the challenges to installing heat pumps in manufactured housing? Is the market ready for heat pumps in manufactured housing?

Market Penetration of Various Measure Packages

An estimated 27 to 30 percent of newly manufactured homes purchased in California are ENERGY STAR certified. The remaining new homes are built to HUD code standards.

About 50 percent of newly manufactured homes in California prefer natural gas for space heating, water heating, cooking, and clothes drying, while the other half opt for electricity. (Source: Data provided by Brady Peeks for NEEM homes shipped in California; he noted a similar split for HUD and ENERGY STAR homes). If a homeowner decides to use electric HVAC and water heating systems, the

remaining appliances are also electric, because it is not worth the additional cost of adding a gas line for the remaining appliances. In some areas propane is used for stoves, bypassing the need for natural gas infrastructure to the home. In general, Southern California tends to use more natural gas than Northern California, because there is less natural gas infrastructure in Northern California.

Around 90 percent of the water heaters in manufactured homes are gas or electric 40- or 50-gallon tank water heaters. Tankless water heaters are not very common because of their associated cost. It is often more cost-effective to add two square feet to the manufactured home floor plan than to install a tankless water heater.

Typical HVAC systems in manufactured homes include 80 to 95 percent AFUE electric or gas furnaces. For one progressive manufactured home factory, the breakdown of HVAC systems installed in their homes is an estimated 60–65 percent heat pumps, 8–10 percent electric resistance heating, and 25–30 percent gas heating.

Associated Incremental Costs

Based on the information obtained during stakeholder engagement, the incremental cost of upgrading the HVAC and water heating system from standard equipment to higher-efficiency equipment varies depending on the factory and the home model. Before 2020, a typical manufactured home upgrading from standard HUD code to ENERGY STAR certified costs between $2,000 to $3,000. There would be an additional cost for installing heat pumps in these homes.

Upgrading the air conditioning unit that sits on a furnace to a heat pump costs an additional $1,000 with a five-year payback period.

To drive any meaningful change the manufactured housing market, high-efficiency homes must be cost-competitive with lower-efficiency homes. Most homebuyers in this market have a tight budget, so cost reduction is key.

Barriers to Installing and Operating Heat Pumps in Manufactured Homes

CODES AND STANDARDS

The HUD Code, established in 1976 and last updated in 1994, sets the minimum efficiency standards for manufactured homes. However, efforts to strengthen these standards have faced obstacles, with attempts to increase minimum energy efficiency blocked and delayed. Stakeholders have pointed out that federal preemption under the HUD Code restricts the ability of the California Department of Housing and Community Development (HCD) to implement the state's Building Energy Efficiency Standards or other more rigorous energy efficiency requirements as the base case for manufactured homes in California.

ELECTRIC SERVICE LIMITATIONS

Nearly 70 percent of the manufactured homes sold in California are installed in mobile home parks. This is especially true in Southern California. Approximately 75 percent of mobile home parks are master metered, resulting in less than 100-amp electric service available per lot. This amperage will not support an all-electric manufactured home. There is concern that an all-electric mandate for new construction manufactured homes in California will not be supported by the infrastructure currently in place.

UTILITY METERING INFRASTRUCTURE

Stakeholders have observed that a significant number of mobile home parks still use master-metered utilities, ranging from half to over 85 percent in various service territories. In such setups, utility costs are transferred from park owners to residents, typically included in a fixed "slip fee" unrelated to individual usage. Consequently, stakeholders highlight that residents making home efficiency improvements may not fully reap the savings, as these are distributed among all park residents in master-metered systems without individual sub-metering by park owners.

COST OF ALL-ELECTRIC MANUFACTURED HOMES

Interest rates began increasing in 2023, resulting in customers qualifying for smaller home loans. The manufactured housing industry has reacted by making the homes more affordable. This often means downgrading the fit and finish in manufactured homes and installing standard HVAC and water heating systems rather than high-efficiency systems.

The customer base for manufactured homes is often low- to moderate-income, so they are unable to afford the incremental cost of purchasing a higher-efficiency home.

Because manufactured homes sit on leased land, it can be difficult for homeowners to secure the typical long-term, low-interest-rate home loans to cover the cost of more efficient manufactured homes.

EQUIPMENT CONCERNS

There are not many heat pump water heaters currently available that will work within the constraints of a manufactured home, but this is changing. Since 2022, some new heat pump water heaters specifically designed for manufactured homes have entered the market.

The use of heat pump water heaters in manufactured homes might also requires additional paperwork to be filed, which is an added burden for manufactured home fabricators. Feedback from stakeholders indicates that manufactured homes are occasionally shipped without water heating equipment, placing the responsibility on the homeowner to manage the installation. This process introduces extra paperwork, a step that could be avoided if Domestic Hot Water (DHW) systems were installed at the factory.

Manufactured homes typically have a 95 percent AFUE gas furnace installed, which is already an efficient technology and comes with additional benefits to the factories assembling these homes, leaving little incentive to replace the gas furnace with a heat pump. For instance, a 95 percent AFUE gas furnace has plastic vents, so the system can be installed at the factory requiring only a coupler to be installed onsite, which doesn't require a site inspection. Additionally, it is unclear if the payback period is advantageous for customers considering replacing 95 percent AFUE gas furnaces with heat pumps, which may make it a tough sell to customers.

Often manufactured homes are shipped without the heating systems installed, placing the heat pump installation burden on the homeowner and local retailer. Shipping the home without the heating system installed is advantageous for the factories and is compliant with the DOE's ZERH MH standard and HUD regulations.

FLOOR PLAN MODIFICATIONS

Installing heat pumps in manufactured homes often requires modifications to the floor plan to accommodate sufficient system air access, reduce potential system noise, create an access point for

system maintenance, and determine a location to exhaust potentially cooler air. Some factories have decided to embrace all-electric manufactured housing design and have altered their home floor plans to accommodate heat pumps. However, this comes with the burden of the cost of redrawing floor plans, training staff on building the new floor plan and educating installers on how to properly install the new technology.

Not only do factories have to consider where to place heat pump technologies in their floor plans, but envelope upgrades are also needed to ensure the heat pumps function properly. This includes potentially upgrading the insulation, windows, and thermostats.

EDUCATION AND AWARENESS

Heat pumps are still a new technology for homebuyers, retailers, and contractors. Education is needed to inform all of these stakeholders about the benefits of heat pumps and how they function. Customers and contractors tend to have a negative perception of heat pumps, due to earlier iterations of the technology, which is a barrier to their use and installation.

The landlords or park managers at mobile home parks often act as the gatekeepers for the community. This puts an additional burden on the industry to not only inform and convince a potential homebuyer to go all-electric but also to convince the gatekeepers of the benefit of supporting all-electric homes.

Recommendations

eTRM Measure Package Development

The project aimed at fostering the development of an electronic Technical Reference Manual (eTRM) measures package for electrifying newly built manufactured housing in California. This initiative aligned with complementary efforts like the Vermont Energy Investment Corporation (VEIC) market assessment to holistically enhance the energy efficiency of the manufactured housing sector. Our approach involved detailed energy savings and cost analysis, alongside insights from manufacturer and stakeholder interviews, ensuring a comprehensive understanding of the market's needs and barriers. By establishing baseline and measure case assumptions, we meticulously modeled energy savings for various improvements, including HVAC, DHW systems, and induction cooktops, leveraging programs like ESMH and the NEEM program. Our findings underline the potential for significant energy savings through envelope upgrades and the adoption of high-efficiency HVAC, DHW, and cooking equipment in newly manufactured homes. Incremental cost analyses revealed the economic implications of transitioning to more efficient systems, while stakeholder insights emphasized the importance of market readiness, educational efforts, and incentive structures for encouraging the adoption of heat pumps and other energy-efficient technologies.

Integrating Heat Pump Technologies and Envelope Upgrades in Manufactured Homes

To ensure the successful placement of heat pump technologies in manufactured homes, it is recommended that manufacturers not only consider the optimal locations within floor plans for such technologies but also undertake necessary envelope upgrades to guarantee their efficiency. These

steps are critical to ensure that heat pumps operate effectively, contributing to the overall energy efficiency and sustainability of newly constructed manufactured housing in California. Incentives and Tax Credits

The 45L tax credit has played a role in pushing the manufactured housing market towards electrification. This has resulted in one of the three major manufactured housing factories committing to 100 percent ZERH by 2024, forcing these homes to go all-electric. The drawback of the tax credit is that it primarily goes to corporations, leaving little incentive for the local retailers to install heat pumps and create more efficient homes. There is also no guarantee that the tax credit will be passed along to the customer. One progressive manufactured home factory was able to pass the ZERH rebate along to customers, resulting in the price of a ZERH being the same as a HUD home. However, this price reduction is not sustainable in the long term.

- The recommendation is to offer incentives at the retailer level that would benefit the all-electric housing market. There is a need to create an incentive structure that benefits the installation of heat pumps at the local retailer level.
    - A further consideration for how best to structure the incentive is that not all the manufactured homes fabricated within the state of California will be installed in the state.
    - Additionally, many customers who have purchased a manufactured home do not have an address yet, so these homes are designated stock or display homes and account for approximately 20 percent of new construction manufactured homes.

Marketing and Outreach

Stakeholders noted that engaging community organizations is a crucial strategy for accessing mobile home parks in DACs or low-income areas. They emphasized the importance of cohesive, packaged solutions across programs to prevent confusion among residents about available offerings.

- Stakeholders highlighted community meetings and using utility data as effective outreach methods, enabling residents to better understand the potential reductions in their bills.
- Stakeholders also suggested supporting the development of local workforce capacity to build trust with manufactured home residents.

Codes and Standards

To encourage the voluntary adoption of new manufactured homes constructed to higher efficiency levels than those mandated by the HUD Code, raising awareness among homeowners and mobile home parks about the benefits of such homes will be needed. This would ideally include outreach programs that highlight the advantages of ENERGY STAR and NEEM standards, emphasizing energy efficiency, cost savings, and environmental impact. Additionally, incentivizing manufacturers would also help, encouraging them to continue their voluntary adoption of these standards by exploring potential benefits or support mechanisms that lead to a broader market uptake of more energy-efficient manufactured homes.

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 manufactured homes to meet a higher efficiency level, even if voluntary programs are not adopted.

- As the development of new measure packages progresses, closely monitor and integrate the impending energy efficiency standards set to take effect in January 2025 for manufactured housing and to ensure that the new measure package aligns with these updated standards to meet the elevated efficiency levels mandated by the evolving regulations.
- In response to the anticipated shift towards fully electrified manufactured housing units and mobile home parks due to a few local or regional electrification codes, proactively engage with relevant stakeholders, including policymakers, manufacturers, and residents. Develop educational initiatives to inform stakeholders about the upcoming electrification requirements and the benefits of fully electrified MMH units.
- Establish a collaborative framework to address potential challenges associated with this transition, ensuring a smooth and well-coordinated implementation of electrification measures within the affected jurisdictions. This proactive approach will contribute to a successful and sustainable integration of electrified manufactured homes in compliance with emerging codes and regulations.

Utility Metering Infrastructure

As part of the planning process for the MHP-UCP, the CPUC created a priority list of master metered mobile home parks for the investor-owned utilities (IOUs) to convert to direct metering. The priority list was based on a risk assessment that included electric capacity, installation dates of gas systems, leak history of gas systems, proximity to areas of high temperatures for locations that had been affected by natural disasters, and whether the park is located in a DAC area. This presents an opportunity to focus efforts on locations already prioritized for utility conversion upgrades.

Converting metering to individual lots 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 its electrical capacity. Stakeholders also noted that the incremental cost of upgrading electrical service to 200-amp instead of 100-amp is small relative to the cost already incurred for construction and trenching. The CPUC is exploring whether 200-amp service should be the minimum standard.

Appendix A: Interview Design

The project team developed an initial interview guide for manufactured housing fabricators, as shown below. As more information was gained during the stakeholder interview process, the guide was modified to allow the interview team to explore additional topics and areas of interest with the different types of stakeholders.

Introduction

Hi **<CONTACT NAME>.** Thank you again for taking the time to speak with us today. As a reminder, my name is **<YOUR NAME>.** I work for TRC, a national research firm, conducting research for the state of California.
Our goal today is to hear about your perspectives on the all-electric manufactured housing market. This discussion should last around 45 minutes.
All of your responses will be completely anonymous, meaning your name will not be attributed to any individual responses.
Do you have any questions before we begin?
[PAUSE TO ANSWER ANY QUESTIONS]

To assist with note-taking, would it be okay to record this call? All individual responses will be kept confidential, and your candid input is encouraged.
[IF NEEDED: *We will not be distributing the recording to anyone outside of the TRC research team.***]**

[YES OR NO COMMENT – START RECORDING THE CALL]
[NO] OK, we will not be recording this call.

1. To start, can you please introduce yourself? Please tell me your name and a brief description of your role at **[COMPANY NAME]**.
2. What has been your experience with customer demand in general over the last 5 years for manufactured housing – would you say it has increased, decreased, or been about the same?
    a. Why do you think customer demand has **[INCREASED, DECREASED, OR REMAINED CONSISTENT]**?

       Have there been any changes in your supply chain in the last 5 years? If so, what have you experienced?
3. Using your best estimate, approximately what percentage of newly manufactured homes are standard (HUD code), ENERGY STAR® certified, and NEEM certified in 2023?
    a. What percentage of homes are all-electric versus combination gas and electric?
4. What challenges, if any, have you faced selling high-efficiency manufactured homes to customers compared to standard-efficiency homes?

a. What is the price difference between a standard-efficiency home and a high-efficiency home? (*Either cost to manufacture or cost to the customer)*

Section A: Types of systems installed in manufactured housing

5. What types of water heating systems are put into the manufactured homes your company produced or planned to produce in 2023?
   a. What percentage of manufactured homes your company produced or plans to produce in 2023 have **[LIST EACH OF THE TECHNOLOGIES MENTIONED]**?

      (*The approximate percentage is ok. Please base the percentage on the total manufactured housing units you sell or manufacture –> interviewer take note of which*)

   b. What is the upfront cost for installing **[LIST EACH OF THE TECHNOLOGIES MENTIONED]**?

6. What type of space heating and cooling systems are put into the manufactured homes your company produced or planned to produce in 2023?
   a. What percentage of manufactured homes your company produced or plans to produce in 2023 have **[LIST EACH OF THE TECHNOLOGIES MENTIONED]**?

   (*The approximate percentage is ok. Please base the percentage on the total manufactured housing units you sell or manufacture –> interviewer take note of which*)

   b. What is the upfront cost for installing **[LIST EACH OF THE TECHNOLOGIES MENTIONED]**?

Section B: Heat pumps for manufactured housing

7. What are the challenges and benefits associated with having heat pumps for space heating in manufactured homes?
8. Are there any design considerations needed for placing heat pumps in manufactured housing compared to placing standard HVAC or water heating equipment? (such as space constraints, additional insulation, etc.)
9. How would you describe customer awareness or demand for heat pumps in manufactured homes?

Section C: Wrap-up and closing

10. Do you have any additional thoughts on water heating or space heating and cooling for manufactured housing that we have not yet covered today?
11. Do you have any additional thoughts on the market for heat pumps in manufactured housing that we have not yet covered today?

Great, thank you so much for your input today. Those are all of the questions I have for you today.
I hope you have a great rest of your day. [END CALL]

Appendix B: Energy Saving Results for All Measure Cases

Please see the energy savings results for all 3,456 measure cases in the separate Excel spreadsheet with the name "ET23SWE0031_Manufactured Housing Electrification Measure Development Support_Energy Savings Analysis Sheet.xlsx".

This file lists the savings from three different sources. These sources include prototype energy modeling for HVAC and envelope measures, DEER water heater calculator for DHW measures, and savings estimate for induction cooking from CPUC-approved workpapers for all measure cases, which are usually required in support of the workpaper measure development. Therefore, we think it is important to provide this standalone Excel spreadsheet along with the main report. We focused on savings results in representative CZs and measure packages in this report. we have provided all the results are provided for readers who may wish to review any additional results not shown in the report.

The Excel spreadsheet contains five tabs. The name of each tab and its contentsare explained below:

Total Energy Savings: This tab contains the energy savings for all three end uses combined — HVAC, DHW, and cooking. The savings are calculated against both the HUD-1 baseline (all electric) and HUD-2 baseline (mixed fuel). For each measure case, we calculated the kWh savings, peak demand kW reduction, and therm savings.

HVAC & Envelope: This tab contains HVAC and envelope savings only coming out of the DEER prototype energy modeling.

DHW: This tab contains the DHW savings only coming out of the DEER water heater calculator v5.1.

Induction: This tab contains the cooking savings only coming from SWAP013 and SWAP015 workpaper.

Notes: This tab contains the naming convention used in the other tabs along with their description.

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