Market and Technical Evaluation of Multifamily In-Unit Heat Pumps

Final Report

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Executive Summary

This report examines the market opportunity and technology performance of 120-volt and 240-volt (120V/240V) variable speed, high-efficiency in-unit heat pumps for use in direct replacement of less efficient room air conditioning units and displacing or replacing in-unit gas or electric heating in California multifamily buildings. The market opportunity and technology performance are examined and informed through a review of the existing multifamily building stock in California and a technical review of new in-unit heat pump solutions, building energy modeling, and interviews with key market stakeholders including manufacturers, multifamily program implementers, consultants and property managers, and national, regional, and state level energy efficiency organizations.

The findings from this study identified specific market and technical barriers and opportunities to guide future market development actions to accelerate the adoption of low global warming potential (GWP), in-unit heat pumps with a focus on affordable housing applications for both new construction and existing housing.

Summary of Findings

- Multifamily buildings in California account for 32 percent of the residential housing stock, with approximately 58 percent of all multifamily building stock being constructed prior to 1979. Heat pumps are estimated to account for six percent of all heating ventilation and air-conditioning (HVAC) systems in the multifamily market. Most multifamily units with electric heating systems use electric resistance heat while just over 50 percent of all multifamily units use natural gas as their primary heating fuel.
- Market stakeholders identified several opportunities and barriers for in-unit heat pump technology. Opportunities included increased demand for space cooling where there is currently none, as well as a desire to retire aging and poor-performing in-unit gas wall furnaces. Building characteristics (such as window type), building modification, permitting restrictions, and utility payment structures were identified as barriers.
- Manufacturers have recently developed a variety of packaged in-unit heat pump solutions that address gaps in existing heat pump designs related to performance, installation requirements, and affordability.
- Manufacturers have responded to recent market opportunities by developing new, in-unit heat pump models capable of providing heating at low outdoor temperatures, offering heat recovery ventilation and mechanical designs for specific affordable housing applications.
- Current federal standards, test procedures, and voluntary specifications (e.g., ENERGY STAR® and Consortium for Energy Efficiency [CEE]) reflect the designs and applications of traditional heat pump technology solutions, including packaged terminal heat pumps, split (ductless/ducted), and central/packaged heat pumps. However, evaluating new in-unit heat pump models with these existing test procedures does not provide representative in-situ performance values and complicates comparison to other heat pumps and less efficient, conventional gas and electric space conditioning solutions.
- Packaged window heat pumps have the additional barrier of being federally categorized as room air conditioners and are certified under an Association of Home Appliance Manufacturers (AHAM) test procedure covering appliances, whereas other heat pump products are evaluated under Air Conditioning, Heating, and Refrigeration Institute (AHRI) test

procedures covering heating and cooling equipment. The separate categorization of the new heat pump products prevents simple comparison and assessment of heating and cooling solutions for multifamily applications.
- Manufacturers of in-unit heat pumps are actively advocating for updates to federal test procedures and standards and voluntary specifications to support the market development of these alternative heat pump solutions.
- Modeling results demonstrate that in-unit heat pumps can reduce energy usage and, depending on baseline fuel type and climate zone, reduce utility costs. The greatest total energy and greenhouse gas (GHG) savings can be achieved over a baseline with gas heat and cooling, averaging 35 percent across all scenarios. While cold climate regions can achieve closer to 40 percent total energy savings due to higher heating demand, even low heating demand locations such as the Los Angeles (LA) basin area can achieve close to 20 percent total energy savings.

Summary of Barriers and Opportunities for In-Unit Heat Pumps

- The wide range of existing space conditioning designs in multifamily buildings requires a diverse set of heat pump solutions, including in-unit window and packaged heat pumps.
- Early and sustained access to incentives and other market support is necessary for ongoing technical innovation, performance improvements, and market adoption of new in-unit heat pumps.
- Increasing access to significant tax credits and rebates through the Inflation Reduction Act (IRA) is a key opportunity area for in-unit heat pump manufacturers, as well as multifamily property owners and tenants.
- The interdependent nature of the financial costs and benefits between multifamily property owners and tenants and associated utility and regulatory requirements needs to be overcome to support the mutual benefit of in-unit heat pumps.
- Increased documentation of existing space conditioning equipment and building characteristic data, especially for affordable housing, is important for supporting the best design and cost-effective heat pump solutions.
- New plug-in 120V window heat pumps and other in-unit packaged heat pumps may serve as important technical solutions for multifamily units with limitations of existing electrical panel and service capacity.
- Increasing cold climate performance, capacity, and operation of in-unit heat pumps is important for expanding the application in historically cold and mild climates increased opportunity in multifamily buildings in California and nationally.
- Addressing limitations and gaps in existing federal standards, test procedures, and voluntary specifications (e.g., CEE and ENERGY STAR®) is critical for evaluating and comparing the performance of new window and in-unit packaged heat pumps to conventional heating and cooling equipment and alternative heat pump solutions.
- Additional in-situ performance evaluation of window and in-unit packaged heat pumps, as well as lab testing, is needed to inform ongoing product improvements, customer satisfaction and support incentives through national, state and utility incentive programs.

- Energy modeling of in-unit heat pumps emphasizes the opportunity of in-unit heat pumps in high cooling demand locations, but additional modeling of proposed equity-based rate structures, time-of-use rates, and local natural gas and electricity pricing is needed.

Abbreviations and Acronyms

Acronym	Meaning
AC	Air Conditioning
ACEEE	American Council for an Energy-Efficient Economy
AHAM	Association of Home Appliance Manufacturers
AHRI	Air Conditioning, Heating, and Refrigeration Institute
ASHP	Air Source Heat Pumps
CalTF	California Technical Forum
CEC	California Energy Commission
CEE	Consortium for Energy Efficiency
CEER	Combined Energy Efficiency Ratio
COP	Coefficient of Performance
CPUC	California Public Utilities Commission
eTRM	Electronic Technical Reference Manual
EER	Energy Efficiency Ratio
ERV	Energy Recovery Ventilator
GHG	Greenhouse Gas
GWP	Global Warming Potential
HSPF	Heating Seasonal Performance Factor
HTR	Hard-to-Reach
HVAC	Heating, Ventilation, and Air Conditioning
IOU	Investor-Owned Utility

Acronym	Meaning
IRA	Inflation Reduction Act
NEEP	Northeast Energy Efficiency Partnerships
NYCHA	New York City Housing Authority
NYPA	New York Power Authority
NYSERDA	New York State Energy Research and Development Authority
NREL	National Renewable Energy Laboratory
PTAC	Packaged Terminal Air Conditioning
PTHP	Packaged Terminal Heat Pumps
PWHP	Packaged Window Heat Pumps
RACs	Room Air Conditioners
RASS	California Residential Appliance Saturation Study
RUBS	Ratio Utility Billing Systems
SEER	Seasonal Energy Efficiency Ratio
SPVHP	Single Packaged Vertical Heat Pumps
US DOE	U.S. Department of Energy
UA	Utility Allowance

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Introduction

Developing targeted solutions for electrifying existing multifamily buildings is urgently needed to achieve California's decarbonization goals. Multifamily buildings satisfy tenant heating and cooling needs through whole building systems, in-unit systems, or often both, with whole building heating systems and, when applicable, in-unit window air conditioners. Whole building heating and air conditioning (AC) systems bring significant costs and technical challenges for whole building solutions such as variable refrigerant flow heat pumps and serve as significant barriers to clean heating and cooling adoption. With the ongoing impacts of climate change, the need for AC in California is increasing, especially in historically milder climate regions. As the need for all-encompassing solutions increases, manufacturers are being challenged to develop new heat pump technologies to provide heating and cooling with the lowest energy usage and greenhouse gas (GHG) impact possible.

In response to these critical needs and challenges, manufacturers have introduced a variety of in-unit heat pump models that expand the options for renovating or displacing traditional heating, ventilation, and air conditioning (HVAC) systems in multifamily buildings. These in-unit heat pump solutions are categorized in this report as packaged window heat pumps (PWHP), packaged terminal heat pumps (PTHP), and single packaged vertical heat pumps (SPVHP). Additional heat pump solutions, notably central heat pumps, ductless heat pumps, and ducted heat pumps, have proven to be effective for multifamily buildings, however they are not a primary focus of this research.

Emerging multifamily in-unit heat pump designs offer an alternative and potentially lower cost, and simpler installation option for retrofitting California multifamily buildings to simultaneously address the increasing need for AC in traditionally mild California climate zones, while also mitigating the negative impact of GHG emissions associated with cooling and conventional in-unit heating.

This report examines the market opportunity and technology performance of 120V and 240V variable speed, high-efficiency in-unit heat pumps for use in direct replacement of less efficient room AC units and displacing or replacing in-unit gas or electric heating in California multifamily buildings. Additional design options including low global warming potential (GWP) refrigerants will also be assessed. The market opportunity and technology performance have been examined and informed through a review of the existing multifamily building stock in California and technical review of new in-unit heat pump solutions, interviews with market stakeholders and manufacturers, and results from building energy modeling. Throughout this effort the project team reviewed the growing knowledge about these products by coordinating closely with national and other statewide initiatives and California programs such as the Consortium for Energy Efficiency (CEE), New York Power Authority, TECH Clean California, Energy Solutions, Building Initiative for Low-Emissions Development Program, California Market Transformation Program, and the EPIC grant program. Direct interviews were performed with three leading manufacturers of window and alternative wall-hung heat pumps identified in the initial project market research.

The findings from this study (when followed by laboratory and field demonstrations) can accelerate the adoption of low GWP in-unit heat pumps, especially for use with new and existing affordable housing in which the renter is responsible for the electric bills.

Background

To drive development of new electrification products that would better serve the heating and cooling needs of existing multifamily buildings and hasten the transition to fossil-free heating sources, New York City Housing Authority (NYCHA), New York Power Authority (NYPA), and New York State Energy Research and Development Authority (NYSERDA) released the New York Clean Heat for All Challenge. This industry competition directed manufacturers to develop a packaged cold climate heat pump that could be installed through an existing window opening to provide heating and cooling on a room-by-room basis in multifamily buildings. The goal was to reduce or eliminate many of the cost drivers inherent to existing heat pump technologies, enabling rapid, low-cost electrification of buildings to reduce GHG emissions.

The technology development propelled by the New York challenge has led to increased market opportunities for emerging in-unit heat pump products nationwide.

According to the 2019 California Residential Appliance Saturation Study (RASS), saturation of individual unit AC is 21 percent for multifamily buildings with five or more units. The United States Census 2020 American Community Survey results indicate that California has over 3.35 million multifamily buildings with five or more units, or 25 percent of the total housing stock. Inefficient packaged terminal air conditioners (PTAC) or combinations of wall-hung gas or electric space heaters, room air conditioners (RAC) and portable air conditioners are installed in many affordable housing multifamily buildings in California to meet tenant and owner heating and cooling needs. New technologies coming into the U.S. market, such as window and wall mounted packaged heat pumps, offer potentially greater energy savings compared to the existing heating and cooling solutions and expanded flexibility for replacement.

Below is a list of recent market developments identified at the outset of this study that have spurred increased focus on new in-unit heat pump technologies. Additional details on these and other market developments are included in the Findings section of this report.

- Electric Program Investment Charge (EPIC) Grant—In 2019 the California Energy Commission's (CEC) EPIC program awarded a grant for the "scale-up [of] a manufacturing line of quieter, less expensive, and easy-to-install, retrofit window electric heat pumps." (CEC 2019)
- New York Clean Heat for All Challenge—In 2021 a request for proposals in New York solicited for the development of a window-installed cold climate heat pump with a commitment of over 24,000 units.
- CEE Super-Efficient Room Conditioner Initiative—In 2022, the CEE launched a new initiative aligned with and building on the New York solicitation to promote the "manufacture, availability, and installation of attractively priced, efficient window heat and cooling units for apartment renters."

Overview of In-Unit Heat Pumps

In-unit heat pumps differ from traditional air source heat pumps (ASHP) by their packaged form factor, which has several advantages such as ease of installation, improved aesthetics, occupant-controlled space conditioning, and allows incremental displacement or replacement of central or in-unit heating and cooling systems. Traditional ASHP equipment is split into an outdoor and indoor unit (or units), connecting the primary components—the compressor, the condenser, and the evaporator via refrigerant lines that run through a penetration in the wall. The in-unit equipment described in this report is self-contained or "packaged," encapsulating all components internally. While some in-unit options allow for ducted distribution, most in-unit heat pumps operate as single-point sources of heating and cooling.

Single packaged (vertical) heat pump.

Source: https://ephoca.com/

Packaged window heat pump.

Source: https://www.gradientcomfort.com/

Packaged terminal heat pump.

Source: https://www.friedrich.com/products/professional/ptac

Figure 1: Heat pump categories

In this report in-unit heat pumps are broken into three primary categories:

- Single packaged (vertical) heat pumps[1]
- Packaged window heat pumps
- Packaged terminal heat pumps

SPVHPs are similar to PTHPs but are not designed to fit the specific form factor of the traditional PTAC. Rather than resting in a through-the-wall sleeve, SPVHPs can be installed in mechanical closets, mounted to the wall, or mounted to the ceiling. Some models can be equipped to run ductwork throughout an apartment or other space, allowing for space conditioning in separate rooms in an apartment. Unlike a window-mounted unit, they do require contractor involvement, particularly in multifamily applications, as most models require penetrations to be drilled in an exterior wall on the building. Some models have optional adaptors that allow them to utilize an existing window opening. In addition, some SPVHPs can also be equipped with an energy recovery ventilator (ERV) to provide conditioned fresh make-up air to an apartment.

[1] Single package vertical heat pumps (SPVHP) are typically located in an interior closet or wall in a multifamily unit. However, as new wall hung heat pump designs have a horizontal form factor – and do not meet packaged terminal heat pump definition for installation in a sleeve – they are currently categorized as an SPVHP.

PWHPs are mounted into a window, typically with minimal disruption to the building; most units require little or no contractor involvement (i.e., electrical, gas, plumbing or building construction work) and carry the option of a do-it-yourself install. Different form factors of PWHPs exist, including traditional AC window box styles and new ‘saddlebag’ designs, which straddle the windowsill with the interior and exterior components hanging on either side. Existing PWHP available today are designed for vertical, hung windows, serve as point source heating and cooling, and can serve as a replacement for traditional window AC units. Some manufacturers also offer portable ‘wheelie’ or ‘roll-up’ units; these units also tend to be simple to install and best suited for single-hung, double-hung, or sliding windows, but were not a primary focus of this report.

PTHPs are defined in current federal standards as being mounted into a sleeve in an exterior wall. PTHPs are commonly deployed in hotel rooms or apartments, as they allow temperature regulation on a room-by-room basis. They can be used in retrofit applications when replacing PTAC units, using the same sleeved penetration. Several PTHP models are currently available on the market and while they are relevant for multifamily retrofits, they are best applied where PTAC units already exist.

Objectives

The primary objectives of this evaluation were to 1) understand market opportunities, 2) determine technology performance, 3) identify barriers to increased heat pump adoption and 4) deliver actionable recommendations for accelerating market and technology developments for in-unit heat pump solutions.

Understand Market Opportunities

The objective of conducting primary research on in-unit heat pumps for multifamily buildings is to gain a comprehensive understanding of the market opportunities for this technology. This research involved directly collecting new data from the target audience, which included multifamily building owners, affordable housing developers, standard setting organizations, contractors, and manufacturers. The research focused on identifying specific barriers and targeted replacement opportunities for low GWP in-unit heat pump adoption in multifamily buildings in California. The findings from this research have enabled the project team to make informed recommendations based on product specifications, costs, and sales channels of traditional and new low GWP in-unit heat pump products, and to better understand the potential energy savings and environmental benefits of this technology. Overall, the objective of this research was to identify and capitalize on the market opportunities for in-unit heat pumps in multifamily buildings.

Determine Technology Performance

The project evaluated the performance of in-unit heat pumps for multifamily buildings by using multiple research methods. The project team first analyzed existing literature on multifamily building characteristics, income, technology solutions, equipment standards, and performance criteria to establish a baseline for the current market. The project team then conducted research through stakeholder interviews with multifamily market actors, manufacturers, and market opportunity leads to supplement and validate research findings. The goal was to obtain a comprehensive understanding of the performance of in-unit heat pumps, identify gaps in existing research, and determine opportunities for further research and development of this technology.

Identify Barriers to Increased Heat Pump Adoption

The project team conducted a comprehensive market study that evaluates the barriers to adoption of variable speed, high-efficiency in-unit and window heat pumps in multifamily buildings in California. The study identified the major challenges that hinder the widespread adoption of these heat pumps as a direct replacement for inefficient window and PTAC units and in-unit gas or electric heating. The project explored and analyzed the market opportunity and technology performance of in-unit heat pump designs, with a particular focus on identifying and addressing the various barriers to their adoption, such as cost, installation complexity, product awareness, and performance.

Deliver Actionable Recommendations

The findings have provided valuable insights into the feasibility and potential impact of using in-unit heat pump solutions in retrofitting multifamily buildings in California and may help inform future policy and market interventions to facilitate their wider adoption. This study provides actionable recommendations developed from the project team's analysis of the technology, building energy modeling and interviews with key market stakeholders including manufacturers, multifamily program implementers, consultants and property managers, and national, regional, and state level energy efficiency organizations.

Methodology and Approach

This research study included both market evaluation and technical evaluation components. The market evaluation analyzed market trends, size, segmentation, and opportunities for heat pumps, while the technical evaluation assesses energy efficiency, installation requirements, maintenance, and cost-effectiveness of various technologies. The findings from the literature review were synthesized to provide qualitative and quantitative assessments, as well as recommendations for future research.

Market Evaluation

The market evaluation focused on the current state of the multifamily heating and cooling market in California, as well as market developments nationally that were driving increased focus and opportunities for in-unit and window heat pumps. This included an analysis of market trends, market size, market transformation, market segmentation, market barriers, and opportunities for in-unit heat pumps. The intent of this market evaluation was to provide valuable insights into the current state of the market and technology.

The project team conducted a literature review to comprehensively evaluate and characterize the state of HVAC systems in multifamily buildings in California and new national and regional initiatives supporting innovations in the market for in-unit heat pumps. To ensure relevance and quality of the literature, the selection was limited to published material dating from 2015 to present. The collated sources were prioritized towards industry-relevant material, with premiums being placed on energy impacts; market and technical evaluations; heat pump market transformation and electrification; baseline and potential studies; and financial implications related to energy efficiency such as tenant and ownership structures (tenure) and energy code burden. Research directly connected to the California Public Utilities Commission (CPUC), CEC, California Technical Forum (CalTF), and the California Investor-Owned Utilities (IOUs), was also prioritized.

Parallel to the literature review, the project team conducted a series of outreach interviews with stakeholders from the California multifamily market familiar with electrification efforts and barriers, as well from national and regional organizations supporting new heat pump initiatives. These stakeholders included individuals with direct contracting, retrofit, and program implementation experience, and were asked a series of open-ended questions regarding the existing multifamily housing landscape in California, conventional and heat pump in-unit space conditioning solutions and barriers to adoption of heat pumps. A list of those interviewed can be found in Appendix A: HVAC Energy Use.

Technical Evaluation

The technical evaluation focused on aspects of in-unit heat pumps for multifamily applications. This included an analysis of the energy efficiency impacts, installation requirements, maintenance requirements, performance characteristics, and cost-effectiveness of the technology.

Additionally, National Renewable Energy Laboratory (NREL) ResStock 2022 data[2] was heavily leveraged in determining key characteristics of multifamily buildings and determination of the measure baseline. NREL ResStock was developed in support from the U.S. Department of Energy (US DOE) and offers real-time data visualization of an immense range of market factors and information. Through a combination of multiple public and private data sources, statistical sampling, sub-hourly building simulations, and high-performance computing, NREL ResStock provides granularity on modeling diverse housing stock and distributional impacts of building technologies across different communities.

The findings from the secondary literature review were synthesized to identify gaps and topics for focus of the primary research component through stakeholder interviews. The findings include a narrative summary of the key takeaways as well as qualitative and quantitative assessments of the data. The secondary literature review also identified gaps in the standards, test procedures, specifications and field evaluations and recommendations for future research. The limitations may include the lack of research on certain aspects of baseline equipment in multifamily buildings and the need for more rigorous research design in future studies.

Findings

This section covers a review of in-unit heat pump market developments, findings, and insights from building energy modeling and interviews with key market stakeholders including manufacturers, multifamily program implementers, consultants and property managers, and national, regional and state level energy efficiency organizations; summary and analysis of current multifamily building stock in California; summary of the packaged heat pump solutions on the market today; review of

[2] ResStock data utilized was Data Table with Characteristics and Annual Energy Use metadata from the 2022.1 Release, Publication date October 2022, Building Stock represented U.S. residential sector circa 2018, TMY3.

existing standards, specifications, test procedures and identified gaps; and building energy modeling results for evaluating energy impacts on multifamily buildings.

Market Evaluation

In-Unit Heat Pump Market Developments

As highlighted earlier in the report, several recent market developments spurred increased focus on new in-unit heat pump technologies as a potentially scalable solution for addressing affordability and compatibility issues with existing multifamily buildings. The market developments addressed gaps in existing heat pump designs related to performance, installation requirements and affordability.

Table 1: Summary of In-Unit Heat Pump Market Developments

	Summary of In-Unit Heat Pump Market Developments
California Window Heat Pump Innovation Grant and Evaluation	In 2022 a new, 120V window-installed heat pump design was brought to market offering customers a “quieter, less expensive, and easy-to-install, retrofit window electric heat pumps” (CEC 2019) compared to conventional window installed room air conditioners. In addition, the heat pump functionality allowed for supplemental heating capabilities in mild climates. The development of the product was funded in part through a CEC EPIC grant and was offered for sale direct to customers. Following the product launch, in 2023 100 units were installed as part of an evaluation with a multifamily property and single-family homes in Tracy and Fresno California.[3] The evaluation was to assess customer satisfaction with the window installed heat pumps.

[3] The evaluation was funded by the California Strategic Growth Council and the Electric Power Research Institute and conducted by Redwood Energy.

	Summary of In-Unit Heat Pump Market Developments
NY Clean Heat for All	A solicitation released as part of the New York Clean Heat for All Challenge, was an industry competition directed at heating and cooling equipment manufacturers to develop a new electrification product that can better serve the needs of existing multifamily buildings and hasten the transition to fossil-free heating sources (NYSERDA 2022). Specifically, the requirements were to develop a packaged cold climate heat pump that could be installed through an existing window opening to provide heating and cooling on a room-by-room basis in multifamily buildings. The goal was to reduce or eliminate many of the cost drivers inherent to existing heat pump technologies, enabling rapid, low-cost electrification of buildings to reduce GHG emissions.NYCHA committed to purchasing 30,000 units from the awarded vendors and to invest an initial $70 million, to purchase and install the new equipment as well as provide additional improvements to the building envelopes and hot water systems. If successful, NYCHA will deploy the technology at more than 50,000 apartments over the next 10 years to meet space heating and cooling needs with zero on-site emissions. The envisioned product would enable rapid, low-cost electrification of multifamily buildings by reducing or eliminating many of the cost drivers inherent to existing heat pump technologies when used in resident-occupied apartments. These include costly electrical upgrades, long refrigerant pipe runs, drilling through walls and floors, and other construction that results in high project costs and significant disruption to residents. The partnership between NYCHA, NYPA, and NYSERDA will test innovative products and proposals for cost-effective heating and cooling solutions for NYCHA's portfolio, which includes 2,198 residential buildings. NYSERDA is supporting the effort by providing additional funding from the Regional GHG Initiative operating plan, which calls for the electrification of heating in New York City public housing to improve energy performance, decrease emissions, and improve resident comfort. NYSERDA will assist with drafting the product specifications and project commissioning as well as measurement and verification for the demonstration units. In August 2022, two manufacturers were selected through the NYPA solicitation and awarded seven-year contracts for the development and delivery of cold climate PWHPs.

Summary of In-Unit Heat Pump Market Developments	
CEE Super-Efficient Room Conditioner Initiative[4]	As the new PWHP designs will be applicable to the multifamily sector across the U.S. Northeast and nationally, NYCHA and NYSERDA initiated engagement with other large public housing authorities and housing agencies in the US and Canada, as well as utility and state efficiency programs through a partnership through the bi-national CEE Super-Efficient Room Conditioner (SERC) initiative. The CEE initiative would serve to achieve economies of scale by leveraging a "price match" component to the New York solicitation. The long-term goal of the initiative is to displace less efficient in-unit heating and cooling equipment through the "manufacture, availability, and installation of attractively priced, efficient window heat and cooling units for apartment renters." The SERC initiative is drafting specifications to support including a labeling program that allows consumers to identify super-efficient room conditioners in the market. The labels will provide information on the product's energy efficiency, performance, and environmental impact, making it easier for consumers to make informed decisions. The SERC Initiative is a voluntary program supported by manufacturers, utilities, government agencies, and other stakeholders who recognize the potential energy savings and environmental benefits of super-efficient room conditioners.
NEEP Cold Climate ASHP Specification & List[5]	In 2021 the Northeast Energy Efficiency Partnerships (NEEP) Heating Electrification Initiative introduced new categories in its cold climate ASHP specification for PTHPs and SPVHPs to support utility programs seeking to identify and support adoption of in-unit heat pump technologies able to perform in colder climate conditions.

Source: Project Team

Insights and Feedback from Market Stakeholders

Conversations with market stakeholders provided insights regarding current multifamily housing stock, existing heating and cooling technologies, space cooling presence statewide, housing code regulations, widely accepted aesthetics, and economic factors and barriers to electrification in general. Stakeholders included contractors and implementers with retrofit experience in the California market, consumer advocates with knowledge of the multifamily building stock, and sustainability focused staff at an affordable housing provider. Overall, those interviewed are excited about emerging in-unit heat pump technologies and the opportunities they present, and space heating and cooling electrification in general, but hesitant as to whether the PWHPs on the market today are a fitting product solution for the California multifamily housing market and building stock.

In terms of the current multifamily housing stock, stakeholders shared that most multifamily housing buildings in the state are "garden-style," built in the second half of the last century, typically consisting of one-to-three story walk-ups with outdoor areas, similar to a campus-like setting. Most of

[4] https://library.cee1.org/system/files/library/14726/CEE_Super-EfficientRoomConditionerInitiative_Feb2022.pdf

[5] https://neep.org/heating-electrification/ccashp-specification-product-list

these buildings have horizontal slider windows, although individuals reported that both horizonal slider and vertical double-hung windows have a presence in the California multifamily housing market and that a solution is necessary for both. While a variety of heating technologies exist in the market today, including some PTACs and mini-split heat pumps, gas wall furnaces were reported to be the most common heating technology among multifamily housing units. Since these systems are unitary, tenants are most often paying the heating costs accrued from the use of gas wall furnaces.

The California Housing Code, as well as properties' various guidelines and policies, emerged as topics during conversations, particularly when discussing the prevalence of heating and cooling technologies as well as regulations relating to aesthetics. While the state housing code requires space heating be provided for every unit available for rent, providing space cooling is not mandated statewide, and therefore is far less prevalent in milder climates, especially in affordable housing. [6,7] Consumer advocates shared that cooling is more common among market-rate properties, as it often provides a significant value-add to those looking to renovate and/or modernize a property. Among the existing cooling infrastructure discussed with those familiar with the current multifamily housing stock, window AC units seemed to be the most common technology among those without an existing heat pump, although there was mention of some properties not permitting the use of window units, often for aesthetic reasons. Property guidelines and policies were also brought up while discussing PTHP options, and the potential risk that creating new and/or additional penetrations in a building posed to both aesthetic and leakage issues.

ECONOMIC FACTORS AND BARRIERS

Economic advantages and barriers were significant factors in overall electrification efforts and heat pump adoption that appeared throughout conversations with stakeholders. The individuals shared economic factors specific to and affecting the California multifamily housing market, helping to inform a broader analysis of state-specific barriers to in-unit heat pump technology. The issue of split incentives of costs and benefits between owners and tenants was raised as a familiar, yet critical, barrier to heat pump adoption and electrification in general. Utility Allowances (UAs) were mentioned as a significant barrier to the technology in affordable, regulated housing. UAs are estimates of the expenses households in applicable subsidized housing incur for different types of utilities. These allowances are then reduced from monthly rent payments. Since typical, currently existing UAs are calculated based on average costs related to electric resistance heating costs, they can lead to a lack of incentive for owners to install heat pump technology.

An additional economic barrier exists in a common scenario, where installing an in-unit heat pump in a residence replaces heating from a central system. In these situations, the risk of costs shifting to the tenant arises, as they would then be responsible for the expense of heating costs previously covered by the owner. Ratio Utility Billing Systems (RUBS) were also mentioned as a utility payment

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[6] During a June 2023 meeting, the Los Angeles City Council voted to conduct a study on requiring cooling in all residential rental units and assess program assistance for low- and moderate-income tenants with air conditioning costs. Los Angeles Times, June 3, 2023. https://www.latimes.com/california/story/2023-06-03/los-angeles-explores-a-cooling-mandate-for-all-rental-units

[7] In 2022, the hearing was cancelled for California state assembly bill AB 2597 which would "require the Department of Housing and Community Development to develop and propose mandatory building standards for safe maximum indoor air temperature in existing dwelling units".

structure currently employed and acting as a barrier, as these are based off centralized heating systems and would need reframing in the face of in-unit heat pump adoption.

These stakeholders' insights were valuable to paint the picture of existing multifamily housing infrastructure and construction, typical retrofit strategies, tenant and owner perspectives, as well as various market actors' experiences.

Evaluation of Existing California Multifamily Housing Market

Key Characteristics of Multifamily Buildings

The residential housing stock in California totals approximately 13.8 million units, with multifamily apartments accounting for approximately 32 percent of the residential housing stock (NREL n.d.). As seen in Figure 2 below, the majority of multifamily units (74.6 percent) reside in buildings that are comprised of five or more units. Since 2009, the construction of multifamily residences has equaled that of single-family homes, with multifamily units representing 50 percent of new housing stock in California (Berkland, Pande and Moezzi 2018).

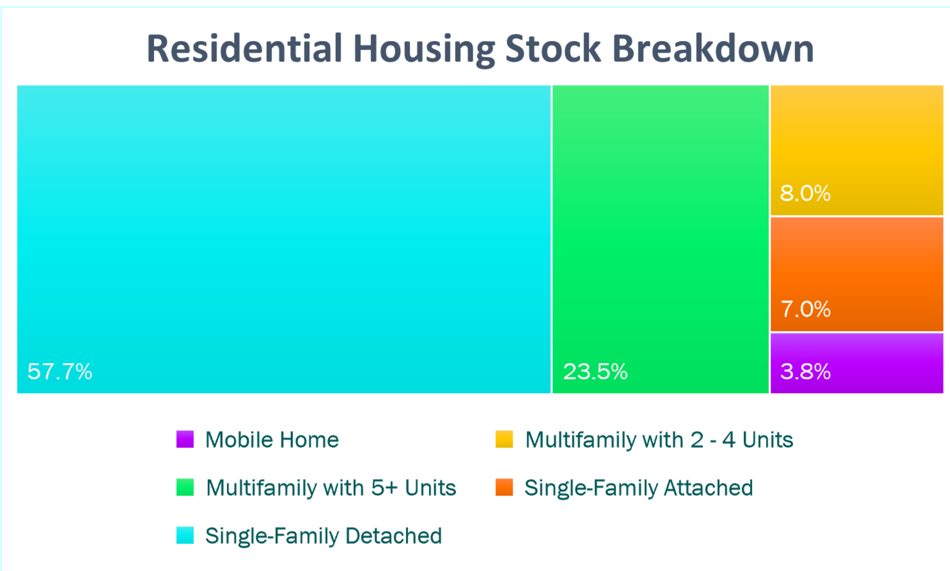

Figure 2: Breakdown of the residential housing stock in California

Source: NREL ResStock

The construction of multifamily buildings in the state steadily rose decade over decade beginning in the 1940s, reaching a peak in the 1970s when the greatest volume (21.9 percent, of the existing multifamily buildings) was built. Since the 1970s, construction of multifamily buildings has steadily declined over each decade, as seen in Figure 3 below. Recent construction of new buildings, dating back to 2010, only accounts for 4.2 percent of the multifamily unit stock.

Building vintages provide a window into the baseline characteristics of the market, which can heavily influence measure assumptions, energy savings impacts, installation and equipment replacement scenarios, and data modeling inputs. Vintage can also lead to assumptions on applicable building codes and insulation conditions.

The California Building Standards Commission created the state's first energy-focused building code in 1976, named the Energy Efficiency Standards for Residential and Non-Residential Buildings.[8] Multifamily buildings constructed prior to the state's adoption of these energy codes could, in theory, benefit from energy efficiency program intervention. Approximately 58 percent of the existing multifamily building stock was constructed prior to 1979.

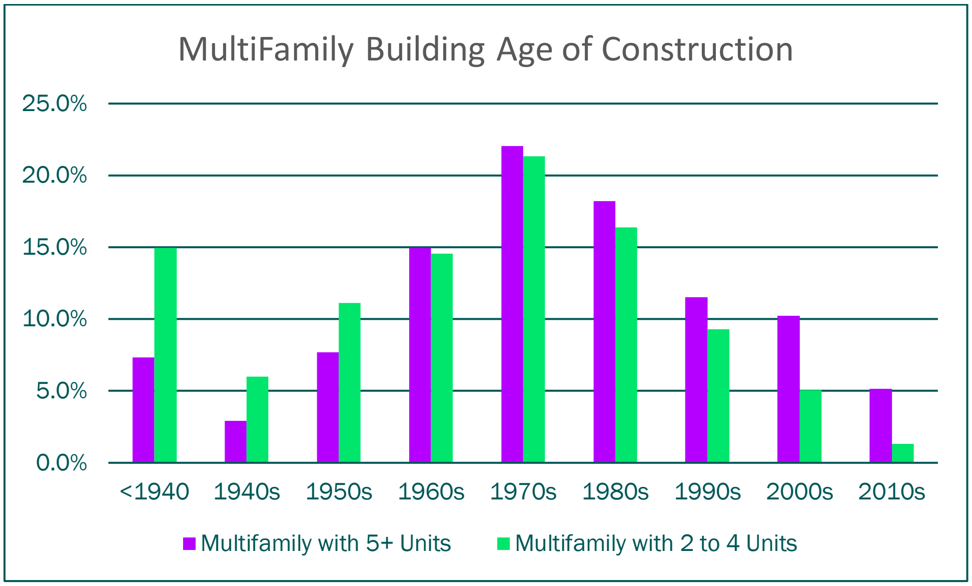

Figure 3: Vintage of multifamily buildings in California based on date of construction

Source: NREL ResStock

Characterization of Baseline Heating and Cooling Systems

A characterization of the baseline heating and cooling systems in multifamily buildings can help inform the potential for in-unit heat pumps. Primary heating fuel type, incidences of cooling equipment, and distribution of shared versus in-unit systems were all data points collected and analyzed. Characterizations of the baseline equipment can help dictate the most likely replacement scenarios for in-unit heat pumps. Additionally, understanding the saturation of baseline systems aids in the quantification of installation costs associated with the heat pump, such as electrification upgrades, and disposal costs of the existing HVAC system.

Table 2 details the building-level distribution of shared HVAC systems and the presence of ductwork. The saturation of shared or central HVAC systems has precipitously declined in multifamily buildings since the 1940s. Before 1940, 57 percent of multifamily buildings with five or more units had a shared HVAC system. However, since the 1980s, 80 to 83 percent of multifamily buildings with five or more units were built with in-unit HVAC systems.

[8] California Energy Commission. The Buildings Energy Efficiency Standards are part of the California's Building Standards Code (Part 6 of Title 24). The current standards, the 2022 energy code, was adopted on August 11, 2021, requiring any building whose permit applications are applied for, on, or after, January 1, 2023, must comply.

Natural gas and electric represent over 93 percent of primary heating fuel types across all climates and building types in California, with the remaining consisting of propane, oil, other or no reported heating fuel type. Heat pumps are estimated to account for six percent of all HVAC systems in the multifamily market, electric systems are dominated by electric resistance systems, accounting for approximately 86 percent of all electric heating systems. Although 51.6 percent of multifamily units use natural gas as their primary heating fuel, electric heating systems are the primary heating system in the cold and very cold climate regions of the state.

These values are sourced from NREL ResStock data and benchmarked for accuracy against California's Residential Appliance Saturation Study (Palmgren, et al. 2021). The results of that baseline study showed that 54 percent of multifamily buildings with less than five units had natural gas as the primary heating fuel type, while buildings with five or more units came in at 59 percent. Additionally, heat pumps were estimated to have a penetration of five percent and nine percent, respectively, in the two different sized multifamily buildings.

Table 2: Building-Level Shared HVAC and Ducting Presence in Residences in California

RECS Building Type (with height)	Vintage Bin	No Shared HVAC		Shared Heating Only		Shared Cooling Only	Shared Heating and Cooling
		Ducts Present	No Ducts	Ducts Present	No Ducts	Ducts Present	Ducts Present
Single Family Detached	< 1940	54%	46%				
	1940-79	66%	34%				
	> 1980	91%	9%				
Mobile Home	< 1940	78%	22%				
	1940-79	73%	27%				
	> 1980	88%	12%				
Single Family Attached	< 1940	52%	38%	4%	6%	0%	
	1940-79	65%	28%	1%	5%	1%	0%
	> 1980	85%	13%	1%	0%	0%	1%
Multifamily with 2 - 4 Units	< 1940	37%	32%	8%	14%	1%	9%
	1940-79	51%	24%	7%	15%	0%	2%
	> 1980	76%	13%	6%	3%	1%	1%
Multifamily with 5+ Units (1 - 3 Stories)	< 1940	23%	20%	24%	29%		4%
	1940-79	40%	25%	13%	15%	2%	6%
	> 1980	67%	13%	9%	6%	1%	4%
Multifamily with 5+ Units (4+ Stories)	< 1940	22%	21%	22%	31%		4%
	1940-79	35%	28%	12%	18%	0%	6%
	> 1980	72%	11%	7%	5%	2%	3%

Source: NREL ResStock

Table 3: Primary Heating Fuel by Climate Region in Residences in California

Building America Climate	RECS Building Type (with height)	Heating Fuel					
		Natural Gas	Electricity	None	Propane	Other Fuel	Fuel Oil
Cold & Very Cold	Multifamily with 2 - 4 Units	38%	57%				5%
	Multifamily with 5+ Units (1 - 3 Stories)	33%	62%		5%		
	Multifamily with 5+ Units (4+ Stories)	43%	57%				
Hot-Dry & Mixed-Dry	Multifamily with 2 - 4 Units	64%	32%	4%	0%	0%	
	Multifamily with 5+ Units (1 - 3 Stories)	48%	46%	5%	0%	0%	0%
	Multifamily with 5+ Units (4+ Stories)	46%	47%	7%	0%	0%	
Marine	Multifamily with 2 - 4 Units	66%	31%	2%	0%	0%	0%
	Multifamily with 5+ Units (1 - 3 Stories)	46%	49%	4%	0%	0%	
	Multifamily with 5+ Units (4+ Stories)	42%	52%	4%	1%	1%	

Source: NREL ResStock

Table 4: Distribution of Heating Systems in Multifamily Buildings in California

RECS Building Type (with height)	Vintage Bin	Natural Gas				Electricity				None
		Natural Gas Fuel Boiler	Natural Gas Fuel Furnace	Natural Gas Fuel Wall/Floor Furnace	Natural Gas Shared Heating	Electricity ASHP	Electricity Baseboard	Electricity Electric Furnace	Electricity Shared Heating	None
Multifamily with 2 - 4 Units	< 1940	10%	30%	11%	24%	0%	10%	5%	6%	4%
	1940-79	6%	34%	6%	18%	3%	9%	12%	7%	4%
	> 1980	3%	50%	3%	5%	5%	8%	18%	5%	2%
Multifamily with 5+ Units (1 - 3 Stories)	< 1940	4%	16%	3%	35%	3%	5%	4%	20%	10%
	1940-79	4%	23%	4%	18%	4%	12%	14%	15%	6%
	> 1980	2%	33%	2%	9%	8%	9%	23%	9%	4%
Multifamily with 5+ Units (4+ Stories)	< 1940	4%	16%	2%	33%	1%	7%	4%	23%	10%
	1940-79	6%	20%	5%	19%	3%	10%	11%	18%	7%
	> 1980	1%	32%	1%	5%	10%	10%	28%	9%	4%

Source: NREL ResStock

Gaps in Multifamily Building Market Data

SPECIFICITY OF EQUIPMENT

One gap identified in the characterization of multifamily buildings is the specific type of heating and cooling equipment reported on. The literature reviewed containing baseline information on HVAC systems collated system type at a high level for ease of reporting. NREL ResStock (2022.1 release), 2019 California RASS, and the 2021 California Potential and Goals Study did not provide more specificity on the equipment definitions (Guidehouse 2021).[9] For example, for the saturation of cooling equipment in the multifamily sector depicted in Figure 3, room air conditioning (RAC) was listed as a cooling equipment type, but additional specificity (e.g. window air conditioners, PTACs, and other types of portable air conditioners) was not provided. This becomes important to know as, with the different configurations of in-unit heat pumps evaluated in this study, the installation scenario is very dependent on the type of room air conditioner present on-site. Without the distinct breakdown of room air conditioner type, a clear gap in market data exists.

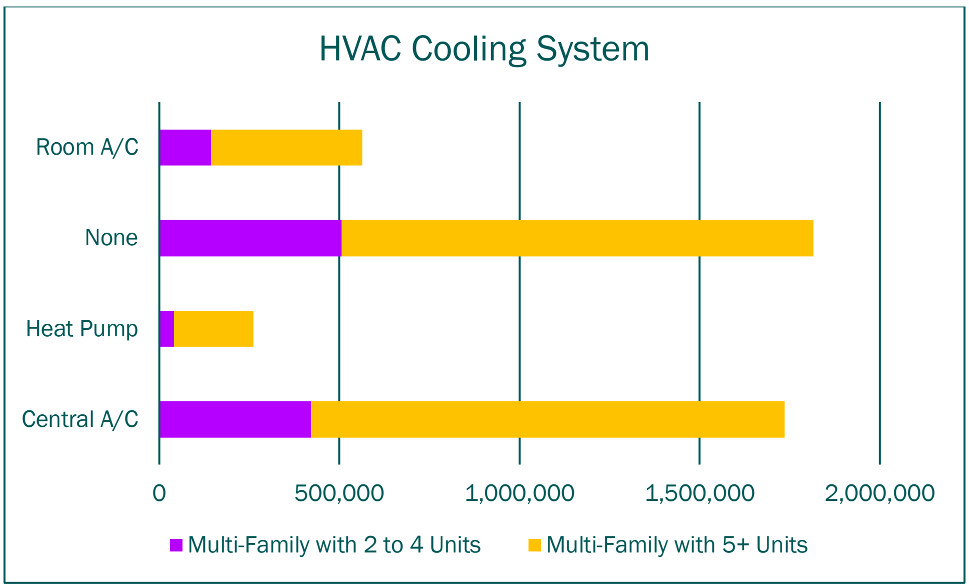

Figure 4: HVAC cooling type in multifamily buildings in California by number of units

Source: NREL ResStock[10]

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[9] Potential study conducted statewide for California IOUs. The 2021 iteration is the most recently available, as the 2023 version is currently under development with publication scheduled in Q2 of 2023. The Potentials and Goals Study provides an iterative categorization of the existing baseline and leveraged RASS literature for the multifamily sector.

[10] Note that the California RASS estimated that 20 to 21 percent of multifamily buildings in California have room air conditioners. This is a wide separation from the estimates gathered from NREL ResStock data, detailed in Figure 4.

In 2008, the US DOE issued a final rulemaking establishing a more stringent federal standard and test procedure for the PTAC and PTHP market.[11] In 2012, the national market for PTACs and PTHPs was estimated to be approximately 450,000 units installed in that year, 70 percent of which were hypothesized to be for the accommodations market (i.e. hotel, motel, etc.) (Jiang, et al. 2009).

Leveraging a similar split in room air conditioners (RACs) as derived from a PTHP market study in New York, the project team is estimating that there are approximately 97,500 units in the multifamily market in California that use a PTAC.[12]

AFFORDABLE VS. MARKET RATE TRENDS

Another gap identified in the key characteristics of market data for multifamily buildings is how the HVAC system type applies to low-income households and how that might differ from market rate units. NREL ResStock allows users to manipulate their dataset, filtering for income levels, poverty rates, housing stock, and HVAC equipment type, among many other options. When filtering the data set for reporting income-per-households, the project team saw very little differentiation in HVAC equipment splits. They remained relatively consistent with reports on the market as a whole. However, when the inverse was applied, filtering for the highest income earners (households earning over $200,000), the saturation of units without cooling equipment jumped from the average of 41.5 percent to 53 percent. These findings appear to be antithetical to the traditional understanding of cooling equipment penetration in high-earning households and recommend further research of equipment saturation in the low-income community. CalNEXT Project #ET22SWE0033 is currently underway and focused on developing data gaps within low-income multifamily buildings which would help inform equipment saturation.

Financial Characteristics of Multifamily Building Stock Owners and Renters

Leveraging U.S. Census data, the project team built on the mechanical characteristics of the multifamily market and layered it with financial characteristics. While looking at the tenure of multifamily units, it identified that approximately 90 percent of the market is made up of renters (NREL n.d.).

This introduces the challenge of the split incentive barrier associated with the costs and benefits when considering incentivizing energy efficiency upgrades. The idea is that potential improvements, such as energy-saving improvements, may not benefit the party investing in them, thus compromising or impairing investment decisions.

Tenure is a key consideration for energy efficiency program barriers as it impacts customer decision making and purchasing habits; targeted marketing and outreach for the program; and other financial considerations and impacts. As shown in Figure 5, most of those in owner-occupied units report earning over $100,000 in annual household income. However, 42 percent of renter households

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[11] Department of Energy (DOE), Energy Conservation Program: Energy Conservation Standards for Packaged Terminal Heat Pump Air Conditioners and Packaged Terminal Heat Pumps (Final Rule) 10 CFR Part 431. See DOE's discussion regarding shipment projections for standard and non-standard PTAC and PTHP equipment and the results of shipment projections in the PTAC and PTHP energy conservation standard technical support document at: Docket Number EERE-2012-BT-STD-0029).

[12] The market study estimated that PTACs represented 17.3 percent of all existing in-unit room air conditioners. Additionally, 63% were estimated to be window air conditioners and 19.7 percent through-the-wall air conditioners.

report earning less than $50,000, potentially making them eligible for income-based utility programs.

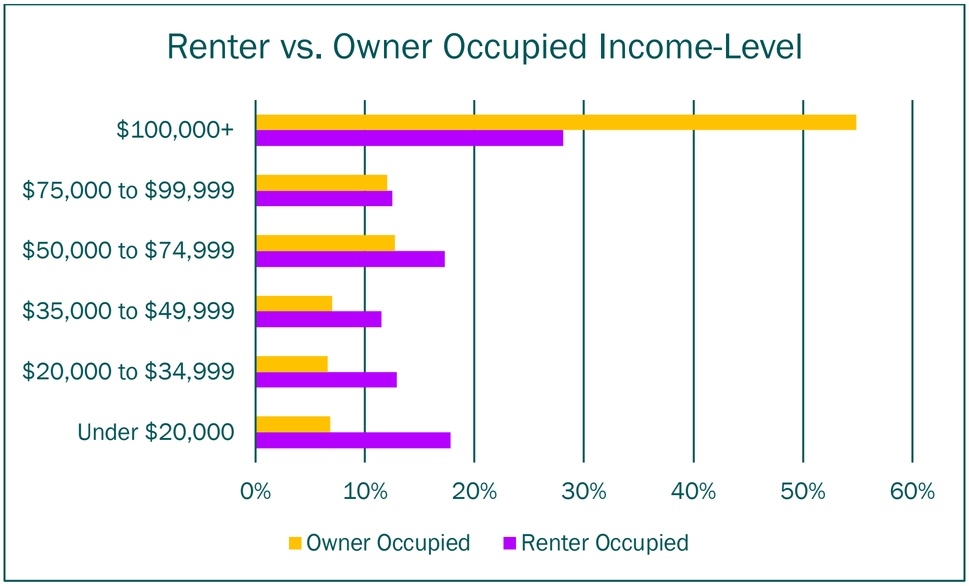

Figure 5: Income-level for multifamily units in California by tenure

Source: United States Census, American Community Service, Financial Characteristics, California, 2021

Energy Cost Burden for Multifamily Residents in California

As part of the literature review the project team attempted to quantify the energy cost burden for multifamily units in California. This is identified as another gap in the key market characterization. Four studies were reviewed that provided critical information on the multifamily market, but fell short of quantifying the energy cost burden, also highlighting the need for further research. These were:

- Accelerating Electrification of California's Multifamily Buildings, Association for Energy Affordability, May 2021
- Cultural Factors in Energy Use Patterns of Multifamily Tenants, Energy Research and Development Division, California Energy Commission, February 2018
- Tri-County Regional Energy Network, Multi-Family Program Market Research and Analysis, Frontier Energy, September 2020
- How High Are Household Energy Burdens, An Assessment of National and Metropolitan Energy Burden across the United States, American Council for an Energy-Efficient Economy (ACEEE), September 2020

Figure 6 below highlights the allocation of household income towards monthly housing costs. This does not quantify the income allocation towards energy utilities and only covers rent, mortgage, and other monthly housing costs.

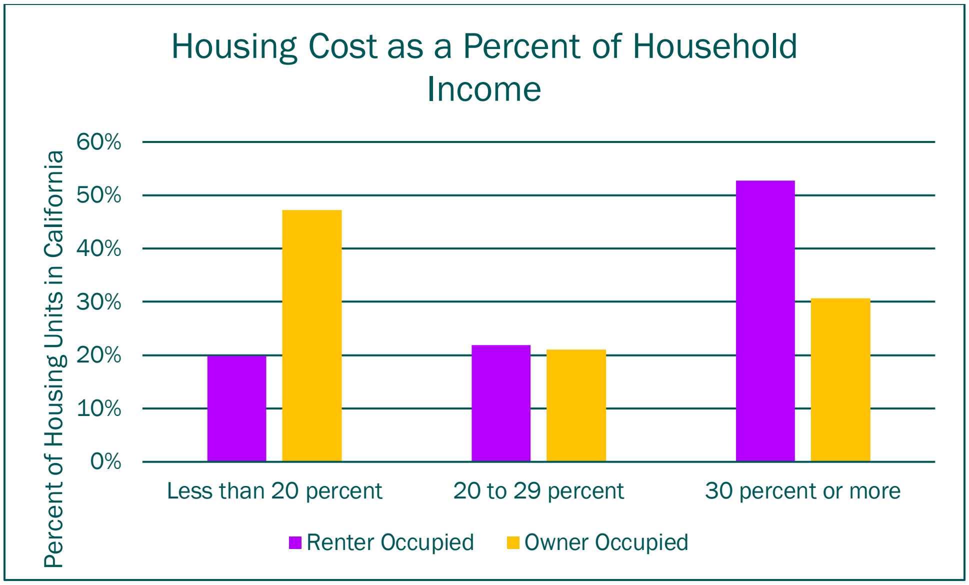

Figure 6: Monthly housing costs as a percentage of household income by tenure in California

Source: United States Census, American Community Service, Financial Characteristics, California, 2021

Energy burden is the percentage of annual household income allocated to energy and utility expenses. The energy burden experienced by households is influenced by several factors, and energy bills are not the sole driver, especially for low-income households. Other factors include income inequality, inefficient housing stock, and level of investment in energy efficiency. This has a direct impact on the key characteristics of the multifamily market, as more affordable units are often older, and in less efficient buildings with poor insulation and energy intensive HVAC systems.

The ACEEE study referenced above estimated the median energy burden for the Pacific region (Washington, Oregon, and California) at 2.3 percent (and 6.8 percent for low-income households). The study estimated that approximately nine percent of households in the Pacific region experience severe energy burdens, defined as an energy burden of over 10 percent. The median annual energy expenditure for the Pacific region is estimated to be $1,680.

Energy burdens are positively correlated with building vintage. At the national level, for buildings built before 1980, the median energy burden is 3.4 percent, compared to 2.8 percent for buildings built after 1980.

Low-income households are disproportionately affected by energy burdens compared to market-rate households. At the national level, 47 percent of low-income multifamily households in buildings with five or more units experience high energy costs burden, defined as energy burden over six percent, compared to only 22 percent for the same building types in the overall multifamily market.

Existing Building Electrical Infrastructure

Table 5 describes general amperage ratings based on building vintage for multifamily buildings. Generally, there has been a planned modernization of building stock over the years, with recent new construction buildings having increased electric capacity to account for more stringent electrical code requirements and increase in the number of electrical appliances in buildings.

Table 5: Electrical Infrastructure Serving Individual Residential Units by Multifamily Building Vintage

Infrastructure Type	Building Vintage and Capacity per Unit			
	Pre-1950	1950 – 1974	1974 – 2010	2010 – present
Whole-Building Infrastructure (overall service size)	10 – 20 A per unit	15 – 45 A per unit	20 – 70 A per unit	25 – 70 A per unit
In-Unit Infrastructure	30 – 40 A	30 – 60 A	60 – 90 A	100 – 150 A
Appliances and End Uses (branch/circuit) Infrastructure	Two 15 A circuits	Two to six 15 A circuits and one to two double-pole 20 – 30 A circuits	Five to seven 15 – 20 A circuits and one to three double-pole 20 – 50 A circuits	Six to eight 15 – 20 A circuits and three to four double-pole 20 – 50 A circuits

Source: Accelerating Electrification of California's Multifamily Buildings, Association for Energy Affordability, May 2021

Newer buildings are well-poised for strategic electrification projects, requiring little electrification infrastructure improvements. However, buildings constructed prior to 1950 have existing electrical infrastructure that may be insufficient to support in-unit heat pumps (AEA 2021). Buildings where owners are planning electrical modernization are ideal candidates for fuel-switching and other energy efficiency upgrades.

The current electrical infrastructure is another key gap in the characterization of the multifamily market in California. For the 208/240 V in-unit heat pump models, it is unclear how many potential installation locations would require electrical infrastructure upgrades. For units with through-the-wall or PTACs, no capacity and infrastructure improvements are necessary as both systems likely utilize 240V, 15–30 A breakers. However, for units that only employ window air conditioners, or have no cooling, upgrades will be necessary. The estimated cost for installing a 1-40 and 1-100 A, two pole circuit breaker, is $1,050 (CPUC 2021).[13]

Estimate of California Market Potential

There are some technical considerations that must be addressed when implementing in-unit heat pumps. For example, a building's electrical infrastructure may need to be upgraded to support the increased energy demand. More importantly, existing HVAC systems will dictate appropriate replacement scenarios. Units already employing heat pumps are unlikely to install this measure. Additionally, buildings with central systems are unlikely candidates.

[13] Estimated cost includes labor and material costs associated with electrical infrastructure upgrades and does not cover any other measure incremental costs such as installation of new equipment and removal of replaced systems.

Given the key market characteristics, the project team is estimating the total technical market potential to be approximately 717,000 units. This equates to 16.4 percent of the total multifamily market in California. This is a relatively conservative estimate as units without cooling were removed as a potential baseline option for this measure. The installation of this measure does not preclude participation for these sites; however, the energy savings impacts may be diminished as a cooling load is added to the residence. If sites with no cooling are included in the potential analysis, the total market potential jumps to 2.5 million units.[14]

Technical Evaluation

Several packaged heat pump solutions exist in the market or are currently under development that could serve as replacements for the in-unit HVAC equipment commonly found in multifamily buildings today. These packaged heat pumps are available in a variety of form factors intended for different applications and require varying levels of skill to install. Table 6 provides a summary of the product offerings from some of the main brands that surfaced in the project team's initial research for in-unit packaged heat pump equipment on the market. The table focuses on manufacturers who offer PWHPs and SPVHPs, as the market for through the wall PTHPs as PTAC replacements is already well established.[15]

Multiple manufacturers, including Gradient, Midea, Friedrich, Olimpia Splendid, and Soleus, offer PWHPs, with varying form factors and purposes. Some are primarily intended for cooling and only offer heat pump heating capabilities in moderate temperatures, often with a cutoff around 40°F, while others are built specifically for cold climates and can operate in heat pump mode in negative outdoor temperatures.

The other types of in-unit heat pumps available on the market and researched for this evaluation generally fell into two categories, ones that are intended to be surface mounted on interior walls or ceilings and ones that are intended to be recessed into walls or ceilings. Those that are intended to be surface mounted are commonly mounted on an exterior wall, with two penetrations required through the wall to connect the unit to the outdoor air, and the units typically deliver the heating and cooling directly to the space without interior ductwork. Alternatively, some models can be hung on the ceiling or on an interior wall, utilizing ductwork or 'adapters' to connect the unit to the outdoor air. The units that are intended to be recessed or hidden from view are typically located in a utility closet or space and can be affixed to an exterior wall to directly provide outdoor air or can be supplied via ductwork. Typically, these units deliver warm and cool air via ductwork, however some can also be directly vented into the space.

A sample of currently available in-unit heat pump product offerings in the U.S. is captured in Table 6.[16]

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[14] Measure baseline density is assumed to be all multifamily units with in-unit heating or cooling system, or 72 percent of the market. Efficient measure saturation is assumed to be all multifamily units utilizing heat pumps, or 5.2 percent of the market. Technical suitability accounts for sites that would not be good candidates for this measure, such as buildings that require electrical infrastructure updates, or sites that don't have adequate room for the placement of an in-unit heat pump, comprising 9.3 percent of the market.

[15] AHRI lists 900 active PTHP models available in the U.S. market, however NEEP's cold climate air ASHP list only identifies 3 models that meet the ccASHP specifications.

[16] This list is intended for illustrative purposes and does not indicate preference or comprehensiveness of all potential manufacturers.

Table 6: Summary of Product Offerings

Brand	Summary of Product Offerings
Gradient	Gradient offers their flagship PWHP saddle unit, which can heat and cool in moderate climates and utilizes R-32 refrigerant. They also have developed a cold climate version of the saddle unit for the New York Clean Heat for All challenge, which requires heat pump operation down to 0°F.
Midea	Midea offers a PWHP with a traditional in-window, box form factor, as well as a portable ('wheelie') unit with a unique hose-in-hose design for balanced air circulation. Both are intended for moderate climates with the heat pumps operating down to 41°F and utilizes R-32 refrigerant. Midea has also developed a cold climate PWHP with a saddle form factor for the New York Clean Heat for All challenge, which requires heat pump operation down to 0°F.
Friedrich	Friedrich offers four PWHP units in their Kuhl series which have a traditional in-window box form factor. They are intended for moderate climates and the heat pumps will not operate below 40°F. Friedrich also offers a dual-hose portable ('wheelie') unit in their ZoneAir series, which will provide heating down to 14°F.
Epocha	Epocha's AIO series of packaged heat pumps offer a variety of surface-mounted and recessed configurations for in-unit heating and cooling. Their units also allow for an optional Energy Recovery Ventilator component if fresh air delivery through the unit is also desired. Epocha's Wall Mounted, Wall Mounted Pro, and Ceiling Suspended units require two round penetrations through the exterior wall upon which they are mounted and provide heating and cooling directly to the space. Epocha has also partnered with Thermaduct to offer duct adaptors so that their Wall Mounted Pro can be installed in a variety of configurations and take advantage of existing facade penetrations. For example, they offer Window adaptors that allow the unit to vent through a portion of an existing window, while the rest of the window remains operable. Their Ceiling Ducted and Vertical Stack units are recessed in a utility closet or chase and deliver heating and cooling to the room via ductwork. The capacities and efficiencies vary between the units but they all have reported heating capacities down to 5°F.
Ice Air	Ice Air offers two types of in-unit packaged heat pumps. Their RSXC series is a wall mounted unit that requires two penetrations through the exterior wall and delivers heating and cooling directly to the space. These units have reported capacities down to -5°F. Ice Air also offers a vertical stack packaged heat pump that is hidden in a utility closet or chase and delivers heating and cooling to the space via ductwork. Their 8SPXC12 and 8SPXC24 units have reported heating capacities down to -5°F, while their 8SPHP series provides heat pump heating down to 38°F.
Olimpia Splendid	Olimpia Splendid offers two units in their Maestro series that are wall mounted packaged heat pumps. They require two penetrations through the exterior wall and provide heating and cooling directly to the space. They also have a Dolceclima product that is a PWHP portable ('wheelie') unit with a single-hose configuration. The minimum operating temperature in heating mode is 5°F for all of their units.
Soleus Air	Soleus Air offers three different models of PWHP portable ('wheelie') units, all with single-hose configurations. Their PSH-08-HP-01 and PSH-09-HP-01 units have a minimum outdoor operating temperature of 61°F and their FEA-12-HP unit has a minimum outdoor operating temperature of 55°F.

Source: Project Team

Several models include low-GWP refrigerant alternatives (e.g., R-32) reflecting broader HVAC transitions away from high GWP refrigerants (e.g., R410-a) due to the risk of leakage of refrigerants. Commonly, refrigerants used in heat pumps have a GWP more than 2000 times as potent as natural refrigerants like CO2; one of the most prevalent ones, R410-a, has a GWP of 2,087. Evidence suggests that refrigerants leak into the atmosphere from these systems, contributing to GHG emissions (Butrymowicz, et al. 2018). PWHPs are currently available in both R410-a and R32 models.

Specifications, Standards and Test Procedures

HVAC equipment falls under a variety of national performance standards, test procedures, and industry-standard specifications. Federal standards and test procedures are established by the US DOE and differ by equipment type. Manufacturers work with third-party certification bodies to certify equipment; standard performance is met according to associated test procedures. Manufacturers can elect to test and certify equipment to voluntary performance specifications used by state and utility energy efficiency programs. These voluntary specifications include ENERGY STAR®, CEE, as well as other regional specifications, notably the NEEP cold climate ASHP specification. Voluntary specifications serve to establish higher efficiency or identify additional testing, performance metrics or targets for manufacturers. Typically, manufacturers submit performance data or self-certify to meet the voluntary specifications through either in-house or third-party testing.

Heat pumps are tested according to US DOE standards to determine Heating Seasonal Performance Factor (HSPF), Energy Efficiency Ratio (EER), Seasonal Energy Efficiency Ratio (SEER), as well as Coefficient of Performance (COP) and heating and cooling capacity at several outdoor air temperatures. Specifically, the US DOE's test procedures for ductless, centrally ducted, and packaged heat pumps are described in Appendix M1 of the Code of Federal Regulations, Part 430, which outlines the uniform methods for measuring the energy efficiency of heating and cooling equipment. This is commonly referred to as Appendix M1. It is standard to publish COPs at 47°F, 17°F, and, for cold-climate models, 5°F outdoor air temperature.

Standards and Specification Gaps

While in-unit heat pumps for multifamily housing are a rapidly developing product category, existing federal test procedures or standards, as well as higher voluntary specifications including ENERGY STAR, CEE and NEEP's specification for cold climate ASHPs, are limited in their ability to properly capture the operation and performance of these products. Table 7 below shows a comparison of the existing federal standards and voluntary specification categorizations for heat pump equipment:

Table 7: Federal Regulations, Standards, Industry Listings

Equipment Type	Regulations, Standards, Industry Listings				
	Applicable Federal Regulation	Performance Metrics	AHRI Testing Standard	CEE Listing	NEEP Listing
Window AC/HP	10 CFR §430 Subpart B Appendix F	Combined Energy Efficiency Ratio (CEER), Capacity	N/A	No	No
SPVAC/SPVHP	10 CFR §431.96 Appendix G/G1	EER, COP, IEER[17], Capacity	AHRI 390	Yes	Yes
PTAC/PTHP	10 CFR §431.96 Paragraph (g)[18]	EER, COP, Capacity	AHRI 310/380	Yes	Yes

Source: Project Team

PWHP models available in the market are currently tested as reverse cycle-enabled window-unit room air conditioners. They receive a unique cooling performance metric, CEER, which accounts for efficiency at multiple temperature points and cooling loads. Based on the packaged nature of the units, they cannot be tested as mini-split heat pumps. It can be challenging to test them according to the central AC and heat pump standards of Appendix M1, as these units are typically not designed for ducted distribution; when ductwork is added to test units under Appendix M1 and central heat pumps, the performance of the air handlers in the units diminishes considerably (Epocha 2023). More often, PWHPs are tested under Appendix F of the Code of Federal Regulations (CFR), Part 430, which applies to room air conditioners. (EPA 2015).

PTHPs can be tested according to typical PTAC procedures and standards, AHRI 310-380. This is a unique standard, however, applying only to wall-sleeve mounted units. Only units built with a PTAC form-factor are tested under this US DOE equipment classification (CSA Group and AHRI 2017).

Testing methods for SVPHPs under AHRI 390 are largely like those used for PTHPs. Both unit types are defined as factory-assembled packaged equipment. Testing methods and performance outputs under the AHRI standards are similar. However, AHRI distinguishes between the unit types based on

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17 Beginning on December 4th, 2023, voluntary representations of IEER for SPVAC/SPVHP units must be tested in accordance with Appendix G1. (Department of Energy 2022)

18 On May 12th, 2023, the DOE proposed an amendment to the test procedures for PTAC/PTHP units that would relocate the existing test procedures from Paragraph (g) to a new appendix H to subpart F of part 431. They also proposed to establish a new appendix H1, that would include PTAC/PTHP testing procedure requirements for new seasonal efficiency metrics, namely seasonal cooling performance (SCP) and seasonal heating performance (SHP), as well as a new dehumidification efficiency (DE) metric. This would better align the appendix structure to that of the requirements for SVPAC/SVPHP units and would establish test procedure requirements if the DOE adopts standards for SCP, SHP, and DE metrics in the future. (Department of Energy 2023)

the difference in form factor. Specifically, AHRI notes that a SVPHP "is intended for exterior mounting on, adjacent interior to, or through, an outside wall" rather than in a wall sleeve (AHRI 2021).

In conversations with stakeholders, they shared that nascent efforts are underway to advocate for an assessment and modifications to existing federal standards and test procedures through US DOE, AHRI and AHAM to better accommodate new in-unit heat pump models. CEE and ENERGY STAR are evaluating options for updates to their respective voluntary specifications for window and packaged heat pumps and options for adopting interim modified test procedures. Establishing new voluntary specifications would likely involve manufacturers' voluntary submittal of performance ratings (e.g. HSPF2 and SEER2) based upon agreed upon modified test procedures. Reporting of performance values on these new in-unit heat pump models would allow them to be equitably compared to other heat pump solutions and included in more local and state efficiency rebate programs. Moreover, questions remain regarding the federal tax credits and rebates for heat pumps emerging from the Inflation Reduction Act (IRA); many in-unit heat pumps do not seem to qualify for these credits and rebates as they are currently categorized and rated based on existing federal standards and test procedures. To establish the minimum performance requirements for the equipment available for incentives, the IRA adopts CEE's performance standards. Specifically:

> "Electric or natural gas heat pumps, electric or natural gas heat pump water heaters, central air conditioners, natural gas or propane or oil water heaters, natural gas or propane or oil furnaces or hot water boilers: must meet or exceed the highest efficiency tier (not including any advanced tier) established by [CEE] that is in effect as of the beginning of the year in which the property is placed in service." (IRS 2022)

CEE performance standards include specifications for split ducted heat pumps, ductless heat pumps, and PTHPs. Standards vary by region to account for climate differences. Table 8 references minimum requirements for the region that includes California.

Within California, the IOUs and various local, regional, and statewide programs provide incentives to support heat pump adoption. Incentive programs are delivered through a combination of midstream rebates offered at the point of sale, as well as downstream rebates to contractors and homeowners with an emphasis on split and packaged heat pump systems.

While several HVAC equipment types are eligible to receive the Comfortably CA midstream rebates, support for residential or individual unit heat pump installations in multifamily applications is limited to split systems (Comfortably CA 2023). The equipment must be listed on AHRI's Heat Pumps and Heat Pump Coils list; meet minimum performance requirements as described in the program's QPL; and must replace an existing gas furnace and a central AC unit. Currently heat pumps may be certified to meet either SEER/HSPF or SEER2/HSPF2 requirements, however the SEER2 requirements are included for comparison to other national and regional specifications.

Table 8 : Comfortably CA Requirements for Midstream Incentives

Performance Tier	Comfortably CA - Heat Pump Performance Requirements (SEER2)	
	SEER2	HSPF2
Tier 1	≥ 15.2	≥ 7.7
Tier 2	≥ 16	≥ 8.0
Tier 3	≥ 16.9	≥ 8.1
Tier 4	≥ 17.8	≥ 8.1

TECH Clean California provides multifamily incentives for heat pumps at a statewide level, emphasizing market transformation and heat pump adoption over specific savings targets. Consequently, equipment requirements are considerably less stringent than those established by Comfortably CA. Equipment must replace a non-heat pump system and must meet the relevant AHRI testing standard, as well as Title 24 code minimum standards. Whereas Comfortably CA only offers incentives for split systems, TECH Clean California also provides rebates for PTHPs, SPVHPs, and other unitary heat pump products. Although the program supports packaged units, it does not currently include PWHP-style units. Additionally, it is not designed for direct-to-consumer rebates, which reduces the potential impact for self-installation of PWHPs in multifamily buildings.

Table 9: CEE Requirements for IRA Incentives

Equipment Type	CEE Requirements for IRA Incentives – Southern Region (2023)		
	SEER2	EER2	HSPF2
Ducted ASHP	≥ 15.2	≥ 11.7	≥ 7.8
Ductless ASHP	≥ 16.0	≥ 12.0	≥ 9.0
Packaged ASHP (PTHP)	≥ 15.2	≥ 10.6	≥ 7.2

Source: Project Team

In the Northeast, NEEP establishes performance standards with a special emphasis on cold climate heat pumps (ccASHPs). NEEP identifies that a typical HSPF rating does not adequately account for heating performance at low temperatures and seeks to establish a database of heat pumps that are best suited for efficient heating in cold climates. NEEP requires that ccASHPs are tested to the AHRI standards and federal regulations listed in Table 10 below. Many energy efficiency programs throughout the Northeast leverage the NEEP ccASHP list when setting requirements for rebates programs.

Table 10: NEEP ccASHP Performance Requirements

Equipment Type	NEEP ccASHP List Performance Requirements (Version 4.0)		
	SEER2	HSPF2	COP at 5°F
Ducted ASHP	≥ 14.3	≥ 7.7	≥ 1.75
Ductless ASHP	≥ 15.0	≥ 8.5	≥ 1.75
PTHP and SPVHP	N/A	N/A	≥ 7.2

Source: Project Team

NEEP requests that manufacturers submit data on capacity and COP at outdoor air temperatures of 47°F, 17°F, and 5°F. Additional NEEP requirements include the use of a variable capacity compressor.

The CEE and NEEP standards provide minimum requirements for ducted and ductless heat pumps, and PTHPs. However, NEEP includes the additional product category and a minimum performance requirement for SPVHPs. For the New York solicitation, NYCHA established minimum performance targets specifically for PWHPs, shown in Table 11 below. Because PWHPs are difficult to test according to typical federal testing standards—namely, M1—the unique NYCHA standard focuses on COP and unit capacity at a variety of outdoor air temperature targets, rather than EER2, SEER2, and HSPF2. However, manufacturers have initiated testing using a modified version of the new M1 test procedure to better align with and compare to other heat pump and conventional heating and cooling products.

Table 11: NYCHA Solicitation Minimum Performance Requirements

Equipment Type	NYCHA PWHP Performance Requirements		
	Capacity at 17°F	COP at 17°F	Notes
PWHP	≥ 8,300 Btu/hr	≥ 1.85	Must operate at 0°F without electric resistance backup

Source: Project Team

In addition to these performance requirements, NYCHA imposes physical requirements that address form factor, method for dealing with condensate, installation time and complexity, indoor sound level, controls, and remote connectivity, as well as air leakage through the window opening. These requirements reflect NYCHA's goal to deploy these units in multifamily units typical of New York City.

As noted for the NYCHA PWHPs, similar challenges arise when testing other in-unit heat pumps for seasonal and operational performance (e.g., HSPF2, SEER2, and EER2), complicating head-to-head performance comparisons. Manufacturers may opt to seek waivers from DOE to either modify existing requirements in test procedures and/or test under a category that does not match the retrofit opportunity of their equipment if a different testing standard is more likely to provide higher performance outcomes. AHAM is considering modifications to their existing RAC-1 test procedure to test PWHPs that are categorized as window unit air conditioners; in addition, testing methods and performance metrics for RACs do not align with the current heat pump standards and voluntary specifications listed above.

Modeling and Savings

To estimate potential savings for in-unit heat pumps in California multifamily buildings, multiple scenarios of existing space conditioning systems, climate zones and building characteristics were modeled utilizing BEopt and the OpenStudio Parametric Analysis Tool (PAT), building energy optimization tools developed and supported by NREL.

In Phase I, the project team developed two baseline models for an 840ft^2 middle unit in a low-rise multifamily building with characteristics of a 1970s-era build in Los Angeles, California for both natural gas and electric heating systems. The characteristics of a prototype low-rise multifamily building, the most common multifamily unit type in California, were extracted from ResStock metadata. Two fuel sources were considered for heating in the baseline to represent common types of HVAC systems in the current market. A natural gas furnace with 80 percent AFUE and an electric furnace with 100 percent AFUE were considered in the two baseline models. For the proposed measure, two market-ready heat pumps with published documentation were tested in the energy model: 1) a SPVHP, 10.3 HSPF 18 SEER. and 2) a mini-split heat pump (32.2 SEER2 and 11.9 HSPF2). Phase I modeling of the SPVHP unit was based on published data for an older model while the project team worked with the manufacture to get performance data for the new model included in Phase II.

The two heat pumps were selected to compare the performance of an in-unit heat pump unit against a mini-split unit. The mini-split represents the current mainstream replacement option in a typical heat pump retrofit scenario. The model demonstrates the performance of the two heat pump options vis-a-vis the selected baselines as well as the direct performance differences between the in-unit heat pump and the mini-split. This three-way comparison explores the in-unit heat pump as an alternative to mini-splits in a retrofit scenario.

Results show that retrofitting with in-unit heat pumps can save between 11 percent and 23 percent of total energy use. A summary of simulated results for predicted energy use, utility costs, and indirect CO2e emissions is presented in Table 12 below. Heating energy use was reduced remarkably with either of the two heat humps in comparison to the baselines (between 79 percent and 89 percent). For cooling energy use, savings vary between 13 percent and 53 percent depending upon which HVAC system improvement is applied. Overall, HVAC system improvement reduced HVAC energy use by 34 percent and 64 percent, respectively, in the model with the SPVHP and mini-split (Table 13).

Table 12: Simulated Results for Predicted Total Annual Energy Use, Annual Utility Costs, and Annual Indirect CO2e Emissions

Criteria	Scenarios for HVAC System			
	Baseline with Natural Gas Furnace	Baseline with Electric Furnace	Mini-Split	SPVHP
Total Energy Use (MBtu)	36.9	36.0	28.4	32.1
Utility Cost (USD)	$1,589	$1,752	$1,285	$1,514
CO_2e Emissions (lb)	5,519	5,409	4,244	4,816

Source: Project Team

Table 13: Simulated Results for Predicted HVAC System Annual Energy Use by Fuel and End Uses

Energy Use Category		Scenarios for HVAC System			
		Baseline with Natural Gas Furnace	Baseline with Electric Furnace	Mini-Split	SPVHP
Fuel Use (MBtu)	Electricity	8.8	12.2	4.5	8.3
	Natural Gas	4.3	-	-	-
End Use (MBtu)	Heating	4.4	3.5	0.5	0.7
	Cooling	8.7	8.7	4.1	7.6
Total HVAC Energy Use (MBtu)		**13.1**	**12.2**	**4.5**	**8.3**

Source: Project Team

In Phase II, energy modeling of the baseline and improved scenarios was expanded to include additional climate zones, unit sizes, and location within the building (top, bottom, middle units). Additionally, the baseline heating system assumptions were modified to reflect a wall hung furnace with an efficiency of 67 AFUE to align with the California electronic Technical Reference Manual (eTRM) measure characterization for Ductless HVAC, Residential, Fuel Substitution (Version SWHV050-02, July 22, 2021). The baseline cooling efficiency was also modified to align with the California eTRM. Three cooling baselines were modeled: no cooling, 9.8 EER, and 11 EER. The two cooling baseline efficiencies reflect the Ductless Heat Pump, Residential (SWHC044-02, July 21, 2021) and Ductless HVAC, Residential, Fuel Substitution measure characterizations, respectively. The improved scenario is based on the manufacturer reported performance of an in-unit heat pump (11.67 EER and 3.39 COP) and modeled as a Packaged Terminal Heat Hump (PTHP). Table 14 summarizes the variables modeled. Ultimately, 288 models for baseline and 48 models for improved scenarios were generated in PAT.

Table 14: Summary of Variables for Baseline and Improved Scenarios.

	Variable 1	Variable 2	Variable 3	Variable 4
Baseline and Improved				
CEC Climate Zone/Location	10/Riverside	4/San Francisco	12/South Lake Tahoe	11/Truckee Tahoe
Unit Size (sf)	333	617	853	1138
Unit Location	Top	Middle	Bottom	-
Baseline				
Cooling	None	9.8 EER	11 EER	-
Heating	Electric resistance, no ducts, 100% efficiency	Wall furnace, 67 AFUE	-	-
Improved				
Cooling	PTHP 11.67 EER	-	-	-
Heating	PTHP 3.37 COP	-	-	-

Building energy consumption, utility cost, and CO2e emissions were compared in the scenarios with in-unit heat pump to that of typical baseline scenarios in the market—natural gas furnaces and electric resistance furnaces, with and without room air-conditioners. In-unit heat pumps typically lowered energy usage and CO2e emissions vis-à-vis baseline scenarios; however, due to the low cost of liquid natural gas, utility costs remained lower in many of baseline scenarios with natural gas appliances.

Results show that retrofitting with in-unit heat pumps can save up to 35 percent of total energy use depending upon the baseline HVAC system type and efficiency. Table 15 reflects the average energy consumption, utility costs, and emissions across all climate zones, unit sizes, and unit locations. The improved scenario shows higher total utility costs than the gas heat baseline. This is due to the lower utility cost rate of natural gas (~6 times lower than electricity rate). Table 16 shows the utility cost rates and emissions factors assumptions used for utility costs estimations. These assumptions were extracted from BEopt v3.0.1 and reflect simple state average utility rates based on the most recently available EIA data. Emissions factors for electricity reflect Cambium data per ANSI/RESNET 301 (e.g., long-run marginal, Low RE Cost scenario, etc.), averaged across all GEA regions, and for gas eGRID data per ANSI/RESNET 301 (e.g., combustion plus pre-combustion).

Table 15: Average Predicted Annual Energy Consumption, Annual Utility Costs, and Annual Indirect CO2e Emissions Across All Climate Cones, Unit Sizes, and Unit Locations.

	Baseline						Improved
	Gas Heat (67 AFUE)			Electric Heat (100% Eff)			
	With Cooling		No Cooling	With Cooling		No Cooling	
	9.8 EER	11 EER		9.8 EER	11 EER		
Total Energy Consumption (Mbtu)	60.0	59.4	49.5	50.1	49.5	41.1	38.7
% energy savings	35%	35%	22%	23%	22%	6%	
Utility Cost ($)	1,825	1,785	1,388	2,759	2,719	2,182	1,998
% cost savings	-10%	-12%	-44%	28%	27%	8%	
Emissions (lb CO2e)	8,895	8,804	7,325	7,534	7,443	6,169	5,807
% emissions savings	35%	34%	21%	23%	22%	6%	
Heating (Mbtu)	29.9	29.9	25.4	20.1	20.1	17.0	9.4
Cooling (Mbtu)	5.5	4.9	0.0	5.5	4.9	0.0	4.8
Electricity Consumption (kWh)	3,952	3,776	2,339	9,829	9,653	7,332	6,497
NG Consumption (MMBTU)	46.5	46.5	41.5	16.5	16.5	16.1	16.6

Table 16: Assumptions for annual utility cost rates and annual indirect CO2e emissions factors

	Electricity	Natural Gas
Utility Rates	$12/month fixed cost $0.2285/kWh	$12/month fixed cost $1.066/therm
Emissions Factors (CO2e)	518.5 lb/MWH	147.3 lb/MBtu

Baseline models with gas heat system type have higher energy savings than models with electric heat because of lower heating system efficiency. Highest energy savings (40 percent) are achieved in the models with gas heat in the colder locations in California: South Lake Tahoe and Truckee Tahoe (CEC Climate Zones 11 and 12) (Figure 7). Due to low heating demand, Riverside (CEC Climate Zone 10) that represents Los Angeles basin has the lowest energy savings in comparison to the other climate zones regardless of all other variables. However, in-unit heat pump in Riverside can save between 12 percent to 18 percent of total energy use in the units that have cooling systems depending on the heating system type, unit size, and cooling system efficiency. Negative electricity savings shown in Figure 7 are due to the fuel switch from natural gas to electricity and the addition of cooling to the models lacking a cooling system.

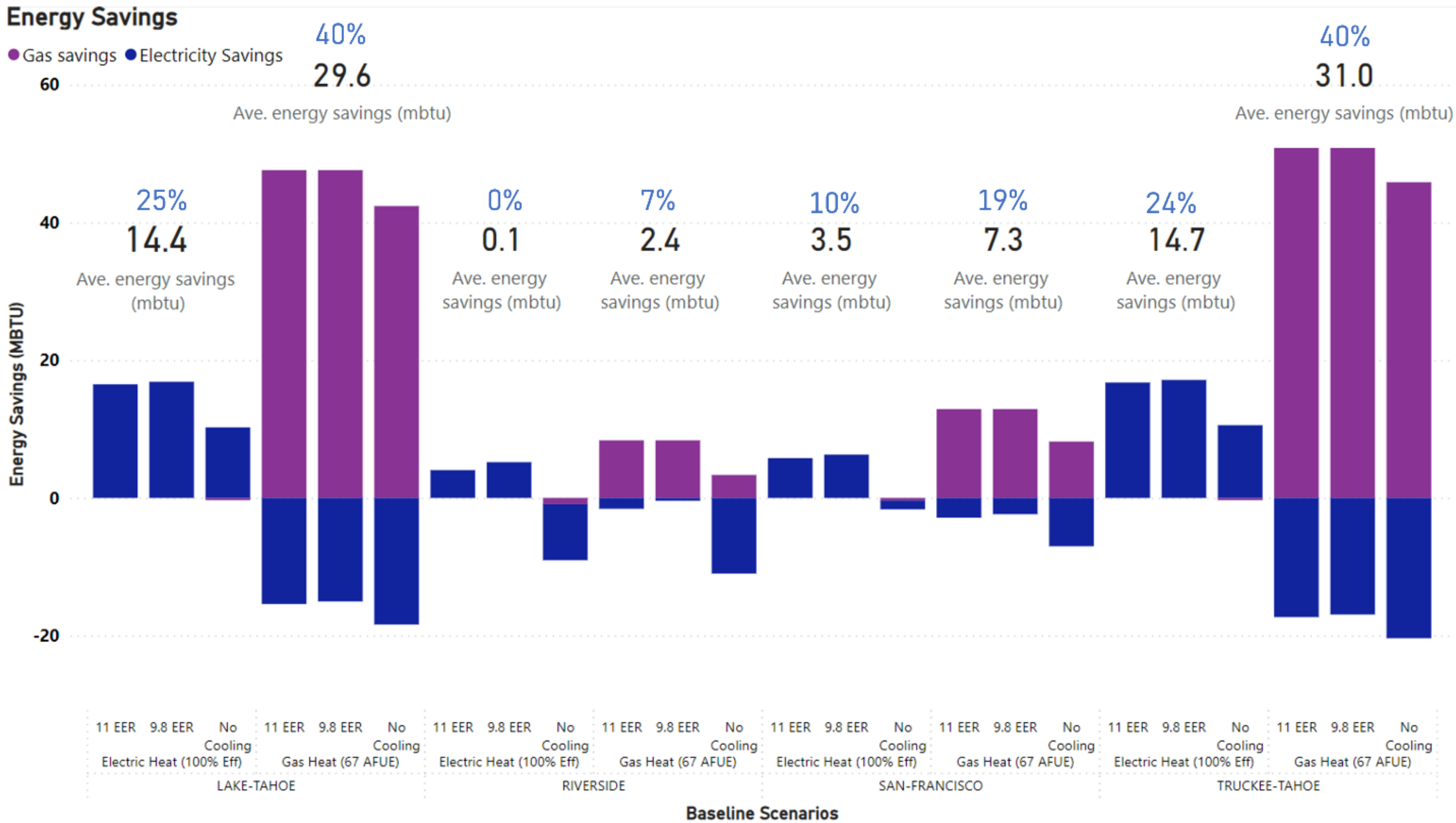

Figure 7: Average energy savings in baseline scenarios.

Regardless of location and weather conditions, utility cost savings in majority of baseline models with gas heating systems are negative (i.e., utility costs increased) because of switching to electricity which has higher price rates than natural gas (Figure 8). Models with gas heat in South Lake Tahoe and Truckee Tahoe show the highest increase in utility costs while having the highest energy savings among all baseline models. In contrast, baseline models with electric heat in South Lake Tahoe and Truckee Tahoe yield the highest utility cost savings (~30%) because of the high heating demand and using electricity as the fuel source in the baseline. Models with electric heat in Riverside and San Francisco that have cooling systems can save up to 19 percent and 25 percent of utility cost, respectively, depending upon the unit size and cooling system efficiency.

Summary Recommendations

- Utility cost savings, while positive for electric heat baseline scenarios, are negative across majority of scenarios with a gas heat baseline using simple average California utility rates. Ongoing California utility regulatory proceedings developing income-graduated fixed charges, as well as local utility natural gas, electricity and time of use (TOU) rates could significantly impact energy modeling results of cost-effectiveness and adoption of in-unit heat pumps and warrant additional research. It is recommended to further investigate specific local utility rates structures such as low income, TOU rates etc. to evaluate consumer cost impacts in fuel switching scenarios.
- Simulated results for heating and cooling end-uses demonstrate high cooling demand in LA basin (Figure 9 in Appendix B). Therefore, baseline scenarios with no cooling system in Riverside are invalid for savings assessments and such comparison undervalues the in-unit heat pump contribution. Hence, for Riverside (LA basin), although both energy consumption and utility costs increase when retrofitting to in-unit heat pump in comparison to all baseline models without cooling systems, implementing the improved scenario is recommended based on the potential energy, CO_2e emissions, and utility cost savings.

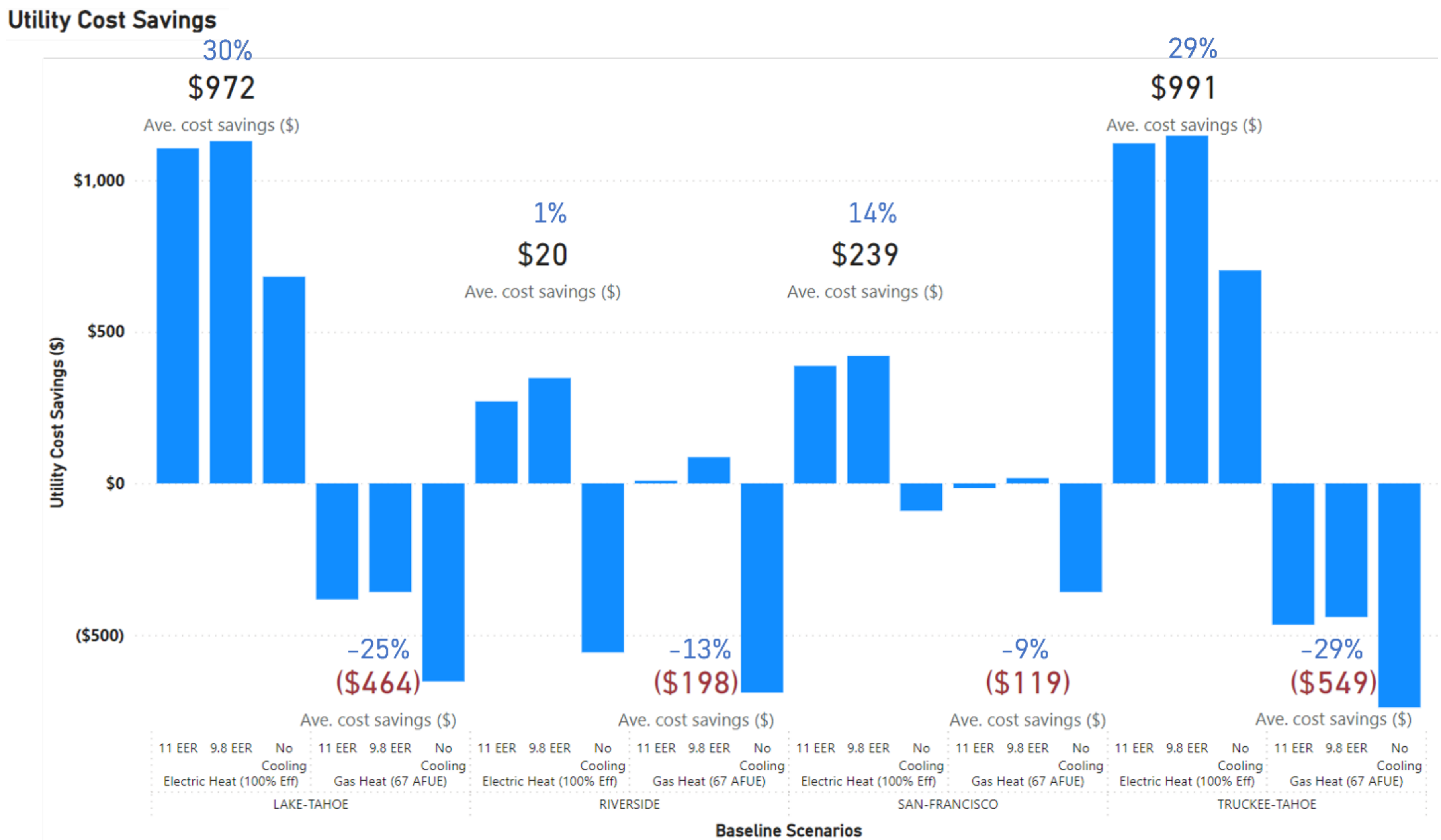

Figure 8: Average utility cost savings in baseline scenarios.

Market Barriers and Opportunities for In-Unit Heat Pumps

The findings from this study identified specific market and technical barriers and opportunities to guide future market development actions to accelerate the adoption of low GWP, in-unit heat pumps with a focus on affordable housing applications.

Table 17: Market Barriers and Opportunities

Market Barriers	Opportunities
Diverse, building-specific heat pump design needs	The wide range of age, design, and space conditioning needs in the California (and national) multifamily building stock requires a diverse set of appropriate heat pump solutions. Support for the necessary investment in new product development by manufacturers, highlighted by the recent introduction of new window and in-unit packaged heat pumps, requires increased early support by federal, state and local housing agencies, as well as federal, utility and state incentive programs.
Split incentive of costs and benefits of in-unit heat pumps	Installation of in-unit heat pumps can lead to a split incentive barrier for multifamily tenants and building owners. Evaluating, updating, and aligning existing financial instruments like UAs and ratio utility billing systems is necessary to address property owner capital investments and potential cost-shift to tenants of operational costs with the addition of in-unit heat pumps.
Lack of detailed data on installed heating and cooling equipment	Aggregating detailed data on existing heating and cooling equipment (e.g., type, capacity, etc.), important building characteristics (e.g. window orientation, equipment location, etc.) and local or building specific limitations on equipment permitting or siting is critical to guiding investment in appropriate heat pump solutions for California's market rate and affordable multifamily buildings,
Limitations on electrical capacity for heat pumps	Older (pre-1974) vintage multifamily buildings generally have a limited capacity to support electrification measures. New 120V plug-in, low load packaged window and wall-hung heat pumps should be evaluated as a potentially cost-effective alternative solution. However, more significant electrical capacity upgrades may be necessary and will require longer-term and consistent investments by utilities and building owners.
Need for consistent investment in innovation	Manufacturers and stakeholders highlighted the need for consistent and significant investment through federal tax credits and state and local utility incentives to support the development and sustained market adoption of new in-unit heat pump technologies. The recent passage of the IRA resulting federal tax credits and state funding for heat pumps was identified as a critical pathway for supporting the new in-unit heat pump technologies, but access to that funding is limited by the lack of appropriate federal standards and test procedures.

Market Barriers	Opportunities
Cost-effectiveness limited due to wide range in electric and natural gas costs	Energy cost savings, while positive for electric heat baseline scenarios, are negative across all scenarios with a gas heat baseline using simple average California utility rates. It is recommended to further evaluate consumer cost impacts in fuel switching scenarios based on potential future changes to state policies, individual utility rates and low income and TOU rate structures. Regardless of potential negative cost savings, implementing the improved scenario is recommended in high cooling demand locations, such as the LA basin, as energy and cost savings are realized for cooling in all scenarios except for no cooling baseline.

Technical Barrier	Opportunities
Limited operation, performance, and capacity in colder climates	Prior to the New York Clean Heat for All Challenge, window heat pumps were not available that could operate below approximately 40°F. The New York solicitation included requirements for operation below 0°F, minimum heating capacity of 8,300 btu/hr and 1.85 COP at 17°F and capability for managing condensate and defrost internal to the units. As expanded cold climate functionality impacts cost and performance, a better assessment of regional climate and housing space conditioning applications would help inform manufacturers product design for specific market needs.
Lack of representative test procedures	New in-unit heat pump designs, notably window and interior wall/ceiling mounted models, do not map to existing federal test procedures to accurately represent their application, use and performance. Absent a representative test procedure – and capability to compare performance to other heat pump solutions – standards and voluntary specifications will be impossible to be set by federal agencies and other regional, national, and utility-specific programs. The inability to accurately compare performance and capabilities of in-unit heat pumps will limit tenant and building owner's ability to properly identify, compare and select models that best fit their climate and specific space conditioning needs. Initial discussions between manufacturers, DOE, EPA, CEE and regional and national efficiency programs and utilities are informing potential shorter-term and longer-term strategies for establishing an appropriate test procedure. CalNEXT will be assessing existing heat pump test procedures, as well as potential modifications, to inform the development of a federal test procedure for PWHPs (CalNEXT Project, Emerging "Micro" Heat Pumps: Testing and Heating Performance Metrics #ET23SWE0034).

Technical Barrier	Opportunities
Lack of field and laboratory testing of in-unit heat pumps	As many of these in-unit heat pump models are new to the U.S. market and function differently than existing ductless or ducted split heat pumps, laboratory testing based on representative test procedures, as well as field evaluations in different regional climates and housing applications, is important to validate performance, as well as tenant or homeowner use and satisfaction. Lab and field evaluations for these new-to-market PWHP models are being conducted in the Northwest, New York and California and will be important early sources of data for utility programs, housing agencies, and federal agencies to properly develop test procedures, specifications and incentive programs to support in-unit heat pump market development.
Absence of representative federal standard and advanced specifications for in-unit heat pumps	The absence of appropriate federal standard(s) or advanced specification is directly tied to the concurrent development of a new or modified test procedure applicable to new in-unit heat pump models. In addition, existing standards for PTHPs, single vertical packaged heat pumps or room air conditioners can prescribe requirements, limitations on applicability or differences in performance metrics that prevent equitable comparison to other heat pump solutions and their respective seasonal heating and cooling performance and capacity at different outdoor air temperatures. Modifying existing or developing a new federal standard will be critical to supporting longer term development and diversity of the heat pump solutions in the market. In the shorter term, manufacturers and utility programs are advocating for an accelerated pathway for the development of advanced voluntary specifications by CEE to permit access to the new federal tax credits and forthcoming rebates established through the recent IRA legislation.

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Appendix A: HVAC Energy Use

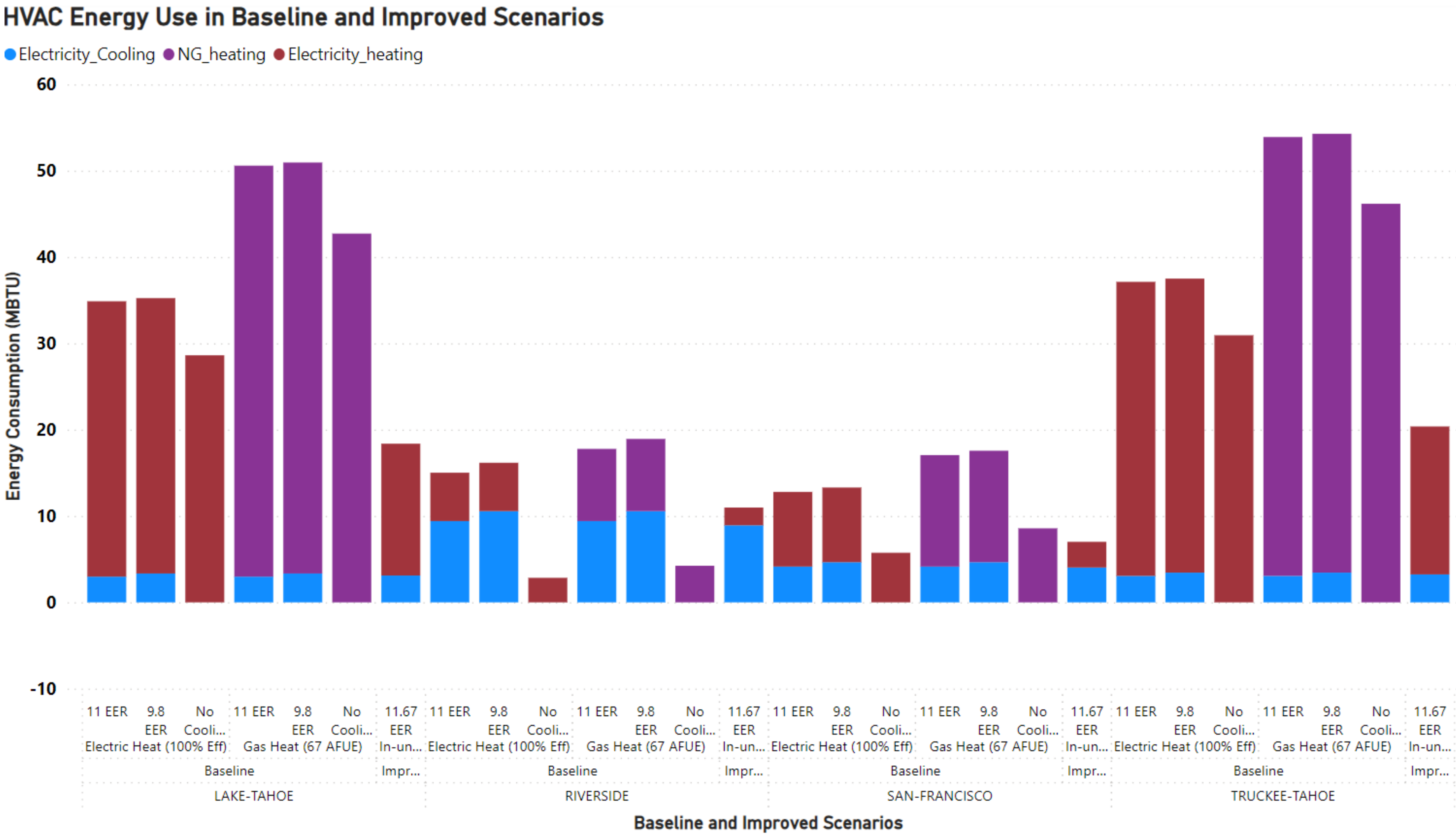

Figure 9: Average heating and cooling end-uses for baseline and improved scenarios in each location.