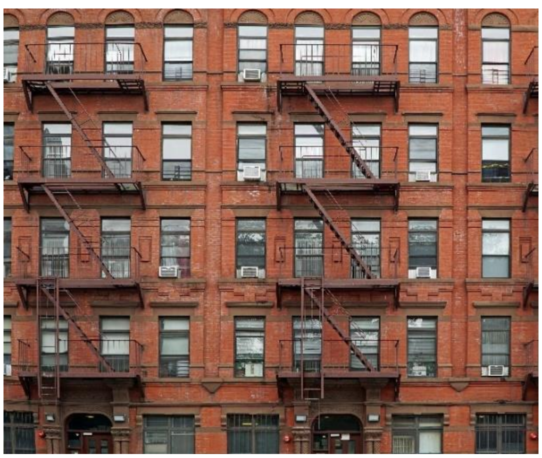
Emerging “Micro” Heat Pumps: Modeling, Testing, and Space-Conditioning Performance Metrics

Final Report

ET23SWE0034



Prepared by:

Pradeep Bansal Energy Solutions

Kiri Coakley Energy Solutions

Zyg Kunczynski Energy Solutions

Jeremy Wojtak Energy Solutions

Aniruddh Roy Energy Solutions

December 17, 2024

Disclaimer

Executive Summary

In pursuit of California's ambitious goal of installing six million heat pumps by 2030, emerging technologies such as "micro" heat pumps (MHPs) can serve as additional options for heating and cooling needs in certain single family and multifamily buildings. MHPs have the potential to displace electric units installed in walls, ceilings, baseboards or floors, built-in fossil fuel room heaters, portable electric heaters, and inefficient room air conditioners (RACs) and portable air conditioners (PACs) with backup electric resistance heaters. MHPs are self-contained, up to 120V, and have variable-speed compressors that can provide space cooling and heating in ambient temperatures down to 5 degrees Fahrenheit (ºF) or lower for spaces up to 1,000 square feet. They are available in various form factors, namely saddle, through-the-wall, window, and portable. Because they can be easily self-installed and are highly efficient, they could be particularly impactful for lower-income households and renters.

This report summarizes the outcomes of the research performed on some core objectives, namely a) development of an investigative testing plan to address heating, cooling, dehumidification, and performance with native controls, b) engagement with key stakeholders, c) selection and testing of sample MHPs in a nationally-recognized testing laboratory and d) modeling of cooling and heating loads in EnergyPlus™ to estimate fractional bin hours for MHPs in mid-rise apartment and single family prototype buildings in California's climate zones.

The United States (U.S.) Environmental Protection Agency (EPA) finalized its Test Method to determine RAC heating mode performance in July 2024, defining new heating performance metrics for room heat pumps, i.e., RACs that use reverse-cycle refrigeration as the prime heat source, and encompassing products with both single-speed and variable-speed compressors. The efficiency metrics and reporting requirements recently considered by the Consortium for Energy Efficiency (CEE) include combined energy efficiency ratio (CEER), heating energy efficiency ratio (HEER), coefficient of performance (COP) at various temperatures, capacity ratio with reporting of defrost capabilities, reporting of meltwater disposition, and a refrigerant global warming potential (GWP) lower than 700.

The CalNEXT project team networked with manufacturers, trade associations, state agencies, and regulatory bodies. The team conducted interviews with Friedrich, GD Midea, GE Appliances, Gradient, and Gree. The project team also received invaluable input from the Association of Home Appliance (AHAM); the Air-Conditioning, Heating, and Refrigeration Institute (AHRI); CEE, EPA, and the New York State Energy Research and Development Authority (NYSERDA). All stakeholders are eager to better understand the performance of MHPs and to use test data to optimize incentive programs and federal tax credits.

The project team tested several MHP and single-speed units across available form factors. However more models are becoming available soon from other manufacturers that should also be tested to get a comprehensive understanding of performance. This project team therefore recommends further investigative testing, via CalNEXT or in collaboration with other interested parties, so that duplicative testing efforts can be minimized and all involved stakeholders realize the intended benefits of these testing efforts. Additional testing opportunities beyond the tests executed under

this project include running load-based procedure(s), standby and off mode, and dehumidification tests.

The EnergyPlus modeling and computed fractional heating bin and cooling bin hours across various California-based climate zones were compared to the U.S. national averages established by the EPA and U.S. Department of Energy (DOE). In addition, performance metrics for some California-based climate zones were calculated. Since fractional heating bin hours influence the HEER calculations, future incentive programs within California could potentially use this analytical approach to estimate program-related savings. Further modeling efforts could adapt the results presented in this report to Database of Energy Efficiency Resources (DEER) prototypes and aid measure package development associated with incentive programs.

Abbreviations and Acronyms

Acronym	Meaning
ACEEE	American Council for an Energy-Efficient Economy
AHAM	Association of Home Appliance Manufacturers
AHRI	Air-Conditioning. Heating, and Refrigeration Institute
ANSI	American National Standards Institute
ASAP	Appliance Standards Awareness Project
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.
BEopt	Building Energy Optimization Tool
CA IOUs	California Investor-Owned Utilities
CalMTA	California Market Transformation Association
CBECC	California Building Energy Code Compliance
CCD	Compliance Certification Database
CH4A	Clean Heat for All
CEE	Consortium of Energy Efficiency
CEER	Combined Energy Efficiency Ratio
COP	Coefficient of Performance
CZ	Climate Zone
DAC	Disadvantaged Communities
DEER	Database of Energy Efficiency Resources
DOE	Department of Energy

Acronym	Meaning
EIA	Energy Information Administration
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
GWP	Global Warming Potential
HEER	Heating Energy Efficiency Ratio
HVAC	Heating, Ventilating, and Air Conditioning
IECC	International Energy Conservation Code
MHP	Micro Heat Pump
M&V	Measurement and Verification (or, sometimes, Validation)
MT	Market Transformation
NEEA	Northwest Energy Efficiency Alliance
NEEP	Northeast Energy Efficiency Partnerships
NREL	National Renewable Energy Laboratory
NRTL	National Recognized Testing Laboratory
NYCHA	New York City Housing Authority
NYPA	New York Power Authority
NYSERDA	New York State Energy Research and Development Authority
OEMs	Original Equipment Manufacturers
PAC	Portable Air Conditioner
PAT	Parametric Analysis Tool
PG&E	Pacific Gas & Electric

Acronym	Meaning
PTAC	Packaged Terminal Air Conditioner
PTHP	Packaged Terminal Heat Pump
RAC	Room Air Conditioner
RASS	Residential Appliance Saturation Study
RECS	Residential Energy Consumption Survey
SCE	Southern California Edison
SERC	Super-Efficient Room Conditioner
STC	Sound Transmission Class
V	Volts

Table of Contents

List of Tables

List of Figures

Introduction

California has set an ambitious goal to install six million heat pumps by 2030 (California Air Resources Board 2022), but the diversity of building applications and ownership, complexity of installations, and affordability of clean heating and cooling solutions pose obstacles to its achievement. Emerging packaged “micro” heat pump (MHP) technologies now offer an added space conditioning option that could be a game changer for owners and renters living in single family and multifamily buildings. This new generation of plug-in packaged window or through-the-wall heat pumps has the potential to rapidly displace polluting in-unit gas-fired furnaces, inefficient window air conditioners, and electric resistance space heaters by eliminating many cost barriers associated with the design, installation, and permitting required for traditional heat pumps. MHPs could be highly beneficial to lower-income households and renters by giving tenants new options for heating and cooling with lower impact on energy bills relative to current inefficient heating options, and lower installed costs relative to central systems for spaces up to 1,000 square feet.

MHPs can be installed without the need for professional labor or acquiring a permit using a standard 110 volts (V), 15-amp wall socket, and come with an inverter-driven variable-speed compressor that allows these units to provide heating even at ambient temperatures down to 5°F or lower for spaces up to 1,000 square feet, potentially eliminating the need for backup heating sources. These units are less expensive than central or other unitary air conditioners or heat pumps and generally do not need professional installation services. These products include unique form factors that can address a variety of needs for a given installed application, e.g., window type, existing through-the-wall footprint, supplemental heating needs, zoning, and more.

This project aims to lay the technical groundwork that will enable the California investor-owned utilities (IOUs) to provide incentives for this rapidly emerging technology to offset the use of currently available inefficient heating alternatives. While several studies are beginning to examine these units in the field, to date, the project team is not aware of any efforts to bring research focused on the gap in the heating test performance of these units.

The project team has worked collaboratively with key stakeholders to test or model the cooling and heating performance associated with MHPs following the United States (U.S.) Environmental Protection Agency’s (EPA’s) Final Test Method for the heating mode issued in July 2024. The project team aims to test several MHPs in a nationally recognized testing laboratory (NRTL), obtain performance data, and share the test results with key stakeholders. In parallel, the team has undertaken modeling efforts in EnergyPlus of heating and cooling loads for single family and mid-rise apartment prototype buildings. This Final Report presents modeling results of MHP units in single family and multifamily buildings specific to California-based climate zones, and uses a 50–50 weighted combination approach for building load data.

Further, the project aims to capture the salient features of the MHP test samples tested in accordance with EPA’s July 2024 Final Test Method to Determine Room Air Conditioner (RAC) Heating Mode Performance. A summary on window types, MHP installation guidelines, the California IOU incentive programs, and the project team’s interactions with numerous stakeholders, including MHP manufacturers, trade associations, state agencies and regulatory bodies — e.g., the Association of Home Appliance Manufacturers (AHAM), the Air Conditioning, Heating, and Refrigeration Institute

(AHRI), the New York State Energy Research and Development Authority (NYSERDA), EPA, the Consortium for Energy Efficiency (CEE), and others) — has also been provided in this Final Report.

Background

How Micro Heat Pumps Can Help Advance California's Goals

In July 2022, California Governor Gavin Newsom set an ambitious goal to deploy six million heat pumps statewide by 2030, with new programs planned specifically to address disadvantaged communities (DACs) (Newsom 2022). This heat pump goal builds upon existing goals established under the 2018 California Senate Bill 100 and its pathway to transition the grid to 100 percent zero-emissions sources by 2045 (California Senate 2018).

The market transformation strategy has relied on a combination of incentives for traditional central heat pumps as replacements for existing gas heating equipment, alongside efforts to conduct performance testing on these products to provide technical validation and inform future incentive program offerings. The U.S. Department of Energy (DOE) is currently working with state and local organizations to support deployment of heat pump technologies (DOE 2022a).

MHPs are entering the U.S. market that could potentially address critical barriers including the high costs to electrify, the skilled labor challenge, limited electrical capacity within existing electric panels, and the split-incentive challenge. Many of these barriers are especially significant for people in DACs. MHPs are self-contained, packaged, plug-in, up to 120V consumer products that provide more efficient heating and cooling through variable-speed operations for spaces smaller than 1,000 square feet. This new generation of technology has the potential to rapidly displace in-unit gas-fired furnaces, window air conditioners, and electric resistance space heaters by avoiding many cost barriers associated with the design, installation, and required permitting for traditional heat pumps. MHPs represent a new electrification pathway that could support initiatives addressing whole building electrification. Until recently, most commercially available RACs and portable air conditioners (PACs) have been cooling-only models or provided heating through electric heat. Increasingly, though, heat pump options without auxiliary electric resistance heaters are emerging in the market. MHPs have the potential to replace inefficient single-speed RACs and PACs and electric resistance space heaters, and they can simultaneously provide an efficient solution to the heating and cooling needs of California's consumers, particularly those living in small spaces.

Traditionally, RAC and PAC use has been mostly limited to air conditioning. Most RAC and PAC models available in the market today are cooling-only models or provide heating through electric resistance heat, and some models are heat pumps. Although consumers have indicated that the ability to heat was one of the least important additional factors in their consideration of different options via a nationally representative survey conducted by the California IOUs, more than 40 percent of consumers placed at least some degree of importance on heating operation as a purchase motivation (DOE 2022b). The survey suggests that consumers use only RACs, only PACs, or a combination of RACs and PACs as primary sources of air conditioning 63 percent of the time; the remaining 37 percent use such products as supplementary cooling devices to central air conditioners or central heat pumps. Consumer motivations to purchase are comparable across both types in terms of purchase motivations, location and ease of installation, and additional features including dehumidification and air filtration.

Some commercially available MHP models are through-the-wall products, which are generally dependent on professional installers. However, manufacturer representatives of such MHPs occasionally receive inquiries from do-it-yourself (DIY) homeowners. Upon further review of manufacturer literature and product databases, the CalNEXT MHP project team found that although such products have previously been rated in accordance with the applicable test procedure for single-package vertical equipment (statutory provisions and DOE consider these as commercial equipment), current product databases classify these products as single-package space-constrained heat pumps meeting the provisions of AHRI Standard 210/240 (AHRI 2024b).[1]

In August 2022, the California IOUs docketed a comment recommending that DOE either align the test procedure for RACs and PACs or differentiate the metrics for these different products, since the efficiency ratings for each are not comparable. Consumers indicated a significant difference in average weekly usage — average PAC usage was approximately 76 percent of RAC usage. The DOE survey results (DOE 2022b) indicated that most PAC and RAC owners were likely to replace their unit with the same type of air conditioner. Further research and consumer education could help increase the likelihood of replacing with an MHP.

The high gas penetration in California's existing residential building stock is a major challenge for the achievement of California's decarbonization goals. The most recent comprehensive study, the 2019 California Residential Appliance Saturation Study (RASS), estimates the number of California households with gas space heating to be 77 percent (DNV 2021), while data from the 2020 Residential Energy Consumption Survey (RECS) further supports this estimate. For those California single family and multifamily units for which heating fuel is known, 79.5 percent rely on natural gas, propane, or wood/pellets (EIA 2022). This is still above the considerable U.S. national average of 52 percent for gas space heating (U.S. Energy Information Administration 2020a).

Table 1 and Table 2 below summarize the equipment used for California residential space heating and cooling according to the 2020 RECS survey of single family and multifamily housing. Excluding central systems and Unknown/Other, about 38 percent and 15 percent of heating equipment, for multifamily and single family respectively, could potentially be replaced by MHPs. For cooling, excluding central systems and Unknown, 47 percent and 50 percent of cooling equipment, for multifamily and single family respectively, could be replaced by MHPs. The actual opportunity may be larger since a portion of Unknown/Other would likely apply, and housing units that currently do not have any such equipment and are therefore not represented in the data might install these units in the future. For more information on windows, please see Appendix D.

1 See Table 2 of AHRI Standard 210/240-2024 for classifications. Through-the-wall MHPs are currently classified as "SCP-HSP-A" and have SEER2, HSPF2, or EER2 ratings.

Table 1: Summary of California Space Heating Equipment (2020)

	Central furnace	Central heat pump	Ductless heat pump, also known as a mini-split	Steam or hot water system with radiators or pipes	Built-in electric units installed in walls, ceilings, baseboards, or floors	Built-in room heater burning gas or oil	Wood or pellet stove	Portable electric heaters	Unknown / Other
Multifamily	34.7%	4.7%	2.2%	1.1%	12.3%	10.8%	0.0%	11.6%	22.7%
Single family	75.9%	2.6%	0.7%	0.9%	1.5%	6.6%	1.9%	3.0%	6.9%

Source: (U.S. Energy Information Administration 2020a)

Table 2: Summary of California Space Cooling Equipment (2020)

	Central air conditioner	Central heat pump	Ductless heat pump, also known as a mini-split	Evaporative or swamp cooler	Portable air conditioner (PAC)	Window or wall air conditioner	Unknown
Multifamily	6.1%	13.4%	17.3%	8.3%	9.7%	11.6%	33.6%
Single family	11.2%	13.8%	17.3%	10.9%	7.4%	14.4%	25.0%

Source: (U.S. Energy Information Administration 2020b)

Transforming this market requires significant stakeholder investment, from manufacturers to policymakers. Incentives for heat pumps through TECH Clean California allocated over $72 million within the first five months of the program launch, and showcased the demand for heat pump systems when the upfront cost barrier is addressed (TECH Clean California 2023).

RACs and PACs have historically been relied upon to serve space cooling needs in smaller spaces, as opposed to the entire dwelling in single family buildings. Although MHPs are expected to offer additional consumer utility compared to RACs and PACs, the CalNEXT MHP project team does not expect a significant shift in consumer behavior and estimates intended room sizes for MHPs to remain comparable to RACs and PACs currently distributed in commerce. The California IOUs previously sponsored a national consumer survey RACs and PACs (DOE 2022b). The survey findings of room sizes are listed below in Table 3.

Table 3: Percent of Customers using RACs and PACs, by Room Size

Room size (square feet)	Percent of customers using RACs	Percent of customers using PACs
Less than 100	13%	10%
Between 100 and 250	29%	34%
Between 251 and 400	27%	30%
Between 401 and 600	23%	20%
More than 600	8%	6%

Source: (DOE 2022b).

DOE has previously assumed that RACs within certain cooling capacity ranges can comfortably cool spaces within certain size ranges (DOE 2023a).[2] The assumptions are listed in Table 4.

Table 4: RACs within Cooling Capacity Ranges

Product Class	Btu/h	DOE assumed that one RAC could comfortably cool a space of this size (square feet)
Product Class 1	< 6,000	< 250
Product Class 2	6,000–7,990	250–349
Product Class 3	8,000–13,990	350–699
Product Class 4	14,000–19,990	700–1,099
Product Class 5a	20,000–27,990	700–1,099

2 See Section 7.3.2.1 of DOE's 2023 technical support document.

Product Class	Btu/h	DOE assumed that one RAC could comfortably cool a space of this size (square feet)
Product Class 5b	≥ 28,000	> 1,800

Source: (DOE 2022b).

EPA has also developed a sizing guide for RACs with cooling capacities ranging between 5,000 and 30,000 British thermal units per hour (Btu/h) while considering room shape, room size, shading within the room, number of occupants, and the intended use of the room (ENERGY STAR 2019).[3]

In the case of PACs, DOE previously determined that sizing charts provided by vendors estimate an intended room size of 525 to 600 square feet, although retail websites have suggested intended room sizes of up to 1,000 square feet (DOE 2016).[4] DOE estimated that PACs would be used about two percent of the time to cool spaces between 600 and 1,000 square feet.

Currently Available Micro Heat Pump Designs

MHPs come in a variety of form factors to match the wide range of existing space conditioning designs and needs in residential buildings as detailed in Table 5. While some window MHP models look like variations of RACs or packaged terminal heat pumps, the industry has also recently introduced more novel form factors including saddlebag designs. However, all in-unit MHPs offered for sale in the United States are alike in being single-package designs. Some MHPs offered for sale elsewhere are also available in split-system configurations. Figure 1 shows examples of some MHP form factors in the U.S. market.

Table 5: Summary of Common Micro Heat Pump Form Factors

MHP Form Factor	Installation Details	Notable Characteristics
"Saddle" Window Heat Pump	The unit straddles the windowsill with an evaporator and fan sitting on the inside and the compressor on the outside of the building.	- Newly-introduced across the industry with high COPs in lower ambient temperatures - Quiet design - Low profile

3 See slide 12.

4 See section 7.2.1 of DOE's 2016 technical support document.

MHP Form Factor	Installation Details	Notable Characteristics
Portable Heat Pump	This design option is in a portable encased assembly that can come with various ducted configurations to discharge heat rejected by the condenser coil during cooling mode and have the condenser coil absorb heat from the unconditioned space air during heating mode.	- Already popular in California - Lower upfront cost - Easy to move from one building or room to another - Takes up floor space - Often noisy while running
Through-the-wall Heat Pump	This is a variation of the single-packaged (vertical) heat pump that can be mounted high or low, and has previously been marketed as such. Manufacturers are currently rating this product as a single-package space-constrained heat pump. It is connected directly to the outdoor unit rather than through refrigerant and electrical lines.	- More intensive installation than other types and is generally dependent on professional installers. However, manufacturer representatives occasionally receive inquiries from DIY homeowners. - Still less difficult than the installation of a central system - Ideal for saving space in any area with open walls - Relatively quiet
Room Air Conditioners (Room Heat Pumps)	These are installed directly inside the window frame. In climates with cooler winters, occupants might remove the unit.	- Simple installation requiring no building modifications - Low upfront cost - Risk of the unit falling out of the window if not secured properly - Obstructs part of the window while installed

Source: 2024 ACEEE Paper

Figure 1: Examples of "saddle," window, portable, and through-the-wall heat pumps.

Photos: Gradient, Friedrich, and Ephoca.

Nationwide Efforts to Promote Micro Heat Pumps

This CalNEXT project began by reviewing existing studies and manufacturer literature related to MHP equipment. The review included reports from the New York Clean Heat for All (CH4A) Challenge, the CEE Super-Efficient Room Conditioner (SERC) Initiative, the EPA ENERGY STAR® Final Test Method, and the Northwest Energy Efficiency Alliance (NEEA) consumer research study on MHPs. Research also included a building stock impact modeling and building energy modeling assessments based on the National Renewable Energy Laboratory (NREL) Building Energy Optimization Tool (BEopt) and the OpenStudio Parametric Analysis Tool (PAT). These efforts evaluated the current market, investigated the potential for MHPs to meet cooling and heating needs, and provided a test procedure that builds the base for future incentives.

In just over two years, MHPs have seen a tremendous level of activity including technology development, field and lab evaluations, as well as product definitions, performance specifications, energy conservation standards, and test procedures as described in further detail below. Table 6 shows several key research activities focused on bringing these new heat pumps to market. Activities also coordinate necessary technical validation to support future incentive programs and tax credits.

Table 6: Key Research Activities for MHP

Initiative/Activity	Organization(s)	Date
Release of federal energy conservation standards final rule on PACs	DOE	January 2020
Release of federal test procedure final rule on RACs	DOE	March 2021
Launch of Clean Heat for All (CH4A) innovation challenge	NYCHA, NYPA, NYSERDA	December 2021
Announcement of CH4A design specifications	NYCHA, NYPA, NYSERDA	February 2022
Lauch of CEE Super-Efficient Room Conditioner Initiative	CEE	February 2022
Announcement of CH4A awardees	NYCHA, NYPA, NYSERDA	August 2022
Release of federal test procedure final rule on PACs	DOE	May 2023
Release of federal energy conservation standards final rule on RACs	DOE	May 2023

Initiative/Activity	Organization(s)	Date
Formation of Industry Working Group (test development)	(6) Manufacturers, (9) Energy Efficiency Organizations, (2) Testing Labs	June 2023
Start of consumer field testing	NEEA	July 2023
Installation of CH4A prototypes	NYCHA, NYPA, NYSERDA	September 2023
Presentation of Industry Working Group findings to CEE	(6) Manufacturers and CEE	September 2023
Completion of multifamily market potential study	CalNEXT	November 2023
Release of ENERGY STAR Final Test Method	EPA	July 2024
Start of laboratory performance testing	CalNEXT	Q4 2024
Start of CH4A: Scaled deployment (30,000 units)	NYCHA, NYPA, NYSERDA	Planned: Q4 2024
Update on Super-Efficient Room Conditioner (SERC) Initiative resulting in 25C tax credits	CEE	Draft version of CEE Residential Room Heat Pump Initiative was issued in September 2024. Final version is pending.

New York's Clean Heat for All Innovation Challenge

In December 2021, the New York City Housing Authority (NYCHA) in collaboration with New York Power Authority (NYPA) and NYSERDA launched the CH4A Challenge. The main intention of CH4A was to engage manufacturers to develop novel heat pump technologies to decarbonize NYCHA buildings and reduce emissions from buildings by 40 percent by 2030 as a steppingstone to 80 percent greenhouse gas (GHG) emissions reductions by 2050. The 2019 California RASS estimates the number of California households with gas space heating to be 77 percent and gas water heating to be 86 percent (DNV 2021). This is significantly higher than the U.S. national average of 52 percent for gas space heating, and 48 percent for gas water heating (EIA 2020).

As per early estimates of 2022, 100 percent of NYCHA cooling was provided by resident-owned RACs. There are currently around 50 million RACs in the United States (NYPA 2022a). For this challenge, NYCHA sought standalone packaged window heat pumps (PWHPs) that could be installed in occupied apartments with limited tenant disruption, no field-installed refrigerant piping, no major electrical upgrades, and no skilled labor required for installation. The units would have to provide adequate heating for buildings in climate zones 4 and 5, the coldest regions within most of the continental United States (see Figures 1 through 4). Noise level of the operating equipment was considered as an additional non-energy and quality of life impact.

In February 2022, NYCHA released their request for an industry proposal, which detailed several requirements all aimed to rapidly decarbonize their multifamily housing stock at scale. Table 7 provides a summary of those requirements, which were also adopted by the CEE SERC initiative. The high-potential retail price remains a barrier as the low-cost models previously available did not provide enough heating to meet NYCHA's requirements; some of these low-cost models use electric resistance while others cannot heat below 40°F.

Table 7: CH4A Key Product Requirements

Attribute	Specification
Retail Price	$3,000 per unit maximum
Electrical Requirements	120 VAC, standard three-prong (NEMA 5-15), 15A outlet
Cooling Capacity	9,000 Btu/h at 95°F outside ambient temperature
Heating Capacity	9,000 Btu/h at 17°F outside ambient temperature
Heating Efficiency	1.85 COP at 17°F outside ambient temperature
Heating Operating Range	Shall operate down to 0°F or below (shall not use electric resistance)
Compressor Type	Shall have variable-speed compressor
Noise	Should not exceed 50dB on low fan mode
Installation Requirements for: • **Condensate Management** • **Refrigerant** • **Install Procedure** • **Install Time**	Drainage for condensate (meltwater) shall not require a plumber
	All refrigerant piping shall be hermetically sealed to minimize the risk of refrigerant leak
	Shall not require drilling through exterior wall
	Installation must not exceed two hours

Source: Project administrator discussions with industry representatives and (Coakley, et al. 2024)

The December 2021 CH4A announcement by NYCHA, NYPA, and NYSERDA led to NYCHA committing to purchasing 24,000 units from some manufacturers for six developments slated for heating plant replacement over a five-year period. NYCHA plans to deplmore than 50,000 apartments over the next 10 years. Under NYSERDA's RetrofitNY initiative, building owners have already pledged to install cost effective net-zero carbon retrofit solutions in over 400,000 dwelling units when such technologies become available.

New York's Governor announced in November 2023 that two manufacturers, Gradient and GD Midea, were awarded contracts to manufacture a total of 30,000 units, and that 72 units were installed in December 2023 for comprehensive monitoring over the course of the winter season (New York State Power Authority 2023). During the September 2024 ENERGY STAR Products Partner Meeting (ESPPM), Midea presented their PWHP product to showcase their role in the CH4A and announced that they will be delivering 20,000 cold-climate PWHP units to help replace outdated heating systems. Midea is continuing their collaboration with government agencies to make consumers aware of relevant incentives and create sustainable space conditioning solutions (Midea 2024).

An initial evaluation of resident satisfaction had a response rate of 38 percent, with 100 percent of respondents indicating that they are either satisfied or neutral with the heating performance of the window heat pumps. Throughout January 2024, the coldest winter period, both models successfully maintained comfortable room temperatures (ENERGY STAR 2024a).

Current Incentives

Inflation Reduction Act

The Inflation Reduction Act (IRA) of 2022 promotes clean energy and includes a federal tax credit of up to 30 percent to cover the cost and installation of qualified energy efficient equipment (www.energystar.gov/about/federal-tax-credits). Qualifying equipment currently includes central heat pumps but not MHPs since CEE has yet to issue qualifying specifications to cover these. This tax credit is available through 2032 and is capped at $2,000 per year for central heat pumps, with a $3,200 yearly cap for all such tax credits combined. The U.S. Department of the Treasury has developed some examples for consumers to consider on purchases that are eligible for both the 25C tax credit and other rebates (Treasury 2024) (America n.d.).

If rebates and/or tax credits were available for MPHs, there would be clear benefits to renters and low-income individuals or families. MPHs can be moved to new residences, representing a unique opportunity for renters to purchase units and claim rebates and/or tax credits.

Incentives in California

The CalNEXT MHP project team performed research on available market incentives as summarized below:

- Most of the current incentives for room heat pumps (see details in Appendix B) are limited to $50–$200, but this range may be too low to meaningfully apply to MHPs. With adequate performance data on space conditioning capacities and efficiencies, higher incentives would likely be appropriate for MHPs. For instance, incentives for other heat pumps such as mini-splits, and ducted or ductless central air systems are typically $2,000 or more.
- There are two statewide programs to promote heat pump technology: 1) Comfortably California, which assists HVAC distributors (Comfortably California n.d.), and 2) TECH Clean California, which assists contractors. The TECH program requires that new high-efficiency equipment replace a non-heat pump system and meet the relevant requirements within AHRI's procedures and California's building standards in Title 24, Part 6. TECH Clean California provides rebates for central heat pump products such as ducted unitary split, single-package,

and mini-split and multi-split heat pumps, but not MHP-style units. Similarly, Comfortably California currently only offers rebates for split or packaged heat pumps in fuel substitution applications (Comfortably California 2024) (TECH Clean California 2023).
- In 2022, Governor Newsom committed to supporting the installation of heat pumps in DACs as part of a goal of seven million climate-friendly homes by 2035 (Newsom 2022). With proper incentives, MHPs could help achieve this goal.

EPA ENERGY STAR Test Procedure Development

In July 2024, EPA published the Final Test Method to determine RAC heating mode performance and is expected to issue a RAC specification with heating performance levels in the future. DOE is expected to incorporate the EPA's Final Test Method into its own test procedure. The agency had previously released its Draft 1 Test Method in December 2023, recognizing the emergence of the unique models of MHPs through the CH4A and the urgency of market adoption of MHPs.

The test procedure development process involved several key stakeholders such as AHAM, the Appliance Standards Awareness Project (ASAP), the California IOUs, original equipment manufacturers (OEMs) (e.g., Gradient, GD Midea, GE, Friedrich, Gree), NEEP, NEEA, and NYSERDA (ENERGY STAR 2024b). Both DOE and EPA recognized the contributions of these stakeholders in making the heating-only test procedure more robust and their efforts to develop the market. The Final Test Method serves as a framework for future specifications developed by EPA and/or CEE; quantifying heating mode performance means that program implementers will have a basis for offering MHPs incentives that meet the heating efficiency energy ratio (HEER) levels set forth in those future specifications.

The ENERGY STAR Final Test Method provides the following definitions for Types 1, 2, 3, and 4 room heat pumps:

- Type 1 heat pump: A room heat pump that does not have active defrost or for which the specified compressor cut-in and cut-out temperatures are not both less than 40°F.
- Type 2 heat pump: A room heat pump that has active defrost and for which the specified compressor cut-in and cut-out temperatures are both less than 40°F but not both less than 17°F.
- Type 3 heat pump: A room heat pump that has active defrost and for which the specified compressor cut-in and cut-out temperatures are both less than 17°F but not both less than 5°F.
- Type 4 heat pump: A room heat pump that has active defrost and for which the specified compressor cut-in and cut-out temperatures are both less than 5°F.

The CalNEXT project team found that MHPs with variable-speed compressors that provide heating at lower temperatures are typically available in Types 3 and 4. No Type 2 MHPs were commercially available for the duration of this project. The project team selected Type 1, 3, and 4 units for project testing, so variable-speed units could be compared with a single-speed unit.

The ENERGY STAR Final Test method and the CEE Residential Room Heat Pump Initiative address combined energy efficiency ratio (CEER), HEER, coefficient of performance (COP), capacity ratio, defrost capability, meltwater distribution, and refrigerant global warming potential (GWP). While developing the laboratory test plan for this project, the project team considered the actions taken by

DOE and EPA on RAC and room heat pump test procedures and accounted for applicable issues addressed in other industry consensus procedures or federal test procedures, such as AHRI Standards 210/240-2024 and 1600-2024, Appendix X1 to Subpart B of Part 430, AHRI draft standard 310/380-202x, and Appendix CC1 to Subpart B of Part 430.

Background on DOE Test Procedure Development Efforts

DOE's test procedure Appendix F to Subpart B of Part 430 ("Part 430 Appendix F" for the purpose of this report) does not currently account for the heating performance of room heat pumps and does not reference the heating mode test method as finalized in July 2024 by EPA. The RAC test procedure final rule issued by DOE in March 2021 suggested a lack of data on RACs used for heating. At least one trade association supported DOE's proposal to exclude heating mode tests and noted that the heating mode is not a significant operating mode for RACs (DOE 2021).

EPA issued a final ENERGY STAR Version 5.0 specification on RACs in February 2023 (ENERGY STAR n.d.a). While the specification did not include a heating metric, EPA stated that it was aware of new RAC models with innovative and efficient heating modes. Given the current federal RAC test procedure does not address energy performance in heating mode, DOE and EPA collaborated to develop a heating test method for the purposes of EPA being able to establish a future specification addressing performance.[5] EPA's ENERGY STAR Most Efficient 2024 recognition criteria for RACs has mandated reporting of heating mode efficiency after the publication of the room heat pump heating mode test procedure. The recognition criteria also requires a RAC to have a sound pressure level at or below the sound level requirement of 45dB(A) for the lowest available operational mode, (i.e., the compressor and fan are still in operation but at the lowest cooling output level), and rated following internationally recognized International Standards Organization (ISO) or American National Standards Institute (ANSI) test procedure (ENERGY STAR 2024c). EPA announced in September 2024 that the ENERGY STAR Most Efficient 2025 final criteria removed sound requirements for RACs based on the evolution of the market to feature only variable-speed compressors, and such products have improved sound performance. The EPA will consider whether sound requirements are warranted in the future through the ENERGY STAR specification revision process (Office of Air and Radiation 2024). In recent years, EPA has prioritized its focus on the potential for electric heat pumps to deliver energy-efficiency gains, pollution reduction, and cost-savings to consumers, and in doing so, proposed to sunset the certification pathway to the ENERGY STAR label for certain air-conditioning systems (Office of Air and Radiation 2024). It is possible that EPA could expand such actions to other consumer products if the market begins to experience a sufficient penetration of MHPs.

Cooling-Related Issues Between Air-Enthalpy and Calorimeter Approaches

Two testing procedures are primarily relied upon for measuring a product's space conditioning capacity, namely the calorimetric or the air enthalpy method (also referred to as a psychrometric test method). The calorimetric room method measures the energy input to the unit under test serving a known load added into the conditioned room. Test chambers are typically limited to less than 42,000 Btu/h cooling capacity for non-ducted products. In contrast, the air enthalpy method is typically

5 Id (see section 6).

employed in psychrometric chambers, and is geared towards ducted equipment, but can accommodate non-ducted products if needed.

Using the calorimeter test method, the lowest outside temperature for which heating mode performance can be tested is about 47°F dry bulb/43°F wet bulb test condition. In comparison, the air-enthalpy test method can perform heating mode tests with outdoor temperatures as low as 5°F dry bulb/4°F wet bulb test condition. The air-enthalpy test method also enables frost accumulation heating mode tests to be performed at 35°F dry bulb/33°F wet bulb conditions, such that the energy consumption associated with defrost cycles can be appropriately addressed within the heating performance metric. The capacities of the units tested in this project range from 6,000 to 12,000 Btu/h, which are on the low end of test chamber capacity. This could lead to uncertainty during low-speed tests. The laboratory may need to readjust its apparatus to increase its chance of maximizing repeatability.

The RAC test procedure set forth in Part 430 Appendix F uses a calorimeter test method to determine the cooling capacity and associated electrical power input of a RAC. Part 430 Appendix F also incorporates by reference ANSI/ASHRAE Standard 16–2016, a procedure that permits an air-enthalpy test method in addition to the typical calorimeter test method.

Heating Mode Test Method Development

Part 430 Appendix F currently prescribes cooling mode test conditions and measurements in section 4, and the CEER calculations in section 6. Part 430 Appendix F incorporates by reference ANSI/AHAM RAC–1–2020 and prescribes no heating mode tests. Prior to the issuance of the 2021 test procedure final rule, Part 430 Appendix F incorporated by reference ANSI/AHAM RAC–1–2008. Although ANSI/AHAM RAC–1–2015 prescribes heating capacity test conditions (section 5) and heating performance test provisions addressing heating capacity, electrical input, application heating capacity, maximum operating conditions, and outside coil de-icing, DOE did not incorporate these provisions into Part 430 Appendix F, and the provisions were subsequently removed during the publication of ANSI/AHAM RAC–1–2020.

A limitation of ANSI/ASHRAE Standard 16–2016 is that it does not include provisions to conduct cyclic tests (DOE 2023b).[6] This negates the possibility of considering the incorporation of certain optional cyclic tests set forth in the federal test procedure for central air conditioners and heat pumps (DOE 2023c).[7] The unit's compressor is cycled on and off for specific time intervals during a cyclic test, and information gathered during this test is necessary to calculate a heating degradation coefficient.

Heating Cyclic Degradation Coefficient

The cyclic degradation coefficient varies depending on product type — it is currently 0.25 for central heat pumps and is proposed as 0.30 for PTHPs. EPA's July 2024 Final Test Method on RAC heating mode performance allows manufacturers to perform optional cyclic tests that may yield heating degradation coefficients that are better than the default values assigned in the Final Test Method,

---

6 See section III.F.3.

7 See Table 14A for all applicable heating mode tests for units having a variable-speed compressor other than variable-speed, non-communicating coil-only heat pumps.

i.e., 0.38 for single-speed room heat pumps and 0.44 for variable-speed room heat pumps (ENERGY STAR 2024d).[8] EPA and DOE relied on PTHP test data to generate the coefficient of degradation for room heat pumps because these units are similar in construction and geometry (ENERGY STAR n.d.b).[9] Although the CalNEXT MHP project team included this topic as part of its test plan, the tests were unable to be executed due to other priority testing issues; this topic remains an investigative testing opportunity.

CEE Draft Room Heat Pump Initiative: An Impetus for Investigative Testing

CEE, a consortium primarily of utility efficiency program administrators from across the United States and Canada, works toward accelerating energy-efficient products and services in targeted markets (CEE n.d.). CEE establishes product-related tier levels that yield meaningful levels of energy savings beyond DOE's federal minimum efficiency standard, and program administrators rely on these tier levels to set incentives.

CEE's current specification on RACs has been in effect since May 2022 and prescribes Tier 1 and Tier 2 CEER levels along with connected criteria, but does not include any provisions for heating, dehumidification, performance with native controls, or sound performance. After initially considering the "residential super-efficient RAC" terminology in 2023, CEE transitioned towards aligning with the terminology in EPA's Final Test Method. Although EPA's Final Test Method does not explicitly include the term "micro heat pump," the MHP project team considers the term to include single-phase 110–120V room heat pumps in various form factors, including through-the-wall room heat pumps and portable heat pumps. Stakeholders have informed the CalNEXT MHP project team that CEE issued an industry stakeholder letter in September 2024 on residential room heat pumps, and specified the following draft criteria:

A. Cooling performance: Tier 1, 2, and advanced tier CEER minimum levels in accordance with the test procedure at 10 CFR 430, Subpart B, Appendix F or, a DOE-approved test procedure waiver pursuant to 10 CFR Part 430.27 (Btu/watt-hour).

B. Heating performance measured per the ENERGY STAR Final Test Method: Tier 1, 2, and advanced tier HEER minimum levels, an advanced tier COP_5 minimum level, a Tier 2 COP_{17} minimum level, indication of active or passive defrost, and Tier 2 and advanced tier minimum capacity ratio levels. CEE has proposed HEER requirements to ensure adequate performance (COP values) across most temperature bins.

C. Refrigerant GWP ≤ 700.

D. CEE aspires to find a balance between performance and technological feasibility, and hence has sought input from its industry partners on several points, including the following:

8 See note in section 7.2, page 17.

9 Like PTHPs, room heat pumps typically use capillary tubes for refrigerant expansion, while mini-splits typically use electronic expansion valves (EEVs) and thermal expansion valves (TXVs), which have drastically different coefficients of degradation. Geometrically, room heat pumps are more like PTHPs than mini-splits because they are installed in a single package rather than as a split system. These differences also affect the coefficient of degradation.

a. Comment whether the suggested tiered specifications appropriately encourage MHPs penetration into the market.
b. Share any experimental (or field) data with CEE that may map with the proposed specifications.
c. Suggest features that may be considered for an open, automated demand response requirement (e.g., OpenADR, CTA-2045, BACnet), to be potentially launched from January 1, 2026.
d. Suggest any missing items that should be considered, including noise level and installation requirements.
e. Suggest additional attributes that will enhance the impact of utility programs and 25C tax credits by increasing penetration of MHPs.

In parallel, EPA is working on developing its own room heat pump specification, likely for publication in 2025 or 2026. While they will likely continue to rely on DOE for data, test data from these efforts could be considered in these specifications. Their intent is to align with 25C federal tax credit levels as determined by industry stakeholders and CEE.

Outreach to Industry and Stakeholders

Objectives and Methodology

The project team conducted outreach to manufacturers, energy efficiency groups, and government agencies to discuss the status of MHPs, existing market challenges, and potential next steps to move the market along. These stakeholders also provided feedback on various existing industry test procedures to determine which were most appropriate. This feedback is helpful to support the effective development of necessary market incentives for MHPs, and it was essential to the project team's development of the test plans detailed in Table 8 and Table 9.

Specifically, the project team interviewed four manufacturers, two industry trade associations (AHRI and AHAM), one state agency (NYSERDA), EPA, and CEE, and briefly engaged with representatives of the California IOUs, California Market Transformation Administrator (CalMTA) and NEEA. We provided background on CalNEXT and 110-120V heat pumps and requested information in certain topic areas. Interview materials are detailed in Appendix C: Stakeholder Outreach Materials.

Results

Insight from Manufacturers

The CalNEXT project team has appreciated input from manufacturers and other industry partners such as AHAM, AHRI, EPA, Friedrich, GD Midea, GE Appliances, Gradient, and Gree. Manufacturers were most interested in what rebates and tax incentives might apply to their projects. They are confident in the technology's ability to deliver heating in cooler climates and expect more MHP offerings to be available in the United States in coming years.

The project team was able to address most manufacturer concerns about rebates and tax incentives by summarizing this project process and associated timeline. Manufacturers have agreed to provide test samples to support ongoing laboratory testing efforts to measure MHP performance.

One of the manufacturers, Gradient, informed the CalNEXT MHP project team that 36 of their MHP units were already installed in New York apartments as part of the NYCHA study for in-field testing. To date, the units have been meeting performance expectations, providing data for further system and control improvements, according to the manufacturer interview. System uncertainties have thus far been within expected bounds. Gradient estimates that 120V window MHPs can fit roughly half of all residential windows in the United States and that potentially 19 million installations in multifamily homes are possible using these systems (ENERGY STAR 2024a). GE Appliances, a major manufacturer of room air conditioners, has stated that the approximate room air conditioner shipments in the United States is between five and seven million units (ENERGY STAR 2024e).

Discussions with GD Midea focused on their unit that fully meets NYCHA requirements; this unit uses an inverter-driven rotary compressor with vapor injection and can be adjusted to saddle-style construction with no auxiliary heater.

Another manufacturer's team stated that testing pertaining to A2L[10] refrigerants has been particularly challenging in recent times, due to the fact that they must plan for refrigerant transition across multiple product platforms, beyond MHPs.

It is clear from engagement with manufacturers that incentives drive development. Since current federal regulations and incentive programs focus on cooling performance, current designs tend to be optimized for cooling.

Insight from Trade Associations

The project team also spoke with AHAM and AHRI, both trade associations that represent manufacturers. AHRI helped confirm that PTHPs and single packaged vertical heat pumps (SPVHs) under the scope of AHRI Standards 310/380-2017 and AHRI 390-2021, respectively, should be excluded from the scope as they are considered three-phase commercial equipment by DOE, are rated at higher voltages (i.e., 208V, 230V, or 265V), and are therefore not within the scope of this CalNEXT project. The project team has continued to connect with AHAM, and such interactions with industry have led to at least one major manufacturer directly reaching out to continue working on this effort as a stakeholder.

Insight from Government

The CalNEXT Team met with NYSERDA in July 2024. NYSERDA has suggested that room heat pumps could be important for New York, as more than40 percent of existing buildings in the state have a room or window air conditioner and improved heat pump technologies are being sought for space heating solutions to achieve decarbonization mandates. The background section of this report describes the Clean Heat for All program on which NYSERDA collaborated with other New York authorities.

[10] A2L refrigerants are those characterized by ASHRE as having low flammability, lox toxicity, and low global warming potential

Performance Data Collection

Objectives

In overseeing laboratory testing, the project team aimed to produce datasets for two primary reasons: 1) to determine preliminary trends on the heating performance of MHPs currently available in the U.S. market, and 2) to investigate EPA's Final Test Method on room heat pumps with different MHP form factors. The HEER values of the tested units will assist stakeholders reviewing this report to gain a better understanding of the range of HEER values across products with differing configurations, heat pump types, and compressor types. The aim of laboratory testing was also to provide insights on the cooling and dehumidification performance of these MHPs, dehumidification testing was not performed since heating and cooling tests took higher priority.

Performance data provides insights to make recommendations to advance the overall understanding of these products, their comparative performance (or relative rank order) based on product features, and identification of opportunities to improve test procedures for the sake of representativeness. More importantly, the findings may assist with the development of market incentives to support equitable and efficient heating and cooling solutions. For example, HEER was only recently prescribed as the heating metric by DOE and EPA, and stakeholders have communicated the need to see how related laboratory testing can help identify the rank order of highly efficient MHPs compared to a basic heat pump scenario. In addition, laboratory testing efforts can provide valuable insights into repeatability and reproducibility of measurements during testing.

Methodology

The project team gathered data on five Types 1, 3, and 4 portable, window, and through-the-wall units with either single-speed or variable-speed compressors. The project team was unable to find any commercially available Type 2 MHPs to test.

The project team selected a variety of MHP form factors: "saddle," portable, room heat pump with a slide-out chassis, and through-the-wall. All but one product included a variable-speed compressor; cooling capacities were between 8,000 and 12,000 Btu/h; and heating capacities ranged from 4,500 to 10,500 Btu/h. Most selected products contained an R-32 refrigerant; one contained an R-410A refrigerant.

Since the HEER metric has just been established, there are no readily available published data showing typical HEER values for single-speed and variable-speed products based on laboratory tests. The project team relied upon a reverse-cycle single-speed room heat pump as a basic heat pump scenario. The project team was unable to consider a stakeholder's suggestion of using a RAC with an electric resistance heater in the basic heat pump testing, since this would have been out of scope.[11]

---

[11] The project team very much appreciates the stakeholder's suggested approach of using a RAC with an electric resistance heater as a basic scenario. The two key reasons were: 1) The use of electric strip backup heat usually increases the amperage requirement considerably and can be significantly more than the typical amperage values for a heat pump or an air-conditioning product, depending on ambient temperatures. This can lead to very expensive electrical infrastructure upgrades for replacement equipment. Additionally, one of the core purposes of this MHP project was to facilitate the wider adoption of heat pump technology to offset the use of inefficient electrical resistance heating options. 2) Stakeholders

However, the CalNEXT MHP project team encourages all interested parties to consider this comment in any ongoing or future testing initiatives.

The project team developed test plans to evaluate cooling, heating, and dehumidification functions, and performance of variable-speed MHPs configured in native controls (default manufacturer settings). Although sound-related performance is of importance to valued industry stakeholders such as AHAM and sound performance has been prioritized in EPA's ENERGY STAR Most Efficient recognition program, the project team did not include sound performance in its test plans since the core objective of was to investigate performance related to energy consumption.

Test Plan for Variable-Speed MHPs

Table 8 describes the project team's test plan provisions for variable-speed MHPs.

have previously recommended that DOE and EPA create design requirements governing the operation of supplemental heat, including limitations on when the resistance heater may operate in response to set point changes and when compressor operation is still possible (ENERGY STAR 2024d). Since the EPA Final Test Method is performed under steady-state operating conditions, transient and short-term conditions — e.g., brief resistance heat that supplements or replaces heat pump operation to satisfy a new setpoint — are beyond the scope of this test. However, the Resistance Heat Controls Verification Procedure (RH_CVP procedure) does address any resistance heat operation at representative outdoor temperatures and during steady-state operating conditions, which can represent significant hours of operation. Selecting such a product as a basic heat pump scenario for laboratory investigative testing would have been counterintuitive to the steps taken by DOE and EPA in the Final Test Method on RAC heating mode performance.

Table 8: Tests for Variable-Speed Micro Heat Pumps

Test Chamber	Test Mode	Test Description
Tests in Psychometric Chamber (Air Enthalpy Method)	Heating Mode Tests	1. Perform all required and optional heating mode tests in Table 9 (applicable to Type 3 units) or Table 10 (applicable to Type 4 units) of ENERGY STAR Final Test Method (ENERGY STAR 2024). 2. For Type 4 units, perform the $H_{x,max}$ test down to the lowest achievable outdoor temperature. 3. Perform the following Controls Verification Procedures (CVP) if unit includes auxiliary electric resistance heater: a. Perform RH_CVP specified in the ENERGY STAR Final Test Method; and b. Perform heating-specific CVP set forth in Appendix I (AHRI 2024a). 4. Follow provisions of section 6.3 of the ENERGY STAR Final Test Method on cut-in and cut-out temperatures. Record T_{on}, T_{off}, and calculate T_L. 5. Run the $H1C_1$ and $H2_2$ tests following Table 14A of Appendix M1 to Subpart B of 10 CFR Part 430 (DOE 2023c). Calculate Heating-Mode Cyclic-Degradation Coefficient using calculations in Section 3.8.1 of Appendix M1 using the results of the Appendix M1 $H1C_1$ test, and the $H_{1,FULL}$ test from the ENERGY STAR Final Test Method.

Test Chamber	Test Mode	Test Description

Tests in Psychometric Chamber (Air Enthalpy Method)	Cooling Mode Tests	1. For all MHPs, perform G_1 and I_1 tests in accordance with Table 8 of Appendix M1. Use G_1 and I_1 tests results to calculate Cooling-Mode Cyclic-Degradation following Section 3.5.3 of Appendix M1 to Subpart B of 10 CFR Part 430.
		2. For variable-speed single-duct PACs, run test configurations 2B and 2C in Table 2 of AHAM PAC-1-2022. Conduct the test following the ambient conditions for test configurations 2B and 2C, and measure cooling capacities ($Capacity_{SD\_Full}$ and $Capacity_{SD\_Low}$) and input power values (P_{SD_Full} and P_{SD_Low}). For variable-speed dual-duct PACs, run test configurations 1C and 1E in Table 2 of AHAM PAC-1-2022 in accordance with Section 4 of Appendix CC1.
		3. For variable-speed dual-duct PACs, contractor shall also run modified test configurations 1C and 1E such that the applicable airflow and static pressure provisions outlined in AHAM PAC-1-2022 are reset to account for new return air temperature evaporator inlet (indoor) air temperature is at 75°F dry bulb and 63°F, and the condenser inlet temperature is at 95°F dry bulb and 75°F wet bulb.
		4. For PACs, run the off-cycle mode test in section 8.2 and standby and off mode tests in section 8.3 of AHAM PAC-1-2022. In accordance with section 4 of Appendix CC1, when conducting standby power testing using the sampling method described in section 5.3.2 of IEC 62301, if the standby mode is cyclic and irregular or unstable, collect 10 cycles or 30 minutes' worth of data, whichever is greater. As discussed in Paragraph 5.1, Note 1 of IEC 62301, allow sufficient time for the unit to reach the lowest power state before proceeding with the test measurement.
		5. For PACs, calculate SACC and AEER per Section 5 of Appendix CC1.
		6. Perform the following CVP for all MHPs:
		  a. Perform cooling-specific CVP set forth in Appendix I to AHRI Standard 1600-2024 (AHRI 2024a); and
		  b. Run the following cooling CVP if the manufacturer provides a remote controller or thermostat specific to this unit:
		    1. Stabilize the indoor room at 80°F dry bulb/67°F wet bulb, and 82°F dry bulb/65°F wet bulb with unit running in cooling in the lowest stage thermostat setting for 10 minutes.
		    2. Turn off the lowest stage thermostat setting and wait 5 minutes.
		    3. Turn on the lowest stage thermostat signal.
		    4. Wait for compressor to ramp up for up to 60 minutes, or when the compressor speed/power draw remains constant for over 15 minutes.
		    5. Reduce indoor temperature to 78°F.
		    6. Wait for compressor to ramp down for up to 60 minutes, or when the compressor speed/power draw remains constant for over 15 minutes.
		    7. If unit does not ramp down, reduce indoor temperature to 76°F to see if it does. Pass criteria: If unit adjusts compressor speed/power up through step 3 and down through step 4 in more than 2 distinct steps, unit has load-based control. If unit does not adjust compressor speed/power, it does not have load-based control. Specify this in test report summary.

Test Chamber	Test Mode	Test Description
Tests in Calorimetric Chamber	Cooling Mode Tests	1. Perform required tests in Appendix F to Subpart B of 10 CFR 430 (DOE 2024a). 2. In conjunction with bullet 1, also run all four test conditions in Table 1 of Appendix F at an evaporator inlet (indoor) air of 75°F dry bulb and 63°F wet bulb. For instance, after running "Test Condition 1" in accordance with Appendix F, leave the 95°F dry bulb and 75°F wet bulb outdoor room conditions fixed while adjusting the indoor room conditions from 80°F dry bulb and 67°F wet bulb to 75°F dry bulb and 63°F wet bulb.
Test room in accordance with AHAM DH-1-2022	Dehumidification Tests	Follow these steps for MHPs that are not PACs: 1. In cooling full airflow, measure and report the following in test report: a) measured full airflow; and b) measured indoor air-side total cooling capacity. 2. In cooling low airflow, measure and report the following in test report: a) measured low airflow; and b) measured indoor air-side total cooling capacity. 3. In cooling intermediate airflow, measure and report the following in test report: a) measured intermediate airflow; and b) measured indoor air-side total cooling capacity. Follow these steps for PACs: 4. For variable-speed single-duct units, use results for test configuration 2C to calculate sensible heat ratio (SHR) using Section 4.5 of Appendix M1 to Subpart B of 10 CFR Part 430 (DOE 2023c). For variable-speed dual-duct units, use results for test configuration 1E to calculate SHR using Section 4.5 of Appendix M1 to Subpart B of 10 CFR Part 430 (DOE 2023c). 5. Contractor shall use the following test procedures to determine dehumidification capacity in pints/day and an integrated energy factor in liters/kilowatt hour ("kWh") or suggest an alternate test method on dehumidification performance specified in Appendix X1 to Subpart B of Part 430 (DOE 2024b). a. In cooling full airflow, Contractor shall measure and report the following in the test report: i. Measured full airflow; and ii. Measured indoor air-side total cooling capacity. b. In cooling low airflow, Contractor shall measure and report the following in the test report: i. Measured low airflow; and ii. Measured indoor air-side total cooling capacity.
Reverberation Room or Free Field Over a Reflecting Pane	Sound	1. Test the MHP using ISO Standard 3741 if a reverberation room is used. Otherwise, test the MHP in a free field test room in accordance with ISO Standard 3744. 2. Measure sound power of the indoor and outdoor portions of the unit per ISO 3741 in cooling mode high-speed and low-speed operation.

The CalNEXT MHP project team's test plan prescribed the provisions in Table 9 for single-speed products.

Table 9: Tests for Single-Speed Products

Test Chamber	Test Mode	Test Description
Tests in Psychometric Chamber (Air Enthalpy Method)	Heating Mode Tests	1. Perform all required and optional heating mode tests in Table 3 of ENERGY STAR Final Test Method (ENERGY STAR 2024). 2. Follow provisions of section 6.3 of ENERGY STAR Final Test Method to record cut-out and cut-in temperatures. Record T_{on} and T_{off}. 3. Record COP and heating capacity at each heating mode test. Calculate HEER using ENERGY STAR Heating Mode Performance Test Reporting Template (ENERGY STAR 2024). 4. Run the H1C test in accordance with Table 11 of Appendix M1. Calculate Heating-Mode Cyclic-Degradation Coefficient using calculations in Section 3.8.1 of Appendix M1 using the results of the Appendix M1 H1C test, and the $H_{1,FULL}$ test from the ENERGY STAR Final Test Method (ENERGY STAR 2024).
Tests in Psychometric Chamber (Air Enthalpy Method)	Cooling Mode Tests	1. For all MHPs, run the C and D tests in accordance with Table 5 of Appendix M1. Use C and D test results to calculate Cooling-Mode Cyclic-Degradation in accordance with Section 3.5.3 of Appendix M1 to Subpart B of 10 CFR Part 430. 2. For single-speed single-duct PACs, run test configuration 2A in Table 2 of AHAM PAC-1-2022. Conduct the test in accordance with the ambient conditions for test configuration 2A, and measure cooling capacity ($Capacity_{SD}$) and input power (P_{SD}). For single-speed dual-duct PACs, run test configurations 1A and 1B in Table 2 of AHAM PAC-1-2022. Conduct the test in accordance with the ambient conditions for test configuration 1A and 1B, and measure cooling capacity ($Capacity_{SD}$) and input power (P_{SD}). 3. In addition to bullet 2, Contractor shall run modified test configurations 2A, 1A and 1B such that the applicable airflow and static pressure provisions set forth in AHAM PAC-1-2022 are reset to account for new return air temperature evaporator inlet (indoor) air temperature at 75°F dry bulb and 63°F, and the condenser inlet temperatures remain unchanged. 4. Run the off-cycle mode test in section 8.2 and standby and off mode tests in section 8.3 of AHAM PAC-1-2022. In accordance with section 4 of Appendix CC1, when conducting standby power testing using the sampling method described in section 5.3.2 of IEC 62301, if the standby mode is cyclic and irregular or unstable, collect 10 cycles or 30 minutes' worth of data, whichever is greater. As discussed in Paragraph 5.1, Note 1 of IEC 62301, allow sufficient time for the unit to reach the lowest power state before proceeding with the test measurement. 5. Calculate SACC and AEER per Section 5 of Appendix CC1. 6. Run the C and D tests in accordance with Table 5 of Appendix M1. Use C and D test results to calculate Cooling-Mode Cyclic-Degradation in accordance with Section 3.5.3 of Appendix M1 to Subpart B of 10 CFR Part 430.

Test Chamber	Test Mode	Test Description
Test room in accordance with AHAM DH-1-2022	Cooling Mode Tests	1. Perform all required tests in Section 5.2.1.1 of AHAM RAC-1-2020 in accordance with the provisions of Section 3.1 of Appendix F. 2. In conjunction with bullet 1, the Contractor shall also run the test conditions in Section 5.2.1.1 of AHAM RAC-1-2020 at an evaporator inlet (indoor) air of 75°F dry bulb and 63°F wet bulb. For instance, after running the test in bullet 1, the Contractor may choose to leave the 95°F dry bulb and 75°F wet bulb outdoor room conditions fixed while adjusting the indoor room conditions from 80°F dry bulb and 67°F wet bulb to 75°F dry bulb and 63°F wet bulb.
	Dehumidification Mode Tests	1. Contractor shall use the following test procedures to determine dehumidification capacity in pints/day and an integrated energy factor in liters/kilowatt hour on dehumidification performance specified in Appendix X1 to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Dehumidifiers (DOE 2024b). 2. In cooling full airflow, Contractor shall measure and report the following in the test report: a) Measured full airflow; and b) Measured indoor air-side total cooling capacity.
Reverberation Room or Free Field Over a Reflecting Pane	Sound	1. Test the MHP using ISO Standard 3741 if reverberation room is used. Otherwise test the MHP in a free field test room in accordance with ISO Standard 3744. 2. Measure sound power of the indoor and outdoor portions of the unit per ISO 3741 in cooling mode high-speed and low-speed operation.

Results

Before this project, the CalNEXT MHP project team had not partnered with nationally recognized testing laboratories (NRTLs). While we were able to collect some test results summarized within this section, we also experienced the following issues, which should be considered by other interested parties pursuing parallel investigative testing efforts:

- Delays in new client onboarding and a scarcity of available psychrometric or calorimetric chambers prevented the project team from completely executing its test plans.
- The CalNEXT MHP project team in partnership with the NRTL experienced challenges while attempting to run the $H_{2,int}$ heating mode test for at least one MHP form factor. The test was performed with the unit ducted in both the outdoor and indoor rooms. The NRTL was unable to shut down its airflow measurement code tester during the unit's defrost operation on the inlet air location where the blower pushed air through a low flow nozzle. Another observed issue was that the unit staged its airflow down to low speed from high speed after a defrost test but was unable to stage its speed up to high without manual intervention such as resetting the unit by shutting it down or switching over to cooling mode operation.
- While attempting to run test condition 4 following DOE's Part 430 Appendix F, the necessary test tolerances were not achieved since the test chamber was not equipped to handle cooling capacities lower than 5,000 Btu/h. The laboratory may need to make additional adjustments to its apparatus to maximize repeatability.

The project team recommends that stakeholders involved in ongoing and future testing efforts build upon the findings presented in this section.

The heating results of tested MHPs were compared with the results of a single-speed product. COPs at 47°F for tested MHPs ranged between 1.9 and 4.8 whereas the single-speed product had a COP of 3.1. For tests at lower temperatures, COPs for MHPs ranged between 1.35 and 2.61 at 17°F. One MHP's COP at 5°F far exceeded the proposed advanced tier minimum of 1.75 in the draft CEE specification. On part-load cooling, initial test results resulted in a CEER of over 17 for a unit.

Table 10 and Table 11 illustrate calculated HEER, Heating Seasonal Performance Factor 2 (HSPF2), and the regional variations of those metrics for California climate zones based on the 50–50 weightings developed for multifamily and single family prototype buildings. Appendix A summarizes the methodology on weightings. The regional variations in HEER and HSPF2 suggest potentially improved heating performance across the analyzed California climate zones for MHPs installed in those regions, likely due to milder heating fractional bin hours relative to the national average.

Table 10: Example HEER Calculation for a Tested MHP and Corresponding Regional HEER Values

HEER	$HEER_{CA}$ Hot Dry	$HEER_{CA}$ Warm Dry	$HEER_{CA}$ Warm Marine	$HEER_{CA}$ Mixed Dry	$HEER_{CA}$ Mixed Marine	$HEER_{CA}$ Cool Dry	$HEER_{CA}$ Cold Dry
10.1	12.4	12.1	12.1	11.1	12.0	10.8	10.8

Table 11: Example HSPF2 Calculation for a Tested MHP and Corresponding Regional HSPF2 Values

HSPF2	$HSPF2_{CA}$ Hot Dry	$HSPF2_{CA}$ Warm Dry	$HSPF2_{CA}$ Warm Marine	$HSPF2_{CA}$ Mixed Dry	$HSPF2_{CA}$ Mixed Marine	$HSPF2_{CA}$ Cool Dry	$HSPF2_{CA}$ Cold Dry
10.0	13.6	12.9	14.6	11.5	12.8	11.1	11.2

Summary of Heating and Cooling Test Results

Three MHP units and a single-speed room heat pump were tested in a laboratory in accordance with some aspects of the test plans described in Table 8 and Table 9. Although the CalNEXT MHP project team was able to complete several heating and cooling mode tests, other tests and calculations on dehumidification, controls verification procedures (CVP), sound, cooling and heating cyclic degradation coefficients, and added psychrometric chamber tests present an opportunity for interested parties to continue testing initiatives on these products.

Cooling and heating capacity test results are shown in Figure 2 and Figure 3, respectively. Both cooling and heating capacities were normalized with each product's cooling capacity at 95°F to align with the approach taken in the building load line equation 7.1.2 in EPA's July 2024 Final Test Method (ENERGY STAR 2024). Normalization was necessary to account for the variation in capacities associated with the selected products for testing efforts. On cooling, the tested product capacities at various outdoor conditions during full compressor speed operation mostly aligned with their respective cooling capacities at 95°F. Multiple units were tested at the 95°F outdoor dry bulb temperature, so the blue circle bordering the orange datapoint in Figure 2 is representative of at least three MHP units. The lower normalized cooling capacities at lower outdoor dry bulb temperatures are expected; they are due to the fact that compressor speeds were lower during those tests and cooling loads are expected to be lower in those outdoor temperatures. The team drew similar conclusions from the heating capacity test results on the lower normalized heating capacity percentage trend, with the exception that other contributing factors also played a role, such as lowered delivered heating capacities in colder outdoor dry bulb temperatures and defrost operation.

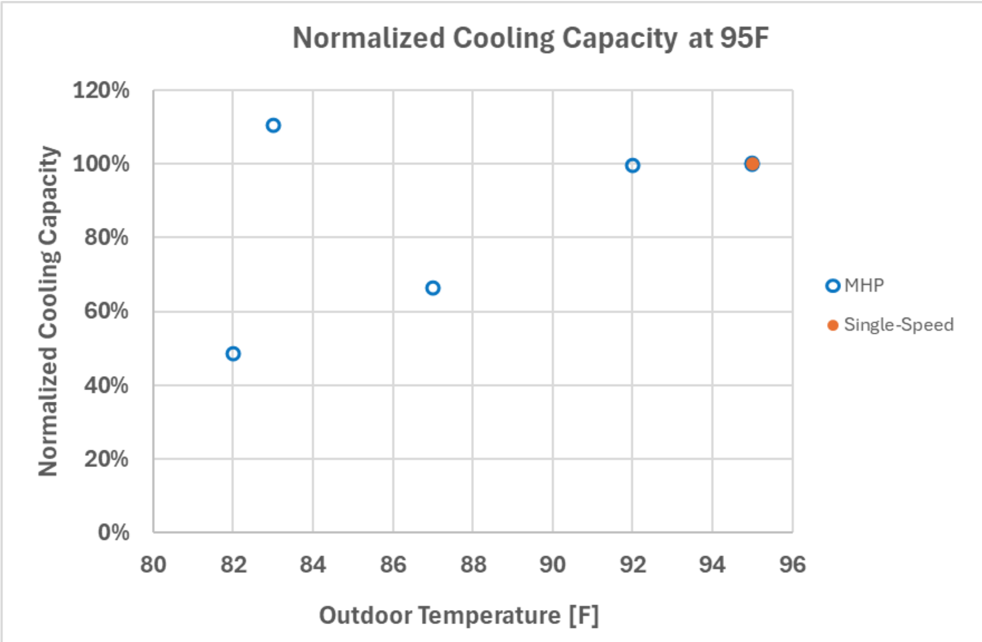


Figure 2: Cooling capacity for 80–96°F outside temperature, normalized to each unit's cooling capacity at 95°F.

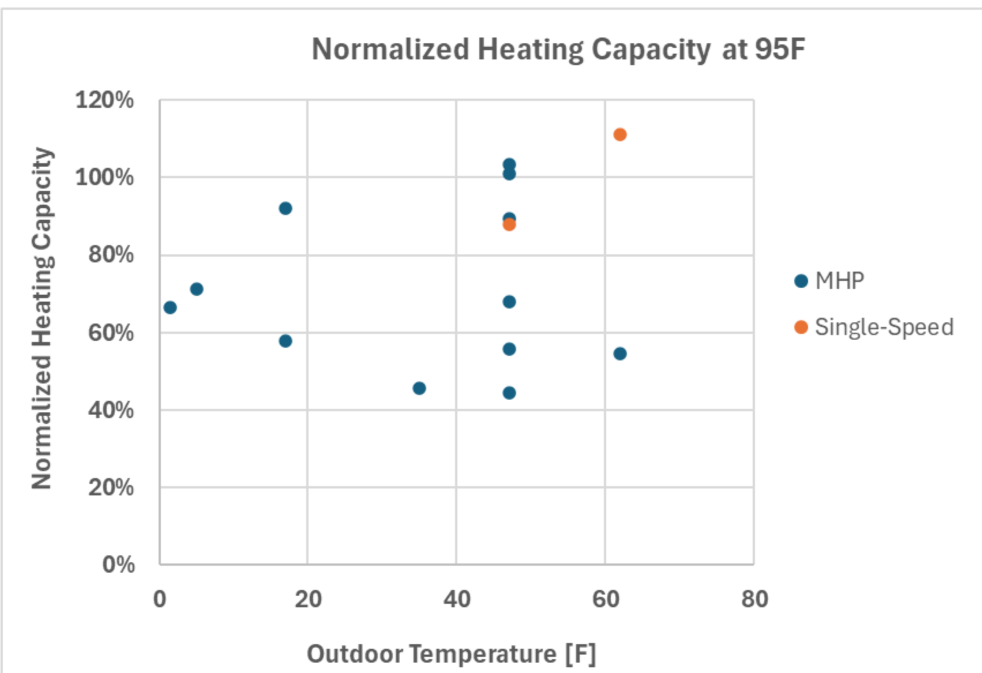


Figure 3: Heating capacity for 0–70°F outside temperature, normalized to each unit's cooling capacity at 95°F.

Cooling and heating efficiency test results are shown in Figure 4 and Figure 5 respectively. On cooling, most calculated energy efficiency ratios were above 12.0 Btu/Wh at various outdoor temperatures whereas in heating, most products demonstrated COPs at or above 2.5, and more so at temperatures greater than or equal to 17 °F. The energy efficiency ratio and COP results in these figures suggest that MHPs can play an effective role in space cooling and space heating needs for California's consumers, particularly for consumers who may be reliant on inefficient systems performing at a COP lower than 1.

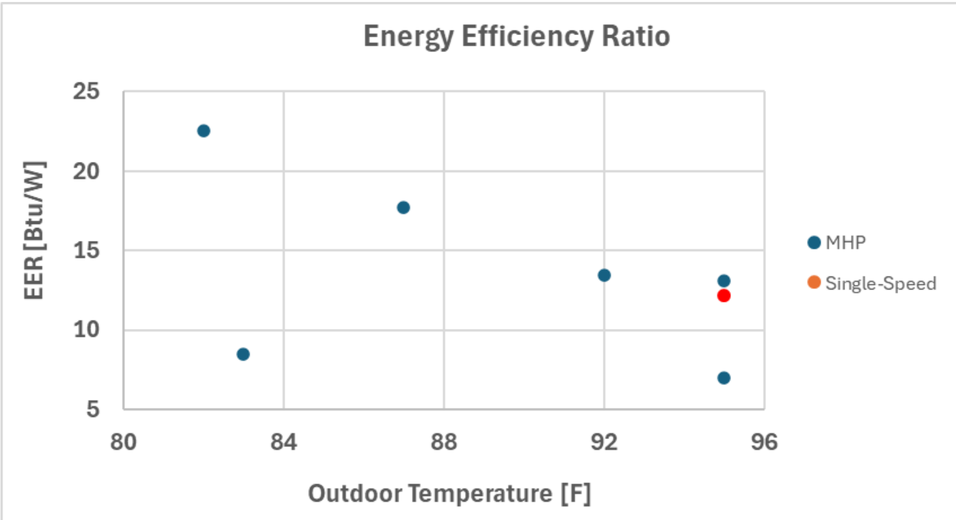


Figure 4: Energy efficiency ratio by outdoor dry bulb temperature.

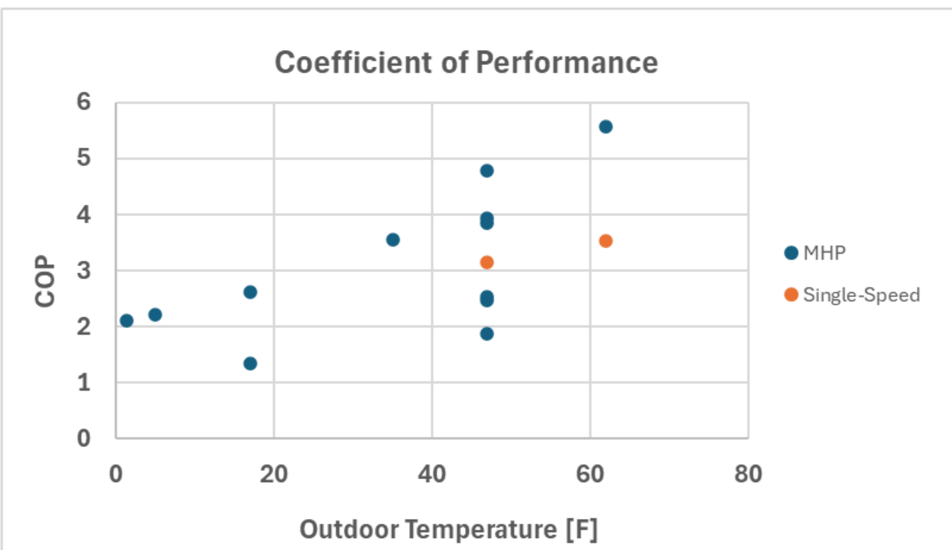


Figure 5: Coefficient of performance by outdoor dry bulb temperature.

The CalNEXT MHP project team also investigated the cooling performance of a product in calorimeter and psychrometer chambers. Initial findings summarized in Table 12 suggest that the product's measured cooling capacities and calculated energy efficiency ratios were higher within the calorimeter chamber. Further investigation of this approach is needed across a representative number of samples since EPA's Final Test method necessitates psychrometric chamber tests for all heating performance at low outdoor temperatures. While it would be good for industry to have options when performing cooling mode tests — this would help manage testing costs and avoid unit setup time across multiple testing chambers — psychrometric testing in cooling mode might produce lower efficiency and cooling capacity values than calorimetric tests would. Additionally, the federal Final Test procedure for RACs currently limits cooling mode tests to calorimeter chambers, a limitation for manufacturers who may prefer using a psychrometric chamber for tests in both cooling and heating modes.

Table 12: Summary of Measured Capacity and Calculated Energy Efficiency Ratios from Tests

Test Number	Outdoor Dry Bulb Temperature	Measured Capacity		Measured EER	
		Calorimetric Room	Psychrometric Room	Calorimetric Room	Psychrometric Room
1	95	100%	97.6%	100%	96.6%
2	92	100%	95.4%	100%	93.1%
3	87	100%	100%	100%	97.4%
4	82	100%	99.7%	100%	96.0%

Additional observations of MHP-related heating performance are as follows:

- Calculated HSPF2 and HEER were 10.0 and 10.1, respectively, so the difference between these two metrics was minimal, and both metrics are representative of product-related average use cycle at a national level. However, as demonstrated in Table 10 and Table 11, California-specific regional variations suggest that installed heating performance of MHPs may benefit California's consumers due to milder heating temperature conditions.
- At an outdoor temperature close to 1.5 °F, performance was well above a COP of 1.75, the proposed advanced tier minimum COP in CEE's draft specification. This suggests there would be little need for supplementary heating at the intended room size. A COP far exceeding the 17 °F CH4A COP requirement of 1.85 would be of additional value to California's consumers.
- At 47 °F, the unit was tested at the lowest, nominal, and full compressor speeds. While the COP at the lowest compressor speed is highest (4.8) relative to both nominal and full speeds, the capacity delivered to the consumer is only 44 percent of the capacity at full speed. This

suggests that program designs should ensure that optimization approaches do not impact the product utility delivered to the consumer.

- One MHP cycled on and off after $H_{1,FULL}$ tests (in accordance with EPA's Final Test Method). Another cycled on and off when in $H_{0,Low}$ and $H_{1,FULL}$ tests. The unit was run in heating modes in accordance with the manufacturer's service manual, but additional engagement is warranted on these tests. A CVP should also be considered in the next round of investigative tests.

Energy Modeling

Fractional heating or cooling bin hours represent the ratio of the number of hours during the heating or cooling season when the outdoor temperature is within a bin to the total number of hours in the season. For example, in Table 15, for California's "Warm Dry" climate zone, the fractional bin hours for heating in the 30–34°F bin is 0.120. This means the outdoor temperature is within that range about 12 percent of hours during the heating season. EPA uses national average heating and cooling fractional bin hours to calculate HEER and CEER values, and these values directly impact savings calculations, so the project team developed specific fractional bin hours for some California climate zones such as cold dry, cool dry, hot dry, mixed dry, mixed marine, warm dry, and warm marine.

Objectives

The objectives of modeling were as follows:

A) Replicate the analysis performed by DOE and EPA on fractional heating bin hours in the July 2024 ENERGY STAR Final Test Method for mid-rise apartment and single family prototype buildings, and summarize heating fractional bin hours in California-based climate zones relative to the U.S. national average in EPA's ENERGY STAR Final Test Method on room heat pumps and DOE's Appendix M1.

B) Develop cooling fractional bin hours in California-based climate zones relative to DOE's Appendix M1.

C) Identify future test procedures and technology transfer opportunities in both heating and cooling modes. The regional variations in calculated HEER values for California climate zones may assist program designers with incentive offerings for California.

Methodology

After discussions with stakeholders, the project team patterned its EnergyPlus modeling on the approach taken by DOE and EPA on mid-rise apartments and single family homes. Appendix A provides details of the team's approach to calculating heating and cooling fractional bin hours. The CalNEXT MHP project team developed these fractional bin hours using a 50–50 weighted combination of building load data for mid-rise apartments and single family homes, and applied them to the calculated nationally-representative HEER and HSPF2 metrics to project the installed performance of MHPs in some California climate zones.

Summary of Results

Initial results for multifamily and single family buildings suggest an improved modeled heating performance for MHPs in California relative to national average MHP use cycles. While these initial results (detailed in Appendix A) are encouraging, the CalNEXT MHP project team recommends all interested parties to continue investigating performance-related opportunities for these products in California. Regional variations in performance should be considered to appropriately incentivize MHP models by climate zone.

The project team has also included findings on cooling fractional bin hours relative to the U.S. national average assumed in DOE's current federal test procedure set forth in Part 430 Appendix F.

Recommended Next Steps

The recommended next steps for MHPs are as follows:

1. Utilize the performance data collected under this project to inform future CalNEXT projects or ensure test plan coordination with key stakeholders including the California IOUs' Codes and Standards team and CalMTA.
2. Continue stakeholder engagement on laboratory performance data at various operating conditions and identify findings that may be useful for future test procedure discussions; focus those discussions on ensuring repeatable and reproducible test results and representative performance metrics.
3. Conduct further laboratory testing on additional MHP form factors as they become available in the marketplace mid-2025 and beyond. As of the date of publication of this report, only through-the-wall and portable MHPs were commercially available for procurement and investigative laboratory testing.
4. Discuss with measure package development teams based in California the usefulness of laboratory testing and energy modeling results towards programs that are ideally customized for California consumers.

References

AHRI. 2024a. "AHRI Standard 1600-2024 (I-P)." Accessed November 2024. https://www.ahrinet.org/system/files/2024-05/AHRI%20Standard%201600-2024%20I-P_0.pdf.

—. 2024b. "AHRI Standard 210/240-2024 (I-P)." *Performance Rating of Unitary Air-Conditioning and Air-Source Heat Pump Equipment.* Accessed November 2024. https://www.ahrinet.org/system/files/2024-05/AHRI%20Standard%20210%20240-2024%20%28I-P%29_0.pdf.

America, Rewiring. n.d. *Federal Energy Efficient Home Improvement Credit (25C).* Accessed November 2024. https://homes.rewiringamerica.org/federal-incentives/25c-heat-pump-tax-credits.

BAYREN. n.d. *Single Family Homeowners.* Accessed November 2024. https://www.bayren.org/residential.

Building Energy Codes Program. n.d. "Prototype Building Models." Accessed January 2024. https://www.energycodes.gov/prototype-building-models.

California Air Resources Board. 2022. *California Rleases World's First Plan to Achieve Net Zero Carbon Pollution.* https://www.gov.ca.gov/2022/11/16/california-releases-worlds-first-plan-to-achieve-net-zero-carbon-pollution/.

California Energy Commission. 2024. "2025 Energy COde Accounting Methodology." March. Accessed November 2024. https://efiling.energy.ca.gov/GetDocument.aspx?tn=255318-1.

California Senate. 2018. "SB-100 California Renewables Portfolio Standard Program: emissions of greenhouse gases." *California Legislative Information.* September 10. leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB100.

2023. *CEE.* April 10. Accessed November 2024. https://cee1.org/news/details/cee-and-the-inflation-reduction-act-25c-tax-credits.

CEE. n.d. Accessed November 2024. https://cee1.org/about/.

Climate One Building. n.d. *Repository of Building Simulation Climate Data.* Accessed January 2024. https://climate.onebuilding.org/WMO_Region_4_North_and_Central_America/USA_United_States_of_America/index.html.

Coakley, Kiri, Kiri Coakley, Tim Minezaki, Pradeep Bansal, and Chris Badger. 2024. "Micro Heat Pumps: Are they ready for prime time?" ACEEE Summer Study.

Comfortably California. 2024. *2024 Qualifying Product List for Contractors.* June. Accessed November 2024. https://www.comfortablyca.com/wp-content/uploads/2024/03/Comfortably-CA-QPL.pdf.

—. n.d. *Working Together to Bring Efficient Heatng and Cooling Statewide.* Accessed November 2024. www.comfortablyca.com/#contact.

DELETE. n.d. Accessed November 2024. https://www.alamedamp.com/407/Rebates-and-Incentives.

delete. 2023. "2022 CEE Residential Appliances Program Summary." September. Accessed November 2024. https://cee1.my.site.com/s/resources?id=a0V7V00000IKusa.

—. n.d. *Database for Incentives and Joint Marketing Exchange (DIME).* Accessed November 2024. https://www.energystar.gov/dime?scrollTo=266&search_text=&sort_by=utility&sort_direction=asc&state_f...

DELETE. n.d. *Electrify Marin.* Accessed November 2024. https://www.marincounty.gov/departments/cda/sustainability/electrify-marin?panelnum=4.

DNV. 2021 California Residential Appliance Saturation Study (RASS). *2021.* CEC-200-2021-005-ES, DNV.

DNV. 2021. *2021 California Residential Appliance Saturation Study (RASS).* CEC-200-2021-005-ES, DNV.

DOE. 2023c. *Appendix M1 to Subpart B of Part 430, Title 10.* Accessed November 2024. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-B/appendix-Appendix%20M1%20to%20Subpart%20B%20of%20Part%20430.

—. 2024b. *Appendix X1 to Subpart B of Part 430, Title 10.* November. Accessed November 2024. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-B/appendix-Appendix%20X1%20to%20Subpart%20B%20of%20Part%20430.

—. 2016. *2016-12 Final Rule Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Portable Air Conditioners.* December. Accessed November 2024. https://www.regulations.gov/document/EERE-2013-BT-STD-0033-0047.

—. 2021. *2021-03-29 Energy Conservation Program: Test Procedure for Room Air Conditioners; Final rule.* March. Accessed November 2024. https://www.regulations.gov/document/EERE-2017-BT-TP-0012-0021.

—. 2023a. *2023-03 Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Room Air Conditioners.* March. Accessed November 2024. www.regulations.gov/document/EERE-2014-BT-STD-0059-0053.

—. 2024a. "Appendix F to Subpart B of Part 430, Title 10." November. Accessed November 2024. https://www.ecfr.gov/current/title-10/appendix-Appendix%20F%20to%20Subpart%20B%20of%20Part%20430.

—. 2023b. "Energy Conservation Program: Test Procedure for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps; Notice of proposed rulemaking and request for comment." May. Accessed November 2024. https://www.regulations.gov/document/EERE-2019-BT-TP-0027-0019.

—. 2022b. *Joint comment response to the published Notice of proposed rulemaking and request for comment.* August. Accessed November 2024. www.regulations.gov/comment/EERE-2020-BT-TP-0029-0020.

—. 2022a. *Using Home Energy Rebates to Support Market Transformation.* https://www.energy.gov/articles/biden-harris-administration-announces-state-and-tribe-allocations-home-energy-rebate.

EIA (United States Energy Information Administration). 2018. *Annual Energy Outlook 2018.* Washington, DC: U.S. Department of Energy.

EIA. 2022. "2020 RECS Survey Data." *Residential Energy Consumption Survey (RECS).* https://www.eia.gov/consumption/residential/data/2020/#squarefootage.

EIA. 2020. *Residential Energy Consumption Survey.* Washington, DC: EIA (U.S. Energy Information Administration).

ENERGY STAR. 2024. *Room Air Conditioner Heating Mode Performance Test Reporting Template.* July. Accessed November 2024. https://www.energystar.gov/sites/default/files/2024-08/ENERGY STAR Room Air

Conditioner Heating Mode Performance Test Reporting Template.xlsx.
—. 2024f. *Test Method to Determine Room Air Conditioner Heating Mode Performance.* July. Accessed November 2024. https://www.energystar.gov/sites/default/files/2024-07/ENERGY%20STAR%20Final%20Test%20Method%20to%20Determine%20Room%20Air%20Conditioner%20Heating%20Mode%20Performance.pdf.
ENERGY STAR. 2024a. *Clean Heat for All: A joint initiative by New York City Housing Authority (NYCHA), New York State Energy Research and Development Authority (NYSERDA), and New York Power Authority (NYPA).* New York City.
—. 2019. *ENERGY STAR Sales Associate Training Room Air Conditioners.* June. Accessed November 2024. www.energystar.gov/sites/default/files/asset/document/ENERGY_STAR_Room_AC_Training_2019.pdf.
—. n.d.a. *ENERGY STAR Version 5.0 Requirements for Room Air Conditioners.* Accessed November 2024. https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%205.0%20Room%20Air%20Conditioners%20Specification%20and%20Partner%20Commitments.pdf.
—. 2024e. "Products Partner Meeting." https://www.energystar.gov/sites/default/files/2024-10/Window%20of%20Opportunity%20Final%20Combined%20508C.pdf.
—. 2024d. "Program Requirements Product Specification for Room Air Conditioners." *Draft Final Test Method.* April. Accessed November 2024. https://www.energystar.gov/sites/default/files/2024-04/ENERGY%20STAR%20Final%20Draft%20Test%20Method%20to%20Determine%20Room%20Air%20Conditioner%20Heating%20Mode%20Performance.pdf.
—. 2023. "Program Requirements Product Specification for Room Air Conditioners." *Draft 1 Test Method.* December. Accessed November 2024. https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Draft%201%20Test%20Method%20to%20Determine%20Room%20Air%20Conditioner%20Heating%20Mode%20Performance.pdf.
—. 2024c. "Recognition Criteria Room Air Conditioners." Accessed November 2024. www.energystar.gov/sites/default/files/asset/document/Room%20Air%20Conditioner%20ENERGY%20STAR%20Most%20Efficient%202024%20Final%20Criteria.pdf?_gl=1*1fhnvu4*_ga*MjA2MzA4MjU1OS4xNjkwNDAwNTMy*_ga_S0KJTVVLQ6*MTcwMDY4MTkzMy42Ny4wLjE3MDA2ODE5MzMuMC4wLjA.
—. 2024b. *Room Air Conditioner Specification Version 5.* Accessed November 2024. https://www.energystar.gov/products/room_air_conditioner_specification_version_5_2.
—. n.d.b. "Test Method to Determine Room Air Conditioner Heating Mode Performance Draft 1 Stakeholder Comment Response Matrix." Accessed November 2024. https://www.energystar.gov/sites/default/files/2024-03/ENERGY%20STAR%20Draft%201%20Test%20Method%20to%20Determine%20Room%20Air%20Conditioner%20Heating%20Mode%20Performance%20Comment%20Response%20Matrix%20%281%29.pdf.
Midea. 2024. *Midea Showcases Heat Pump Innovation at 2024.* Press Release, Midea.
2023. *New York State Power Authority.* Accessed November 2024. www.nypa.gov/news/press-releases/2023/20230920-heat.

Newsom, Gavin. 2022. "Office of the Governor." July 22. www.gov.ca.gov/wp-content/uploads/2022/07/07.22.2022-Governors-Letter-to-CARB.pdf.

Office of Air and Radiation. 2024. "Final Recognition Letter for ENERGY STAR Most Efficient 2025." September. Accessed November 2024. https://www.energystar.gov/sites/default/files/2024-09/ENERGY%20STAR%20Most%20Efficient%202025%20Final%20Criteria.pdf.

n.d. *Regulations.gov.* www.regulations.gov/comment/EERE-2020-BT-TP-0029-0020.

TECH Clean California. 2023. *Creating pathways to achieve California's decarbonization goals.* techcleanca.com.

—. 2024. *Public Data.* May. techcleanca.com/public-data/.

The White House. 2021. *FACT SHEET: President Biden Takes Executive Actions to Tackle the Climate Crisis at Home and Abroad, Create Jobs, and Restore Scientific Integrity Across Federal Government.* January 27. https://www.whitehouse.gov/briefing-room/statements-releases/2021/01/27/fact-sheet-president-biden-takes-executive-actions-to-tackle-the-climate-crisis-at-home-and-abroad-create-jobs-and-restore-scientific-integrity-across-federal-government/.

—. 2023. *Justice40.* https://www.whitehouse.gov/environmentaljustice/justice40/.

Treasury, U.S. Department of the. 2024. *Coordinating DOE Home Energy Rebates with Energy-Efficient Home Improvement Tax Credits: An Explainer.* July. Accessed November 2024. https://home.treasury.gov/news/featured-stories/coordinating-doe-home-energy-rebates-with-energy-efficient-home-improvement-tax-credits-an-explainer#_ftn6.

U.S. Energy Information Administration. 2022. "2018 Commercial Buildings Energy Consumption Survey, Consumption and Expenditures Highlights." *COMMERCIAL BUILDINGS ENERGY CONSUMPTION SURVEY (CBECS).* December. Accessed April 6, 2023. https://www.eia.gov/consumption/commercial/data/2018/pdf/CBECS%202018%20CE%20Release%202%20Flipbook.pdf.

—. 2020b. "2020 RECS Survey Data." Accessed November 2024. https://www.eia.gov/consumption/residential/data/2020/index.php?view=microdata.

U.S. Energy Information Administration. 2020a. *Residential Energy Consumption Survey.* Survey Data Results, Washington, DC: EIA.

UCLA Luskin Center for Innovation. 2019. "Move to All-electric Buildings will Trigger Significant Demand for Skilled Workers." *UCLA Luskin Center for Innovation.* November 13. https://innovation.luskin.ucla.edu/2019/11/13/move-to-all-electric-buildings-will-trigger-significant-demand-for-skilled-workers/.

Appendix A: Details of Energy Modeling

The CalNEXT project team evaluated the energy modeling approaches undertaken by DOE and EPA on room heat pumps to yield heating fractional bin hours (ENERGY STAR 2023).[12] The load line and fractional bin hours were developed by analyzing a 50–50 weighted combination of national building load data for mid-rise apartments and single family homes, assuming no oversizing for the average cooling load at 95°F and that heating load equal to the typical 95°F cooling load occurs at -15°F. (ENERGY STAR 2024).

The project team assumed most installations would be in the following building types, per the available rulesets in the 2025 Research Version of the California Building Energy Code Compliance (CBECC) software: one-story single family, two-story single family, small single family, single family existing building, multifamily low-rise garden, multifamily loaded corridor, multifamily mid-rise mixed use, and multifamily high-rise mixed use.[13]

Given that DOE and EPA deemed mid-rise apartments and single family prototypes appropriate for the development of a new heating metric for MHPs, the project team also considered these prototype buildings for the cooling metric while running an exercise to validate the heating fractional bin hours in the ENERGY STAR Final Test Method. Prior efforts initiated by AHAM on room air conditioner hours of operation in cooling mode have resulted in the current federal test procedure assuming an annual operation of 750 hours for active cooling mode, and 5,115 hours for total inactive mode and off mode (or 2,557.5 hours for each mode).[14] The project team's modeling efforts took this background information into consideration.

The project team used the following modeling process for the mid-rise apartment prototype:

1. **Prototype Building Model:** The project team used the 2004 Mid-rise Apartment Prototype building model relied upon for the development of ANSI/ASHRAE/IES Standard 90.1 (Building Energy Codes Program n.d.).[15]
2. **Setpoint Modifications**: The cooling and heating setpoints were set at 72°F in lieu of default values of 70°F for heating and 75°F for cooling. The unoccupied thermostat setpoints were left unchanged from their default values, which are 60°F (heating) and 85°F (cooling), however, only occupied zones were accounted for in the results. The project team based these assumptions on extensive discussions within a standards technical committee proceeding led by AHRI, its member companies, and other non-industry stakeholders such as the California IOUs.

---

[12] See notes on pages 16 and 17.

[13] Residential HVAC Performance Final Codes and Standards Enhancement Initiative Report; 2025 California Energy Code; See Table 22.

[14] Per Appendix B of ANSI/AHAM RAC-1-2015, AHAM initiated a project in 1974 to determine the annual hours of operation for room air conditioners and investigated all factors influencing room air conditioner operation while basing calculations on field-verified test data.

[15] See Table 1.

3. **Simulations:** The simulations were run in EnergyPlus v22.1, and the following output variables were recorded in hourly increments:
    a. Site Outdoor Air Dry Bulb Temperature (°F)
    b. Site Outdoor Air Wet Bulb Temperature (°F)
    c. Site Outdoor Air Relative Humidity (%)
    d. Site Wind Speed (m/s)
    e. Zone Mean Air Temperature (°F)
    f. Cooling Coil Total Cooling Rate (W)
    g. Cooling Coil Sensible Cooling Rate (W)
    h. Cooling Coil Latent Cooling Rate (W)
    i. Heating Coil Heating Rate (W)
4. **Climate Zones (CZ):** Table 13 summarizes the representative cities for each of the U.S. ANSI/ASHRAE/IES Standard 90.1 and International Energy Conservation Code (IECC) thermal zones, thermal CZ names, representative cities, and the corresponding California CZ where applicable. The project team relied upon 2007 to 2021 typical meteorological year (TMYx) weather files (Climate One Building n.d.).

Table 13: IECC and ANSI/ASHRAE/IES Standard 90.1 Thermal Climate Zones and Corresponding California Climate Zones with Representative Cities

IECC and ANSI/ASHRAE/IES Standard 90.1 Thermal Zone	Thermal Climate Zone	Thermal Climate Location	Corresponding California Climate Zone (if applicable) and Representative City
1A	Very Hot Humid	Miami International Airport, Florida	
2A	Hot Humid	Tampa/MacDill AFB, Florida	
2B	Hot Dry	Tucson/Davis-Monthan AFB, Arizona	Climate Zone 15 (Palm Springs International Airport)
3A	Warm Humid	Atlanta/Hartsfield Jackson International Airport, Georgia	
3B	Warm Dry	El Paso International Airport, Texas	Climate Zones 7 (San Diego International Airport), 8 (Fullerton Municipal Airport), 9 (Hollywood Burbank Airport), 10 (Riverside Municipal Airport), 11 (Red Bluff Airport), 12 (Sacramento Executive Airport), and 13 (Fresno Yosemite International Airport)
3C	Warm Marine	San Diego/Brown Field Municipal Airport, California	Climate Zones 2 (Sonoma County Airport), 3 (Metro Oakland International Airport), 4 (Paso Robles Airport), 5 (Santa Maria Airport), and 6 (Los Angeles International Airport)
4A	Mixed Humid	New York/John F Kennedy International Airport, New York	
4B	Mixed Dry	Albuquerque International Sunport, New Mexico	Climate Zones 14 (Palmdale Regional Airport) and 16 (Blue Canyon Nyack Airport)
4C	Mixed Marine	Seattle-Tacoma International Airport, Washington	Climate Zone 1 (Arcata Airport)

IECC and ANSI/ASHRAE/IES Standard 90.1 Thermal Zone	Thermal Climate Zone	Thermal Climate Location	Corresponding California Climate Zone (if applicable) and Representative City
5A	Cool Humid	Buffalo Niagara International Airport, New York	
5B	Cool Dry	Denver/Aurora/Buckley AFB, Colorado	Climate Zone 16 (Blue Canyon-Nyack Airport)
5C	Cool Marine	Port Angeles/William R Fairchild International Airport, Washington	
6A	Cold Humid	Rochester International Airport, Minnesota	
6B	Cold Dry	Great Falls International Airport, Montana	Climate Zone 16 (Blue Canyon-Nyack Airport)
7	Very Cold	International Falls International Airport, Minnesota	
8	Subarctic/Arctic	Fairbanks International Airport, Alaska	

Source: Corresponding California Climate Zone (if applicable) and Representative City found at (California Energy Commission 2024)

The project team relied upon the cooling fractional bin hours set forth in Appendix M of the federal test procedure for central air conditioners and heat pumps (DOE 2023c). Table 14 summarizes the cooling fractional bin hours in California-based CZ relative to the U.S. national average cooling fractional bin hours set forth in Appendix M1. The cooling fractional bin hours do not add up to 100 percent for all thermal CZ since the project team patterned the analytical approach on the approach previously taken by DOE and only considered cooling loads at temperatures greater than or equal to 65°F. However, regional variations can have an impact on a product's applied cooling seasonal efficiency. For instance, the seasonal cooling performance of a product installed in a Warm Marine thermal CZ could be better than its rating based on the national average cooling fractional bin hours since most of the bin hours fall into in the milder bin temperature ranges.

Table 14: Cooling Fractional Bin Hours in California-Based Climate Zones Relative to DOE Appendix M1 for Multifamily Prototypes

Bin Temperature Range (°F)	DOE Appendix M1 Region IV	Hot Dry	Warm Dry	Warm Marine	Mixed Dry	Mixed Marine	Cool Dry	Cold Dry
65–69	0.214	0.056	0.065	0.304	0.113	0.191	0.142	0.150
70–74	0.231	0.099	0.112	0.271	0.164	0.150	0.163	0.153
75–79	0.216	0.148	0.159	0.137	0.163	0.135	0.141	0.152
80–84	0.161	0.157	0.188	0.036	0.166	0.100	0.151	0.124
85–89	0.104	0.158	0.162	0.003	0.135	0.050	0.115	0.110
90–94	0.052	0.141	0.133	0	0.067	0.012	0.046	0.036
95–99	0.018	0.127	0.067	0	0.031	0	0.003	0.008
100–104	0.004	0.063	0.017	0	0.001	0	0	0

Figure 4 displays the percentage of cooling energy consumption in mid-rise apartment prototype buildings for each thermal CZ listed in Table 14. It is worth noting that 0.3 percent of the total cooling load for Hot Dry thermal CZ is between 105°F and 109°F, a bin temperature range that is not accounted for in the seasonal cooling efficiency metric calculation in Appendix M1.

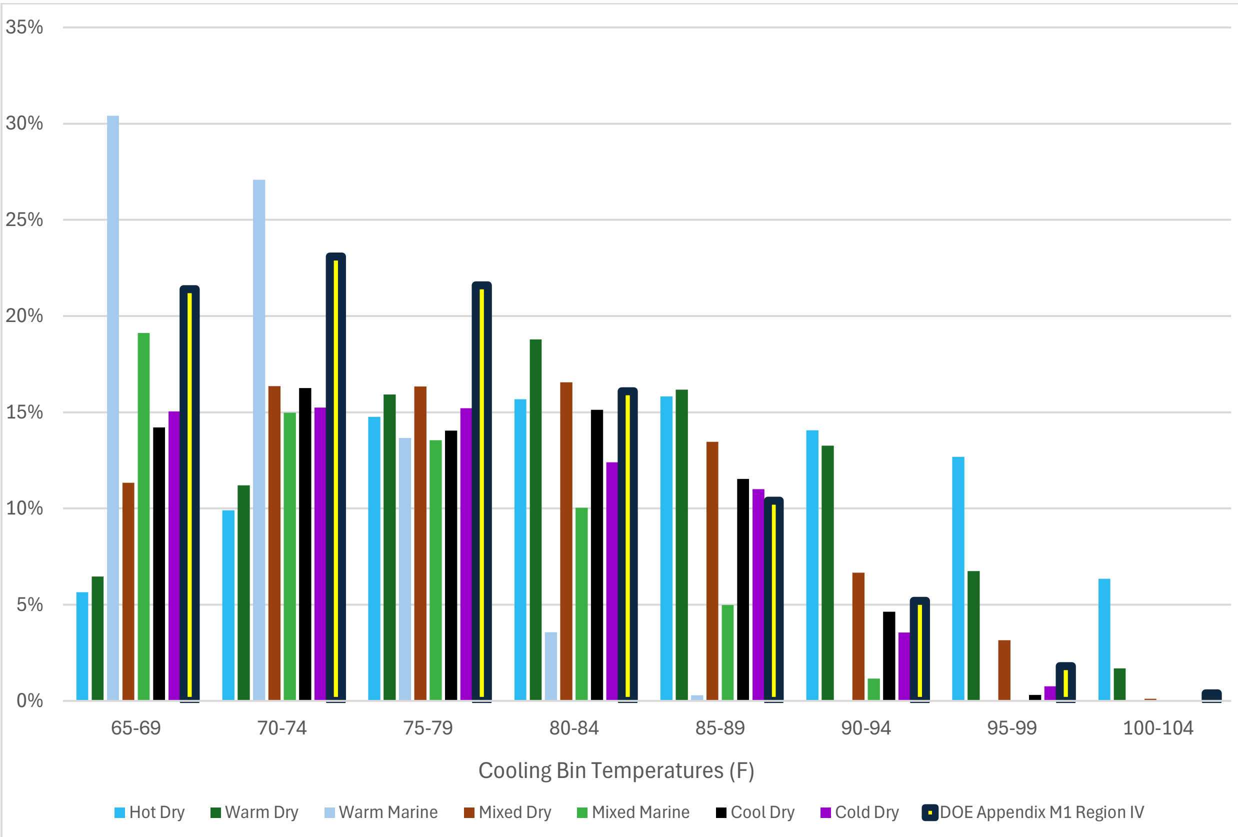


Figure 4: Percentage of cooling energy consumption across bin temperature ranges in various thermal climate zones for multifamily prototypes.

Table 15 summarizes the heating fractional bin hours in California-based CZs compared to the U.S. national average heating fractional bin hours set forth in Appendix M1 for central heat pumps, and the heating fractional bin hours for room heat pumps within ENERGY STAR Final Test Method. The heating fractional bin hours do not add up to 100 percent for all thermal CZs since the project team patterned the analytical approach around the approaches taken by DOE and EPA, and considered heating loads only at temperatures less than or equal to 64°F. In addition, all of the heating fractional bin hour results for California-based CZs incorporated temperature bin adjustments using the California climate files referenced during the 2025 rulemaking proceedings on California's Building Standards (Title 24, Parts 1 and 6). These climate files indicate an insignificant percentage of heating fractional bin hours below the 20–24°F range. Consequently, the CalNEXT MHP project team truncated the bin percentages at temperatures below 20°F from the EnergyPlus results. This truncation made the heating fractional bin hour results more representative of California's CZs.

Table 15: Heating Fractional Bin Hours in California-Based Climate Zones Relative to DOE's Appendix M1 and EPA's ENERGY STAR Final Test Method on Room Heat Pumps for Multifamily Prototypes

Bin Temperature Range (°F)	DOE Appendix M1	ENERGY STAR Final Test Method	Hot Dry	Warm Dry	Warm Marine	Mixed Dry	Mixed Marine	Cool Dry	Cold Dry
60–64	0	0.017	0.025	0.012	0.089	0.004	0.004	0.003	0.002
55–59	0	0.044	0.067	0.031	0.285	0.014	0.024	0.008	0.006
50–54	0.103	0.077	0.188	0.079	0.448	0.035	0.105	0.025	0.026
45–49	0.093	0.136	0.224	0.130	0.169	0.077	0.203	0.046	0.060
40–44	0.100	0.181	0.226	0.253	0.008	0.126	0.281	0.085	0.101
35–39	0.109	0.177	0.202	0.296	0	0.229	0.207	0.175	0.182
30–34	0.126	0.133	0.045	0.129	0	0.285	0.105	0.180	0.148
25–29	0.087	0.081	0.020	0.046	0	0.122	0.038	0.114	0.106
20–24	0.055	0.062	0.001	0.018	0	0.066	0.033	0.114	0.123

Figure 5 displays the percentage of heating energy consumption in mid-rise apartment prototype buildings for each thermal CZ listed in Table 15. Some CZs demonstrated a small but measurable heating load within the 65–69°F bin temperature range although that bin temperature range is typically associated with cooling loads. In comparison, Table 15 confirms that the 20–24°F bin temperature range is the lowest at which any heating energy consumption occurs in a California-based CZ, so if they ever become commercially-available, Type 2 MHPs should be able to adequately address the heating needs of all consumers based in California.

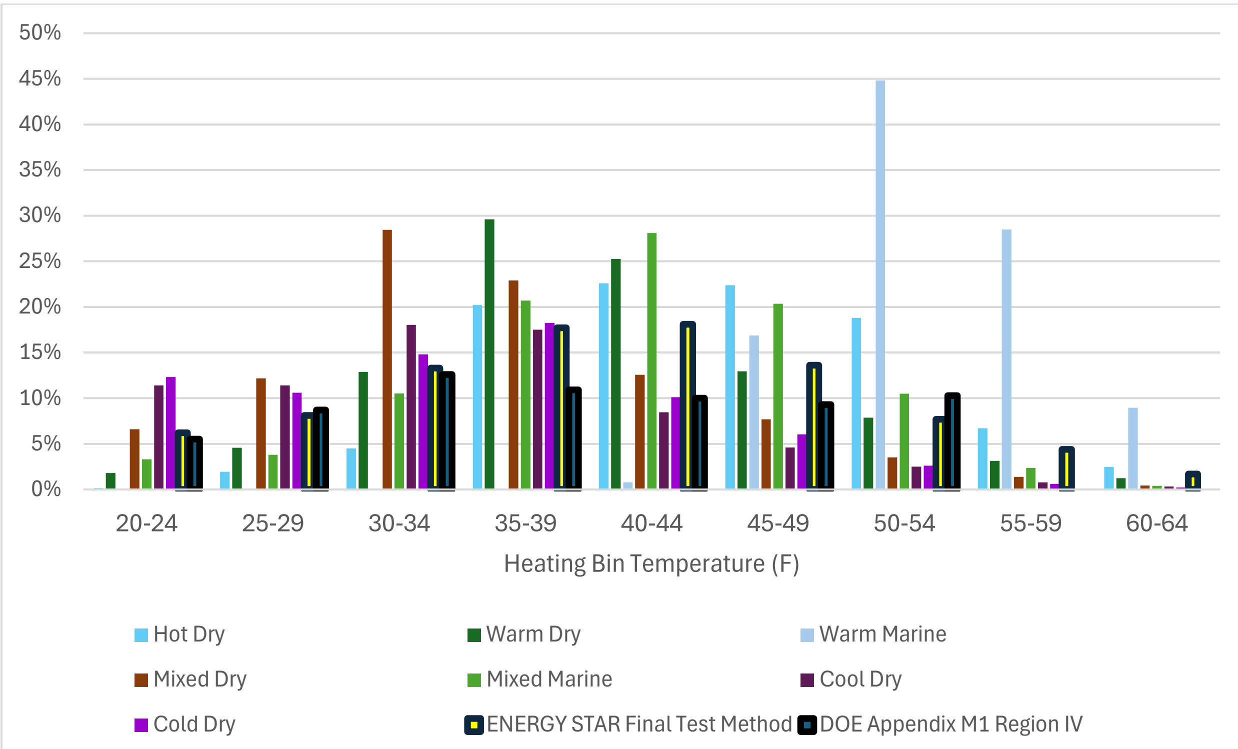


Figure 5: Percentage of heating energy consumption across bin temperature ranges in various thermal climate zones for multifamily prototypes.

The project team used the following modeling process for the single family prototypes:

1. **Prototype Building Model:** The project team used the Pacific Northwest National Laboratory (PNNL) 2009 Single Family Detached House Prototype for the development of IECC 2009 standard (Building Energy Codes Program n.d.).[16]
2. **Setpoint Modifications**: The cooling setpoint was set to 75°F and heating setpoint to 72°F in lieu of default values of 75°F for cooling and 72°F for heating. The project team based these assumptions on the inputs provided by PNNL for their version 2 simulations used on August 2, 2023.
3. **Foundation Type:** The foundation type for single family prototypes was dependent upon the climate zone. For single family prototypes in CZs 1-4A, slab was modeled. For single family prototypes in CZs 4B-8, heated basement was modeled.[17]
4. **Oversize factor of heat pump:** A factor of two was used for this input in all single family prototype models.[18]
5. **Continuous Ventilation:** There was no continuous ventilation operation in all single family prototype models.[19]
6. **Duct Losses:** Duct losses were eliminated in all single family prototype models.[20]
7. **Simulations**: The simulations were run in EnergyPlus v9.5, and the following output variables were recorded in hourly increments:
    a. Site Outdoor Air Dry Bulb Temperature (°F)
    b. Site Outdoor Air Wet Bulb Temperature (°F)
    c. Site Outdoor Air Relative Humidity (%)
    d. Site Wind Speed (m/s)
    e. Zone Mean Air Temperature (°F)
    f. Cooling Coil Total Cooling Rate (W)
    g. Cooling Coil Sensible Cooling Rate (W)

---

[16] See Table 4.

[17] PNNL Assumptions listed in a private DOE stakeholder conversation titled, “Central Air Conditioners and Heat Pumps” PowerPoint presentation on August 8-9, 2023.

[18] PNNL Assumptions listed in a private DOE stakeholder conversation titled, “Central Air Conditioners and Heat Pumps” PowerPoint presentation on August 8-9, 2023.

[19] PNNL Assumptions listed in a private DOE stakeholder conversation titled, “Central Air Conditioners and Heat Pumps” PowerPoint presentation on August 8-9, 2023.

[20] PNNL Assumptions listed in a private DOE stakeholder conversation titled, “Central Air Conditioners and Heat Pumps” PowerPoint presentation on August 8-9, 2023.

h. Cooling Coil Latent Cooling Rate (W)

i. Heating Coil Heating Rate (W)

8. **Climate Zones (CZ):** The same representative cities for each of the U.S. ANSI/ASHRAE/IES Standard 90.1 and IECC thermal zones were also used for this analysis, that includes thermal CZ names, representative cities, and the corresponding California CZ where applicable as listed in Table 13 above. The project team relied upon 2007 to 2021 typical meteorological year (TMYx) weather files (Climate One Building n.d.).

The project team relied upon the cooling fractional bin hours set forth in Appendix M of the federal test procedure for central air conditioners and heat pumps (DOE 2023c). Table 16 summarizes the cooling fractional bin hours in California-based CZ relative to the U.S. national average cooling fractional bin hours set forth in Appendix M1. The cooling fractional bin hours do not add up to 100 percent for all thermal CZ since the project team patterned the analytical approach on the approach previously taken by DOE, and considered cooling loads at temperatures only greater than or equal to 65°F. However, regional variations can have an impact on a product's applied cooling seasonal efficiency. For instance, the seasonal cooling performance of a product installed in a Warm Marine thermal CZ could be better than its rating based on the national average cooling fractional bin hours since most of the bin hours are comprised in the milder bin temperature ranges.

Table 16: Cooling Fractional Bin Hours in California-Based Climate Zones Relative to Appendix M1 for Single Family Prototypes

Bin Temperature Range (°F)	DOE Appendix M1 Region IV	Hot Dry	Warm Dry	Warm Marine	Mixed Dry	Mixed Marine	Cool Dry	Cold Dry
65–69	0.214	0.024	0.022	0.238	0.048	0.171	0.095	0.046
70–74	0.231	0.062	0.061	0.371	0.138	0.208	0.168	0.112
75–79	0.216	0.120	0.138	0.246	0.192	0.235	0.178	0.164
80–84	0.161	0.152	0.214	0.071	0.230	0.184	0.232	0.210
85–89	0.104	0.181	0.218	0.006	0.204	0.095	0.196	0.192
90–94	0.052	0.181	0.213	0.001	0.117	0.023	0.080	0.184
95–99	0.018	0.173	0.092	0	0.051	0	0.006	0.070
100–104	0.004	0.092	0.028	0	0.002	0	0	0.010

Figure 6 displays the percentage of cooling energy consumption in single family prototype buildings for each thermal CZ listed in Table 16. It is noted that 0.6 percent of the total cooling load for Hot Dry thermal CZ is between 105°F and 109°F, a bin temperature range that is not accounted for in the seasonal cooling efficiency metric calculation in Appendix M1.

Compared to multifamily prototypes, single family prototypes have fewer cooling fractional bin hours in the 65–70°F range. However, this trend gradually reverses and in the 85–90°F-and-above temperature ranges, single family prototypes have larger cooling fractional bin hours. This suggests that single family homes may require more cooling at higher temperatures relative to multifamily cooling needs. This can be due to the building design and layout, as single family homes do not have shared wall space, leading to greater exposure to outdoor temperatures. Single family homes also typically have higher air leakage, which leads to higher cooling demands in warmer temperatures.

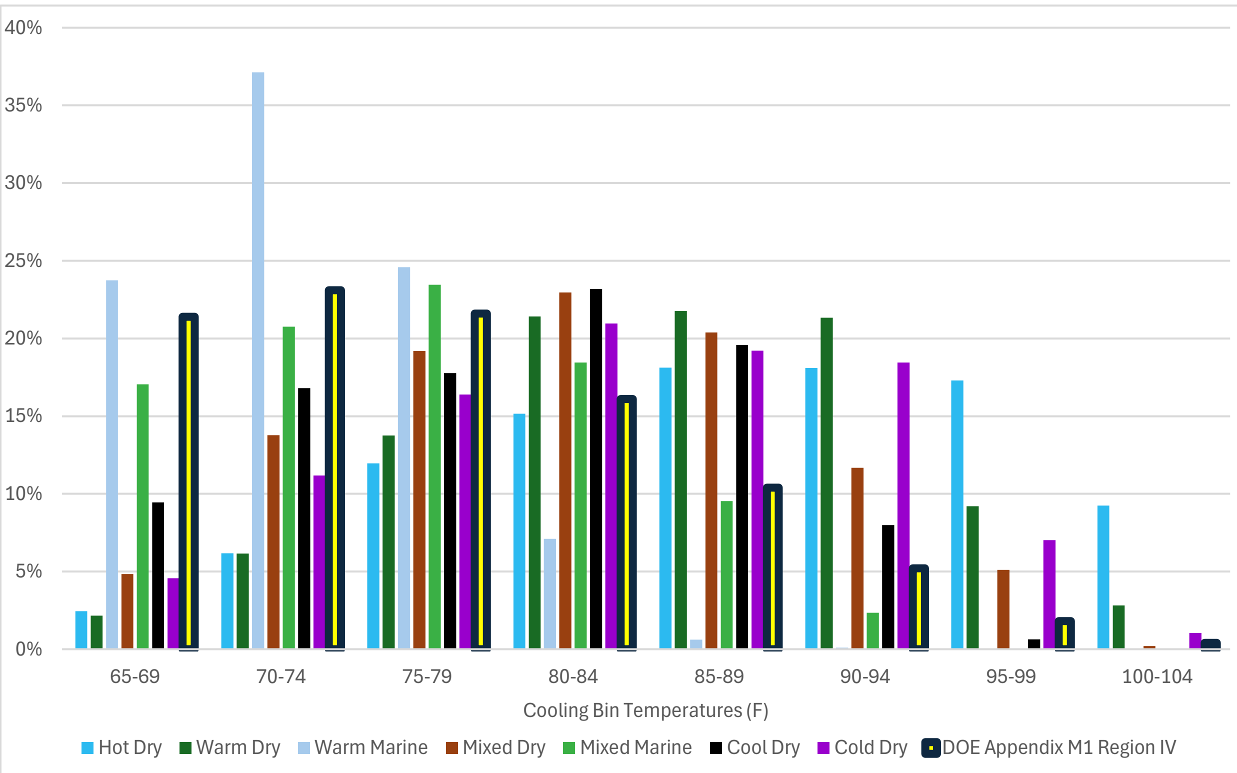


Figure 6: Percentage of cooling energy consumption across bin temperature ranges in various thermal climate zones for single family prototypes.

Table 17 summarizes the heating fractional bin hours in California-based CZ relative to the U.S. national average heating fractional bin hours set forth in Appendix M1 for central heat pumps, and the heating fractional bin hours for room heat pumps within EPA's ENERGY STAR Final Test Method issued in July 2024. The heating fractional bin hours do not add up to 100 percent for all thermal CZ since the project team patterned the analytical approach around the approaches taken by DOE and EPA, and considered heating loads at temperatures only less than or equal to 64°F or greater than 20°F.

Table 17: Heating Fractional Bin Hours in California-Based Climate Zones Relative to Appendix M1 and EPA's ENERGY STAR Final Test Method on Room Heat Pumps for Single Family Prototypes

Bin Temperature Range (°F)	DOE Appendix M1 Region IV	ENERGY STAR Final Test Method	Hot Dry	Warm Dry	Warm Marine	Mixed Dry	Mixed Marine	Cool Dry	Cold Dry
60–64	0	0.017	0.016	0.006	0.070	0	0.001	0	0
55–59	0	0.044	0.069	0.036	0.338	0.009	0.020	0.003	0.004
50–54	0.103	0.077	0.202	0.080	0.405	0.026	0.094	0.015	0.021
45–49	0.093	0.136	0.233	0.155	0.181	0.078	0.225	0.041	0.061
40–44	0.100	0.181	0.222	0.256	0.006	0.126	0.282	0.082	0.097
35–39	0.109	0.177	0.192	0.283	0	0.240	0.210	0.176	0.180
30–34	0.126	0.133	0.042	0.120	0	0.295	0.101	0.181	0.144
25–29	0.087	0.081	0.019	0.041	0	0.121	0.036	0.116	0.103
20–24	0.055	0.062	0.001	0.018	0	0.063	0.032	0.118	0.118

Figure 7 displays the percentage of heating energy consumption in single family apartment prototype buildings for each thermal climate zone listed in Table 17. Some climate zones demonstrated a small but measurable heating load within the 65–69°F bin temperature range although that bin temperature range is typically associated with cooling loads.

Table 17 confirms that the 20–24°F bin temperature range is the lowest at which any heating energy consumption occurs in a California-based climate zones, so commercially available Type 2 MHPs should be able to adequately address the heating needs of consumers based in California.

Compared to single family prototypes, multifamily prototypes have larger heating fractional bin hours in the 60–64°F range. However, as temperatures decrease, single family prototypes generally have larger heating fractional bin hours. This suggests that single family homes may require more heating at lower temperatures relative to multifamily heating needs. This can be due to the building design and layout, as multifamily units often share walls with adjacent units, which helps reduce heat loss, leading to lower heating needs in the 60–64°F range. Multifamily units typically also have higher occupancy density, resulting in more heat generated from occupants, appliances, and lighting, which can reduce heating needs in milder temperatures.

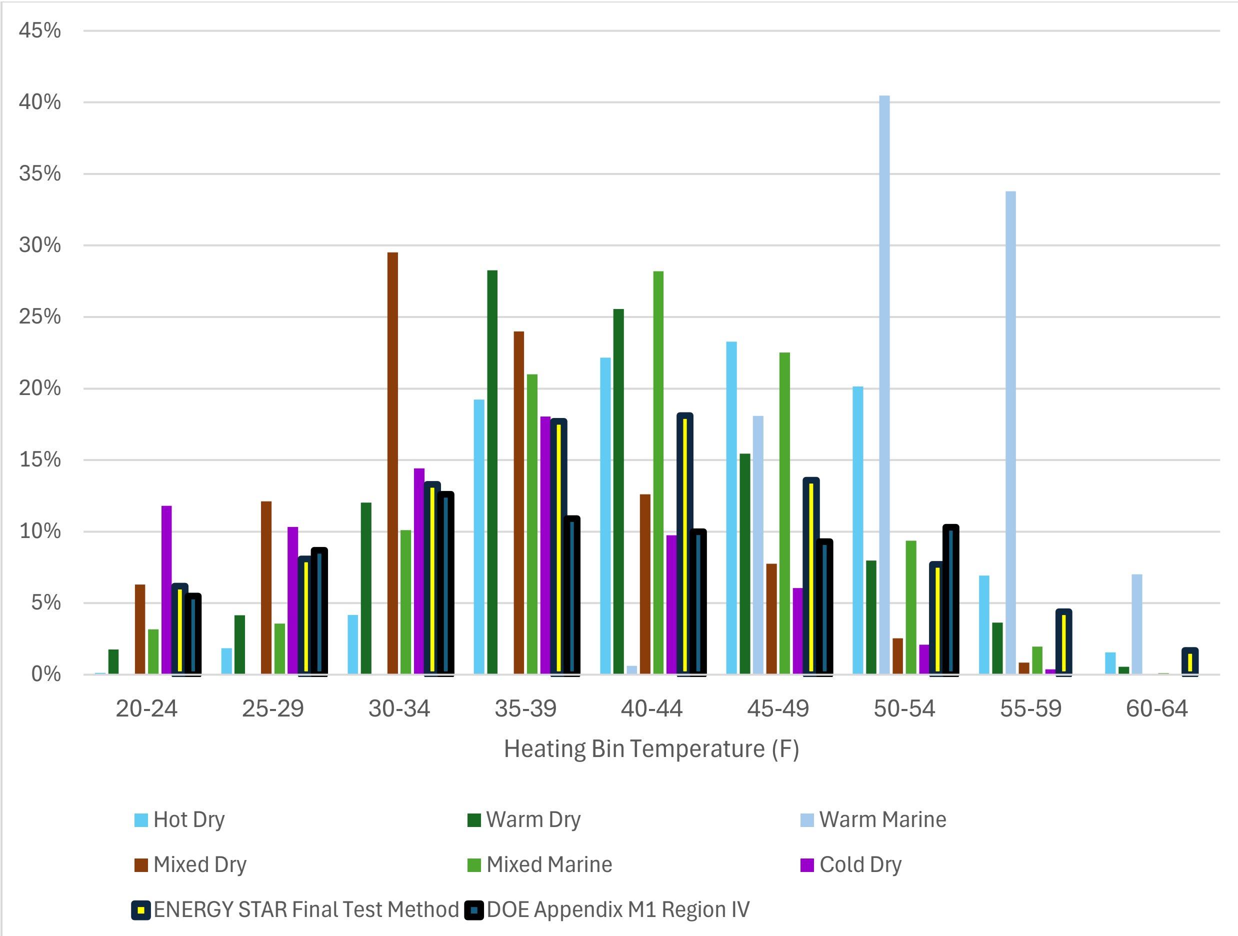


Figure 7: Percentage of heating energy consumption across bin temperature ranges in various thermal climate zones for single family prototypes.

The 50–50 weighted combination of energy modeling load data for mid-rise apartments and single family prototypes are shown below in Table 18 and Figure 8 for cooling relative to Appendix M1 and Table 19 and Figure 9 for heating relative to Appendix M1 and EPA's ENERGY STAR Final Test Method on Room Heat Pumps.

Table 18: 50–50 Weightings of Multifamily and Single Family Prototypes for Cooling Fractional Bin Hours in California-Based Climate Zones Relative to Appendix M1

Bin Temperature Range (°F)	DOE Appendix M1 Region IV	Hot Dry	Warm Dry	Warm Marine	Mixed Dry	Mixed Marine	Cool Dry	Cold Dry
65–69	0.214	0.040	0.044	0.271	0.081	0.181	0.119	0.098
70–74	0.231	0.081	0.087	0.321	0.151	0.179	0.166	0.133
75–79	0.216	0.134	0.149	0.192	0.178	0.185	0.160	0.158
80–84	0.161	0.155	0.201	0.054	0.198	0.142	0.192	0.167
85–89	0.104	0.170	0.190	0.005	0.170	0.073	0.156	0.151
90–94	0.052	0.161	0.173	0.001	0.092	0.018	0.063	0.110
95–99	0.018	0.150	0.080	0	0.041	0	0.005	0.039
100–104	0.004	0.078	0.023	0	0.002	0	0	0.005

The cooling fractional bin hours do not add up to 100 percent for all thermal climate zones since the project team patterned the analytical approach on the approach previously taken by DOE, and considered cooling loads at temperatures only greater than or equal to 65°F. However, regional variations can have an impact on a product's applied cooling seasonal efficiency. For instance, the seasonal cooling performance of a product installed in a Warm Marine thermal CZ could be better than its rating based on the national average cooling fractional bin hours since most of the bin hours are in the milder bin temperature ranges (65–69°F, 70–74°F, and 75–79°F).

Figure 8 displays the percentage of cooling energy consumption in both single family (50 percent) and multifamily (50 percent) prototype buildings for each thermal CZ listed in Table 18.

California's population-dominant climate zones are the Warm Dry and Warm Marine climate zones. In the 65–69°F bin, the weighting for warm marine CZ (0.271) is higher than that of DOE Appendix M1 (0.214), while Warm Dry CZ (0.0435) is lower than DOE Appendix M1. For the 70-74°F bin, Warm Marine also has a higher weighting (0.321) compared to DOE Appendix M1 (0.231), while Warm Dry (0.0865) remains lower. This highlights that Warm Marine has a greater cooling fractional weight than DOE Appendix M1 in the lower temperature bins, indicating a greater need for cooling in this temperature range in the Warm Marine climate.

In the moderate temperature bins (75–79°F and 80–84°F), Warm Dry has slightly lower values than DOE Appendix M1 in the 75–79° F range but is higher in the 80–84° F range, suggesting a shift where more cooling is needed in slightly warmer temperatures. Warm Marine consistently has lower values than DOE Appendix M1 in these bins, indicating less demand for cooling in moderate temperatures compared to DOE Appendix M1.

For the higher temperature bins (85°F and above), Warm Dry consistently has higher values than DOE Appendix M1, indicating a greater need for cooling as temperatures increase in this climate. Warm Marine, on the other hand, has substantially lower values or even zero values in these bins, showing that cooling needs are minimal at high temperatures in the Warm Marine climate as the temperatures rarely reach this high.

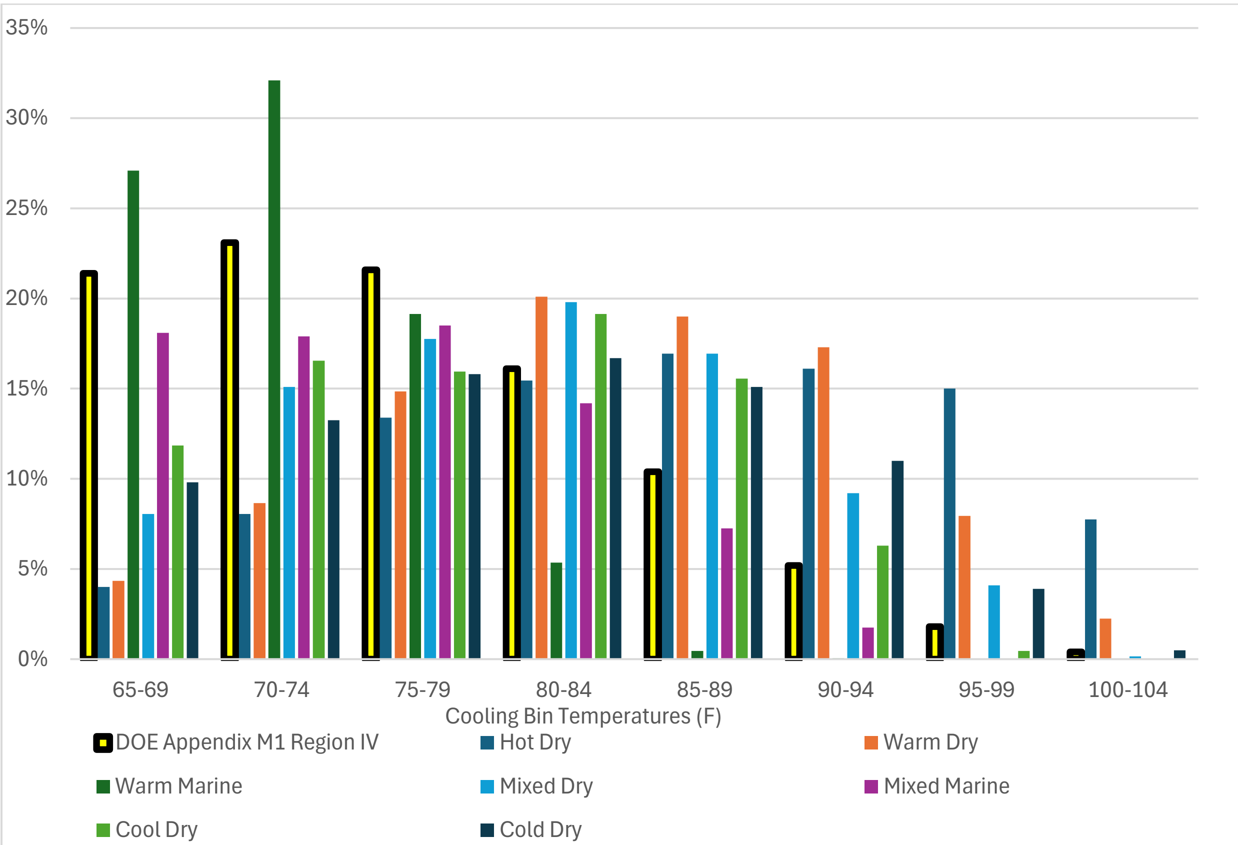


Figure 8: Percentage of cooling energy consumption across bin temperature ranges in various thermal climate zones for single family (50 percent) and multifamily (50 percent) prototypes.

Table 19: 50–50 Weightings of Multifamily and Single Family Prototypes for Heating Fractional Bin Hours in California-Based Climate Zones Relative to Appendix M1 and EPA's ENERGY STAR Final Test Method on Room Heat Pumps

Bin Temperature Range (°F)	DOE Appendix M1 Region IV	ENERGY STAR Final Test Method	Hot Dry	Warm Dry	Warm Marine	Mixed Dry	Mixed Marine	Cool Dry	Cold Dry
60–64	0	0.017	0.021	0.009	0.080	0.002	0.003	0.002	0.001
55–59	0	0.044	0.068	0.034	0.312	0.012	0.022	0.006	0.005
50–54	0.103	0.077	0.195	0.080	0.427	0.031	0.100	0.020	0.024
45–49	0.093	0.136	0.229	0.143	0.175	0.078	0.214	0.044	0.061
40–44	0.100	0.181	0.224	0.255	0.007	0.126	0.282	0.084	0.099
35–39	0.109	0.177	0.197	0.290	0	0.235	0.209	0.176	0.181
30–34	0.126	0.133	0.044	0.125	0	0.290	0.103	0.181	0.146
25–29	0.087	0.081	0.020	0.044	0	0.122	0.037	0.115	0.105
20–24	0.055	0.062	0.001	0.018	0	0.065	0.033	0.116	0.121

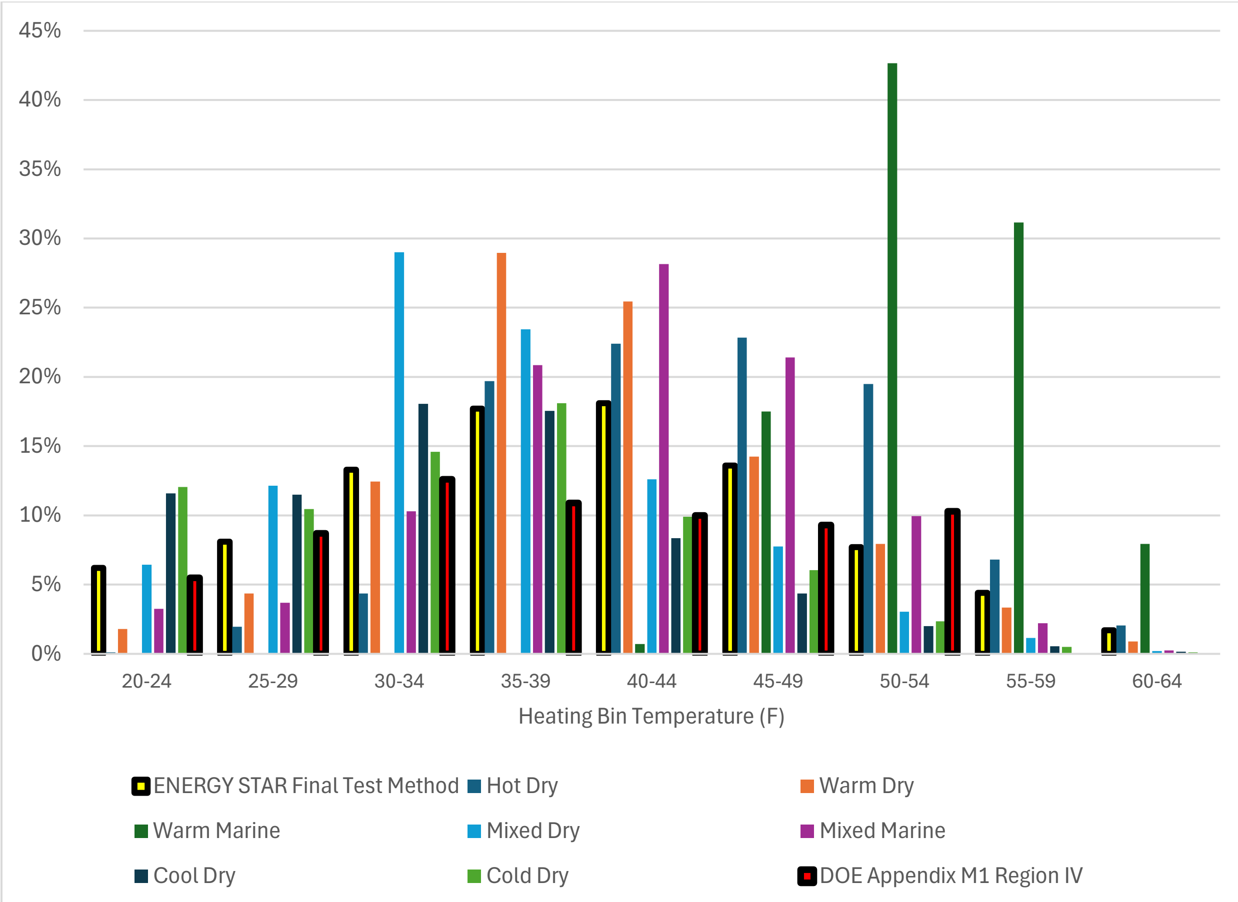


Figure 9: Percentage of heating energy consumption across bin temperature ranges in various thermal climate zones for single family (50 percent) and multifamily (50 percent) prototypes.

Generally, the Warm Dry CZ has lower or comparable heating fractional bin hours to the ENERGY STAR Final Test Method across most temperature bins, with some higher values in the mid-temperature bin ranges (40–44°F and 35–39°F). For higher and mid-temperatures bin ranges, Warm Marine shows consistently higher weightings compared to ENERGY STAR, especially in the 50–54°F range, indicating significantly higher heating needs. However, as temperatures drop (34°F and below), Warm Marine has minimal or zero weightings, suggesting no cooling demand in lower temperatures, in contrast with some minimal values in ENERGY STAR. Warm Dry generally requires cooling in line with or slightly below ENERGY STAR'S values, while Warm Marine has higher cooling needs in warmer temperatures but aligns with ENERGY STAR or requires less cooling as temperatures decrease.

Appendix B: Summary of Currently Offered IOU Incentives in California

The incentives offered by various California IOUs are summarized below:

- 2022 CEE Residential Appliances Program Summary.
- Out of the various CA IOUs (e.g., LADWP, PG&E, SMUD, SolCalGas and SCE) operating in California, only LADWP offers $50 online or mail-in rebate for room air conditioners."
- Database for Incentives and Joint Marketing Exchange (DIME).
- Golden State Rebates offers mail-in rebates of $15 on the purchase and installation of select room air conditioning during 09/26/2022 through 12/31/2024.
- Electrify Marin — This program offers rebates of up to $500 (and income-qualified rebate of $2,000) to single family property owners for the replacement of natural gas appliances with efficient all-electric heat pump space heater.
- BayRen — Implements energy savings programs on a regional level in collaboration with the nine bay area counties. They offer up to $200 as incentives to replace gas furnace and air conditioner system with high efficiency heat pump meeting their efficiency criteria for single family homes, multifamily homes, and small/medium businesses.
- Alameda Municipal Power — The program offers incentives of up to $1,500 for complete replacement of gas furnace equipment with a heat pump HVAC system. New construction is not eligible
- Silicon Valley Clean Energy — SCVE offers up to $2,500 as rebates for single family homes, accessory dwelling units (ADUs), and multifamily homes (four dwelling units or fewer) for gas furnace replacement with a heat pump HVAC system.
- Peninsula Clean Energy — PCE offers up to $2,500 incentives to residents of San Mateo County or the City of Los Banos for the substitution of gas-heating units with qualifying heat pump HVAC systems. They collaborate with the BayRen program to maximize customer incentives.
- Truckee Donner PUD — TD PUD provides rebates for AHRI certified Heat Pumps replacing electric heat, gas backup or replacing gas finance from $200 per ton to $800 per ton to its residential customers.
- Roseville Electric Utility — REU provides incentives of up to $600/ton from gas equipment replacement with heat pumps.
- DSIRE Database — As already stated earlier, the DSIRE database mentions numerous other such rebates being offered by its constituents in California, however, most of them relate to either mini splits or ducted or ductless central air systems, but none specifically state MHP.
- Additional California incentives
    - Imperial Irrigation District (IID) – Incentives vary from $150 per ductless mini-split system and $400 for gas to electric conversion; and $100/unit to a qualifying ENERGY STAR Room Air Conditioner
    - Lassen Municipal Utility District: $100–125/ton
    - Burbank: $160–250/ton of cooling
    - SMUD: $2,000 for two-stage package heat pump and $3,500 for variable-stage heat pump
    - Roseville: $250–600/ton

    - City of Lompoc: $250/ton for heat pump, $250/ton for ductless mini-split
    - Lodi: $250/ton of cooling
    - Plumas-Sierra Rural Elec Coop: $100–350/ton
    - City of Riverside: $150–250 per ton
    - Pasadena: Up to $190/ton
    - Modesto:
    - Heat Pump: $450–700
    - Mini-Split Heat Hump: $350 per unit
    - LADWP: $100/ton
    - Anaheim: Up to $200/ton for heat pump
- Azusa — This program of the City of Azusa offers rebates from $100/ton to $2,000/ton for weatherizing homes and replacing gas equipment with various ENERGY STAR-rated packaged and ductless heat pump systems.
- City of Healdsburg — The program offers incentives of up to $1,500 per unit for air source/cooled heat pumps with a tiered approach for existing electric heat upgrades, and gas-to-electric conversions for residential properties.
- Electrify Santa Monica — This program offers rebates for electric appliances and electric vehicle chargers. New electric equipment must replace existing gas equipment.
- Sonoma Clean Power — This program offers incentives of up to $1,000 to residential customers in Sonoma and Mendocino Counties for installing efficient air source heat pump systems to replace gas equipment.
- Trinity PUD — This program offers a "cleaner heating" incentive in the form of a rebate/credit of $700 to a limited number of qualified District customers who purchase an energy efficient, electric heat pump for their home.
- Energy Savings Assistance (ESA) Multifamily Program — The CPUC together with IOUs, including PG&E, SCE, SCG and SDG&E, administer Energy Savings Assistance Program to support low-income residents throughout California with a budget of $200 million/year. Income qualifying properties can receive no-cost energy efficiency, appliance and weatherization upgrades to residential units.

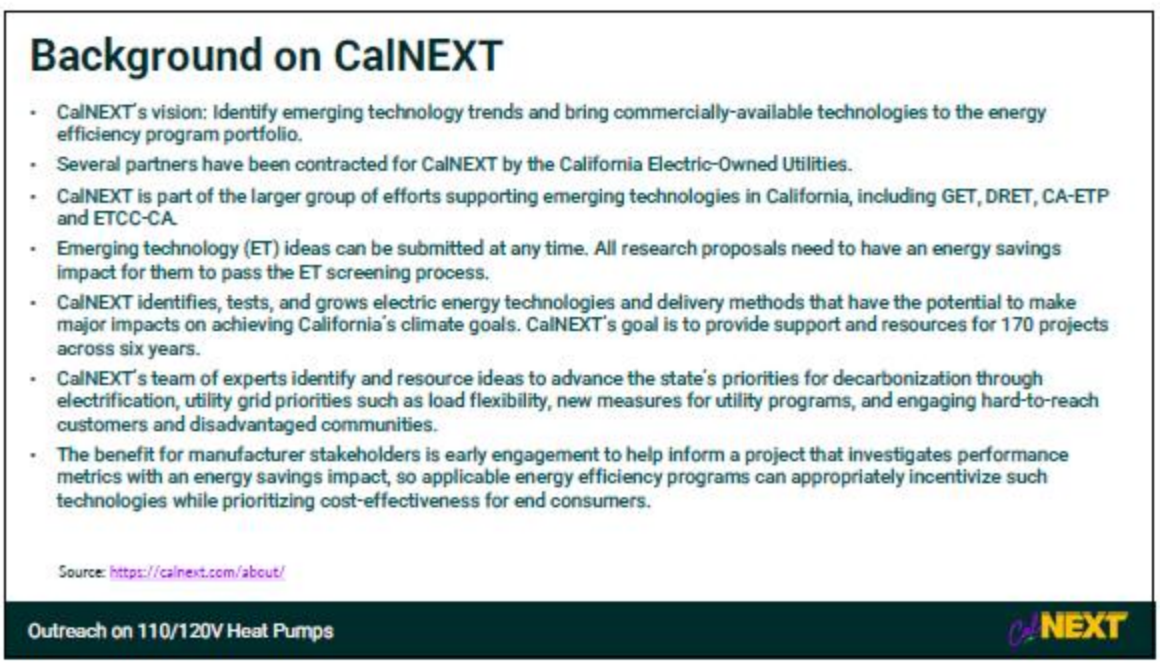
Appendix C: Stakeholder Outreach Materials

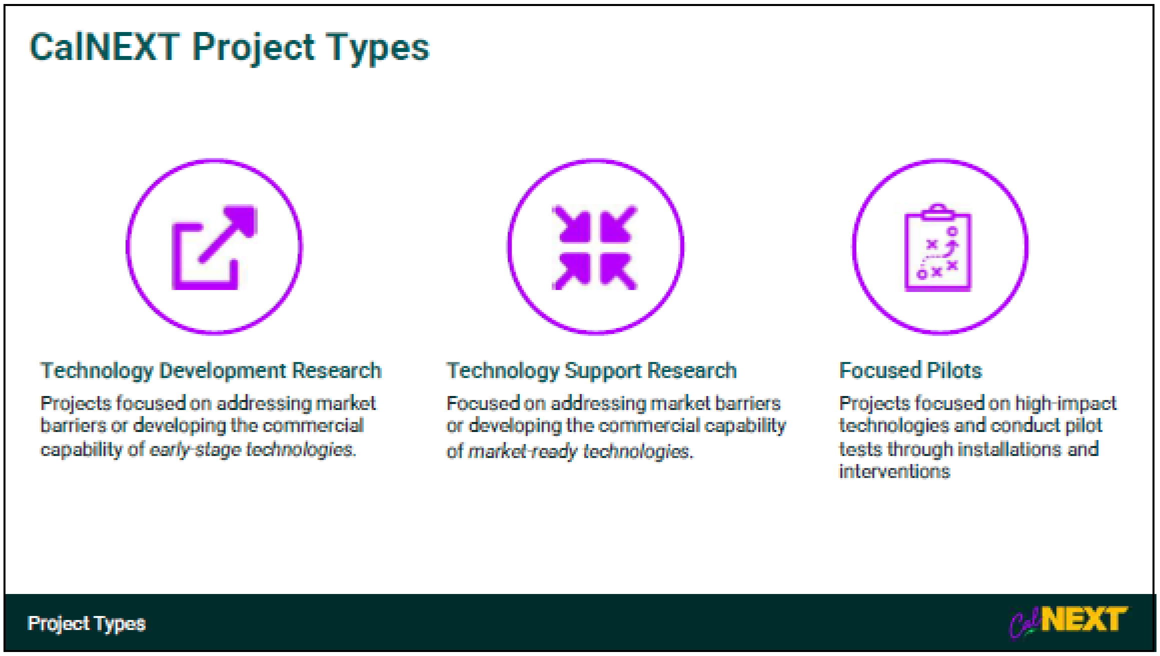
List of Questions for Stakeholders

- Are you aware of new MHP models that qualify for the NYCHA cold climate criteria, and the corresponding model sizes and cooling/heating capacities?
- What are the novel features of MHP that provide heating in cold ambient temperatures, including but not limited to specific compressor technologies incorporated in these technologies?
- What refrigerants do they currently use and what opportunities exist for future refrigerant use?
- How do these systems handle defrost, i.e., active or passive? What aspects of passive defrost are most important to consider in incentive programs?
- What metrics related to sound should be considered in incentive programs on MHPs?
- What is the average retail price of these MHPs by cooling and heating capacities?
- Do these commercially available MHPs have any wireless connectivity features that should be incentivized, and if so, how should they be addressed in performance metrics?
- Do these MHPs provide any utility demand side features during inactive sessions?
- Do these MHPs have any onboard control, wireless thermostat, remote controller, or other native controls that should be considered in performance testing efforts?
- Are there any other features/aspects of MHPs that should be considered by the project team?
- Do you have any additional thoughts to offer on a heating-specific test method and metric on MHPs? Is your organization generally supportive of EPA's ENERGY STAR Final Draft heating mode test procedure for room HPs?
- Can EPA's ENERGY STAR Final Draft heating mode test procedure also be applicable to portable or through-the-wall HPs?
- How will the incentive program help you – any pros or cons?
- What would you like to see to move forward in this space to facilitate consumer adoption of MHPs?

Stakeholder Presentation

1

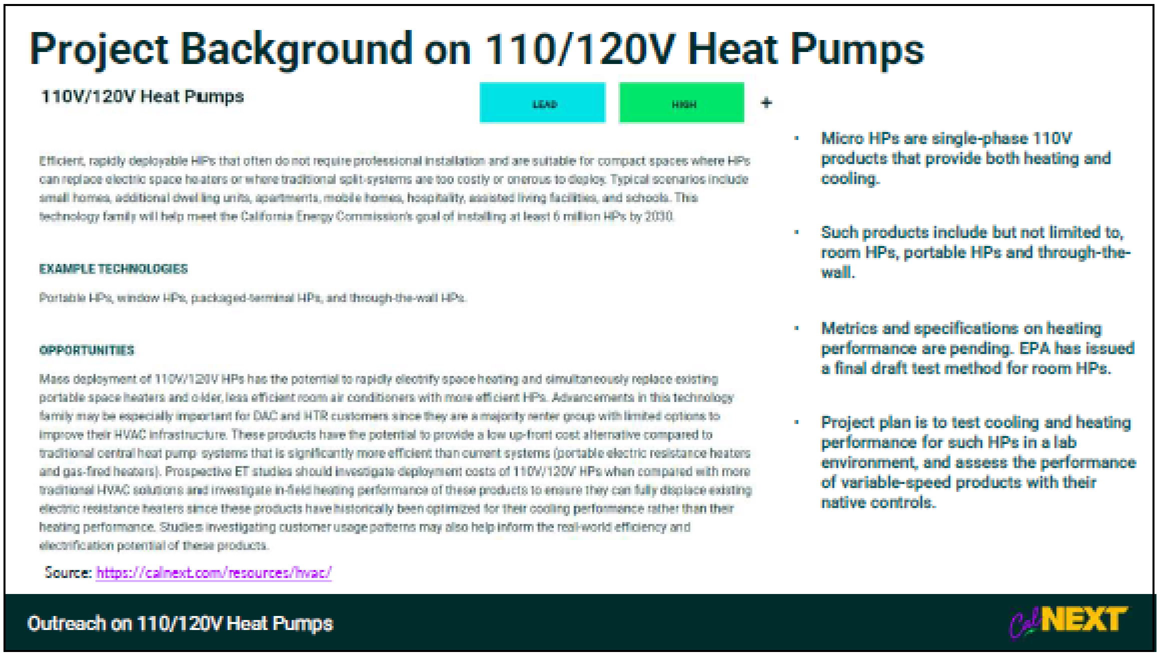



CalNEXT Project Types
Technology Development Research
Projects focused on addressing market barriers or developing the commercial capability of *early-stage technologies.*
Technology Support Research
Focused on addressing market barriers or developing the commercial capability of *market-ready technologies.*
Focused Pilots
Projects focused on high-impact technologies and conduct pilot tests through installations and interventions
Project Types
CalNEXT

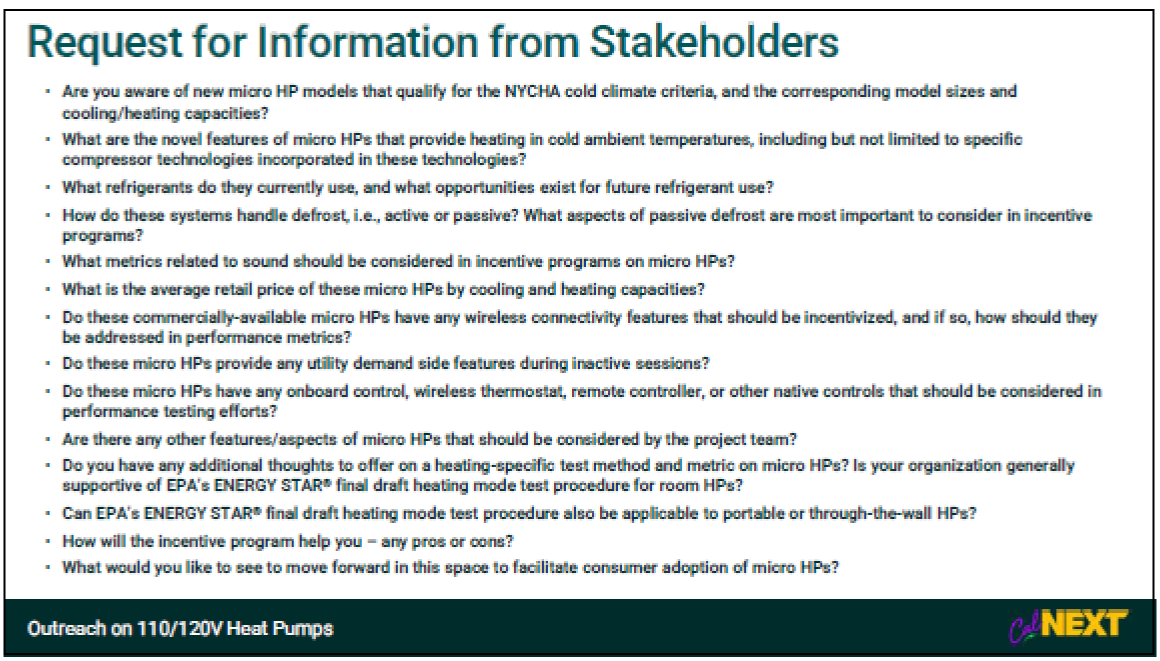
3


Partner Team
Energy Solutions
veic
aesc
alternative energy systems consulting
ORTIZ
THE ORTIZ GROUP
TRC
UCDAVIS
UNIVERSITY OF CALIFORNIA
CalNEXT Partners
CalNEXT

4


Project Background on 110/120V Heat Pumps
110V/120V Heat Pumps
LEAD
HIGH
+
Efficient, rapidly deployable HPs that often do not require professional installation and are suitable for compact spaces where HPs can replace electric space heaters or where traditional split-systems are too costly or onerous to deploy. Typical scenarios include small homes, additional dwelling units, apartments, mobile homes, hospitality, assisted living facilities, and schools. This technology family will help meet the California Energy Commission's goal of installing at least 6 million HPs by 2030.
EXAMPLE TECHNOLOGIES
Portable HPs, window HPs, packaged-terminal HPs, and through-the-wall HPs.
OPPORTUNITIES
Mass deployment of 110V/120V HPs has the potential to rapidly electrify space heating and simultaneously replace existing portable space heaters and older, less efficient room air conditioners with more efficient HPs. Advancements in this technology family may be especially important for DAC and HTR customers since they are a majority renter group with limited options to improve their HVAC infrastructure. These products have the potential to provide a low up-front cost alternative compared to traditional central heat pump systems that is significantly more efficient than current systems (portable electric resistance heaters and gas-fired heaters). Prospective ET studies should investigate deployment costs of 110V/120V HPs when compared with more traditional HVAC solutions and investigate in-field heating performance of these products to ensure they can fully displace existing electric resistance heaters since these products have historically been optimized for their cooling performance rather than their heating performance. Studies investigating customer usage patterns may also help inform the real-world efficiency and electrification potential of these products.
Source: https://calnext.com/resources/hvac/
Micro HPs are single-phase 110V products that provide both heating and cooling.
Such products include but not limited to, room HPs, portable HPs and through-the-wall.
Metrics and specifications on heating performance are pending. EPA has issued a final draft test method for room HPs.
Project plan is to test cooling and heating performance for such HPs in a lab environment, and assess the performance of variable-speed products with their native controls.
Outreach on 110/120V Heat Pumps
CalNEXT

5


Request for Information from Stakeholders
Are you aware of new micro HP models that qualify for the NYCHA cold climate criteria, and the corresponding model sizes and cooling/heating capacities?
What are the novel features of micro HPs that provide heating in cold ambient temperatures, including but not limited to specific compressor technologies incorporated in these technologies?
What refrigerants do they currently use, and what opportunities exist for future refrigerant use?
How do these systems handle defrost, i.e., active or passive? What aspects of passive defrost are most important to consider in incentive programs?
What metrics related to sound should be considered in incentive programs on micro HPs?
What is the average retail price of these micro HPs by cooling and heating capacities?
Do these commercially-available micro HPs have any wireless connectivity features that should be incentivized, and if so, how should they be addressed in performance metrics?
Do these micro HPs provide any utility demand side features during inactive sessions?
Do these micro HPs have any onboard control, wireless thermostat, remote controller, or other native controls that should be considered in performance testing efforts?
Are there any other features/aspects of micro HPs that should be considered by the project team?
Do you have any additional thoughts to offer on a heating-specific test method and metric on micro HPs? Is your organization generally supportive of EPA's ENERGY STAR® final draft heating mode test procedure for room HPs?
Can EPA's ENERGY STAR® final draft heating mode test procedure also be applicable to portable or through-the-wall HPs?
How will the incentive program help you – any pros or cons?
What would you like to see to move forward in this space to facilitate consumer adoption of micro HPs?
Outreach on 110/120V Heat Pumps
CalNEXT

Appendix D: Windows

Window Specifications and MHP Installation Guidelines

Window Types and Installation Guidelines

It is perhaps not surprising that there are more than 20 window types available in the U.S. market; the most popular types include single-hung, double-hung, picture, casement, bay, sliding, awning, and skylight (Figure 7). Out of these various designs, the three most popular ones that can easily accommodate MHPs are: standard windows (single-hung and double-hung slide up and down), slider windows (slide left and right), and casement windows (swing out), as shown in Figure 10. The MHPs with other form factors can be installed either in windows or through the wall.

The current ENERGY STAR Version 5.0 specification on room air conditioners details the following two window criteria for casement applications, and these criteria are aligned with the definitions set forth in the 10 CFR Part 430.2 of the federal regulations:

- Casement-only: A Unit designed for mounting in a casement window with an encased assembly with a width of 14.8 inches or less and a height of 11.2 inches or less.
- Casement-slider: A Unit with an encased assembly designed for mounting in a sliding or casement window with a width of 15.5 inches or less.

In view of the various form factors (as specified in Table 1 earlier in the report), the following points are noteworthy:

1. Manufacturers offer window installation kits which most people can install without professional help.
2. Larger-capacity units are heavier and are accompanied by slide-out chassis to assist with window installs.
3. To qualify for ENERGY STAR, these self-installed products should come with the installation material, including the weather stripping and/or gasket materials to minimize air leaks (seal) between the unit and the window opening (i.e., area between unit and window sash, and the unit and windowsill [if bottom mounted], or window head [if top mounted]). Room air conditioner side curtains must be tight fitting to minimize air leaks and contain insulation in the panel with a minimum insulation value of R1. EPA will likely require these installation provisions for ENERGY STAR certified MHPs in its pending specification.

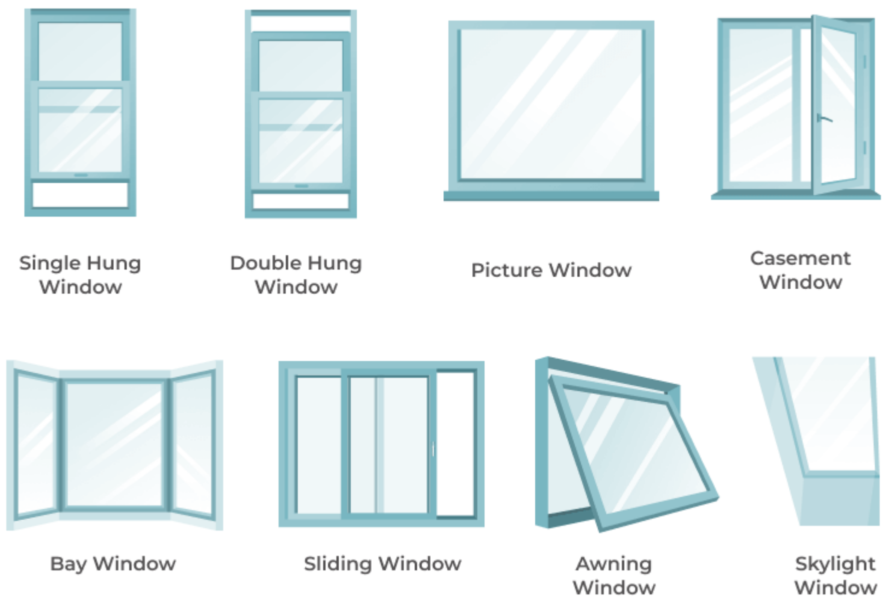


Figure 10: Most popular window types in the United States.[21]

Figure 11: Three popular U.S. window types that can accommodate MHPs: single- and double-hung sliders, and casement windows.[22]

21 Adapted from www.modernize.com/windows/types

22 Adapted from www.ajmadison.com/guides/air_conditioner/window/?srsltid=AfmBOoo7EcW4G-b_Xj25YuKJNXHwvW63glScgr195zqqBjgP3rmClzhf

International Window Types and Installation Issues with MHPs

Note that window designs and styles also vary internationally. Some of the popular styles in Europe, Australasia and Northern Ireland seem to be the “tilt and turn” windows as shown in Figure 12. They variously swing inward from vertical hinges, tilt inward from horizontal hinges, or open outwards from a handle at the bottom of the window.

The U.S. manufacturers of MHPs are aware of these window types, where installing MHP is challenging. At this stage, MHP manufacturers do not seem to have plans to address this matter for the uptake of MHPs in homes with such window types.

Figure 12: European and Australasian windows opening outwards or inwards (i.e., tilt and turn style).[23]

Market Size of Windows and Potential of MHPs in the United States

The U.S. market for windows was valued at $12.32 billion in 2022, and is expected to grow at a compound annual growth rate (CAGR) of 3.6 percent from 2023 to 2030 (Grand View Research, 2024). Of this U.S. market, the single and double-hung windows segment is valued at $6.55 billion, i.e., these two window types account for about 53 percent of the market share. They are increasingly common in apartments, while double-hung windows are preferred in Northeast and Midwest regions.

Further, Ahren et al. (2023) estimated that most multifamily buildings in California that account for 32 percent of the residential housing stock, use electric resistance heat while just over 50 percent of all multifamily units use natural gas as their primary heating fuel. Heat pumps account for about six percent of all HVAC systems in the multifamily market. This suggests that MHPs offer a significant potential in the decarbonization and electrification of U.S. homes in the future.

In discussions with industry experts such as AHAM, a standard window comprises of the following window types: a) double-pane laminated; b) double-pane; c) single-pane laminated; d) single-pane; and e) E90. Specified window STC ratings and window construction can play a role in sound pressure measurements within a laboratory testing environment.

The CalNEXT MHP project team reviewed DOE’s CCD (last accessed August 22, 2024) and found that all 20 casement-slider basic models currently being distributed in commerce are room air conditioners without reverse cycle heating capabilities. While the through-the-wall form factor may be a novel approach to deal with window type applications such as casement-slider and awning, such technologies are required to be installed in a professional manner, and must be supported by the

[23] The first image is adapted from https://vinyllight.ca/european-windows-vs-american

appropriate building infrastructure such that holes can be drilled to structurally set up the product. The portable heat pump form factor is also an option for such window applications.

Approximately 57 percent of single family buildings in the state of California are currently single family detached homes. Approximately 60 percent single family buildings have double- or triple-pane windows.[24] The most common range of windows in housing units within the United States are six to nine windows, or 10 to 15 windows. 63 percent housing units have double-pane glass windows, 35 percent have single-pane glass windows, and nearly two percent have triple-pane glass windows.[25] Based on available data on window types in the United States, the CalNEXT MHP project team has concluded that window and saddle-mount form factors can serve most U.S. consumers' space conditioning needs.

[24] Per RECS 2020 State Data available here: https://www.eia.gov/consumption/residential/data/2020/state/pdf/State%20Structural%20Characteristics.pdf

[25] Per Table HC2.1 of RECS 2020.