eTRM Heat Pump Baseline Systems Assessment

Final Report

ET23SWE0024

Prepared by:

Lysandra Medal TRC
Ritesh Nayyar, PE TRC
Lake Casco, PE TRC
Angel Moreno TRC
Abhijeet Pande TRC

December 15, 2023

Acknowledgements

The project team informing this work extends beyond those directly tasked with this report. The project team gratefully acknowledges the contributions of the TRC staff: Marc Fountain, Mostafa Tahmasebi, and Yiyi Chu.

The research was directly supported by meetings and interviews with several industry experts. The project team particularly thanks representatives from SCE, SDG&E, and the Cal TF Measure Screening Committee.

Disclaimer

Executive Summary

Objective

The purpose of this project is to evaluate how various measure packages related to heat pump (HP) space-conditioning system upgrades can be expanded to address a variety of baseline systems found in California's existing homes and multifamily dwelling units.

Key Findings and Recommendations

Measure Package Review

The project team prioritized six retrofit pathways that are present in the current market but are missing from the existing measure packages (see Table 1), based on the review of TECH (2021), RASS (2019), and CEDARS Claims (2020–2022) data. The project team recommends further studies and energy modeling to inform the potential updates to the measure packages.

Table 1: Recommended New Baseline Cases for HP Measure Offerings

Baseline Case	Central Ducted HP, Measure Case *(Number of TECH Participation)*	Central Mini-Split or Multi-Split HP, Measure Case *(Number of TECH Participation)*	% TECH Program Participation
Central Forced Air Electric Furnace Only	**Recommended 1** *(24)*	**Recommended 2** *(45)*	0.6%
Central Forced Air Gas Furnace Only	SWHC045 *(3,420)*		28%
Floor or Wall Gas Furnace Only		SWHC044 *(2,295)*	19%
Central AC + Central Forced Air Electric Furnace	**Recommended 3** *(40)*	**Recommended 4** *(11)*	0.4%
Central AC + Central Forced Air Gas Furnace	SWHC045 *(5,190)*		42%
Central AC + Floor or Wall Gas Furnace		**Recommended 5** *(1,002)*	8%
Window Room AC + Central Forced Air Electric Furnace		Not Recommended *(21)*	0.2%
Window Room AC + Central Forced Air Gas Furnace	**Recommended 6** *(53)*		0.4%
Window Room AC + Floor or Wall Gas Furnace		SWHC044 *(139)*	1%
Central Mini-Split or Multi-Split HP		SWHC050 *(0)*	0%
Central Ducted HP	SWHC049 *(0)*		0%

Market Potential Assessment

- Over the last three years, 66,234 tons of HP capacity was installed across all program types for residential measure packages.
- These HP installations replaced a range of HVAC systems, and roughly 51 percent of installations retrofitted baseline systems that had no pre-existing cooling system.

- The recommended baseline systems that warrant further analysis have considerable market presence.
- Heating system saturation is dominated by Central Forced Air Gas Furnaces (73 percent), followed by floor or wall gas furnaces (9 percent), and Central Forced Air Electric Furnaces (7 percent). An additional 11 percent of the heating systems included portable electric heaters, central HPs, and other systems.
- The saturation of cooling systems is dominated by central Acs. (74 percent) for central systems and by window room ACs (80 percent) for zone cooling systems.

Recommendations

- Program Year (PY) 2026 Updates: There is a potential for the recommended systems to be included in the PY_2026 updates. This inclusion is contingent upon the interest of the California investor-owned utilities (IOUs) and the availability of program resources. The project team acknowledges that bandwidth may be a constraint due to multiple models being run statewide.
- Midcycle Implementation: In the event that these recommendations are not incorporated into the PY 2026 updates, there is a possibility of implementing them as midcycle updates. These can go live as soon as they are approved, which offers a flexible and timely approach to updating the measure packages.

Abbreviations and Acronyms

Acronym	Meaning
AC	Air Conditioning
AR	Accelerated Replacement
Cal TF	California Technical Forum
CARE	California Alternate Rates for Energy
CEDARS	California Energy Data and Reporting System. Website: https://cedars.sound-data.com/
COP	Coefficient of Performance
CPUC	California Public Utilities Commission
CZ	Climate Zone
DAC	Disadvantaged Communities
DEER	Database for Energy Efficiency Resources
DX	Direct Expansion
EE	Energy Efficiency
EER	Energy Efficiency Ratio
ET	Emerging Technology
eTRM	The California Electronic Technical Reference Manual
GHG	Greenhouse Gas
HP	Heat Pump
HSPF	Heating Seasonal Performance Factor
HTR	Hard-to-Reach
HVAC	Heating, Ventilation, and Air Conditioning

Acronym	Meaning
IOU	Investor-Owned Utility
kBTu/hr	Thousand British Thermal Units Per Hour
kWh	Kilowatt-hour
MAT	Measure Application Type
NR	Normal Replacement
NTG	Net-to-gross
PA	Program Administrator
PG&E	Pacific Gas & Electric
PI	Program Implementer
PTAC	Packaged Terminal Air Conditioner
PTHP	Packaged Terminal Heat Pump
PY	Program Year
RASS	Residential Appliance Saturation Survey. Website: https://www.energy.ca.gov/data-reports/surveys/2019-residential-appliance-saturation-study
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SEER	Seasonal Energy Efficiency Ratio
SFD	Single Family Dwelling
SWHC	Statewide eTRM measure IDs. It stands for Statewide Heating, Ventilation, and Air Conditioning.
TAC	Technical Advisory Committee
TECH	California working data sets that provide anonymous space and water heating-related data gathered from incentive applications submitted by TECH participating contractors and qualified product lists. Website: https://techcleanca.com/

Acronym	Meaning
TPM	Technology Priority Map
TSB	Total System Benefit, an expression, in dollar value, of the lifecycle energy, capacity, and GHG benefits of a utility's energy efficiency program portfolio. The metric encourages programs to target "high value" load reduction and longer-duration energy savings while being fuel agnostic. (CPUC, 2021)
UEF	Uniform Energy Factor
WH	Water Heating

Table of Contents

List of Tables

List of Figures

Introduction

Heat pump (HP) space-conditioning systems are an important technology in the residential sector for both energy efficiency (EE) and decarbonization efforts. This project aims to address gaps in current EE portfolio offerings for residential HPs when retrofitting existing buildings with existing systems currently not addressed as baseline systems in measure packages. As the state increases electrification efforts, the lack of baseline systems that are present in the current market is a barrier to incentivizing HP retrofits. The California Electronic Technical Reference Manual (eTRM) is the official repository for deemed measures used by Program Administrators (PAs) and Program Implementers (PIs) under the purview of the California Public Utilities Commission (CPUC). The eTRM has several individual measure packages that address deemed savings for HP-related technologies that together form the technical basis for most of the state's electrification efforts.

The existing measure packages may have addressed some of the major baseline conditions, but the options can be limited and may not accurately reflect many retrofit opportunities. This project reviewed existing measure packages to identify where there are differences in baseline system assumptions, how those affect savings claims and how they may impact electrification efforts. The project also addresses how any proposed changes to the measure packages will impact the new total system benefit (TSB) metric when developing savings compared to the existing offerings.

Objectives

The purpose of this project is to evaluate how various measure packages related to HP space-conditioning system upgrades can be expanded to address a variety of baseline systems found in California's existing homes and multifamily dwelling units.

The primary outcomes of this project are recommendations for updates to various measure packages related to HP space-conditioning system upgrades. Specifically, the outcomes include:

- Documented gaps in the current measure packages for residential HP space-conditioning systems including: (a) base case fuels (b) base case systems
- Recommendations for updates to existing measure packages, with the anticipation that the eTRM governing bodies (California Technical Forum (Cal TF) Technical Advisory Committee (TAC) and Cal TF Members) can consider them for adoption
- Measure support for disadvantaged communities (DACs) and hard-to-reach (HTR) customers
- Energy and TSB savings impacts

Methodology & Approach

Error! Reference source not found. illustrates the project methodology, which includes four scopes: review measure packages, assess market potential, collaborate with Cal TF and investor-owned utilities (IOUs), and estimate savings and impact.

Figure 1. Project Methodology

Measure Package Review

The project team reviewed all measure packages involving residential HP space conditioning as well as controls (such as smart thermostats) to evaluate whether the baselines address heating only (i.e., no cooling systems) appropriately. The project team identified gaps in residential HP space-conditioning systems by reviewing current measure packages, particularly related to base case fuels and cooling systems.

To obtain a comprehensive understanding of the current heating, ventilation, and air-conditioning (HVAC) systems in the California market, the project team conducted a detailed review of relevant market data from the Residential Appliance Saturation Survey (RASS), TECH, and California Energy Data and Reporting System (CEDARS) databases.

RASS Data

The RASS is conducted in California and gathers data about household demographics, energy usage, and appliances. The data provides a snapshot of the saturation of various energy-using appliances in residential buildings. The project team characterized the diverse HVAC systems in place for various residential building types across the 16 California climate zones and their respective vintages. Key information that was reviewed includes the system types and prevalence in different building types.

TECH Data

TECH Clean California is a statewide initiative to accelerate the adoption of clean space- and water-heating technology across California homes to help California meet its goal of being carbon-neutral by 2045. The TECH Working Data Sets provide anonymous data gathered from incentive applications submitted by TECH participating contractors as well as qualified product lists. The data is listed on a per-installation basis, so each row represents a unique installation of either a heat pump water heater (HPWH) or HP HVAC system. Similar to CEDARS Claims data, the project team analyzed the market penetration data based on building types, climate zones, and vintages, as well as the prevalence of base and measure case equipment combinations.

CEDARS Claims Data

CEDARS is a data management and reporting system used by the CPUC and utilities. The data serves as a centralized repository for energy program data, including program performance metrics, program costs, and energy savings. To understand the measure package dynamics, the project team

analyzed CEDARS claims data for the three-year span of 2020–2022. Key information that was reviewed included participation data across various climate zones, building types, and measure application types (MATs).

Market Assessment

The project team identified potential markets that could be tapped by including these excluded measures, including consideration to underserved communities such as DACs.

Stakeholder Engagement

The project team worked with representatives from IOUs to identify any known reasons for the exclusion of identified baseline gaps or other such exclusions that may impact the appropriate incentives for HP space conditioning retrofits. Additionally, the project team discussed any interest or challenges that they foresaw regarding the new baselines that the project team is recommending.

Savings and Impact Estimates

The project team reviewed potential savings or additional energy costs (referred to as 'energy penalties') for the excluded measures, particularly for situations where gas heating only systems are upgraded to various HP systems, adding cooling loads where none existed before. One of the key considerations when adding cooling is whether the measure still maintains a good TSB and/or passes the fuel substitution test.

Findings

Table 2 summarizes the mapping of the project outcomes and approaches.

Table 2: Summary of Project Outcome and Approach

Outcome	Measure Packages Review	Collaboration with CalTF and IOUs	Market Potential Assessment	Energy Savings Estimate
Documented gaps in current measure packages	•			
Recommendations for updates to existing measure packages	•	•	•	
Measure support for DAC/HTR customers		•	•	
Energy and TSB savings impacts			•	•

The following provides more detailed findings based on each project outcome.

Gaps in Current Measure Packages

The project team assessed six measure packages focusing on deemed savings for residential HP technologies as shown in

Table 3 (and Appendix A for a more detailed measure description). The project team reviewed the RASS, TECH, and CEDARS databases and identified that the current measure packages do not cover all existing baseline systems, including systems that do not have existing cooling systems. The database review revealed the following gaps:

1. There are no measure packages that specifically target electric resistance-forced air furnaces as a baseline system type. The RASS data indicated that electric resistance furnaces constitute seven percent of the residential heating systems in the market. The TECH data further demonstrated that electric resistance forced air furnaces are being replaced with both central ducted and ductless HP systems. This suggests a potential opportunity to revise both the ducted and ductless HP measure packages to incorporate electric resistance forced air furnaces in the baseline, as substantial TSB values are anticipated.
2. There are no measure packages that specifically address combinations of central and zone conditioning systems, like central air conditioner (AC) and wall/gas furnace or window AC and forced air gas furnace as the baseline system type. The RASS data indicated that central AC is the most prevalent residential central cooling system in the market while window room AC is the most prevalent zonal cooling system in the market. The TECH data further demonstrated that central ACs and wall/gas furnaces are being replaced with ductless HP systems whereas the window ACs and forced air gas furnaces are being replaced with central ducted HP systems. This suggests a potential opportunity to revise both the ducted and ductless HP measure packages to incorporate these combination systems in the baseline as substantial TSB are anticipated due to these being fuel substitution.

Table 3: Residential Measure Packages

Measure Code	Measure Characterization
SWHC050	Ductless HP, Residential
SWHC044	Ductless HVAC, Residential, Fuel Substitution
SWHC045	HP HVAC, Residential, Fuel Substitution
SWHC027	Packaged Terminal AC or Heat Pump, Under 24 kBtu/hr
SWHC049	Seasonal Energy Efficiency Ratio (SEER) Rated AC and HP HVAC Equipment, Residential
SWHC039	Smart Thermostat, Residential

Source: California eTRM

Table 4 shows a matrix of base case equipment and measure case equipment with respect to the measure packages. The measure packages review revealed that different measure packages accommodate different systems. The project team identified a considerable market presence for several existing systems that are not accounted as baseline HVAC options in current measure packages, such as forced air electric furnace, central AC and forced air electric furnace, central AC and floor or wall gas furnace, window room AC and forced air gas furnace. The residential smart thermostat measure (SWHC039) is excluded from the matrix since it has the same base case and measure case equipment. Additionally, while the project team acknowledges a potential gap in the measure packages for smart thermostats, past stakeholder feedback has suggested that the small therm savings do not justify the investment required to address this gap.

1. **Measure packages are tailored to specific HVAC systems in the baseline. For example:**
    - SWHC044 only accommodates either a natural gas gravity wall furnace or a combination of a window AC and a natural gas gravity wall furnace in the baseline.
    - SWHC045 is designed for the replacement of both the existing central AC and gas furnace with a central HP. Other systems in the baseline, such as central forced air electric, central AC with floor or wall gas furnace, and window room AC with central forced air gas furnace are not eligible for incentives under this measure package.
    - SWHC039 focuses on the installation of smart thermostats on HPs or direct expansion (DX) units with gas furnaces. It excludes systems such as packaged terminal AC (PTAC), packaged terminal HP (PTHP), and evaporative cooling from incentives.
2. **Many participants are excluded from incentives due to strict efficiency criteria.**
    - One requirement is that the HP must satisfy both heating and cooling efficiency criteria as specified by a particular measure offering identification (ID). This requirement often disqualifies many project participants from incentives because they must adhere to a specific measure offering ID. A possible solution could be to introduce more measure

offering IDs that encompass a spectrum of heating and cooling efficiencies that the program participant can choose from.

Table 4: Base Case and Measure Case Equipment Matrix

Baseline Case	Central Ducted HP, Measure Case	Central Ductless HP, Measure Case	Central Ducted AC, Measure Case	PTAC or PTHP, Measure Case
Central Ductless HP		SWHC050		
Central AC and Forced Air Gas Furnace	SWHC045			
Forced Air Gas Furnace Only	SWHC045			
Window Room AC + Gravity Wall Furnace		SWHC044		
Gravity Wall Furnace Only		SWHC044		
PTAC				SWHC027
Central Ducted AC			SWHC049	
Central Ducted HP	SWHC049			
Forced Air Electric Furnace	Recommended	Recommended		
Central AC and Forced Air Electric Furnace	Recommended	Recommended		
Central AC and Floor or Wall Gas Furnace		Recommended		
Window Room AC and Forced Air Gas Furnace	Recommended			

Source: California eTRM

This finding highlights the need to address diverse baseline HVAC systems, especially for those systems without existing cooling. The project team further investigated the initial recommended retrofit pathways based on market presence and feedback from the stakeholders; this is discussed later in the Recommendations for Measure Updates section. More information gathered from RASS

data, CEDARS claim, and TECH data is described in the following section.

RASS Data Review

KEY TAKEAWAYS

1. Approximately 28 percent of households do not have any cooling system in place, based on household-weighted average. This is most prevalent in two to four-unit apartments (42 percent), while the lowest saturation is found in single family homes (25 percent).

2. All building types were found to have various types of HVAC systems in place. However, the existing measure packages specify only one baseline HVAC system type based on the specific measure being offered.

COOLING SYSTEMS

The project team reviewed the RASS data to document the different types of cooling systems and heating systems used in single family homes and multifamily dwelling units. As shown in Figure 2, central AC is the most commonly used system for central cooling (74 percent), while window room AC is mostly used for zone cooling (80 percent). Existing heating with cooling systems available account for just over half of the market, while the other 47 percent have no cooling systems.

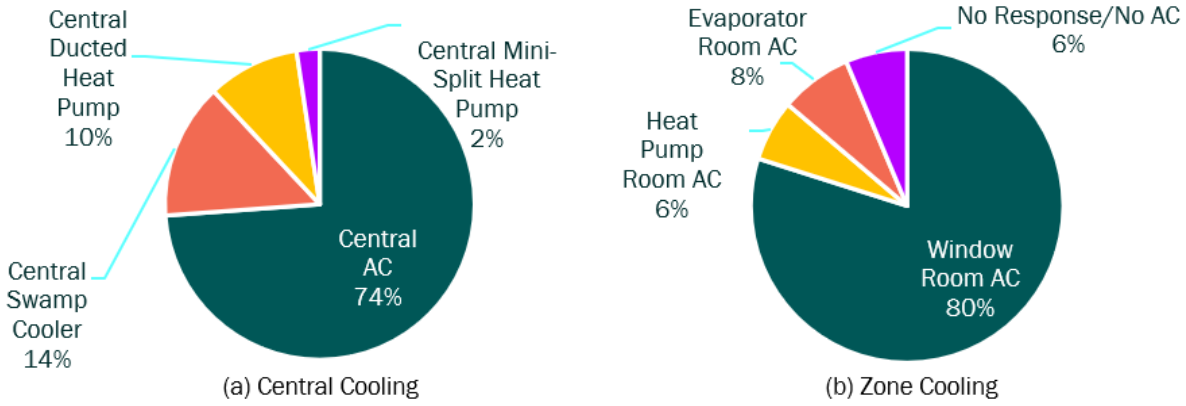

Figure 2. Cooling System Saturation

HEATING SYSTEMS

As shown in **Error! Reference source not found.**, the RASS study unveils a marked preference for gas as the primary source of space heating amongst households, accounting for 69 percent of the choices on average. This is followed by electricity, which constitutes about 20 percent of the primary heating source selection. A minor segment of the market (11 percent) utilizes different means for heating (i.e., not gas or electricity, such as propane and wood).

Table 5: Prevalence of Heating System Fuel Type

Fuel Type	Single Family Saturation	Townhome Saturation	2-4 Unit Apt. Saturation	5+ Unit Apt. Saturation
All Household	25,668 homes	3,434 homes	2,448 homes	5,767 homes
Natural Gas	77%	69%	56%	41%
Electricity	13%	22%	34%	45%
Other (Propane & Wood)	5%	1%	1%	1%
No Response	5%	8%	9%	13%

Source: 2019 RASS Data

The primary central forced air gas furnace emerges as the most popular heating system (73 percent), followed by floor or wall gas furnaces (9 percent), as shown in Figure 3. The primary central forced air gas furnace system is particularly favored in single family homes, while the floor or wall gas furnace system is more common in multifamily homes. On the electricity front, the central forced air electric furnace emerges as a preferred choice.

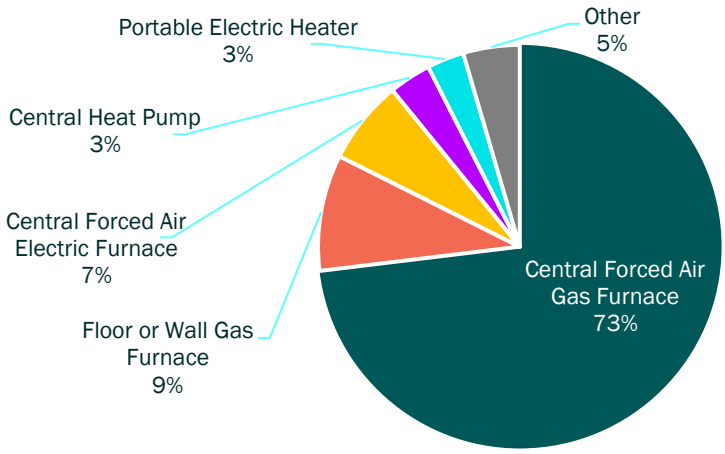

Figure 3. Heating Systems Saturation

CEDARS Claim Review

The project team examined CEDARS claim data spanning 2020 to 2022, conducting a comprehensive analysis of project participation trends. This assessment covered all the 16 climate zones, residential building types (single family, multifamily, and mobile homes), and MATs for the six measure packages shown in Figure 4.

CEDARS and TECH data review revealed that a significant percentage of HPs are installed in places with no previous cooling system. For example, the CEDARS claim data indicated that roughly over half of the HP installations replaced systems where no pre-existing cooling was present.

KEY TAKEAWAYS

1. Over the last three years, 66,234 tons of HP capacity were installed across all program types for residential measure packages. These included ducted, ductless, split, and packaged units.
2. These HP installations replaced a range of HVAC systems, including split/packaged AC with furnace, window AC with furnace, and standalone furnaces.
3. The total of HPs (including ducted, ductless, split, and packaged units) with a combined capacity of 32,567 tons were installed in projects without any prior cooling system, relying solely on central gas furnaces for heating. This analysis underscores that roughly 51 percent of HP installations took place in locations where no pre-existing cooling system was present.

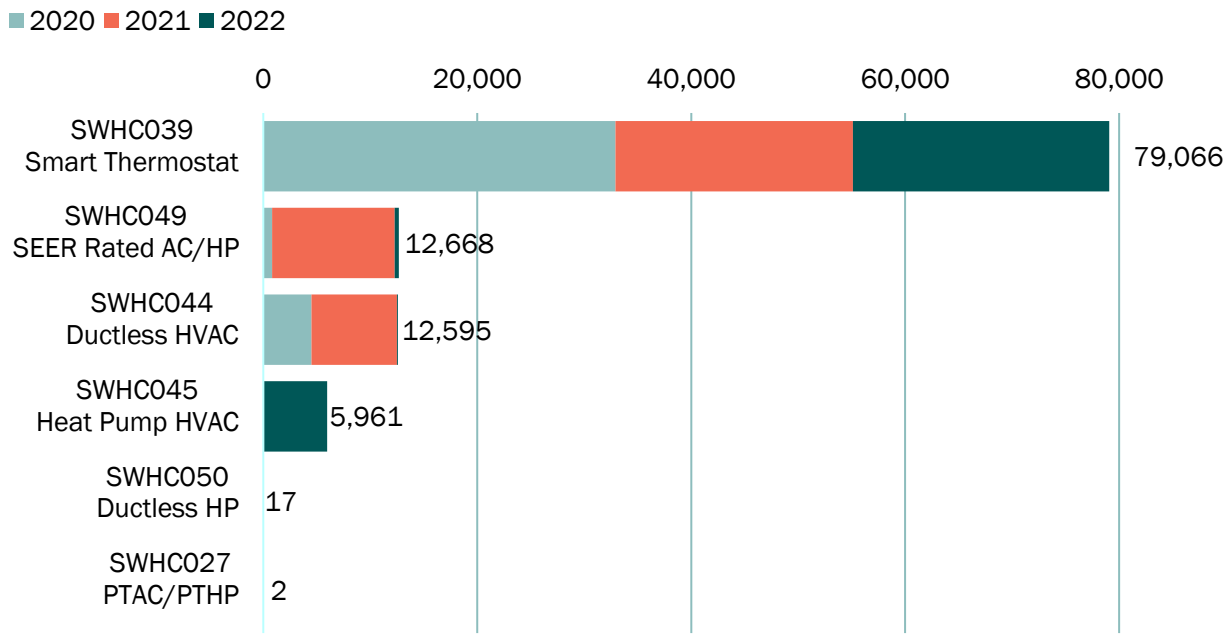

Figure 4. CEDARS 2020–2022 Measure Participation Trends

CLAIMS YEAR 2020

- For the 2020 claim year, the project team did not find any participation data for the SWHC050 and SWHC027 measure packages.

- SWHC039: In 2020, there were 32,909 thermostat installations. Among these, 6,095 thermostats were placed on HPs, accounting for 18 percent of the total, while 26,814 were installed on DX units with gas furnaces, constituting the remaining 82 percent.
- SWHC044: In 2020, there were 4,494 ductless HP installations with a combined capacity of 19,890 tons. Among these, 3,470 HPs were installed at sites with no cooling (only gas furnace for heating) while the remaining 1,024 were installed at sites that had a window AC and furnace as the existing setup.
- SWHC045: In 2020, there were 36 central ducted HP installations with a combined capacity of 60 tons. Among these, seven HPs were installed at sites with no cooling (only gas furnace for heating) while the remaining 29 were installed at sites that had a window AC and furnace as the existing setup.
- SWHC049: In 2020, 835 (split/packaged) AC units were installed, totaling a capacity of 4,068 tons, effectively replacing less efficient units.

CLAIMS YEAR 2021

- For the 2021 claim year, the project team did not find any participation data for the SWHC027 measure package.
- SWHC039: In 2021, there were 22,203 thermostat installations. Among these, 6,594 thermostats were placed on HPs, accounting for 30 percent of the total, while 15,609 were installed on DX units with gas furnaces, constituting the remaining 70 percent.
- SWHC044: In 2021, there were 7,992 ductless HP installations with a combined capacity of 15,814 tons. Among these, 6,096 HPs were installed at sites with no cooling (only gas furnace for heating) while the remaining 1,896 were installed at sites that had a window AC and furnace as the existing setup.
- SWHC045: In 2021, there were 45 central ducted HP installations with a combined capacity of 81 tons. Among these, 5 HPs were installed at sites with no cooling (only gas furnace for heating) while the remaining 40 were installed at sites that had a window AC and furnace as the existing setup.
- SWHC049: In 2021, 11,433 (split/packaged) AC units with a total capacity of 40,793 tons, and 2,696 (split/packaged) HP units with a total capacity of 8,074 tons were installed effectively, replacing less efficient units.
- SWHC050: In 2021, there were 10 ductless HP installations with a combined capacity of 27 tons that were installed, effectively replacing less efficient units.

CLAIMS YEAR 2022

- SWHC039: In 2022, there were 23,954 thermostat installations. Among these, 6,806 thermostats were placed on HPs, accounting for 28 percent of the total, while 17,148 thermostats were installed on DX units with gas furnaces, constituting the remaining 72 percent.
- SWHC044: In 2022, there were 109 ductless HP installations with a combined capacity of 258 tons. Among these, 11 HPs were installed at sites with no cooling (only gas furnace for heating) while the remaining 98 were installed at sites that had a window AC and furnace as the existing setup.
- SWHC045: In 2022, there were 5,880 central ducted HP installations with a combined capacity of 22,174 tons. Among these, 1,263 HPs were installed at sites with no cooling

(only gas furnace for heating) while the remaining 4,617 were installed at sites that had a window AC and furnace as the existing setup.

- SWHC049: In 2022, 400 (split/packaged) AC units with a total capacity of 1,280 tons were installed, effectively replacing less efficient units.
- SWHC050: In 2022, there were seven ductless HP installations with a combined capacity of 16.5 tons that were installed, effectively replacing less efficient units.
- SWHC027: In 2022, there were two high-efficiency ACs with a combined capacity of 45 tons that were installed, effectively replacing less efficient units.

TECH Data Review

The TECH program's website hosts a section where TECH working datasets for both single and multifamily properties can be downloaded. These datasets offer anonymized information sourced from incentive applications submitted by participating TECH contractors, along with qualified product lists. The TECH Clean California program was launched in June 2021. The project team reviewed these datasets and identified the following key findings.

KEY TAKEAWAYS

1. In single family homes, 47 percent of the installed HPs were allocated to homes that did not have any prior cooling, compared with 25 percent for multifamily.
2. About 90 percent of the HPs installed in single family homes and multifamily dwelling units are ducted HPs.
3. About 28 percent of the HPs installed in single family homes are variable speed, compared with 32 percent for multifamily.

SINGLE FAMILY

- Across all 16 California climate zones, a total of 12,067 HPs were installed, boasting a combined capacity of 38,612 tons.
- Out of the total HPs installed, 5,709 HPs were installed for projects that didn't have any cooling before (47 percent).
- Ducted HPs constituted 10,801 (90 percent), whereas 1,266 (10 percent) were ductless, out of the total number of installed HPs.
- The installation encompassed various types of HPs: 7,502 split HPs (62 percent), 1,963 mini-splits (16 percent), 1,468 multi-splits (12 percent), 1,104 packaged HPs (9 percent), and 20 small duct high-velocity system HPs (0.1 percent).
- Of the 12,067 HPs installed, 8,635 were either single-speed or two-speed (72 percent) and 3,432 were variable-speed HPs (28 percent).
- The existing gas systems that were replaced by the HPs are as follows: 11,896 natural gas furnaces (98 percent), 138 electric furnaces (1 percent) and 33 projects had 'other' fuel types.
- As part of this program, a total of 4,947 smart thermostats were installed on these HPs.

MULTIFAMILY

- Across all 14 California climate zones (except 1 and 16), a total of 918 HPs were installed, boasting a combined capacity of 1,787 tons.
- Out of the total HPs installed, 231 HPs were installed for projects that didn't have any cooling before (25 percent).

- Out of total HPs that were installed, 688 HPs were ducted (90 percent) while the remaining 230 were ductless (10 percent).
- This installation included different types of HPs: 526 split HPs(57 percent), 231 mini-splits (25 percent), 57 multi-splits (6 percent), and 104 packaged HPs (11 percent).
- Of the 918 HPs installed, 630 were either single-speed or two-speed (68 percent) and 288 were variable-speed HPs (32 percent).
- The existing gas systems that were replaced by the HPs are as follows: 771 natural gas furnaces (84 percent) and 147 electric furnaces (16 percent).
- As part of this program, a total of 146 smart thermostats were installed on these HPs.

Recommendations for Measure Updates

Based on identifying the current gaps from the existing measure packages, the project team further identified the biggest gaps and sought feedback from the stakeholders, including San Diego Gas and Electric (SDG&E), Southern California Edison (SCE), and the Cal TF Measure Screening Committee (MSC). The feedback includes potential baselines, unit considerations, climate and preexisting conditions, challenges, program approaches, and timeline.

The project team identified the following potential measure pathways, seeing the considerable presence in existing market:

1. **Forced Air Electric Furnace** to **Central Ducted HP**
2. **Forced Air Electric Furnace** to **Central Ductless HP**
3. **Central AC and Forced Air Electric Furnace** to **Central Ducted HP**
4. **Central AC and Forced Air Electric Furnace** to **Central Ductless HP**
5. **Central AC and Floor or Wall Gas Furnace** to **Central Ductless HP**
6. **Window Room AC and Forced Air Gas Furnace** to **Central Ducted HP**

In general, the IOUs perceived that incorporating the identified baseline systems to be replaced with central mini-split or multi-split heat pump would be most feasible given their market prominence in California. There is a considerable opportunity with the window room AC combined with central forced air gas furnace that could transition to central ducted HPs, especially in multifamily and older homes along the coast.

Further review would be needed considering specific climate zones when determining cost-effective baselines for programs. There are operational challenges of introducing multiple baseline system assumptions for the same measure case, such as the need to confirm preexisting conditions for accurate claims. This could be a challenge for upstream or midstream delivery programs. Furthermore, modeling new baseline systems is time consuming and could pose challenges, such as bandwidth considerations that could potentially cause delays in implementing new measures until possibly mid-2024. Budget constraints could also limit the updates to be only for measures that are deemed valuable by PAs or PIs. Another insight is related to the challenge of deciding between upstream and downstream program approaches. For example, the SWHC044 measure may be more

cost-effective as a downstream offering due to its low net-to-gross (NTG) ratios for upstream/midstream offerings from recent evaluations.

Another consideration is the implication of refrigerant use and energy savings. Transitioning from window AC units to mini-splits may not drastically alter refrigerant use. However, the switch from electric resistance heat to a HP provides significant electric energy savings and benefits with the industry's shift towards TSB but adds refrigerant. An important observation is the potential overlapping usage of systems, especially setups combining a window AC and gas furnace. The prospect of both systems functioning simultaneously in real world applications requires consideration of projected savings.

Based on validating the database gaps through discussion with Cal TF and IOUs, the project team further assessed the market potential including its impacts to underserved demographics and conducted a ballpark estimate of the potential energy savings.

Measure Support for DAC/HTR Customers

The project team prepared recommendations for updates to existing measure packages and measure update impacts for HTR community and DAC customers. This included directional estimates for energy and TSB impacts.

CalEPA proposes the definition for DAC customers based on the analysis conducted by California Communities Environmental Health Screening Tool (CalEnviroScreen), which incorporates a variety of different indicators to account for environmental conditions and people's vulnerability to environmental pollutants. Based on the CalEnviroScreen database, 28.7 percent of the population was designated as DAC.

TECH data also includes the DAC information based on the CalEnviroScreen database for the enrolled cities. It shows 7.8 percent of the participants were categorized as DAC. Among these DAC sites, 81 percent of them are single family, while 19 percent of them are multifamily. For single family buildings, the predominant HVAC system is split unitary equipment; however, mini-split is the predominant HVAC system used in multifamily buildings.

RASS data does not provide any DAC information, instead, it provides household income. The income categories are as follows: low income (< $25,000); moderate income ($25,000–$74,999); and high income (> $75,000). Among all the homes that use primary electric heating, 20 percent of them are low-income households.

The extent to which measure updates will impact costs for HTR community and DAC customers depends on factors such as climate zone, electric utility rate, and rate of participation in HP program offerings, and whether or not the existing systems are covered in the measure packages. California Alternate Rates for Energy (CARE) offers discounted rates for low-income households, and rates vary depending on utility, rate schedules, and household consumption. The project team researched

CARE rates and found them to be around $0.27/kWh.[1] Applying this rate to the estimated savings from Table 7 for central ductless HPs, low-income customers could see annual energy cost savings around $350 per ton of HP capacity. For customers with ducted HPs or switching from natural gas heat, there will be additional cost savings potential.

Energy and TSB Savings Impacts

The project team reviewed the potential energy savings and impacts related to the recommended baselines described in previous sections. The project team leveraged modeled energy consumption and savings values from existing approved measure packages to estimate the savings for the new baselines. Additionally, the project team utilized the fuel substitution calculation version 1.1, as established by the CPUC (as summarized in Appendix B). Assumptions used included a lifespan of 15 years, an installation year of 2024, and normal replacement for the measure application. The results indicated positive savings for both the lifecycle of primary energy and CO_2 emissions, which confirmed the measure eligibility as the results passed both aspects of the two-pronged test.

The methodology for each new baseline is described as follows.

ELECTRIC RESISTANCE FURNACE

The RASS data indicated that electric resistance furnaces constitute the third highest residential heating system in the market. The TECH data further demonstrated that the following system types are being replaced with both central ducted and ductless HP systems:

- Central AC and forced air electric furnace
- Forced air electric furnace only (no cooling)

There are currently no measure packages that explicitly incorporate these HVAC systems as a baseline system type. In order to estimate the savings, the project team employed the following calculation methodology:

a. Using energy consumption values from the existing measure package SWHC045, the project team converted natural gas consumption values from a baseline furnace to electric resistance consumption using unit energy conversions and a comparison of code required efficiencies for both furnace types. These new baseline values were used to calculate the savings when installing central ducted HPs to replace the aforementioned two system types. Table 6 shows the average savings across all 16 California climate zones, two measure application types (accelerated replacement (AR), normal replacement (NR)), and two building types (single family and multifamily). The average baseline values were 2,835 kWh/ton for the central AC with forced air electric furnace and 2,640 kWh/ton for the forced air electric furnace without cooling.

[1] Blended rate based on the project team's review of various rate comparison documents published on IOU websites, including https://www.sdge.com/customer-choice/community-choice-aggregation/joint-rate-comparison, https://www.sce.com/customer-service/Community-Choice-Aggregation, and https://www.pge.com/en_US/residential/customer-service/other-services/alternative-energy-providers/community-choice-aggregation/community-choice-aggregation.page#comparecca.

Table 6: Average Savings with Central Ducted HP (kWh/ton)

Measure Case Efficiency (SEER2)	Average Measure Case Energy Consumption for Central Ducted HP (kWh/ton)	Average Savings from Central AC with Forced Air Electric Furnace Baseline (kWh/ton)	Average Savings from Forced Air Electric Furnace (No Cooling) Baseline (kWh/ton)
14.3	884	1,951	1,752
15.2	878	1,957	1,759
16	843	1,992	1,793
16.9	819	2,016	1,817

b. To estimate the savings potential for installing ductless HPs for the above two system types, the project team examined the SWHC050 (ductless to ductless HP) and SWHC049 (ducted to ducted HP) measure packages, and noted that the average savings for the SWHC050 measure package across all California climate zones, all measure application types, and both building types (single family and multifamily) is 193 kWh/ton, and for SWHC049, it is 275 kWh/ton. This indicates that the savings from the ductless HP measure package are approximately 70 percent compared to those of the ducted HP measure package. The project team applied this factor of 70 perecnt to the savings shown in Table 6 to estimate the savings from installing central ductless HPs, as shown in Table 7. The average baseline values were 1,990 kWh/ton for the central AC with forced air electric furnace and 1,853 kWh/ton for the forced air electric furnace without cooling.

Table 7: Average Savings with Central Ductless HP (kWh/ton)

Measure Case Efficiency (SEER2)	Average Measure Case Energy Consumption for Central Ductless HP (kWh/ton)	Average Savings from Central AC with Forced Air Electric Furnace Baseline (kWh/ton)	Average Savings from Forced Air Electric Furnace (No Cooling) Baseline (kWh/ton)
14.3	620	1,369	1,230
15.2	616	1,373	1,234
16	592	1,398	1,258
16.9	575	1,415	1,275

CENTRAL AC WITH WALL OR GAS FURNACE AND WINDOW AC WITH FORCED AIR GAS FURNACE

There are no measure packages that specifically address combinations like central AC and wall/gas furnace or window AC and forced air gas furnace as the baseline system type. The TECH data additionally illustrated the following:

- Central AC and wall/gas furnace being replaced with a central ductless HP system
- Window AC and forced air gas furnace being replaced with a central ducted HP system

To estimate the savings for these baseline systems, the project team referenced a number of measure packages to estimate the baseline kWh, baseline therms, measure case kWh, and measure case therms for these specific systems. Table 8 indicates the source of these values and the average savings.

Table 8: Average Savings with Central Ducted and Ductless HPs (kWh and Therms)

Measure Description	Baseline Description	Baseline kWh/ton	Measure kWh/ton	Savings kWh (%)	Baseline Therms/ton	Measure Therms/ton	Savings Therms/ton (%)
Central Ducted HP	Window Room AC with Forced Air Gas Furnace	2,377	2,531	-154 (-6%)	43	0	43 (100%)
Central Ductless HP	Central AC with Wall Gas Furnace	2,377	2,296	81 (3%)	51	0	51 (100%)

Sources: Central Ducted HP (SWHC045 Measure Case UEC), Window Room AC (SWHC044 Baseline UEC kWh), Forced Air Gas Furnace (SWHC045 Baseline UEC Therms), Central Ductless HP (SWHC044 Measure Case UEC), Central AC (SWHC045 Baseline UEC kWH), Wall Gas Furnace (SWHC044 Baseline UEC Therms)

As the above table shows, there are savings potential and TSB from incorporating these baseline systems in the measure packages due to these being fuel substitution.

COST EFFECTIVENESS ASSESSMENT

The CEDARS data showed that in 2022, 15 percent of the projects were located in Climate Zone (CZ) 10. Hence for the assessment using the Cost-Effectiveness Tool (CET), the project team selected CZ 10 for a test comparison of the TSB. The process involved exporting CET input files from eTRM for the current versions of residential HP measure packages. Specifically, the project team used inputs from CZ 10 HP measures, with kWh and therms savings edited to reflect average values. To ensure consistency with the current eTRM guidelines, the project team updated the run year and quarter to 2024 and Q3. This update also allowed for uniform cost-effectiveness values across all measures. The project team then ran the CET for both proposed and existing offerings from measure packages

for CZ 10, specifically targeting single family, ex-vintage, NR MAT for simplicity. For this process, there were no changes made to any measure or base cost values, given that TSB does not consider these costs.

Table 9: Comparison of TSB to Existing Offerings

Measure Comparison	TSB Average % Change
SWHC049 – Recommendation 1: Ducted HP replacing Central Electric Furnace	431%
SWHC050 – Recommendation 2: Ductless HP replacing Central Electric Furnace	733%
SWHC049 – Recommendation 3: Ducted HP replacing Central Electric Furnace and AC	490%
SWHC050 – Recommendation 4: Ductless HP replacing Central Electric Furnace and AC	649%
SWHC044 – Recommendation 5: Ductless HP replacing Central AC and Zone Gas Furnace	73%
SWHC045 – Recommendation 6: Ducted HP replacing Central Gas Furnace and Window AC	352%

The results indicated an overall improvement in TSB for the new offerings (Table 9). TSB values generally scaled with improved electric savings for energy efficiency measures. However, the TSB values for fuel substitution measures were more complex to interpret due to differing valuation in the CET for kWh and therms. Despite the complexity, there was a positive scale with increased savings in kWh, therms, and net claimable kWh.

Conclusion and Next Steps

The project team identified gaps in the current measure packages and recommends six base case systems to be further analyzed in subsequent studies or considered by IOUs or measure package developers for measure package updates. The proposed potential next steps are as follows:

- PY 2026 Updates: There is a potential for these recommended systems to be included in the Program Year (PY) 2026 updates. This inclusion is contingent upon the interest of IOUs and the availability of program resources. The project team acknowledges that bandwidth may be a constraint due to multiple models being run statewide.
- Midcycle Implementation: In the event that these recommendations are not incorporated into the PY 2026 updates, there is a possibility of implementing them as midcycle updates. These can go live as soon as they are approved by the CPUC, which offers a flexible and timely

approach to updating the measure packages. The approval process for midcycle updates is managed by the CPUC and IOUs who are responsible for the measure development. Although midcycle updates can be proposed for various reasons, such as adding new offerings, they are typically aligned with specific program years. While the stakeholders see values in these recommendations, the project team also acknowledges the limited statewide bandwidth to accommodate such updates and the regulatory obligations to complete PY 2026 updates first before considering additional offerings in the midcycle updates.

- PY 2024 Considerations: Due to time constraints, it is not feasible to include these updates in the PY2024 cycle.

Appendix A: Measure Package Summary

Measure	Base Case Description	Measure Case Description
SWHC050: Ductless HP, Residential	The base case is either a ductless HP or a room unit (HP or AC coupled with electric resistance space heater).	The measure case is a ductless HP (mini- or multi-split) with cooling capacity less than 65,000 Btu/hour and minimum efficiency ratings depending on the install type AR or NR. Minimum seasonal energy efficiency ratio 2 (SEER2) ranges from 15.2 to 20.5, and minimum heating seasonal performance factor 2 (HSPF2) ratings range from 7.8 to 9.1. Minimum SEER (legacy rating system) ranges from 16 to 22, and minimum HSPF (legacy rating system) ratings range from 9.2 to 10.9.
SWHC044: Ductless HVAC, Residential, Fuel Substitution	The base case is defined as either a residential HVAC system with a natural gas gravity wall furnace and an electric window AC unit or a system with only a natural gas gravity wall furnace and no existing cooling unit or load.	The measure case is a ductless HP (mini- or multi-split) with cooling capacity less than 65,000 Btu/hour and minimum efficiency ratings depending on the install type AR or NR. Minimum SEER2 ranges from 15.2 to 20.5, and minimum HSPF2 ratings range from 7.8 to 9.1. Minimum SEER ranges from 16 to 22, and minimum HSPF ratings range from 9.0 to 10.9.
SWHC045: HP HVAC, Residential, Fuel Substitution	The base case for the code condition is defined as a residential central AC unit, DX type, for cooling and gas furnace for space heating or a system with only a natural gas furnace that meets all code minimum requirements.	The measure case is defined as an all-electric residential central air-source HP using electric resistance heating if supplemental heating is required. Minimum SEER ranges from 15.2 to 21, and minimum HSPF ratings range from 7.7 to 10.5.

Measure	Base Case Description	Measure Case Description
SWHC027: Packaged Terminal AC or HP, Under 24 kBtu/hour	The base case is defined as a through-the-wall, self-contained, and less than two ton (≤ 24 kBtu/hour) PTAC or PTHP unit that meets the minimum efficiency specified in the California Building Energy Efficiency Standards (Title 24). Energy efficiency ratios (EERs) depend on the capacity of the system. The eTRM lists baseline EERs for representative capacities that range from 7.61 to 11.9 for cooling mode and the baseline COP ratings for representative capacities range from 2.51 to 3.34 for heating mode.	The measure case is defined as a through-the-wall, self-contained, and less than two ton (≤ 24 kBtu/hr) PTAC or PTHP unit that has an EER and, for PTHP heating mode, a coefficient of performance (COP) that is 20 percent higher than the base case. The eTRM lists measure case EERs for representative capacities that range from 9.13 to 14.28 for cooling mode and the measure case COP ratings for representative capacities range from 3.01 to 4.01 for heating mode.
SWHC049: SEER Rated AC and HP HVAC Equipment, Residential	The base case is defined as a residential central AC unit for cooling and gas furnace for space heating or central HP that meets the code minimum requirements.	The measure case is defined as an AC or HP unit that replaces the same type as the base case equipment by meeting certain tiers of efficiency as listed in the measure package, with a minimum SEER range of 15.2 to 21.
SWHC039: Smart thermostat, Residential	The base case is defined as a setback programmable thermostat per the Impact Evaluation of Smart Thermostats.	The measure case is defined as the installation of a residential smart thermostat with two-way communication and automatic scheduling capabilities.

Appendix B: Fuel Substitution Test

Measure Description	kWh Savings	Therms Savings	Lifecycle Primary Energy Savings (MMBtu at Generation Source)	Test (Pass/Fail)	Lifecycle Emissions Savings Metric tCO_2	Test (Pass/Fail)	Conclusion of Fuel Substitution Test
Ductless HP Replacing Central AC and Zone Gas Furnace_SEER2 15.2_CZ10	42.5	51.5	79.1	PASS	4.2	PASS	Eligible
Ductless HP Replacing Central AC and Zone Gas Furnace_SEER2 16_CZ10	60.0	51.5	79.8	PASS	4.2	PASS	Eligible
Ductless HP Replacing Central AC and Zone Gas Furnace_SEER2 16.9_CZ10	76.9	51.5	80.6	PASS	4.3	PASS	Eligible

Measure Description	kWh Savings	Therms Savings	Lifecycle Primary Energy Savings (MMBtu at Generation Source)	Test (Pass/Fail)	Lifecycle Emissions Savings Metric tCO_2	Test (Pass/Fail)	Conclusion of Fuel Substitution Test
Ductless HP replacing Central AC and Zone Gas Furnace_SEER2 17.8_CZ10	88.1	51.5	81.0	PASS	4.3	PASS	Eligible
Ductless HP replacing Central AC and Zone Gas Furnace_SEER2 18.7_CZ10	102.2	51.5	81.7	PASS	4.3	PASS	Eligible
Ductless HP replacing Central AC and Zone Gas Furnace_SEER2 19.6_CZ10	113.4	51.5	82.1	PASS	4.4	PASS	Eligible

Measure Description	kWh Savings	Therms Savings	Lifecycle Primary Energy Savings (MMBtu at Generation Source)	Test (Pass/Fail)	Lifecycle Emissions Savings Metric tCO_2	Test (Pass/Fail)	Conclusion of Fuel Substitution Test
Ducted HP replacing Central Gas Furnace and Window AC_SEER2 15.2_CZ10	-193.4	43.0	56.1	PASS	3.0	PASS	Eligible
Ducted HP replacing Central Gas Furnace and Window AC_SEER2 16_CZ10	-175.9	43.0	56.9	PASS	3.0	PASS	Eligible
Ducted HP replacing Central Gas Furnace and Window AC_SEER2 16.9_CZ10	-169.7	43.0	57.1	PASS	3.0	PASS	Eligible

Measure Description	kWh Savings	Therms Savings	Lifecycle Primary Energy Savings (MMBtu at Generation Source)	Test (Pass/Fail)	Lifecycle Emissions Savings Metric tCO_2	Test (Pass/Fail)	Conclusion of Fuel Substitution Test
Ducted HP replacing Central Gas Furnace and Window AC_SEER2 17.8_CZ10	-155.0	43.0	57.8	PASS	3.1	PASS	Eligible
Ducted HP replacing Central Gas Furnace and Window AC_SEER2 18.7_CZ10	-130.3	43.0	58.8	PASS	3.1	PASS	Eligible
Ducted HP replacing Central Gas Furnace and Window AC_SEER2 19.6_CZ10	-101.6	43.0	60.1	PASS	3.2	PASS	Eligible