# Residential HPWH Market Study and Measure Gap Analysis

## Final Report

ET23SWE0035


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## Disclaimer

# Executive Summary

The California Electronic Technical Reference Manual (eTRM) currently offers two measure packages for Residential Heat Pump Water Heaters (HPWHs). However, these packages are limited due to the low market penetration of heat pump water heaters (HPWHs) in previous years, resulting in measure offerings that do not cover the full range of installations in the market. Key limitations include eligibility restrictions based on tank size and efficacy, as well as limitations in the water heating savings calculation tool. The objectives of this project are to recommend enhancements to the eTRM measure packages for Residential HPWHs and identify areas to further the development of the DEER calculation tool. Avoided cost calculators and consideration of demand flexibility programs will assist in creating successful eTRM measure packages and transformation of the residential water heating market in the next five years.

To achieve these objectives, the project team collected data from various sources, including the TECH Clean California Program (TECH), the California Energy Data and Reporting System (CEDARS), the Self-Generation Incentive Program (SGIP), the Air-Conditioning, Heating, and Refrigeration Institute (AHRI), and HPWH manufacturers. These sources were compared to current eTRM offerings and insights from supply chain interviews to identify trends and measure opportunities. Interviews were conducted with relevant stakeholders, including a statewide incentive program, three manufacturers, and one installer.

Based on the evidence gathered, the project team offers several recommendations to enhance the eTRM's support for residential HPWHs.

1. The addition of new efficacy tiers to the SWWH025 and SWWH014 measure packages to accommodate HPWHs with Uniform Energy Factor (UEF) values above 4.
2. The addition of new efficacy tiers to both measure packages for HPWHs between 2.60 UEF and 3.30 UEF, particularly addressing 120V HPWHs.
3. Expansion of measure offerings allowing change in tank size.
4. Updates to the DEER Water Heater Calculator that account for current market practices including 120V HPWHs and larger tank sizing, which will, in turn, allow new measure offerings to capture the benefits of those practices.

These recommendations aim to align the eTRM with evolving market dynamics, technological advancements, and efficiency and demand management program offerings, ensuring robust support for residential HPWHs.

# Abbreviations and Acronyms

| Acronym | Meaning |
|---|---|
| Cal TF | California Technical Forum |
| DAC | Disadvantaged Communities |
| DEER | Database of Energy Efficiency Resources |
| EE | Energy Efficiency |
| eTRM | Electronic Technical Resource Manual |
| ET | Emerging Technology |
| GHG | Greenhouse Gas |
| GWP | Global Warming Potential |
| HP | Heat Pump |
| HPWH | Heat Pump Water Heater |
| HTR | Hard-to-Reach |
| HVAC | Heating, Ventilation, and Air Conditioning |
| IOU | Investor-Owned Utility |
| kWh | Kilowatt-hour |
| NEEA | Northwest Energy Efficiency Alliance |
| PA | Program Administrator |
| PG&E | Pacific Gas & Electric |
| SCE | Southern California Edison |
| SDG&E | San Diego Gas & Electric |
| TPM | Technology Priority Map |

| Acronym | Meaning |
|---|---|
| TRC | Total Resource Cost benefit/cost ratio metric of CPUC efficiency measure evaluation |
| WH | Water Heating |

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# Introduction

California deemed energy efficiency measures for residential HPWHs have received significant attention due to the impact of these measures on the state's goals for decarbonization, demand flexibility, and grid resiliency. This project aims to take a broad look at current and anticipated product developments and current program experience to make recommendations for the measure package updates due in 2024 as well as longer-term changes.

# Background

The California Electronic Technical Reference Manual (eTRM) includes two measure packages for residential heat pump water heaters: Heat Pump Water Heater, Residential and Heat Pump Water Heater, Residential, Fuel Substitution. Southern California Edison is the designated Measure Lead for both measure packages. The current measure packages for HPWHs are based on limited information because market penetration for these products has been well below one percent. As a result, detailed market data has been impossible to find. Current limitations include the restriction of eligibility in the eTRM to certain ranges of tank size and efficacy, and limits in the water heating savings calculation tool that prevent full modeling of mixing valve benefits or demand control connectivity.

HPWH product offerings from manufacturers have evolved quickly over recent years. New 120V products have entered the market and the overall number of HPWH offerings has greatly increased. Both the California market and available installation data have undergone significant changes with two initiatives leading those changes:

> The TECH Clean California initiative has funded HPWH projects and gathered project and site data on almost 2,000 HPWH incentives to date. The Self-Generation Incentive Program (SGIP) is a new funding initiative for TECH to utilize in its market transformation efforts that is expected to be the largest source of HPWH incentives in the state when it launches Oct 31, 2023.

The 2023 Potential and Goals Study from Guidehouse and the California Public Utilities Commission (CPUC) suggest potentially massive impacts from Residential Water Heating in the five-year period through 2028: more than $300 million in Total System Benefit (TSB) from Energy Efficiency alone, and, in an Aggressive Fuel Substitution scenario, more than $3.3 billion TSB from Fuel Substitution.

# Objectives

The broad objectives for this project are to suggest near-term additions to the eTRM Measure Packages for Residential HPWHs and to highlight areas where the need for new measure offerings may emerge in the next five years. Factors driving that need include further development of the DEER calculation tool, load curve and hourly impact calculations, demand flexibility programs and protocols for connected appliances, and market technology developments.

CalNEXT's 2022 Residential Water Heater Measure Sizing Package Support project made recommendations for changes to the Heat Pump Water Heater, Residential, Fuel Substitution measure package around tank upsizing. This project aims to build on and expand from that effort by folding in additional data sources and considering measure-offering recommendations in the following additional areas:

- Measures for both base case fuels
- HPWH measure efficacy via Uniform Energy Factor (UEF)
- Further tank size increase measures
- Mixing valves
- CTA-2045 controls and potential future impact on load shapes

Looking at the five objectives above in order, the current Measure Packages are differentiated by base case fuel, so including both is important for broadest applicability. Maintaining harmony between the two may also help reduce program implementation friction. The next two on the list relate to efficacy and tank size, which are the two factors that differentiate the offerings in each measure package. It is important to make sure that the measure offering delineations continue to match the market availability and interest in the years ahead. Furthermore, 120V HPWHs are relatively new on the market and could provide HPWH options to important customer segments and address equity considerations if the often-lower efficacies can be incorporated. The last two objective areas are not directly addressed in current measures but are required components of the CEC's JA13 Heat Pump Water Heater Qualification Requirements, and thus likely to be important in the landscape of future California programs.

## Methodology & Approach

The project started by gathering available data from the TECH Clean California Program (TECH), the California Energy Data and Reporting System (CEDARS), the Self-Generation Incentive Program (SGIP), the Air-Conditioning, Heating, and Refrigeration Institute (AHRI), and HPWH manufacturers, as described in the Initial Findings section of this report.

Interviews have been conducted with the statewide incentive program, three manufacturers, and one installer.

The report outlines the written analyses from the TECH program data relevant to eTRM offerings. Data has been analyzed to highlight trends for residential HPWHs and identify the importance of product and installation types that are and are not covered by the current measure packages. These findings, along with recommendations for the HPWH measure packages and a summary of HPWH data sources, are presented in this Draft Report and will be refined with Stakeholder input for the Final Report.

**Table 1: Measure Offerings in Measure Package SWWH025 (Fuel Substitution)**

| Statewide Measure Offering ID (2-letter code) | Measure Offering Description |
|---|---|
| W | Heat pump water heater, < 45 gal, UEF = 3.30 replacing storage natural gas water heater, 40 gal, UEF = 0.64 |
| X | Heat pump water heater, < 45 gal, UEF = 3.50 replacing storage natural gas water heater, 40 gal, UEF = 0.64 |
| Y | Heat pump water heater, < 45 gal, UEF = 3.75 replacing storage natural gas water heater, 40 gal, UEF = 0.64 |
| AR | Heat pump water heater, > 55 to ≤ 75 gal, UEF = 3.30 replacing storage natural gas water heater, 40 gal, UEF = 0.64 |
| AU | Heat pump water heater, > 55 to ≤ 75 gal, UEF = 3.30 replacing storage natural gas water heater, 50 gal, UEF = 0.63 |
| Z | Heat pump water heater, > 55 to ≤ 75 gal, UEF = 3.30 replacing storage natural gas water heater, 60 gal, UEF = 0.61 |
| AS | Heat pump water heater, > 55 to ≤ 75 gal, UEF = 3.50 replacing storage natural gas water heater, 40 gal, UEF = 0.64 |
| AV | Heat pump water heater, > 55 to ≤ 75 gal, UEF = 3.50 replacing storage natural gas water heater, 50 gal, UEF = 0.63 |
| AA | Heat pump water heater, > 55 to ≤ 75 gal, UEF = 3.50 replacing storage natural gas water heater, 60 gal, UEF = 0.61 |
| AT | Heat pump water heater, > 55 to ≤ 75 gal, UEF = 3.75 replacing storage natural gas water heater, 40 gal, UEF = 0.64 |
| AW | Heat pump water heater, > 55 to ≤ 75 gal, UEF = 3.75 replacing storage natural gas water heater, 50 gal, UEF = 0.63 |
| AB | Heat pump water heater, > 55 to ≤ 75 gal, UEF = 3.75 replacing storage natural gas water heater, 60 gal, UEF = 0.61 |
| AX | Heat pump water heater, > 75 gal, UEF = 3.30 replacing storage natural gas water heater, 50 gal, UEF = 0.63 |
| BA | Heat pump water heater, > 75 gal, UEF = 3.30 replacing storage natural gas water heater, 60 gal, UEF = 0.61 |

| | |
|---|---|
| AC | Heat pump water heater, > 75 gal, UEF = 3.30 replacing storage natural gas water heater, 75 gal, UEF = 0.59 |
| AY | Heat pump water heater, > 75 gal, UEF = 3.50 replacing storage natural gas water heater, 50 gal, UEF = 0.63 |
| BB | Heat pump water heater, > 75 gal, UEF = 3.50 replacing storage natural gas water heater, 60 gal, UEF = 0.61 |
| AD | Heat pump water heater, > 75 gal, UEF = 3.50 replacing storage natural gas water heater, 75 gal, UEF = 0.59 |
| AZ | Heat pump water heater, > 75 gal, UEF = 3.75 replacing storage natural gas water heater, 50 gal, UEF = 0.63 |
| BC | Heat pump water heater, > 75 gal, UEF = 3.75 replacing storage natural gas water heater, 60 gal, UEF = 0.61 |
| AE | Heat pump water heater, > 75 gal, UEF = 3.75 replacing storage natural gas water heater, 75 gal, UEF = 0.59 |
| AF | Heat pump water heater, ≥ 45 to ≤ 55 gal, UEF = 3.30 replacing storage natural gas water heater, 30 gal, UEF = 0.6 |
| AG | Heat pump water heater, ≥ 45 to ≤ 55 gal, UEF = 3.30 replacing storage natural gas water heater, 40 gal, UEF = 0.64 |
| AH | Heat pump water heater, ≥ 45 to ≤ 55 gal, UEF = 3.30 replacing storage natural gas water heater, 50 gal, UEF = 0.63 |
| AI | Heat pump water heater, ≥ 45 to ≤ 55 gal, UEF = 3.30 replacing tankless natural gas water heater, high draw, UEF = 0.81 |

# Findings

## Data Analysis

The Project Team identified data sources for HPWH product information and HPWH Project information. Product databases from AHRI, NEEA and ENERGYSTAR™ supplied views of the range of products on the market. Two data sources provided project information: CEDARS claims and public reporting data from Energy Solutions' TECH Clean California initiative. Both the products and the projects lists have been compared to the current eTRM offerings and considered alongside input from supply chain interviews to examine trends and identify opportunities for added measures.

### AHRI Data

The Project Team collected product data from the AHRI database to show the broad range of HPWH product performance and compare it to current eTRM offerings. This project will analyze AHRI data based on the following characteristics:

- Manufacturer breakdown
- UEF distribution
- Average UEF and tank sizes by eTRM size category
- Unit counts by qualifying eTRM tier

AHRI data has been essential in giving the team the broadest possible view of available HPWH products on the market and trends. Figure 5 in Appendix 3 shows that more recent HPWH listings in green include larger tank sizes (toward the top), higher efficacies (toward the right), as well as new products below the 3.30 UEF minimum currently in the eTRM.

Aligning with the project objectives, the AHRI data points to areas to consider recommending new measures. First, the higher-efficacy products are above 4.00 UEF, which is a logical place to start a new efficacy bin (0.25 UEF above the top of the 3.50 – 3.75 efficacy). Cal TF analysis of the Fuel Substitution measures shows that TRC ratios are low and any increase in savings per unit may help.

Secondly, AHRI data shows larger tank sizes. If benefits of large tanks can be captured in the DEER savings calculator and in demand flexibility calculations, a new tier of tank size measure offerings for tanks above 90 gallons could be created. The project data from the TECH program confirmed use of tanks above 90 gallons on HPWH split systems not included in the AHRI data.

Lastly, AHRI, combined with ENERGY STAR® data reporting the input voltage for AHRI products, is showing products below the current 3.30 UEF minimum, particularly for 120V products, in Figure 1. Especially given the challenges for achieving higher UEF in a 120V HPWH small and inexpensive enough to address the multifamily, DAC, and HTR markets, new offerings below 3.30 UEF should be considered.

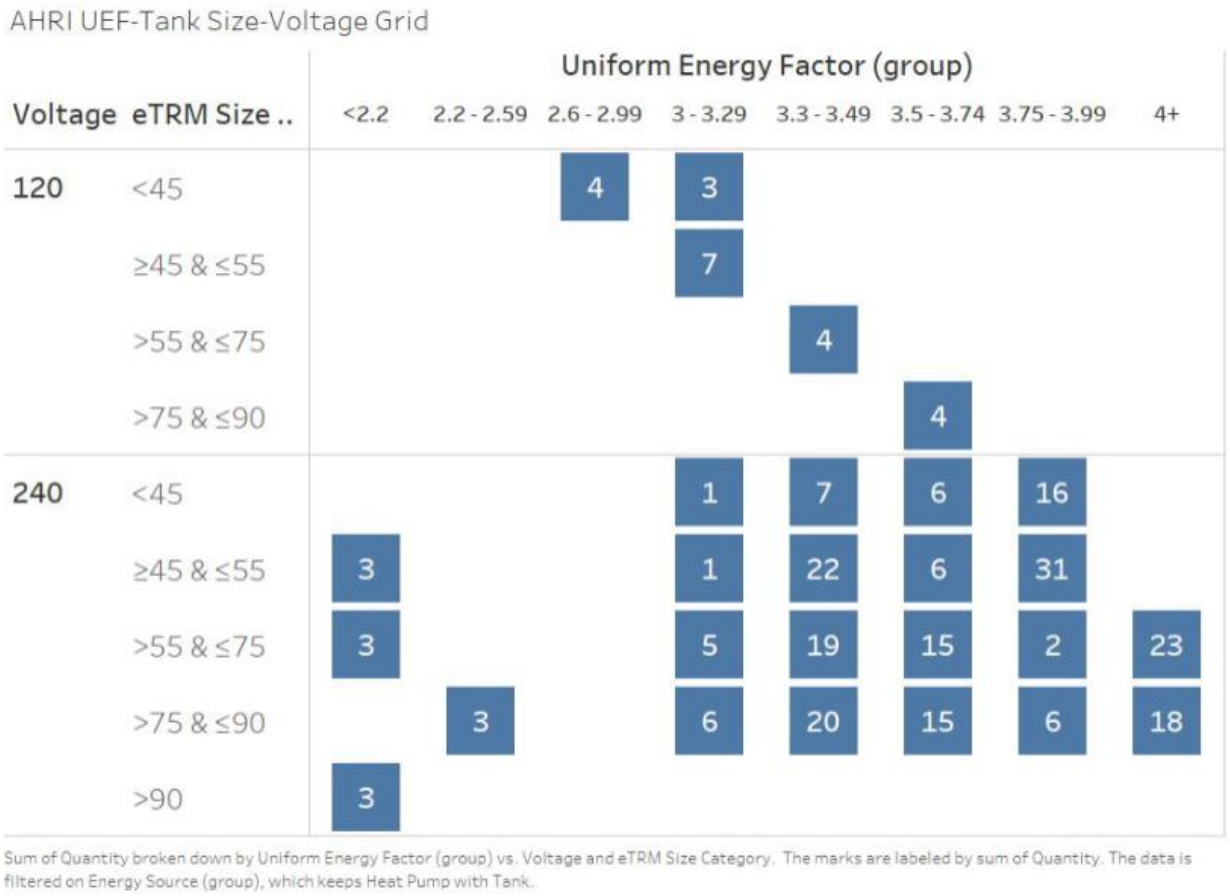


**Figure 1: AHRI HPWH listings binned by Voltage, Tank Size, and UEF**

## TECH Program Data

The Project Team also collected project data from the TECH Clean California Program led by Energy Solutions and analyzed it based on the following characteristics:

- TECH unit counts by eTRM size category (1,850 total units)
- UEF distribution, including by HPWH voltage type
- Average UEF and tank sizes by eTRM size category
- Tank upsizing pairing distribution
- Matching TECH program data to eTRM Offering ID to identify missed opportunities

Initial analysis of TECH data shows that 12 percent of TECH projects were for a combination of Tank Size and UEF that don't match any existing eTRM offering IDs.

The TECH data is extremely useful and generally preferred to CEDARS data as a snapshot of market interest in tank size because its projects were not constrained by the limits of the eTRM, so it can tell us what units are popular even where they do not match the prescribed eTRM offerings, as discussed further in the Next Steps section below. Secondly, TECH collected data on base case water heaters independent of the measure case, so it can tell us where there is resizing of tanks where the eTRM makes an assumption and doesn't allow for certain resizing, as shown in Table 2 below. Nearly

two-thirds of TECH projects were tank upsizes: the base case tank bin was smaller than the measure case tank bin for 65 percent of installations.

**Table 2: TECH projects for each installed Tank Size classified by size change.**

TECH-eTRM Size Category Changes

| eTRM Size Category | eTRM Size Changes | Count Units Installed | % of Total Count along eTRM Size Changes |
|---|---|---|---|
| <45 | Downsize | 20 | 23.81% |
| | Like-for-like | 61 | 72.62% |
| | Upsize | 3 | 3.57% |
| | Total | 84 | 100.00% |
| ≥45 & ≤55 | Downsize | 3 | 0.32% |
| | Like-for-like | 471 | 50.37% |
| | Upsize | 461 | 49.30% |
| | Total | 935 | 100.00% |
| >55 & ≤75 | Like-for-like | 79 | 11.74% |
| | Upsize | 594 | 88.26% |
| | Total | 673 | 100.00% |
| >75 | Like-for-like | 3 | 2.34% |
| | Upsize | 125 | 97.66% |
| | Total | 128 | 100.00% |
| Grand Total | | 1,820 | 100.00% |

## CEDARS Claims

The CEDARS database contains claims for California Energy Efficiency programs going back six years. For recent years the measure claimed should match up to the eTRM Measure Offerings, but recent data may point to trends in program or customer selection of HPWH to be considered in making measure offering suggestions. The data may also point to follow-up questions to ask program implementers and other key stakeholders. The CEDARS data suggests a few key points, particularly by indicating which Program Administrators and Implementers were the most active in HPWH installations in previous years.

The Project Team downloaded and cleaned this data for 2019 to 2022 for further data analysis. The CEDARS data presents significant challenges most notably inconsistent capture of Measure ID and Offering ID across programs, creating significant holes in the dataset until data cleaning can be achieved. Fortunately, this project plans to leverage TECH and AHRI data more significantly than CEDARS data, so this should not create an obstacle to the project.

## Supply Chain Interviews

### Overview

The Project Team posed leading questions to better understand current issues within the eTRM measure package, and potential new technologies that may affect future packages. These ~~our~~ discussions delved into emerging technologies that have the potential to shape future packages. This dialogue also served as an avenue for comprehensive talks regarding prospective alterations to existing technologies, such as efficiency ratings, thermostatic mixing valves (TMV), and tank capacity. In addition, the project team explored supplementary costs that could influence the overall adoption of this measure.

In the context of these interviews, the project team chose to focus the interviews on manufacturers rather than installers, contractors and distributors, as the actual contractors were the focus of the 2022 CalNEXT project ET22SWE0036 Residential Water Heater Sizing Measure Package Support. Furthermore, distributor-related information was largely covered by manufacturers with respect to planning for coming trends in HPWH products.

#### Key Findings

The insights derived from these discussions brought the primary obstacle to the widespread adoption of HPWHs to the forefront: the DEER savings calculator tool currently lacks the capability to factor in the benefits of mixing valves. Regarding the presence of mixing valves in the market, there is a notable emphasis from SGIP in promoting their use. The information from interviews has intentionally been attributed collectively rather than specifically to allow for the frankest exchange of information.

#### Technology Projections

The supply chain interviews also touched on technology projections in the HPWH market. Collective manufacturer input pointed to a foreseeable three-year horizon for greater market availability of split-systems. As 120V units continue to gain popularity in the market, manufacturers are viewing this trend with cautious optimism. These units were initially designed for emergency replacement scenarios, but they are now being increasingly installed for non-emergency residential applications. Furthermore, the intricate electrical requirements of these models present challenges for electrical installation, especially given their compact size, leading to the placement of heaters in closets or confined areas where working around electrical constraints is particularly challenging. Incremental increases in the UEF of this technology are expected over the next few years, though this effort is not the primary focus of product development as market adoption at existing efficacies is viewed as the major roadblock. Conversely, manufacturers are homing in on the lower range of UEF for 120V units, with a primary emphasis on enhancing recovery rates at lower input voltages and ensuring the consistent delivery of the expected water temperature for showering. They are giving precedence to

the improvement of recovery rates rather than focusing solely on UEF, noting that 120V systems with good recovery rates often exhibit lower UEFs.

### Installer Insights

The project team's interviews yielded valuable anecdotal perspectives from HPWH installers. They highlighted the complexity of wiring and piping requirements, emphasizing the need for proper training among plumbers. They noted the additional costs common in HPWH installations, as the units replacing gas heaters are considerably larger size, often requiring some extent of retrofitting to accommodate the extra space. This is a concern for single family homes, where heaters are located in small closets. Additional cost factors also include electrical upgrades, floor drains, and moving water lines.

### eTRM Challenges

Finally, the California manufacturers and installers noted gaps in the eTRM measure offerings, particularly pertaining to tank sizing and UEF. By way of example, manufacturers separately cited market interest in 50 to 80-gallon tanks and 40-gallon tanks, indicating possible trends for both upsizing and downsizing, perhaps better considered simply as a market preference for right-sizing for the application. Installers do anticipate that 120V units in particular will be specified with upsized tanks due to their comparatively slower recovery rates.

## Other California Programs Interviews

### Golden State Rebates

The Project Team wanted to take this opportunity to discuss current issues, potential barriers, and future technologies within the California market. Golden State Rebates is the statewide appliance rebate program that offers HPWH rebates, implemented by CLEAResult. The intention was to draw upon the knowledge of other program implementers to help identify market needs and increase the success of that program and others in the California efficiency portfolio.

During the interview, several key insights emerged. Firstly, the market is currently seeing a significant increase in 120V heat pump water heaters. However, a notable gap exists in the availability of products in this category that meet the minimum UEF value required to qualify for incentives. Secondly, the Team heard an anecdote regarding manufacturers transitioning to low-GWP refrigerants to get incentives for their 120V units. Nonetheless, manufacturers anticipate challenges in meeting stringent standards and have expressed concerns about the associated costs of product development. The Golden State Rebates team at CLEAResult has provided recommendations to their IOU Administrators to lower the UEF minimum for 120V units and update relevant measure packages accordingly.

## Stakeholder Feedback

Conversations with the California Technical Forum (Cal TF), the most recent measure revision contractor at TRC, and the Lead IOU Engineering team at SCE have been scheduled. The Golden State Rebates team will also be contacted and any input provided by these stakeholders will be included in the Final Report.

In the broader context, CalNEXT's HPWH Technology Priority Map revision process, the CPUC lead for TECH/SGIP water heating activities has made clear the Commission's strong interest in HPWH products that utilize low-GWP refrigerants and meet the connectivity requirements for the SGIP program: both JA13 compliant and equipped with a CTA-2045 controller. In terms of objectives of this CalNEXT project, modifications to the eTRM cannot address the absence of these products in the market, and eTRM measure developers tend to focus on product combinations that already exist in the market. More broadly, the supply chain interviews conducted for this project suggested that low-GWP refrigerant products are likely a focus for continued manufacturer research and future product releases.

The CalNEXT team presented the objectives and progress of this project at the CalNEXT quarterly update meeting for IOU Program Administrators on September 28, 2023. The key measure recommendation areas were presented to a statewide audience, and CalNEXT didn't receive feedback on these recommendations or objectives.

# Recommendations

## Measure Offering Additions

Following the structure of the eTRM measure packages for HPWHs, this project's first four recommendations can be characterized as relating to new tank sizes and/or new efficacies. Figure 2displays HPWHs by UEF bin across the horizontal axis and tank size up the vertical axis. The current measure offerings are represented in Green, with three categories of potential addition shown to either side and above them each discussed below.

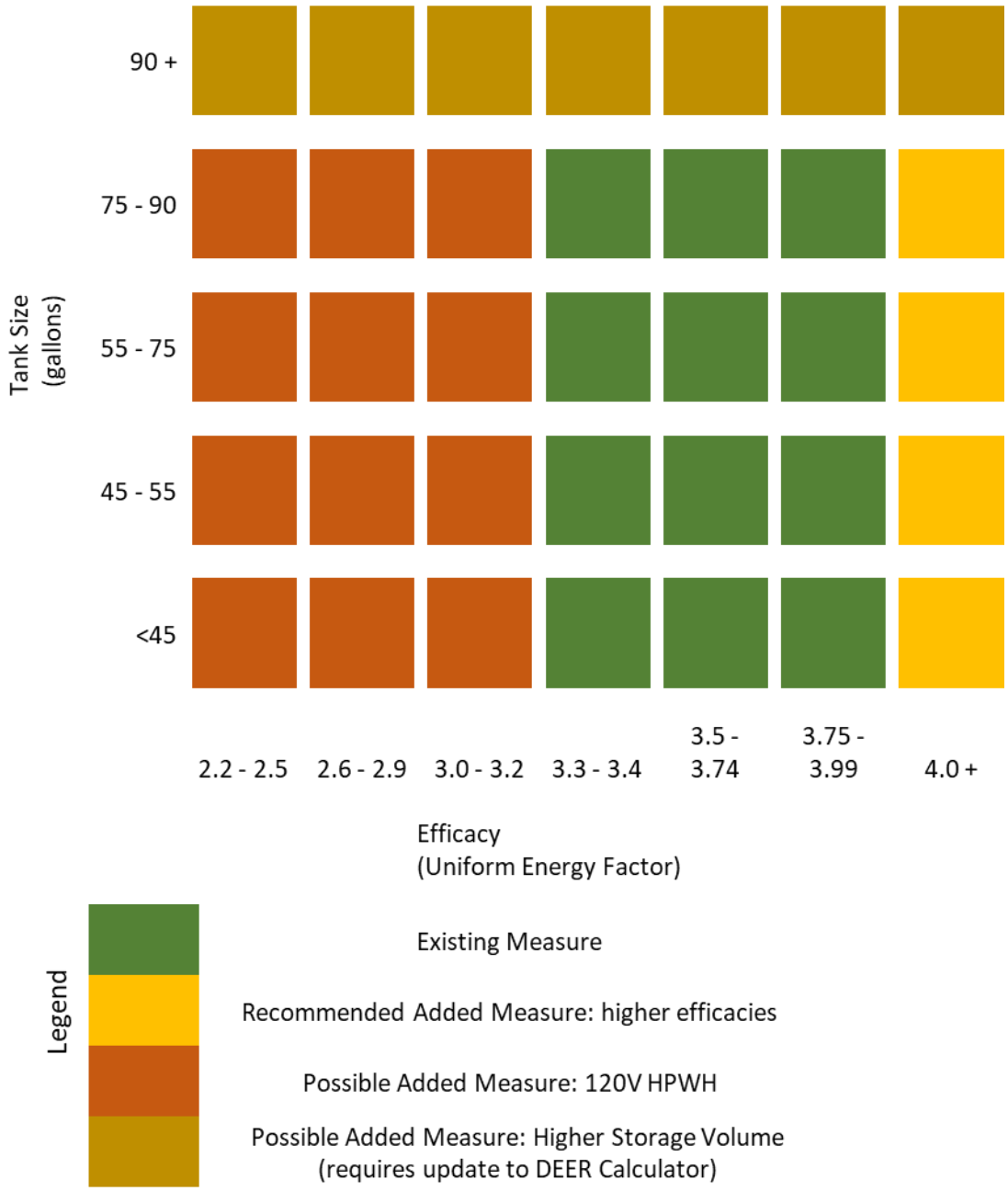


**Figure 2: Existing eTRM measure offerings and possible recommendation areas by UEF and Tank Size**

## Higher Efficacy Tier

As mentioned in the AHRI Data Findings, only in the past two to three years have HPWH products with efficacies above 4.00 UEF become available. This is most easily seen in Figure 2, with only green circles at the extreme right. 4.00 UEF is already 0.25 higher than the current upper bin limit, and 0.25 (or less) is the size of the UEF bins that delineate measure offerings in both HPWH measure packages, so 4.00 UEF is the next logical efficacy bin. A new measure bin will create additional savings and may improve cost-effectiveness metrics which are currently a barrier for the fuel substitution measure package.[2]

The project team recommends a new efficacy bin added to both SWWH025 and SWWH014 measure packages that splits HPWHs above 3.75 UEF into HPWHs between 3.75 and 4.00 UEF and HPWHs above 4.00 UEF.

### Lower Efficacy Tiers, 120V HPWH, and Equity Considerations

AHRI HPWH listings showed numerous product offerings below the minimum efficacy of 3.30 UEF currently used in both SWWH025 and SWWH014 measure packages. These are the products shown within the red box in Figure 3 below: each blue square is a combination of a UEF bin and a Tank Size bin with the number of AHRI-listed HPWHs displayed, while each blank space is a combination of a UEF bin and a Tank Size bin for which there is no AHRI-listed HPWH.

The tested UEF value of a HPWH depends on many factors. In addition to general factors of product design, materials, and cost, a few others are worth noting specifically in context of the HPWH market. Heat pump cycles and the compressors they depend on tend to run more efficiently at higher AC voltages, so products running at 240V may tend to have a UEF advantage. In addition, while 120V products may more easily fit a home's existing electrical infrastructure, they only function with half of the power for a given current as the more common 240V products.

The exchange of heat from a refrigerant fluid to water is facilitated by greater contact surface, so higher-UEF products may correlate with larger physical size. Relatedly, the exchange of heat into water is also facilitated by more time in contact with hot refrigerant fluid, so HPWHs are generally least efficacious at their maximum recovery rate and can achieve higher efficacy when hot water is drawn out more slowly. Many water heaters are called to recharge their tanks faster than their heat pumps can function, so they use electric resistance during those periods; the term Hybrid HPWH is used to describe the combination of heat pump and electric resistance functionality. Electric resistance always has a UEF below 1.0, so operating with electric resistance during test conditions will lower the UEF rating, and operating with electric resistance during home use will lower the practical efficacy. The 120V HPWHs frequently do not include an electric resistance mode because they cannot draw the added input power required to speed up heating by electric resistance, and thus, will not suffer the same reduction in efficacy as 240V Hybrid models when operating under high-draw conditions.

These factors come in to play when considering the needs of potential HPWH customers. Many customers have a limited physical space in which to install their HPWH without costly replumbing and HWPHs already tend to be larger than electric resistance or natural gas water heaters, so designing for smaller size may constrain UEF as described above. The 120V HPWHs have been a major focus of recent manufacturer efforts, to allow customers to benefit from the improved efficacy of heat pumps even where electrical infrastructure prevents installation of a new 240V appliance. A small size and 120V power requirement are both product characteristics that make HPWH accessible to more customers, and in particular make HPWH options accessible to hard-to-reach (HTR) customers and disadvantaged communities (DAC). These customers and communities are more likely to be renters than the average California customer, and to live in a home without an attached garage or other space suitable for a HPWH replacing a smaller water heater. A new appliance may be purchased for these tenants, but electrical upgrades avoided wherever possible, Including 120V and lower UEF products in the eTRM may increase the available options for equity programs in California. At the same time, installing a HPWH with a 2.50 UEF instead of 3.50 will

increase the electric cost of the appliance by 40 percent (if operated similarly to UEF testing profiles), so Program implementers will need to make careful consideration of the future electric bill costs of a HPWH relative to baseline equipment and other HPWH alternatives before promoting lower-UEF measures. A 2023 study from the New Buildings Institute (NBI) on 120V HPWHs similarly recommends their inclusion in existing eTRM measure packages and HPWH programs, including DAC programs.

Figure 3 shows 22 AHRI listings for 120V HPWHs, and 14 of these are rated below 3.30 UEF. Since AHRI does not show voltage, the input voltage for each product was referenced from the ENERGY STAR database. By contrast, a far smaller share of 240V products fall below 3.30 UEF. Lower UEF measure offerings will only exacerbate the issue of low measure cost-effectiveness values for HPWHs replacing natural gas products, but adding these offerings will still help implementers of equity programs for whom cost-effectiveness is a less critical consideration. Cost-effectiveness could be boosted by lower infrastructure and installation costs for a 120V-specific measure offering.

The project team recommend a new efficacy bin added to both SWWH025 and SWWH014 measure packages for HPWHs from 2.60 to less than 2.80 UEF, 2.80 to less than 3.00 UEF, and 3.00 to less than 3.30 UEF. These bins should apply to all tank sizes, as the NBI study specifically points 4-person households to 80-gallon HPWHs.

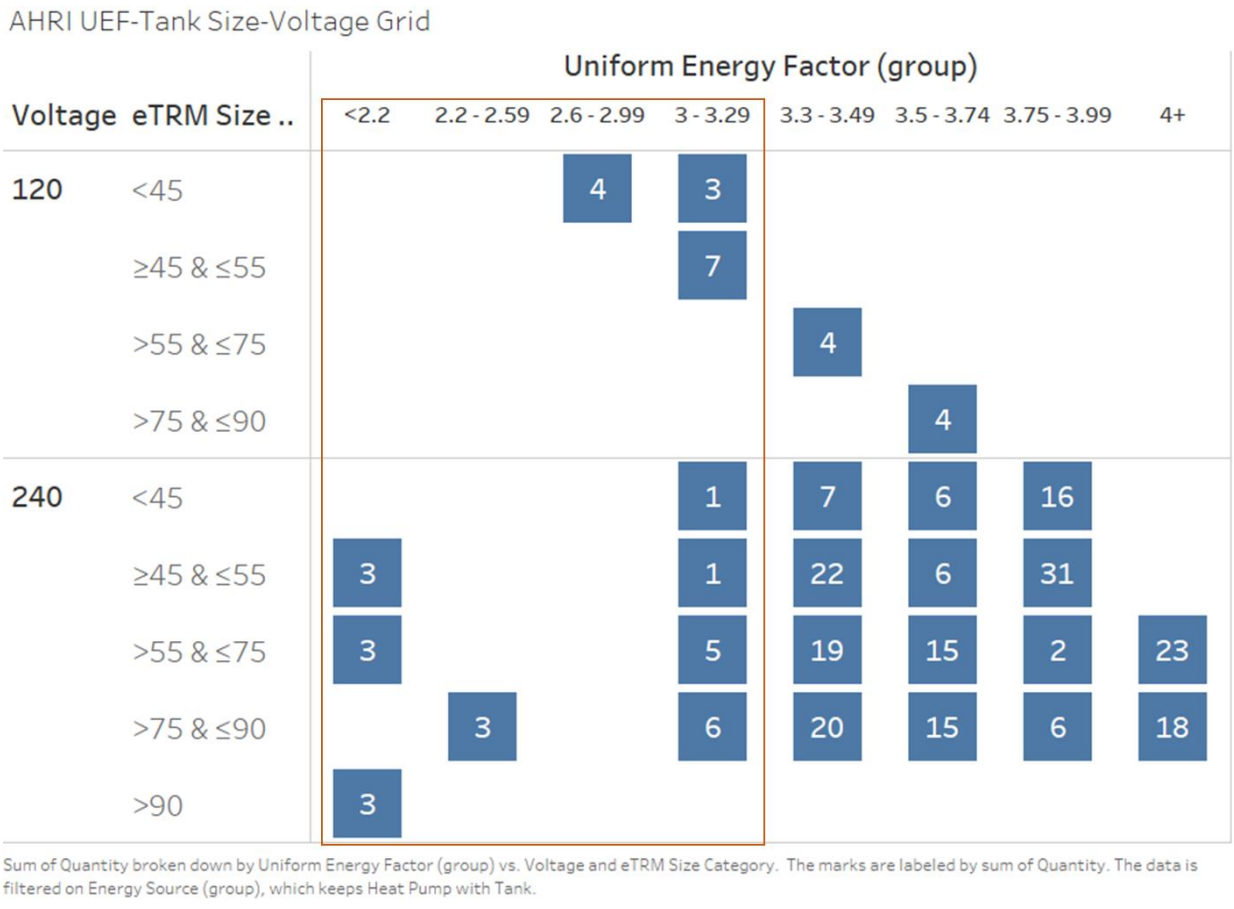


**Figure 3: AHRI HPWH listings highlighting UEFs below 3.30**

## Additional Upsizing

The 2022 CalNEXT project ET22SWE0036 Residential Water Heater Sizing Measure Package Support resulted in the addition of 12 new measure offerings for tank upsizing and contains useful discussion of upsizing generally. That project focused heavily on a Contractor Survey for input that is an important source in considering what upsizing measure offerings to include. The eTRM updates completed in April 2023 resulted in the available measure offerings shown in Table 3.

**Table 3: Current eTRM Measure Offerings by Base Case and Measure Case Tank Size**

| Measure Case Tank Size (gallons) | SWWH014: electric base case tank size | | | | | SWWH025: natural gas base case tank size | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 Gal | 40 Gal | 50 Gal | 60 Gal | 75 Gal | 30 Gal | 40 Gal | 50 Gal | 60 Gal | 75 Gal | Tankless |
| <45 | | | | | | | | | | | |
| >=45 to <=55 | | | | | | | | | | | |
| > 55 to <= 75 | | | | | | | | | | | |
| > 75 | | | | | | | | | | | |

| | |
|---|---|
| | Upsizing Measure |
| | 75 gal to 80 gal measure |
| | like-for-like tank size |
| | no measure offering |

This CalNEXT project can add an additional data source for potential upsizing: the 1,820 HPWH installations under the TECH program which, unlike previous EE programs claims under the eTRM, were not limited to like-for-like tank sizes. The relationship between base case and measure case tank sizes in TECH installations are shown in Figure 4.

The TECH data shows clear upsizing preference: for the 36 percent of TECH installs that were replacing a 40 – 50-gallon tank (green section on the left), the majority chose a 60-gallon tank, the next most popular options were 60-gallon and 80-gallon, and staying with a 40 – 50-gallon tank was the least popular option.

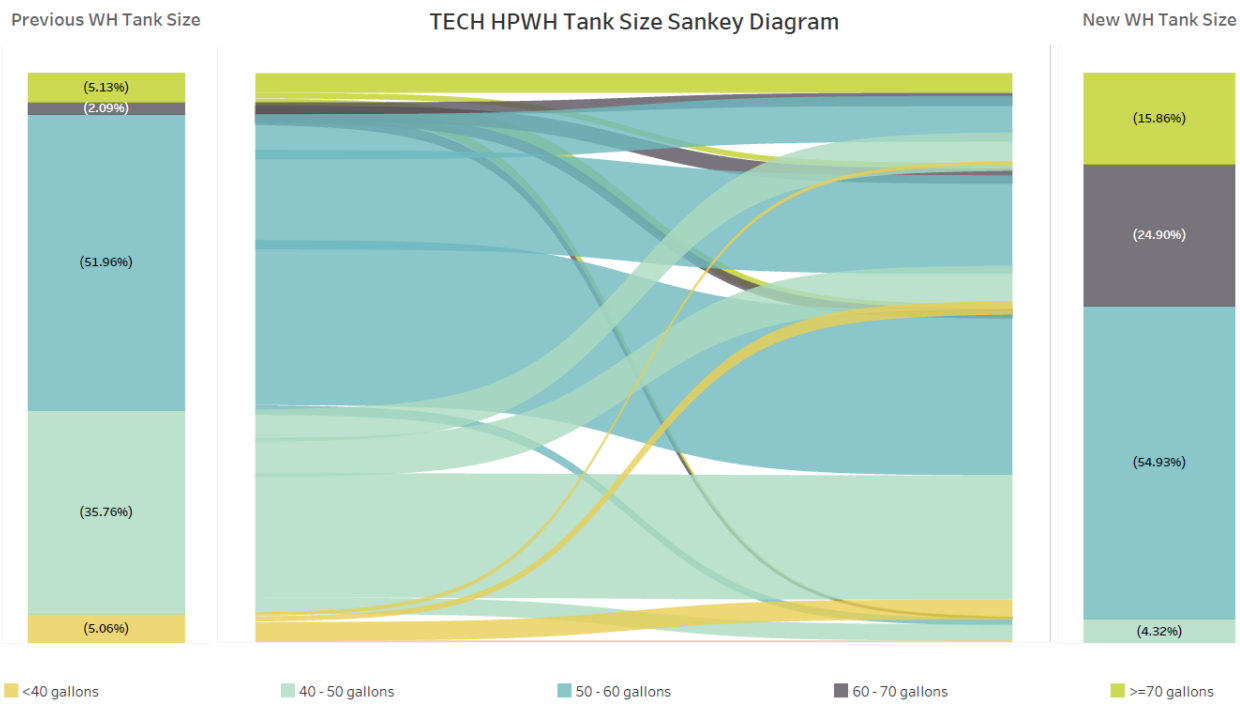


**Figure 4: Base case and measure case HPWH tank sizes in TECH installations**

The data also notes some tank downsizing: relatively small numbers of projects, but some participants decided they didn't need a 60 – 80-gallon tank and chose a 50 or 60-gallon tank instead. These could have been oversized base case equipment or changing needs in the space. TECH didn't collect reasons for the downsizing.

Classifying in terms of the Tank Size bins in the eTRM, the TECH program saw at least one installation utilize every single combination of base case and measure case tank sizes, as shown in Table 4. The project team recommends that the Measure Lead create additional measure offerings for all possible tank size changes. The California Plumbing Code will have its own requirements based on First Hour Rating (the sum of Tank Size and hourly hot water output) but allowing all resizing options will prevent the eTRM offerings from becoming an obstacle to selecting the correct size. If measure engineering complexity or other reasons may preclude allowing every combination into the eTRM, the project team recommends adding the following combinations first:

- Upsizing measure offerings for electric base case (SWWH014) HPWHs of 40, 50, and 60 gallons
- Upsizing measure offerings for tankless water heaters to all sizes of HPWHs
- Upsizing measure offering for 40-gallon natural gas water heaters to 80-gallon HPWHs
- Downsizing measure offering from 50-gallon to 40-gallon HPWHs

Table 4: Base case and Measure case tank sizes in TECH installations

TECH-eTRM Size Category Changes

| Base Case | eTRM Size Category | eTRM Size .. | Count Units Installed |
|---|---|---|---|
| Tankless | <45 | Like-for-like | 8 |
| | ≥45 & ≤55 | Upsize | 20 |
| | >55 & ≤75 | Upsize | 15 |
| | >75 | Upsize | 7 |
| 30 Gal | <45 | Like-for-like | 7 |
| | ≥45 & ≤55 | Upsize | 53 |
| | >55 & ≤75 | Upsize | 15 |
| | >75 | Upsize | 11 |
| 40 Gal | <45 | Downsize | 3 |
| | | Like-for-like | 46 |
| | ≥45 & ≤55 | Like-for-like | 11 |
| | | Upsize | 375 |
| | >55 & ≤75 | Upsize | 181 |
| | >75 | Upsize | 40 |
| 50 Gal | <45 | Downsize | 17 |
| | ≥45 & ≤55 | Like-for-like | 460 |
| | >55 & ≤75 | Upsize | 375 |
| | >75 | Upsize | 51 |
| 60 Gal | <45 | Downsize | 2 |
| | ≥45 & ≤55 | Downsize | 7 |
| | >55 & ≤75 | Like-for-like | 33 |
| | >75 | Upsize | 3 |
| 75 Gal | <45 | Downsize | 1 |
| | ≥45 & ≤55 | Downsize | 9 |
| | >55 & ≤75 | Downsize | 8 |
| | | Like-for-like | 46 |
| | >75 | Like-for-like | 3 |
| | | Upsize | 13 |
| Grand Total | | | 1,820 |

## Higher Volume Tier

One point evident from both the TECH installation data and conversations with supply chain representatives is that water heater tank volume no longer carries the same meaning as it did before the introduction of HPWHs. The same is true of First Hour Rating, the industry term for the sum of the tank volume and the volume of water that can be heated in one hour, reflecting the maximum output of hot water in an hour.

Increased tank volume, for customers willing to purchase it and able to physically accommodate it, is no longer only an indicator of the household size or expected hot water consumption but is also a strategy for improving energy efficiency by ensuring that HPWHs never need to run at its maximum heating capacity. This allows a hybrid HPWH to remain in heat-pump mode and avoid the electric resistance mode that can reduce efficiency by a factor of more than three.

Furthermore, increased tank volume increases the capacity of the HPWH to act as a thermal battery and manages the electric demand in accordance with electric time-of-use rates. This will be of increasing importance with the California program developments discussed in the next section.

However, all these effects of increased tank volume are not able to be captured given the current DEER water heater calculator. New larger-volume products such as the 119-gallon product seen in TECH data may yield value above 80-gallon products in certain instances, but that value cannot be calculated until the assumptions of the DEER water heater calculator are updated with a new Tech ID.

The project team recommends the inclusion of a higher volume tier of HPWH, suggesting 90 gallons as a threshold, but any work on that tier should be coordinated with updated TechID values in the DEER Water Heater Calculator to accommodate calculation of this benefit.

## Further Measure Savings Development

Given the context of low-penetration HPWH technology with a high impact on energy efficiency and a high impact on demand flexibility, there are many interconnected pieces to this market transformation puzzle. Many of the pieces below are part of large, multi-year efforts, but the Program team wanted to mention them to highlight areas where updates can support the transformation of the water heating market.

### Program use of connectivity in HPWHs

HPWHs promotion and market transformation activities are giving significant emphasis to connectivity and intelligent controls for Time-of-Use (TOU) electric rates. The SGIP round of funding for the TECH program contains three requirements with major demand management and grid flexibility implications:

1. JA-13-compliant, meaning incorporating TOU schedules and capable of pre-heating and shedding to shift electric load in response to a received signal
2. A CTA-2045 communication port
3. A thermal mixing valve

The first requirement allows a HPWH to respond to grid needs generally (according to a set schedule) and specifically (according to a demand response signal). The third requirement allows a HPWH to change tank temperature over the course of a demand response event without effect on the temperature of the water provided.

These features create a significant change in the expected impact of a HPWH. Without them, it is an appliance expected to exacerbate grid constraints because bathing, dishwashing, and clothes washing all often occur during summer evening peaks, when electric grid demand net-of-renewables is highest. With these changes, the HPWH has the potential to compensate for the evening grid peaks by preheating a water tank and shedding load during the key evening hours.

This change is significant enough to spur not only these requirements in SGIP HPWH, but other demand management programs from the IOUs that look to maximize the grid benefit of these appliances (i.e.,the PG&E WatterSaver program and the SCE Connected HPWH program).

The current eTRM measure packages for HPWH assume uncontrolled heating: the electric load will correspond to the use of hot water, highest in the evening. If SGIP has its desired impact, this assumption will be wrong, and more importantly may be undermining the decarbonization of the water heating market because the eTRM assumptions lead to lower cost-effectiveness. The TRC benefit-cost ratio (cost-effectiveness) of 0.70 for a 50-gallon HPWH replacing natural gas may create a disincentive for implementers to promote these products, where an accurate accounting of the connectivity benefits might promote them.

Accounting for the benefits of connectivity within the eTRM is not a straightforward ask. The grid-optimal control strategy for any given HPWH is particular to tank size, recovery rate, location, and expected grid condition for that hour. The eTRM cannot create deemed calculations for every possible combination of those factors, even if the TSB calculation could factor in all those pieces. Looking more broadly, neither the eTRM nor the CEDARS repository of EE measure claims are currently used for capturing demand response measures and other demand-focused impacts.

The program team recommends that the Cal TF, IOUs, and CPUC consider where within the system recording and recognition of energy efficiency and demand response claims the grid benefits of HPWH connectivity can be captured and how EE program implementers can benefit from the value created by HPWH connectivity. The project team recommends the Measure Lead study utilization of HPWH connectivity in considering updates to the eTRM and Avoided Cost Calculator.

### DEER Calculator Update

As stated in the discussion above under the Higher Volume Tier, there are good reasons to select a higher HPWH tank volume that are not because of higher expected hot water draw, but because of better efficacy. With the use of demand management controls and a mixing valve as described in the Program utilization of Connectivity in HPWHs section, larger tank volumes increase the size of the potential load shift and increase the amount of time that a HPWH can shed load by relying on stored thermal energy.

These considerations are not included in the DEER Water Heater Calculator. This is entirely understandable since these considerations are entirely new with HPWHs. The logic of the calculator determines the expected hot water draw based on the tank size. This relationship is clearly changing as 65 percent of TECH projects included tank upsizing, so the assumption should be updated.

The calculator also does not successfully calculate the value of a mixing valve and thermal storage generally. Increasing tank size causes the calculator to increase tank losses, but the fraction of heating via electric resistance is a fixed fraction so tank size does not reduce resistance heating. The calculator could instead more explicitly examine the stored energy in the tank hourly, the recovery rate, and then consider whether the urgent, inefficient heating by electric resistance is required.

The load shift aspects of tank sizing could be modeled as part of an upsizing-specific measure or as a retro-commissioning add-on measure, but the efficiency impacts of upsizing could be modeled as part of the base efficiency measure.

The Project Team recommends the CPUC's evaluation contractor, DNV, make updates to the DEER Water Heater Calculator to account for tank upsizing the effects on recovery modes and allow use of thermal mixing valves, TOU-based and signal-based demand controls.

### Load Profile update

The load profile assumptions for water heating in the CPUC Avoided Cost Calculator will be included in future updates.

The project team recommends load profiles be differentiated for JA-13-compliant versus non-JA-13-compliant water heaters, with a reduction for on-peak loads in compliant products. In determining load profiles, it will be important to consider upcoming studies of TECH impacts, including Recurve's meter disaggregation analysis of TECH installations and the metered data study still in development, as well as the interaction with demand management programs.

### Split System and Low-GWP products

Currently, there is only a single manufacturer providing HPWH solutions with a low-GWP refrigerant, $CO_2$, into the California market. Interviews suggest some expectations that new low-GWP products will be introduced in the coming years.

Federal rules on refrigerants announced in July 2023 are expected to impact HVAC Heat Pump equipment, but interviewees and others describe the amount of refrigerant in HPWHs as too small to fall under scrutiny with this rule. Future refrigerant rules may accelerate changes in refrigerants used in the HPWH market.

The TECH statewide HPWH initiative is offering an incentive kicker for low-GWP refrigerants. Projects utilizing the eTRM measures may also apply to TECH to take advantage of this incentive. The project team suggests that the eTRM measure lead closely watch three factors in considering future updates focused on refrigerant:

1. Product introductions and market developments around low-GWP refrigerants
2. The success of the TECH Initiative in promoting low-GWP products
3. The progress of the California energy efficiency portfolio in adapting to the TSB metric and the impact of its valuation of refrigerant leakage.

# Appendix A: Interview Questions for Manufacturers

1. What equipment is on-deck in three to seven years, and how does the equipment fit in with market projections?
2. What do you foresee your best-selling product will be over this timeframe?
3. What are manufacturers targeting with marketing?
4. Are gas-to-electric units targeted?
5. With increased volume of units in the market, will prices drop market-wide?
6. What is the next iteration of UEF system? What will come next?
7. What does UEF look like across the market now?
8. What will it look in two years?
    a. Five years?
    b. Seven years?
9. Do variable-speed HPWHs exist in the future?
10. What ranges in tank sizes are anticipated in the next five years?
11. Will split-systems see an increase in market share?
12. Are there plans for any low/ultra-low refrigerants in HPWH lines?
13. What other HPWH studies do you know of?
14. What obstacles are there to market transformation?

# Appendix 2 - CA Statewide Program Interview Questions

1. What are you participants asking for?
2. Where do you see rebate gaps?
3. What are your obstacles today?
4. Share table of averages and ranges - does this look accurate to your knowledge base?
5. Where are you seeing installs - conditioned vs non-conditioned space?
6. CLEAResult – can you provide data summaries where applicable?
7. Where do you see savings gaps in measure packages/workpapers?
8. What territory are you experiencing the highest influx of requests?
9. Pricing data available?
    a. Relevant to incremental measure cost, anticipate any changes?

# Appendix 3: Supplemental Data Display

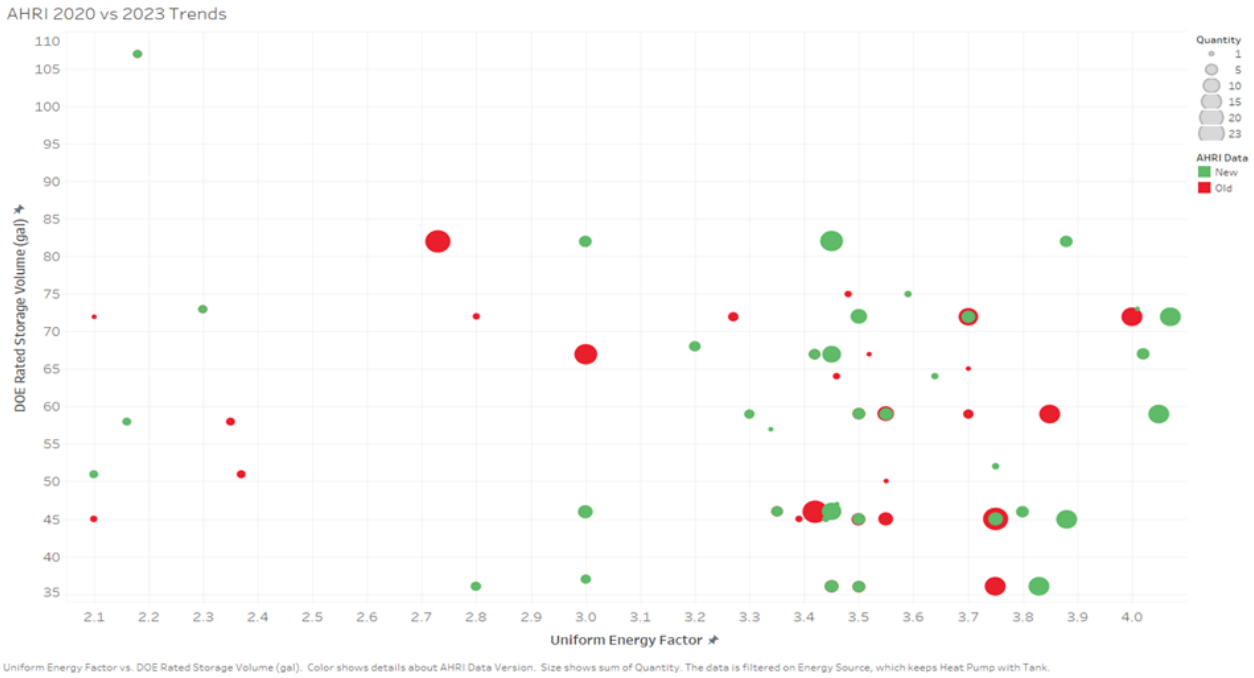


**Figure 5: AHRI HPWH Listings prior to 2020 (Red) and after 2020 (Green)**