Residential Heat Pump Water Heating Market Transformation Initiative

Appendix C: Product Assessment Report

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CalMTA is a program of the California Public Utilities Commission (CPUC) and is administered by Resource Innovations.

Contents

List of Abbreviations

Abbreviation	Definition
AHRI	Air-Conditioning, Heating, and Refrigeration Institute
AWHI	Advanced Water Heating Initiative
CARB	California Air Resources Board
CARE	California Alternate Rates for Energy
CalMTA	California Market Transformation Administrator
CCMS	Compliance Certification Management System
CPC	California plumbing code
CPSC	Consumer Product Safety Commission
CPUC	California Public Utilities Commission
CTA	Consumer Technology Association
DEER	Database for Energy Efficient Resources
DOE	Department of Energy
DR	Demand response
EOL	End of life
ER	Electric resistance
ESJ	Environmental and Social Justice
eTRM	Electronic Technical Reference Manual
FDAS	Flexible Demand Appliance Standards
FHR	First Hour Rating
GHG	Greenhouse Gas
GWP	Global Warming Potential
HPWH	Heat Pump Water Heating
HVAC	Heating, Ventilation, and Air Conditioning
IAQ	Indoor Air Quality
MTI	Market Transformation Initiative
NEEA	Northwest Energy Efficiency Alliance
OECD	Organization for Economic Co-operation and Development
PG&E	Pacific Gas and Electric
RACC	Refrigerant avoided cost calculator
RECS	Residential Energy Consumption Survey
SCE	Southern California Edison
SCT	Societal Cost Test
SDG&E	San Diego Gas and Electric

Abbreviation	Definition
SCAQD	South Coast Air Quality Management District
TOU	Time of Use
TRC	Total Resource Cost
TSB	Total System Benefit
UEF	Uniform Energy Factor

1 Purpose and context

The purpose of the Product Assessment Report is to provide a detailed explanation of the methods used to refine and evaluate the target technology and to share key findings that directly inform development of market transformation strategy and interventions, which are described in the Market Transformation Initiative Plan (MTI Plan).

This report is not intended to provide an exhaustive examination of heat pump water heating (HPWH) products and technology, but rather focuses on the key technical barriers, opportunities, and potential impacts from broader adoption of HPWHs in California, and the implications for development of effective market transformation strategies to achieve that objective. This report focuses on the technical aspects of the product and generally avoids discussion of the HPWH market, which is covered in Appendix D: Market Characterization Report.

2 Executive summary

HPWHs are efficient water heating systems that use a refrigeration cycle to transfer heat from the surrounding air into water stored in a tank. Compared to conventional electric storage water heaters, which generate heat through electric resistance (ER), HPWHs consume significantly less electricity under optimal conditions. Compared to conventional gas storage water heaters,[1] HPWHs offer significant co-benefits, including reduced on-site greenhouse gas (GHG) emissions and improved indoor air quality.[2]

This report provides a technical evaluation of HPWHs to support the California Market Transformation Administrator (CalMTA) with market transformation strategy. Technical findings are informed by a combination of secondary research, data analysis, energy modeling, and avoided cost calculations. Main product assessment findings are listed below, with specific evaluation cases included in parentheses.

Finding 1: HPWHs replacing ER storage water heaters provide consumers with substantial utility bill savings. Replacing a 240-volt 50-gallon, 0.92 uniform energy factor (UEF) ER storage water heater with a 50-gallon, 3.3 UEF, 240-volt, hybrid integrated HPWH product may reduce annual utility bills between $485 and $771 (see Figure 1, standard rates, Case 4 of Table 4).

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[1] In this report, the term "gas" is primarily used to refer to natural gas, although in general usage it may refer to both natural gas and propane.

[2] Pierre Delforge, "Gas Appliances Pollute Indoor and Outdoor Air, Study Shows," Nrdc.Org (blog) (Natural Resources Defense Council, April 29, 2020), https://www.nrdc.org/bio/pierre-delforge/gas-appliances-pollute-indoor-and-outdoor-air-study-shows.

Finding 2: Switching from gas storage water heaters to HPWHs can increase consumer utility bills because of California's high spark ratio.[3] Replacing a 50-gallon, 0.68 UEF gas storage water heater with a 50-gallon, 3.3 UEF, 240-volt, hybrid integrated HPWH product may either increase annual utility bills by $224 or reduce annual utility bills by $40 (see Figure 1, standard rates, Case 2 of Table 4). Replacing the same gas storage water heater with an 80-gallon, 2.2 UEF, 120-volt, hybrid integrated HPWH product may increase annual utility bills between $228 and $558 (see Figure 1, standard rates, Case 1 of Table 4), but may reduce annual utility bills under modified assumptions (see Figure 2 and Figure 8).

Finding 3: California Alternate Rates for Energy (CARE) discounts reduce the absolute value of utility bill impacts for low-income California residents with a 30% to 35% electricity discount and a 20% gas discount. This trend is favorable for this consumer group when switching from a gas storage water heater to a HPWH product (see Figure 1, Cases 1 through 3 of Table 4).

Finding 4: Total avoided costs are greatest in installation cases where a gas storage water heater is replaced by a HPWH product (see Figure 10, Cases 1 through 3 of Table 4). High GHG avoided costs are the primary contributor to high total avoided costs in these installation cases.

Finding 5: 120-volt HPWHs can provide a practical option for replacing gas storage water heaters by potentially eliminating the need for electrical panel or electric service upgrades. Current 120-volt HPWH efficiency and first hour rating (FHR) performance, while less than their 240-volt counterparts, provide acceptable performance for some homes (see Table 2, a 120-volt 65-gallon HPWH product typically has a FHR 5% lower than a 240-volt 65-gallon HPWH product).

Finding 6: HPWHs with load-shifting capability can benefit the grid, but consumers see most benefit when hot water use occurs during peak electricity pricing periods. In California, hot water demand peaks in the morning while electricity demand peaks in the evening, currently limiting savings opportunities. Preliminary modeling of an 80-gallon, 240-volt HPWH product (UEF 3.3) with simple load-shifting controls increased avoided costs by 18% (~$37 per year in savings) accompanied by a 5% increase in annual energy use. Greater benefits may be possible with optimized controls and refined avoidance of peak electricity pricing periods.

Finding 7: Refrigerant choice has minimal impact on energy and grid avoided costs but does impact GHG avoided costs. CalMTA's refrigerant avoided cost calculations show that HPWHs using high global warming potential (GWP) refrigerant like R-134a incur a lifetime refrigerant-related cost of $254. Transitioning to R-32 (a low-GWP option) reduces this cost to $120, while transitioning to R-744 (an ultra-low GWP option) reduces this cost to near $0 (see Table 5).

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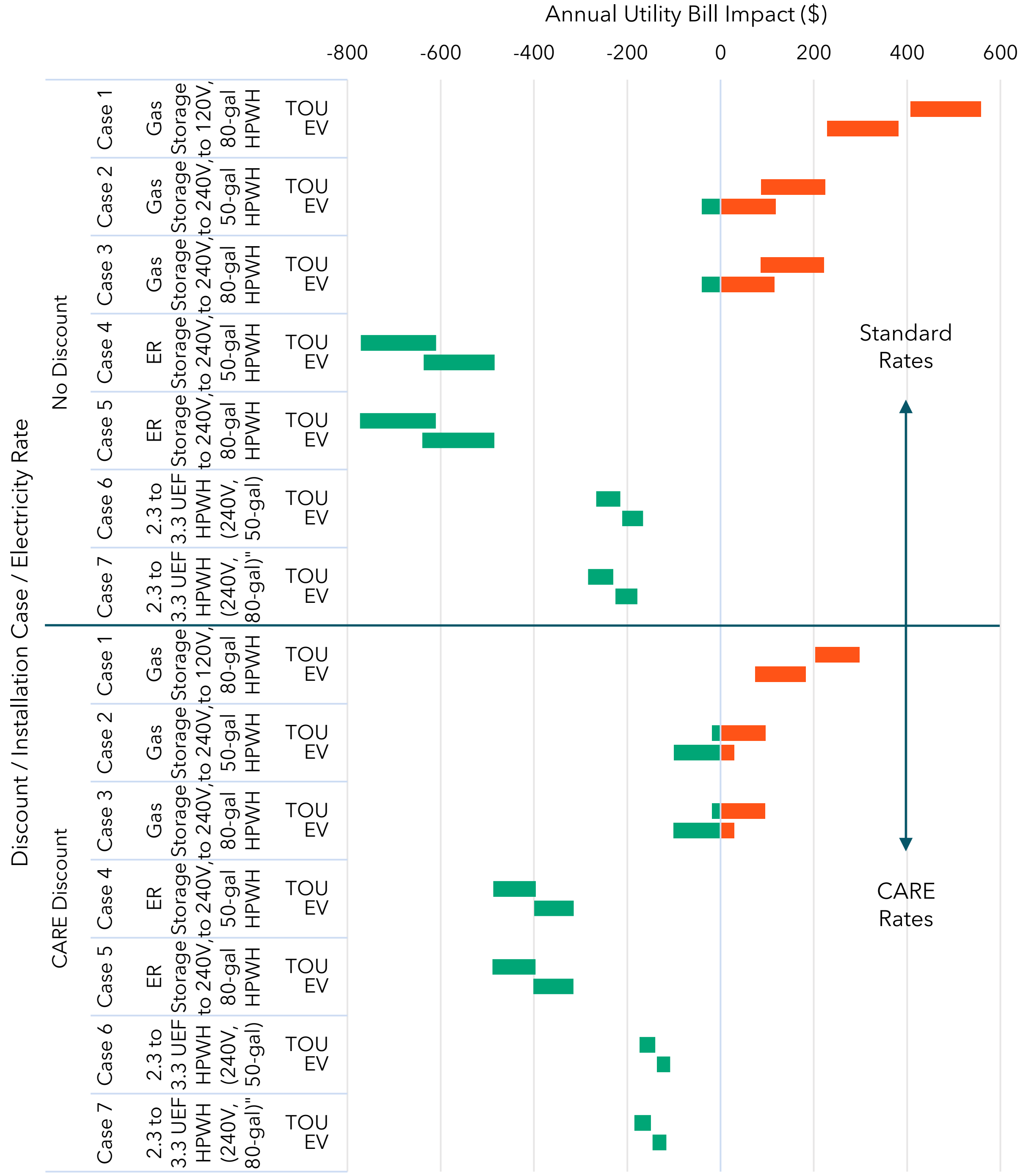
[3] The spark ratio is the ratio in cost to the customer of 1 kWh of electricity to the cost of 1 kWh of natural gas. This is a common metric for assessing the economic practicality of fuel substitution.

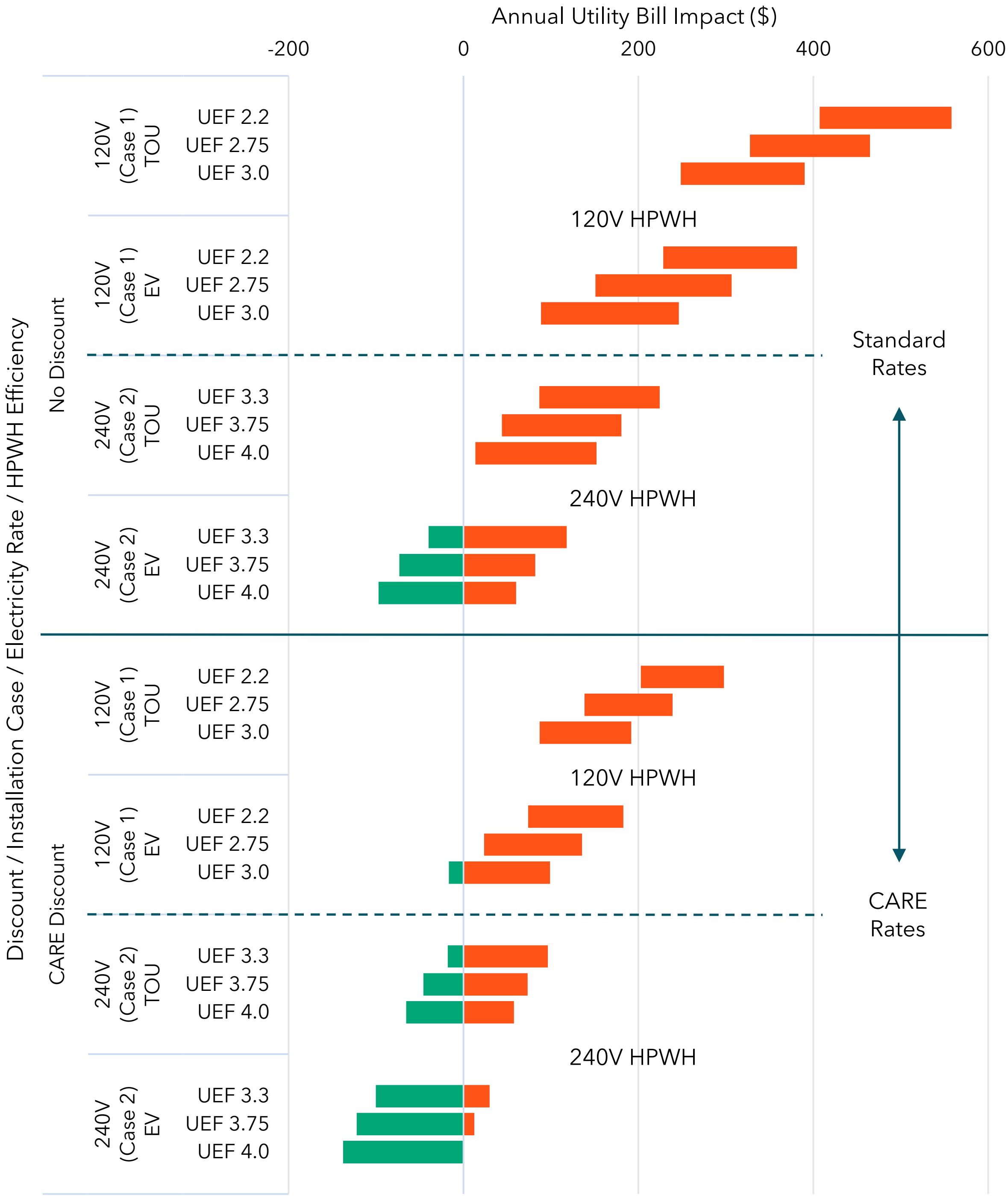
Figure 1. Modeled annual utility bill impact ($) by discount type, installation case, and electricity rate structure, all utilities



Note: Cases 1 through 6 assume a 50-gallon storage volume for the baseline technology, while Case 7 assumes an 80-

gallon storage volume for the baseline technology. Bars represent ranges of potential bill impact outcomes modeled across utilities and natural gas rate structures. Potential bill impact outcomes are based on a weighted average of single-family homes (77%), multifamily homes (19%), and mobile homes (4%) representative of California housing stock. Orange bars represent potential annual utility bill increases, while green bars represent potential annual utility bill savings.

Figure 2. Modeled annual utility bill impact ($) by discount type, electricity rate structure, and HPWH efficiency for fuel substitution cases, all utilities



Note: Cases 1 and 2 assume a 50-gallon storage volume for the baseline gas storage water heater. Bars represent ranges of potential bill impact outcomes modeled across utilities and natural gas rate structures. Potential bill impact outcomes are based on a weighted average of single-family homes (77%), multifamily homes (19%), and mobile homes (4%) representative of California housing stock. Orange bars represent potential annual utility bill increases, while green bars represent potential annual utility bill savings.

3 Product overview and definition

This section provides a general overview of HPWHs and highlights the specific product attributes identified by CalMTA.

3.1 General product overview

Residential water heaters provide hot water for household fixtures like sinks and showers and appliances such as dishwashers and washing machines. In California homes, it is estimated that 77% of water heaters are fueled by natural gas.[4]

HPWHs use heat from the surrounding air to heat water, offering a highly energy-efficient alternative to conventional ER water heaters and a decarbonization alternative to conventional gas-fired water heaters. HPWH systems operate using a refrigeration cycle. A fan draws in ambient air, which passes over an evaporator coil containing refrigerant. The refrigerant absorbs heat and is compressed, increasing its temperature. This heat is then transferred to the water stored in a tank via a heat exchanger. When the HPWH unit is properly installed and operating at ideal temperature conditions, it consumes 3 to 4 times less electricity than standard ER storage models.

3.2 Product definition

The residential HPWH MTI will include products with the following attributes:

- Integrated units or split systems
- Shared- or dedicated-circuit 120-volt and/or 240-volt configurations
- Certified effective storage volume less than or equal to 120 gallons
- Meets ENERGY STAR® Version 5 *Program Requirements for Residential Water Heaters*, including minimum UEF and warranty

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[4] Sweeney, M. et al., tech. 2023. *Demonstration and Assessment of Residential Gas Heat Pump Water Heaters in the Los Angeles Basin* (California Energy Commission - Energy Research and Development Division, June 2023), https://www.energy.ca.gov/sites/default/files/2023-07/CEC-500-2023-047.pdf.

- The scope of the Residential HPWH MTI does not include HPWHs used in nonresidential applications, commercial water heaters, central water heaters, point-of-use water heaters, or other water heating systems composed of multiple heating units.

3.2.1 Integrated units and split systems

Residential HPWHs are offered in two primary configurations: integrated units and split systems.

- Integrated units combine the heat pump and the water storage tank into a single appliance. They have a similar structure to conventional storage water heaters.
- Split systems separate the heat pump unit (compressor and evaporator) from the water storage tank. This design allows for installation flexibility in smaller spaces and in colder climates.
- Split and integrated units are available in both 120-volt and 240-volt configurations.

3.2.2 Supplemental electric resistance heat

Most integrated HPWHs include supplemental ER heat in addition to the heat pump. These are known as hybrid HPWHs. Supplemental ER heat may be used to quickly heat water under high hot-water use conditions or when temperatures around the water heater decrease below the lower compressor cut-off temperature (23°F to 45°F, depending on the unit).[5] HPWHs that meet the MTI definition may include supplemental ER heat, but it is not required for the MTI.

3.2.3 Voltage configurations

HPWHs are available in 120-volt and 240-volt configurations, and a recently released model is dual voltage, providing the option of installation for either 120-volt or 240-volt service.[6] The electrical service and panel capacity of a home determines whether additional appliances can be supported safely. Homes with 100-amp or larger service generally have sufficient capacity for a 120-volt unit, while a 240-volt HPWH unit may require a new 30- or 40-amp double-pole breaker at the panel.

- 120-volt plug-in HPWHs can be installed using a standard electrical outlet and typically draw between 10 and 15 amps. Some models require a dedicated electrical circuit (meaning no other devices share the breaker). Other HPWH units may share an electrical circuit with other electricity-using devices if the total current draw remains within the circuit's rating.

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[5] ENERGY STAR, Heat Pump Water Heater Guide: Best Practices & Technical Considerations for Residential New Construction § (2024), https://www.energystar.gov/sites/default/files/2024-07/ENERGY%20STAR%20Heat%20Pump%20Water%20Heater%20Technical%20Guide%20508C.pdf.

[6] "GE Profile™ GEOSPRING™ Heat Pump Water Heater with FlexCAPACITY," GE Appliances, November 2025, https://www.geappliances.com/geospring-water-heater.

- Today's 240-volt HPWHs are all hybrid units that are typically hardwired and require a dedicated 30-amp circuit. 240-volt units are well-suited for installations where the electrical panel has sufficient spare capacity.

3.2.4 Storage capacity

This MTI includes HPWHs with an effective storage volume less than or equal to 120 gallons. The MTI definition is consistent with the Department of Energy (DOE) 2029 energy conservation standards for electric storage water heaters. The 2029 energy conservation standards effectively require heat pump technology for water heaters with an effective volume greater than or equal to 20 gallons and less than or equal to 120 gallons.[7] While HPWH units with nominal storage capacity less than 40 gallons are not currently available on the market, alignment with DOE standards extends to possible future product development, such as compact or point-of-use HPWHs.

3.2.5 ENERGY STAR

Residential HPWHs under this MTI must meet current ENERGY STAR Program Requirements for Residential Water Heaters (currently Version 5.0 as of the publication of this report). Aligning with ENERGY STAR requirements provides stability for manufacturers by defining eligibility for both national and California programs. As a national program, ENERGY STAR incorporates stakeholder input through a formal process and requires product testing at certified third-party labs using the DOE test procedure. This ensures HPWH products meet verified energy performance standards. Additionally, ENERGY STAR excludes installation requirements, which are beyond the control of manufacturers.

First hour rating

FHR is included in the DOE test procedure for residential water heaters and is the maximum volume of hot water that a water heater can supply within an hour.[8] Effectively, FHR measures how quickly a water heater can recover after substantial hot water use. Residential HPWHs under this MTI must meet the FHR requirements in the most current ENERGY STAR Program Requirements for Residential Water

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[7] Code of Federal Regulations, Title 10, Chapter II, Subchapter D, Part 430, Subpart C, 430.32, Table 14 to Paragraph (d)(2). https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32.

[8] U.S. Department of Energy. 2024. Energy Conservation Program: Test Procedure for Consumer Water Heaters and Residential-Duty Commercial Water Heaters. 10 CFR Part 430; EERE-2019-BT-TP-0032; RIN 1904-AE77. Washington, DC: Office of Energy Efficiency and Renewable Energy. https://www.energy.gov/sites/default/files/2021-12/consumer-wh-tp-nopr.pdf.

Heaters. At the time of writing, ENERGY STAR Version 5.0 requires a minimum FHR rating of at least 45 gallons per hour for all HPWHs.[9]

Uniform energy factor

UEF is the residential water heater overall efficiency metric defined by the DOE test procedure.[10] Products qualifying for the Residential HPWH MTI shall meet the most current minimum UEF requirements in the ENERGY STAR Program Requirements for Residential Water Heaters, which vary by HPWH type. At the time of writing, the ENERGY STAR Version 5.0 UEF requirements are as follows:

- Integrated HPWH: UEF ≥ 3.30
- Integrated HPWH, 120 Volt/15 Amp Circuit: UEF ≥ 2.20
- Split-System HPWH: UEF ≥ 2.20

Warranty

Products qualifying for the Residential HPWH MTI shall meet the most current warranty requirements in the ENERGY STAR Program Requirements for Residential Water Heaters. At the time of writing, ENERGY STAR Version 5.0 requires a part warranty of at least 6 years for residential HPWHs.

3.3 Key product features and attributes

In addition to the Residential MTI requirements discussed above, CalMTA expects the program will evolve to support load shifting and lower–GWP refrigerants as the California market share for HPWHs increases. Load-shifting capabilities can align water heating demand with periods of abundant renewable energy, reducing grid stress and emissions. HPWHs with lower-GWP refrigerants will support California's climate objectives by reducing lifecycle GHG emissions compared to many of today's HPWHs.

3.3.1 Load shift

Products qualifying for the Residential HPWH MTI will support minimizing or shifting load during identified utility-specific high peak-demand hours. Initially, utility interaction is optional, but HPWH products will need to have scheduling or other features that enable the consumer to take advantage of time of use (TOU) rates. As load-shifting protocols and requirements mature, HPWH units entering the market will support real-time, two-way communication with the utility (i.e., send, receive, and act on

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[9] ENERGY STAR, Residential Water Heaters Specification Version 5.0. 2022. https://www.energystar.gov/products/spec/residential_water_heaters_specification_version_5_0_pd.

[10] Uniform Test Method for Measuring the Energy Consumption of Water Heaters, 10 C.F.R. pt. 430, subpt. B, app. E. 2025. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-B/appendix-Appendix%20E%20to%20Subpart%20B%20of%20Part%20430.

utility signals) and shall be certified to the most current version of the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) 1430 standard – Demand Flexible Electric Storage Water Heaters (AHRI 1430).[11]

Load shifting enables consumers to take advantage of lower, off-peak electric rates, and reduces strain on the electric grid. As of 2021, an estimated 1.4% of water heaters installed in the U.S. participate in demand response (DR) programs.[12] HPWHs with load-shifting capabilities can play a major role in advancing California's grid flexibility goals. However, utilities must be prepared to manage these technologies at scale, and fragmented communication protocols need greater standardization. While load-shift-capable HPWHs using Consumer Technology Association-2045 (CTA-2045), OpenADR, and proprietary interfaces are currently available, limited interoperability reduces their effectiveness, scalability, and grid integration potential. In addition, most California TOU electricity rates peak in the evening, while residential water heating demand typically occurs in the morning, limiting savings potential for consumers. As electrification increases and morning demand peaks grow, strategies that shift HPWH unit operation to align with changing grid conditions will become increasingly important.

Of note, the use of thermostatic mixing valves alongside HPWHs (either separate from or integrated in a HPWH unit) is critical to enabling load shift. A thermostatic mixing valve blends hot water from the tank with cold water to deliver a safe, consistent temperature at the consumer point-of-use. This allows a HPWH unit to store water in its tank at higher temperatures and, in turn, heat water in advance of (i.e., "load up" before or shift load away from) peak electricity demand periods.

3.3.2 Lower-GWP refrigerant

Future HPWH models will use lower-GWP refrigerants (GWP_{100} <750), as defined by the California Air Resources Board (CARB).[13] While transitioning from ER water heaters to HPWHs may initially increase avoided costs due to refrigerant impacts, current models assume that all refrigerant is released at end of life (EOL)—an unrealistic assumption for integrated HPWHs with closed refrigerant loops.

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[11] Demand-Flexible Electric Storage Water Heaters, AHRI 1430 (I-P) Addendum 1 (Arlington, VA: Air-Conditioning, Heating, and Refrigeration Institute, 2023), https://www.ahrinet.org/search-standards/ahri-1430-i-p-demand-flexible-electric-storage-water-heaters-addendum-1.

[12] Billimoria, S. et al., publication, The Economics of Electrifying Buildings: How Electric Space and Water Heating Supports Decarbonization of Residential Buildings. (Rocky Mountain Institute, 2018), https://rmi.org/wp-content/uploads/2018/06/RMI_Economics_of_Electrifying_Buildings_2018.pdf.

[13] CARB uses the 100-year global warming potential values (GWP100) as defined in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Working Group Report (AR4), 2007.

Refrigerant leaks can offset the GHG benefits of HPWH adoption, as most residential models still use high-GWP refrigerants. Studies on refrigerant leakage impacts show mixed results,[14] but conservative estimates indicate that meaningful GHG reductions depend on using lower-GWP refrigerants and minimizing leakage.[15]

Future California regulations may be necessary to facilitate the transition of HPWHs to lower-GWP refrigerants.

4 Research objectives and methodology

This section outlines the methods used to address technical assessment objectives outlined in the Residential HPWH Advancement Plan.[16] Given the extensive HPWH research already underway by other organizations, the CalMTA team did not conduct additional lab or field studies and instead relied on existing literature to inform its evaluation. Additional research methods included energy modeling, expert engagement, and analysis of field data, tools, technical specifications, and warranty policies.

4.1 Research objectives

The following describes the primary research objectives and questions investigated by the CalMTA team to support the Product Assessment:

4.1.1 Evaluate current 120-volt and 240-volt HPWH sizing practices to understand if upsizing HPWHs by 1 to 2 sizes when replacing a traditional water heater is justified.

1) Review current HPWH sizing practices in retrofits using field data from the TECH Clean CA Program[17] and other field study results exploring sizing practices and impacts.

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[14] Theresa Pistochini et al., "Greenhouse Gas Emission Forecasts for Electrification of Space Heating in Residential Homes in the US," Energy Policy, 112813, 163 (April 2022): 1–12, https://doi.org/10.1016/j.enpol.2022.112813.

[15] Rachel Murray, Varuna Gopalan, and Peter Biermayer, publication, Heat Pump Buyers Be Wary: Weighing the Effects of Refrigerants (American Council for an Energy-Efficient Economy, 2024), https://www.aceee.org/sites/default/files/proceedings/ssb24/pdfs/Heat%20Pump%20Buyers%20Be%20Wary.pdf.

[16] Katie Teshima and Alexis Allan, rep., Residential Heat Pump Water Heating - Market Transformation Advancement Plan (California Market Transformation Administration and California Public Utilities Commission (CPUC), September 17, 2024), https://calmta.org/resourcereport/residential-heat-pump-water-heating-advancement-plan/.

[17] "TECH Clean CA - Heat Pump Data." https://techcleanca.com/heat-pump-data/download-data/, September 29, 2023.

2) Compare sizing requirements in California's plumbing code (CPC),[18] Northwest Energy Efficiency Alliance (NEEA) tiered incentives,[19] and DOE sizing tool[20] recommendations.

3) Conduct a gap analysis of available sizing tools[21] and sizing requirements[22] and evaluate strengths and weaknesses relative to installation barriers reported in the CalMTA installer survey, focus groups,[23] and field data[24] (e.g., upsizing challenges because of space requirements).

4.1.2 Compile and monitor HPWH design changes, reliability, warranty information, and replacement rates.

1) Collect data from multiple databases including AHRI's certified product directory,[25] DOE's Compliance Certification Management System (CCMS),[26] ENERGY STAR's certified HPWH

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[18] California Plumbing Code § 501.1(2) (Cal. Code Regs. tit. 24, pt. 5)

[19] Northwest Energy Efficiency Alliance (NEEA), "Advanced Water Heating Specification - Version 8.1" (Portland: Oregon, United States, July 15, 2024), https://neea.org/wp-content/uploads/2025/03/Advanced-Water-Heating-Specification.pdf.

[20] "Heat Pump Water Heater Installation Tool," Energy.gov - Office of Energy Efficiency & Renewable Energy - Building America Solution Center, https://basc.pnnl.gov/hpwh_installation_tool.

[21] "Heat Pump Water Heater Installation Tool," Building America Solution Center, U.S. Department of Energy. Cal. Code Regs. tit. 24, pt. 5, § 501.1(2)

[22] Cal. Code Regs. tit. 24, pt. 5, § 501.1(2)

[23] Amanda Maass, Arianna Zrzavy, and Alex Dunn, rep., *Cold Climate Demonstration Installation & Water Heater Installer Focus Group Research* (Northwest Energy Efficiency Alliance and Illume Advising, LLC, February 1, 2024), https://neea.org/wp-content/uploads/2025/03/Cold-Climate-Demonstration-Installation-Water-Heater-Installer-Focus-Group-Research.pdf.

[24] "TECH Clean CA – Heat Pump Data," accessed September 29, 2023.

[25] Air Conditioning, Heating, and Refrigeration Institute (AHRI), "Directory of Certified Product Performance" (Arlington: Virginia, United States, 2025), https://ahridirectory.org/.

[26] U.S. Department of Energy (DOE), "Compliance Certification Management System (CCMS)" (District of Columbia: Washington, United States, 2025), https://www.regulations.doe.gov/ccms.

product list,[27] and the NEEA residential HPWH qualified product list,[28] to evaluate design characteristics and efficiencies of certified HPWHs.

2) Collect and analyze technical specification documents, product handbooks, and warranty documents for all available HPWHs across three major manufacturers (A.O. Smith, Rheem, and Bradford White) to capture design and warranty trends.
3) Analyze HPWH unit repair and replacement data published by Opinion Dynamics in partnership with TECH Clean California to monitor trends in incident cause.[29,30]
4) Evaluate real-world installation characteristics in subsidized projects using TECH Clean California's public reporting dataset,[31] focusing on unit size differences, replacement types, location, and voltage requirements.

4.1.3 Identify electric panel upgrade challenges that prevent HPWH installation and develop an electric panel upgrade decision tree.

1) Leverage recent CPUC and CalNEXT studies to understand statewide electrical panel capacity and estimate the share of homes with sufficient service for HPWH unit installation.
2) Synthesize literature and available cost data to estimate typical expenses associated with electrical upgrades (e.g., panel, circuit, and wiring modifications) and their impact on overall fuel-switching costs.
3) Evaluate emerging strategies to avoid panel upgrades—such as 120-volt HPWHs, circuit-sharing devices, and meter collars—focusing on cost, feasibility, and market readiness.

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[27] U.S. Environmental Protection Agency, "ENERGY STAR Certified Heat Pump Water Heaters List" (District of Columbia: Virginia, United States, 2025), https://www.energystar.gov/productfinder/product/certified-heat-pump-water-heaters/results.

[28] Northwest Energy Efficiency Alliance (NEEA), "Residential Heat Pump Water Heater Qualified Products List" (United States, 2025), https://neea.org/img/documents/residential-HPWH-qualified-products-list.pdf.

[29] Ellen Steiner and Jen Loomis, publication, *TECH Clean California Heat Pump Equipment: Insights into Customer Experience and Satisfaction* (Opinion Dynamics, September 15, 2023), https://techcleanca.com/documents/2377/TECH_Customer_Experience_and_Satisfaction_Final_Report_9.15.23.pdf.

[30] Jen Loomis and Ellen Steiner, publication, TECH Clean California: Insights into Customer Experience and Satisfaction - Wave 2 (Opinion Dynamics, March 31, 2025), https://techcleanca.com/documents/5585/TECH_Updated_Customer_Experience_and_Satisfaction_Report_3.31.2025_Clean.pdf.

[31] "TECH Clean CA – Heat Pump Data," accessed September 29, 2023.

4) Develop a decision tree to outline installation pathways available to contractors that avoid or minimize the need for electrical panel upgrades.

4.1.4 Assess current load flexibility capabilities of residential HPWHs and identify opportunities to support grid demand-response integration.

1) Examine existing HPWH load flexibility models (e.g., Shed, Shape, Shift, Shimmy) with emphasis on Load Shed and Load Shift strategies to assess their potential for grid-responsive operation and renewable energy alignment.
2) Review communication standards and protocols (CTA-2045-B, OpenADR, and proprietary systems) to evaluate compatibility with advanced control strategies and emerging performance standards.
3) Identify technical, market, and consumer barriers to HPWH unit load-shift participation, including equipment costs, interoperability challenges, and awareness gaps.

4.2 Research methods

The Residential HPWH MTI technical team participated in manufacturer and stakeholder interviews with the MTI market research team to better understand HPWH market and technology opportunities and barriers. The team conducted additional research to address the technical objectives summarized above. Data collection, research, and analysis methods are summarized below.

4.2.1 Energy modeling

The CalMTA team conducted whole-building energy modeling using EnergyPlus, DOE's open-source energy modeling software, to simulate annual energy demand using Database for Energy Efficient Resources (DEER) prototypes for the California HPWH Electronic Technical Reference Manual (eTRM) measures, SWWH02532 and SWWH014.33 Current HPWH measures use the spreadsheet-based DEER Hot Water Calculator.34 Future 2026 versions of these HPWH measures will transition to the EnergyPlus ModelKit framework.35 To best align with the energy savings estimates in the eTRM, the

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[32] Database for Energy Efficient Resources (DEER), "HPWH eTRM Measure: Residential, Fuel Substitution, SWWH025-09," 2025, California Technical Forum, https://www.caetrm.com/measure/SWWH025/09/.

[33] Database for Energy Efficient Resources (DEER), "HPWH eTRM Measure: Residential, SWWH014-07," 2025, California Technical Forum, https://www.caetrm.com/measure/SWWH014/07/.

[34] DNV Energy Insights USA, Inc. DEER Water Heater Calculator. V. v5.0 for the DEER2023 Update. California Public Utilities Commission, released April 5, 2022. https://cedars.cpuc.ca.gov/deer-resources/tools/water-heaters/file/2919/download/.

[35] sound-data (GitHub organization). DEER-Prototypes-EnergyPlus (Repository). Python, Ruby. V. D26v2024.12.07.02. Released December 7, 2024. https://github.com/sound-data/DEER-Prototypes-EnergyPlus.

models were used without modification, except to adjust the HPWH unit UEF when the existing eTRM values did not match the MTI product definition. The modeling incorporated DEER models for gas storage, ER storage, 240-volt HPWH, and 120-volt HPWH models for single-family, multifamily, and mobile home building prototypes. Each building type has a unique hot water draw profile with 1-minute resolution developed for the 2026 eTRM measures.

A detailed description of the energy modeling can be found in Appendix B, Attachment 2.

4.2.2 Sizing research

The team analyzed TECH Clean California installation records against CPC FHR requirements36 and DOE's HPWH Sizing Tool37 to quantify real-world sizing trends and document institutionalized best practice. Real world trends in sizing were sourced from various field studies, including but not limited to, NEEA's cold climate focus group,38 Opinion Dynamic's TECH Clean California consumer surveys,39 and NEEA's lab testing for HPWHs in small spaces.40 Comparing field data to research-backed best practices reveals installer behavior and provides a baseline for assessing the need for upsizing.

4.2.3 Product specifications and reliability investigation

To investigate HPWH product reliability despite limited data, the CalMTA team used a multi-source analytical approach combining qualitative and quantitative information. The team compiled data from warranty documents, manufacturer specifications, recall and safety databases from the Consumer Product Safety Commission (CPSC)41 and the Organization for Economic Co-operation and Development (OECD),42 and consumer surveys from TECH Clean California and Opinion Dynamics to

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[36] Cal. Code Regs. tit. 24, pt. 5, § 501.1(2)

[37] "Heat Pump Water Heater Installation Tool," Building America Solution Center, U.S. Department of Energy

[38] Maass, Zrzavy, and Dunn, Cold Climate Demonstration Installation & Water Heater Installer Focus Group Research.

[39] Steiner and Loomis, TECH Clean California Customer Experience Survey (Opinion Dynamics); Steiner and Loomis, TECH Clean California Customer Experience Survey – Wave 2 (Opinion Dynamics).

[40] Larson, Ben, and Sam Larson. Heat Pump Water Heaters in Small Spaces Lab Testing: "The Amazing Shrinking Room." Nos. E22-334. Northwest Energy Efficiency Alliance, 2022. https://neea.org/wp-content/uploads/2025/03/Heat-Pump-Water-Heaters-in-Small-Spaces-Lab-Testing.pdf.

[41] U.S. Consumer Product Safety Commission. "U.S. CPSC Product Recall Database." 2025. https://www.saferproducts.gov/.

[42] Organization for Economic Co-operation and Development (OECD). "Global Recalls Portal." 2025. https://globalrecalls.oecd.org/#/.

identify reliability signals and emerging failure trends. Automated data scraping and text-processing scripts were developed and refined to collect and organize warranty data from major manufacturers (Rheem, A.O. Smith, and Bradford White), with manual review to ensure accuracy. This integrated approach allowed CalMTA to evaluate industry confidence, highlight gaps in publicly available failure data, and propose next-step research strategies to build a robust, evidence-based understanding of HPWH product reliability.

4.2.4 Load flexibility literature and standards review

In this research, we conducted a comprehensive literature and standard review to evaluate HPWH load flexibility strategies and their integration with grid DR programs. We analyzed communication interface standards—including CTA-2045-B, OpenADR, and proprietary manufacturer protocols—to assess interoperability, data exchange capabilities, and alignment with national and regional performance standards such as NEEA's Advanced Water Heater Specification[43] and AHRI 1430-2022.[44] We reviewed manufacturer specifications, program documentation, and pilot results from existing utility DR programs to quantify current participation levels, technical barriers, and incremental equipment costs.

4.2.5 Electric panel upgrade challenges and decision tree

We assessed electric panel readiness for HPWH product installations across California using a mixed-methods approach combining secondary data analysis, industry surveys, and cost modeling. Findings from the CPUC's 2024 consumer and contractor surveys, CalNEXT's emergency replacement study, and New Buildings Institute market assessments were synthesized to quantify panel capacities, installation challenges, and upgrade costs for single- and multifamily homes. Technical specifications of plug-in HPWH models and verified field cost data were analyzed to evaluate alternatives such as panel optimization, circuit-sharing devices, and meter collars.

4.2.6 Barriers and opportunities evaluation framework

In this research, we conducted a comprehensive literature review and developed a structured scoring framework to assess how residential HPWH adoption barriers interact with proposed technical solutions. We analyzed over seventy potential solutions, categorizing them by target domain—device/technology, installation space, or stakeholder group—and scored each against thirteen defined barriers to measure positive, negative, or neutral impacts. Using a qualitative-to-quantitative approach, expert-informed judgments were converted into net impact scores and categorical values to identify solutions with the greatest benefits and minimal unintended consequences. This methodology

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[43] NEEA, Advanced Water Heating Specification, v8.1.

[44] AHRI, AHRI 1430 (I-P) Addendum 1.

allowed us to compare the relative effectiveness of interventions and highlight where combined (or "stacked") solutions could maximize adoption across California's residential market.

5 Technical barriers and opportunities to broader adoption

This section identifies the technical barriers to wider adoption of HPWHs and the opportunities to promote increased adoption of the technology. CalMTA finds that there is not a one-to-one correlation between barriers and opportunities. For example, thermostatic mixing valves that enable HPWHs to preheat water to temperatures greater than 130° F before high usage periods (opportunity) could offset slower recovery times (barrier) *and* enable lower-voltage and/or smaller models that work within existing space constraints better than the HPWHs that are currently available (barrier).

5.1 Panel capacity when replacing a gas water heater

In residences that lack adequate electrical service to support 240-volt HPWH models, installations are more complex and may require adding a dedicated circuit to an electric panel, upgrading the electric panel, or potentially upgrading the home's electrical supply. Electric panel and supply upgrades increase HPWH unit installation cost because an electrician must be engaged in addition to a plumber and/or HVAC technician.[45] Wait times are increased because multiple trades are involved and because of labor shortages in these trades.[46] Replacement time and cost increases are significant constraints during emergency replacements, which represent 46% of water heater replacements.[47]

Shared-circuit 120-volt HPWH models largely avoid electrical capacity constraints because these units plug into existing outlets.[48] However, depending on the home, an outlet may need to be added near the water heater location (i.e., within reach of the built-in electric cord) and/or an additional 30-amp circuit may need to be added to the electrical panel. If the electrical panel does not have space for an

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[45] San Jose Clean Energy. Heat Pump Water Heater. March 30, 2023. https://sanjosecleanenergy.org/heat-pump-water-heater/.

[46] Rathi, Akshat, Olivia Rudgard, and Oscar Boyd. "Labor Shortages Are Holding Back Desperately Needed Electrification." Bloomberg.com, June 5, 2025. https://www.bloomberg.com/news/articles/2025-06-05/labor-shortages-are-holding-back-desperately-needed-electrification.

[47] Opinion Dynamics, and Ellen Steiner. California Water Heating Market Study - Contractor Business Models, Training, and Electrification. California Public Utilities Commission (CPUC), 2024. https://www.calmac.org/%5C/publications/Water_Heater_Market_Characterization_Study_PDA_Final_9_18_2024.pdf.

[48] Khanolkar, Amruta, Mischa Egolf, and Noah Gabriel. Plug-In Heat Pump Water Heater Field Study Findings & Market Commercialization Recommendations. New Buildings Institute, 2023. https://newbuildings.org/resource/plug-in-heat-pump-water-heater-field-study-findings-market-commercialization-recommendations/.

additional electric circuit, panel optimization or a panel upgrade will be required, increasing installation cost.

Opportunities for addressing these barriers include:

- **Shared-circuit 120-volt HPWHs equipped with smart controls** can modulate heating cycles and dynamically manage stored hot water to prevent exceeding panel or outlet capacity, thereby avoiding the need for electrical upgrades.
- **Dual-voltage HPWHs** that operate on 120 volts, with slower recovery, can switch to 240 volts after a panel upgrade, easing emergency replacements.
- **Panel optimization using smart load management devices** enable HPWHs to share existing 240-volt circuits with other high-load appliances (e.g., EV chargers) through auto-switching or prioritization. Plug-and-play smart splitters (e.g., NeoCharge[49]) can manage load dynamically to avoid costly panel upgrades.
- **Meter collar adapters** (e.g., ConnectDER,[50] Pacific Gas and Electric (PG&E) Green Meter Adapter[51]) create new circuits at the utility meter, bypassing the main electrical panel and enabling HPWH installation without panel expansion.
- **Flexible demand appliance standards or an update to California's Title 24 JA13** can be used to standardize communication protocol between water heaters and utilities, ensuring effective adoption and operation of load-flexible HPWHs.
- **Panel-readiness audit and optimization programs** implemented through CalMTA or utility channels to assess household electrical capacity, can identify optimization opportunities (e.g., circuit sharing, meter collars, load balancing), and prioritize installations not requiring panel capacity or service upgrades.

5.2 Efficiency and hot water recovery rate

HPWH product performance can be limited by slower recovery rates, space constraints, and ventilation requirements that affect installation feasibility and user satisfaction. While 240-volt hybrid models with ER backup typically meet household hot water demands, 120-volt units and those operating in heat-

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[49] NeoCharge. "NEMA 10-50 Smart Splitter - EV/Appliance." 2025. https://getneocharge.com/products/nema-10-50.

[50] Crowell, Chris. "Spread the Wealth: Lower Solar Installation Costs with Meter Collar Connection." Solar Builder Magazine, February 19, 2024. https://solarbuildermag.com/news/spread-the-wealth-lower-solar-installation-costs-with-meter-collar-connection/.

[51] Green Meter Adapter (GMA) for Customer Generation. Utility Bulletin TD-7001B-007. Pacific Gas & Electric, 2021. https://www.pge.com/assets/pge/docs/about/doing-business-with-pge/TD-7001B-007.pdf.

pump-only or energy-saver modes recover more slowly, especially under high-demand or cold-climate conditions.

Ventilation and ambient temperature strongly influence HPWH unit performance. HPWHs extract heat from surrounding air and release cool exhaust. In confined spaces, this cooling effect lowers ambient temperature, reducing available heat and HPWH system efficiency. Similarly, in unconditioned or cold environments, low air temperatures can limit heat exchange or disable the heat pump if conditions fall below the compressor's minimum operating range. To maintain FHR requirements in such cases, installers may increase tank size, which can further constrain space and ventilation.

When efficiency or recovery declines, HPWHs may rely more on ER backup—either automatically through system controls or by user selection, increasing energy use and operating costs.

Opportunities to address these challenges include:

- **Implementing smart controls with thermostatic mixing valves** to preheat water before peak demand, increasing available hot water without increasing storage volume. These controls also provide auxiliary benefits, allowing consumers to manage energy use, monitor operation remotely, and extend component life through optimized cycling.
- **Developing compact or slim-profile form factors** to enable greater heat capacity in smaller storage volumes within constrained spaces. Smaller and modular units may reduce labor time, improve stocking and transport efficiency, and simplify repair or part replacement compared to full-unit swaps.
- **Installing split-system HPWHs** where the heat pump system is installed outdoors removes indoor space and ventilation pressures while improving recovery rates through more effective ambient air utilization. This configuration also reduces noise in occupied spaces, improving user comfort.
- **Capitalizing on advanced compressor technologies** (e.g., vapor-injection compressors) to enhance split-system HPWH performance in cold climates. Low refrigerant discharge temperatures associated with vapor-injection compressor designs may also offer improved reliability as compared to traditional compressor designs.[52]

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[52] Wang, Yikai, Zuliang Ye, and Feng Cao. "Performance Investigation of Two-Stage Heat Pump with Vapor Injection Using R410A as Working Fluid." Purdue E-Pubs, 2018. https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=2904&context=iracc#:~:text=3.2%20Effect%20of%20the%20vapor%20injection%20on%20heating%20capacity&text=It%20is%20found%20that%20the,heating%20performance%20is%20more%20obvious.

6 Competitive landscape

This section compares the strengths and weaknesses of incumbent technologies (Table 1) and HPWHs (Table 2). Incumbent technologies include gas storage water heaters, ER storage water heaters, and gas tankless water heaters. Incumbent technology strengths and weaknesses are relative to the MTI Product and assume a 50-gallon storage volume for tank units to facilitate comparison.

Table 1. Strengths and weaknesses of incumbent products

Technology	Strengths	Weaknesses
Incumbent Technology – **50-gallon** Gas Storage Water Heater	• Fast hot water recovery rate (FHR > 80 gal/hr)[53] • Lower cost • Familiar installation • No condensate management (for noncondensing units) • Minimal routine maintenance • Quiet (no compressor) • Efficiency is agnostic to ambient conditions • Not affected by power outages	• Low efficiency (0.68 UEF, baseline unit with high draw pattern, as of May 6, 2029)[54] • Higher GHG emissions • Poorer indoor air quality (IAQ) • Requires flue for ventilation • May increase peak cooling loads, depending on location • Safety risks associated with combustion (fire, explosions)
Incumbent Technology – **50-gallon** ER Storage Water Heaters	• Fast hot water recovery rate (FHR > 60 gal/hr)[55] • Lower cost	• Low efficiency (0.92 UEF, baseline unit with medium draw pattern, before May 6, 2029)[56]

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[53] Reyes, Samantha. "First Hour Rating (FHR) Explained: Why It Matters When Choosing a Water Heater." The Furnace Outlet. https://thefurnaceoutlet.com/blogs/videos/first-hour-rating-fhr-explained-why-it-matters-when-choosing-a-water-heater.

[54] 10 CFR § 430.32(d)(2).

[55] ProMax Water Heaters & Plumbing. "Understanding a Water Heater's First-Hour Rating (FHR)." https://www.promaxwaterheaters.com/blog/understanding-a-water-heaters-first-hour-rating-fhr.

[56] 10 CFR § 430.32(d)(1).

Technology	Strengths	Weaknesses
	• 20 – 40% more efficient than gas storage water heaters • Familiar installation • No condensate management • Minimal routine maintenance • Quiet (no compressor) • Efficiency is agnostic to ambient conditions • No on-site GHG emissions (improved IAQ compared to gas-powered units) • Does not require ventilation • Minimal impact on peak cooling loads compared to gas-powered units	• Higher operating cost than gas water heaters in areas with high electricity costs. • ER draw = 4,500 to 5,500 W • Vulnerable to power outages
Incumbent Technology – Gas Tankless Water Heater	• On-demand hot water; virtually unlimited supply (subject to flow-rate) • Minimal standby losses • Compact, wall-mounted footprint	• Highest upfront cost of all incumbent technologies • More efficient than gas storage water heaters (0.81 UEF, baseline unit with high draw pattern, before May 6, 2029)[58] • Flow-rate limitations, especially in high-draw scenarios • Higher GHG emissions • Requires flue for ventilation

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[58] 10 CFR § 430.32(d)(1).

Technology	Strengths	Weaknesses
	Longer typical life than tank-type units[57] Reduced risk of leaks from stored water	Safety risks associated with combustion (fire, explosions) Use electricity, so vulnerable to power outages

Table 2 summarizes strengths and weaknesses of MTI Products compared to incumbent technologies. The first row in Table 2 compares all integrated HPWHs relative to the incumbent gas or ER storage water heater. The following rows list additional strengths and weaknesses for 240-volt hybrid, 120/240-volt hybrid, 120-volt dedicated-circuit hybrid, and 120-volt shared-circuit hybrid HPWHs. Strengths and weaknesses for each row overlap with the row(s) above. The same approach is followed for identifying and summarizing split-system HPWH products.

UEF values are for a nominal 50-gallon storage tank. FHR will increase for larger tanks since they have more hot water capacity. All UEF and FHR values in Table 2 are from the ENERGY-STAR-certified HPWH product database, downloaded on October 27, 2025.

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[57] Dale, Timothy. "Is a Tankless Water Heater Right for You? Here's When You Really Need One." The Spruce, February 4, 2025. https://www.thespruce.com/tankless-water-heater-pros-and-cons-8782959.

Table 2: Strengths and weaknesses of MTI products compared to incumbent technologies

Product	Compared to 50-gal Gas Storage Water Heater		Compared to 50-gal ER Storage Water Heater	
	Strengths	Weaknesses	Strengths	Weaknesses
MTI Product - Integrated HPWHs	• No on-site GHG emissions • IAQ benefits • Space cooling may reduce peak cooling loads • Highly efficient (~3.3 – 4.1 UEF)[59]	• Higher equipment cost • Higher installation cost • Installation unfamiliar • Space cooling may increase peak heating loads • Efficiency varies with ambient conditions and ventilation • Installation in enclosed spaces may require ventilation • Taller/heavier unit • Condensate management • Compressor noise • Regular heat pump filter replacements	• Reduced utility bill when operating in heat pump mode • Space cooling may reduce peak cooling loads	• Higher equipment cost • Higher installation cost • Installation unfamiliar • Space cooling may increase peak heating loads • Efficiency varies with ambient conditions and ventilation • Installation in enclosed spaces may require ventilation • Taller/heavier unit • Condensate management • Compressor noise • Regular heat pump filter replacements

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[59] Jutras, Nate. "What Is Uniform Energy Factor and Why Does It Matter?" ENERGY STAR, April 29, 2024. https://www.energystar.gov/products/ask-the-experts/what-uniform-energy-factor-and-why-does-it-matter.

Product	Compared to 50-gal Gas Storage Water Heater		Compared to 50-gal ER Storage Water Heater	
	Strengths	Weaknesses	Strengths	Weaknesses
240-volt Hybrid	• 5.7 times more efficient • 65-gal FHR comparable • 80-gal FHR comparable to 25% higher	• 50-gal FHR 5% lower • May require electrical panel upgrade • Emergency replacements may be difficult due to insufficient electrical availability • High FHR achieved with ER • ER draw = 4,500 to 5,500 W	• 3.9 times more efficient • Will not require an electrical panel upgrade • 50-gal FHR comparable • 65-gal FHR comparable to 15% higher • 80-gal FHR 10% to 33% higher	• High FHR achieved with ER
120-volt/240-volt Hybrid	• 5.5 times more efficient	• FHR depends on voltage and amperage • 120-volt use requires a nearby electrical outlet • Requires dedicated electrical circuit • Electrical panel upgrade (if needed) may be postponed	• 3.9 times more efficient • Will not require an electrical panel upgrade	• FHR depends on voltage and amperage
120-volt Dedicated-circuit	• 4.9 times more efficient • No ER	• Requires nearby electrical outlet	A 120-volt HPWH unit would not be used to replace a 240-volt ER water heater	

Product	Compared to 50-gal Gas Storage Water Heater		Compared to 50-gal ER Storage Water Heater	
	Strengths	Weaknesses	Strengths	Weaknesses
		• Requires dedicated electrical circuit • Currently only available with a "medium-draw" FHR		
120-volt Shared-circuit	• 5.5 times more efficient • 80-gal FHR 16% higher • No ER	• 65-gal FHR 5% lower • Requires a nearby electrical outlet	A 120-volt HPWH unit would not be used to replace a 240-volt ER water heater	
MTI Product - Split System HPWHs	• No on-site GHG emissions • IAQ benefits • Quiet • No impact on peak cooling/heating loads	• Higher equipment cost • Higher installation cost • Require heating, ventilation and air-conditioning (HVAC) installer • Installation unfamiliar • Additional outdoor unit • Refrigerant leak potential	• Reduced utility bill • Reduced electric peak since no ER • No impact on peak cooling/heating loads	• Higher equipment cost • Higher installation cost • Requires HVAC installer • Installation unfamiliar • Additional outdoor unit • Refrigerant leak potential
MTI Product – Split System 240-volt	• 4.7 times more efficient • 80-gal FHR 50% higher • No ER	• May require an electrical panel upgrade • Emergency replacements may be difficult due to	• 3.2 times more efficient • 50-gal FHR comparable	

Product	Compared to 50-gal Gas Storage Water Heater		Compared to 50-gal ER Storage Water Heater	
	Strengths	Weaknesses	Strengths	Weaknesses
		insufficient electrical availability • 50-gal FHR 5% lower	• 80-gal FHR 60% higher • No ER	
MTI Product – Split System 120-volt	• 4.5 times more efficient • No ER	• Lower FHR	A 120-volt HPWH unit would not be used to replace a 240-volt ER water heater	

7 Energy and policy landscape

This section discusses the current enacted codes and standards that significantly affect the residential HPWH MTI.

7.1 Federal requirements and voluntary programs

7.1.1 Department of Energy

Current DOE standards for residential electric storage water heaters with a nominal volume greater than 55 gallons must meet a minimum UEF of approximately 2.0.[60] Heat pump technology must be used to achieve this UEF. However, manufacturers and installers have found ways to continue selling ER water heaters by reducing the nominal volume and increasing the set-point temperature and adding mixing valves, which effectively increases the usable volume.

New standards, effective May 6, 2029, will require electric storage water heaters with capacities greater than 20 gallons and up to 120 gallons to meet a UEF between 2.3 and 2.5.[61] These levels are only achievable with HPWHs. Gas water heaters will also need to meet higher efficiency targets but required efficiency improvements are minimal. DOE also introduced a definition for effective storage volume to prevent circumvention of these standards.

DOE updated its test procedures in June 2023, with implementation beginning in December 2023. These procedures define specific ambient conditions for testing HPWHs but do not include metrics for load-shift capability or the energy use of communication modules.

7.1.2 ENERGY STAR

Finalized in July 2022 and effective as of April 2023, ENERGY STAR Version 5.0 includes specifications for both integrated and split-system HPWHs.[62] DR capabilities are supported and recognized but remain optional.

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[60] 10 CFR § 430.32(d)(1).

[61] U.S. Department of Energy. Energy Conservation Program: Energy Conservation Standards for Consumer Water Heaters. 89 FR 37778. Federal Register, 2024. https://www.federalregister.gov/documents/2024/05/06/2024-09209/energy-conservation-program-energy-conservation-standards-for-consumer-water-heaters.

[62] ENERGY STAR, Residential Water Heaters Specification Version 5.0 (2022).

7.2 California requirements and voluntary programs

7.2.1 Title 20 (Appliance Efficiency Regulations)

Due to federal preemption, Title 20 does not establish unique efficiency standards for water heaters. However, the California Energy Commission plans to develop Flexible Demand Appliance Standards (FDAS) that would require water heaters to include demand-responsive features.[63]

7.2.2 Title 24, Part 6 (Building Energy Code)

For single-family buildings, new construction and additions must meet mandatory electric-ready requirements. These include a 240-volt circuit, a condensate drain, and a dedicated space for a HPWH unit.[64] The prescriptive compliance path requires either a HPWH unit or a solar thermal system with electric backup. The performance path still allows gas water heaters but makes compliance more difficult due to the Lifecycle System Cost metric.

In retrofit or replacement scenarios, Title 24 permits the use of gas water heaters due to the cost and logistical challenges of switching to HPWHs. However, regional air quality regulations may override this allowance in some locales by banning gas water heaters.

For multifamily buildings, the 2025 update mandates HPWH product readiness for all systems. The prescriptive path requires HPWHs for individual units, with exceptions for buildings that are four stories or taller. The update also introduces new requirements for ventilation and airflow in small closets where HPWHs may be installed.

Of note, Title 24 Part 6 does not require the installation of a thermostatic mixing valve (a primary component supporting load shift) in any setting (single-family or multifamily, new construction or retrofit/replacement) with a water heater. However, under the performance compliance path, buildings can earn credit for HPWHs that include a thermostatic mixing valve, consistent with Appendix JA13 specifications.[65]

The CPC, part of Title 24 Part 6, uses FHR requirements as a key metric for water heater sizing, but the code is agnostic to water heater technology. Following FHR-based sizing tables may lead to significant

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[63] California Energy Commission. "Flexible Demand Appliance Standards." https://www.energy.ca.gov/proceedings/active-proceedings/flexible-demand-appliances/flexible-demand-appliance-standards.

[64] California Energy Commission. 2022 Building Energy Efficiency Standards for Residential and Nonresidential Buildings. August 2022. https://www.energy.ca.gov/sites/default/files/2022-12/CEC-400-2022-010_CMF.pdf.

[65] California Energy Commission. "JA13 Heat Pump Water Heater Demand Management Systems." https://www.energy.ca.gov/rules-and-regulations/building-energy-efficiency/manufacturer-certification-building-equipment/ja13.

HPWH unit upsizing to achieve required recovery rates, exacerbating installation and space constraint challenges.[66]

7.2.3 Local Reach Codes

Approximately 28% of California's population live in districts that have adopted all-electric codes for new construction.[67] These codes do not apply to existing buildings. Legal challenges, such as the one involving the City of Berkeley's gas ban, have led some districts to repeal or delay enforcement of these codes.[68]

7.2.4 Air quality regulations

In December 2025, CARB proposed a market-based approach (like a cap-and-trade system) to limit sales of GHG- and NOx-emissive space heating, water heating, and pool heating equipment in California.[69] Under this proposal, manufacturers and distributors would be subject to limits on their emissive equipment sales as a share of their total equipment sales, with limits gradually decreasing over time. For water heaters, a 60% emissive equipment sales limit is proposed to start in 2030 and decrease 1% each year until reaching 50% and holding steady thereafter. To provide compliance flexibility, the proposal includes a credit system that would allow manufacturers/ distributors to earn, bank, and trade credits by either selling more zero-emissions units than required, selling innovative technologies, donating equipment, or selling equipment that uses ultra-low GWP refrigerants.

The Bay Area Air Quality Management District (BAAQMD) has adopted a zero-NOx standard for water heaters under 75,000 Btu/hr, effective January 1, 2027.[70]

In Rule 1146.2, the South Coast Air Quality Management District (SCAQMD) adopted a zero-NOx standard affecting water heaters with heat input rates between 75,000 and 200,000 Btu/hr (i.e., larger-size residential gas instantaneous water heaters), effective January 1, 2026, for new buildings and

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[66] Cal. Code Regs. tit. 24, pt. 5, § 501.1(2)

[67] Davis, Lucas. "Three Facts about Electric Heating in California." Energy Institute Blog, May 8, 2023. https://energyathaas.wordpress.com/2023/05/08/three-facts-about-electric-heating-in-california/.

[68] Columbia Law School. "The Climate Litigation Database." California Restaurant Association v. City of Berkeley. n.d. https://www.climatecasechart.com/collections/california-restaurant-association-v-city-of-berkeley_cfec1d.

[69] California Air Resources Board. "Zero-Emission Space and Water Heater Standards." December 11, 2025. https://ww2.arb.ca.gov/sites/default/files/2025-12/December_2025_Workshop_Slides_2.pdf.

[70] Bay Area Air District. "Building Appliances Rule Implementation." https://www.baaqmd.gov/en/community-health/building-appliances-rule-implementation.

January 1, 2029, for existing buildings.[71] In *Rinnai America Corp. v. SCAQMD*, the federal district court for the Central District of California upheld Rule 1146.2, determining it fell outside the scope of Energy Policy and Conservation Act preemption.[72]

On June 6, 2025, the SCAQMD Governing Board voted 7 to 5 to reject Proposed Amended Rules 1111 and 1121.[73] These proposed rules would have established manufacturer sales targets for zero-emission residential furnaces and water heaters under 75,000 Btu/hr, starting at 30% in 2027 and increasing to 90% by 2036.[74]

7.3 Other policies and programs

Several U.S. states and regions have implemented HPWH market transformation programs to accelerate the adoption of energy efficient water heating technologies. These programs aim to reduce GHG emissions, lower energy costs, and support grid flexibility. Below is a summary of key initiatives across the country.

7.3.1 Pacific Northwest (Oregon, Washington, Idaho, Montana)

NEEA leads a long-standing HPWH MTI in the Pacific Northwest. Since the early 2000s, NEEA has worked to increase HPWH product adoption by engaging the supply chain, promoting installer training, and raising consumer awareness.[75] Their efforts have led to a significant increase in HPWH market share, growing from less than 1% to over 17%. NEEA also developed the Advanced Water Heater Specification, which has become a benchmark for product performance and efficiency.[76]

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[71] South Coast Air Quality Management District (SCAQMD). Rule 1146.2. June 7, 2024. https://www.aqmd.gov/docs/default-source/rule-book/reg-xi/rule-1146-2.pdf.

[72] Rinnai America Corp. v. South Coast Air Quality Management District (United States Central District of California July 18, 2025). https://www.climatecasechart.com/collections/rinnai-america-corp-v-south-coast-air-quality-management-district_4199ea.

[73] "South Coast AQMD Board Shoots Down Proposed Rules." BOMA on the Frontline, June 17, 2025. https://www.bomaonthefrontline.com/2025/06/17/how-to-prepare-for-the-proposed-south-coast-aqmd-rules/.

[74] Los Angeles Times. "Regulators Seek to Phase out Gas-Powered Appliances in Southern California." June 4, 2025. https://www.latimes.com/environment/story/2025-06-04/new-rules-would-severely-limit-gas-powered-appliances-in-southern-california.

[75] Northwest Energy Efficiency Alliance (NEEA). Northwest Heat Pump Water Heater Market Progress Evaluation Report #6. February 9, 2022. https://neea.org/resource/northwest-heat-pump-water-heater-market-progress-evaluation-report-6/.

[76] NEEA, Advanced Water Heating Specification, v8.1.

7.3.2 Maine

Although the program's market share impact is not publicly available, Efficiency Maine has successfully replaced many of their mostly ER storage water heaters with HPWHs. The program offers up to $1,100 in instant discounts or $1,050 in mail-in rebates for ENERGY STAR-certified HPWHs. It allows both professional and do-it-yourself installations and provides additional federal tax credit opportunities. Efficiency Maine also offers educational resources and cost comparison tools to help consumers make informed decisions.

7.3.3 Massachusetts and the Northeast

States like Massachusetts, through programs such as Mass Save, offer rebates and incentives for ENERGY STAR HPWHs. These programs are part of broader energy efficiency and electrification strategies aimed at reducing residential energy consumption and supporting climate goals. Similar initiatives are present in other Northeastern states, often coordinated through regional energy efficiency organizations.

7.3.4 National and multi-state initiatives

The ENERGY STAR HPWH Market Acceleration Guide provides a national framework for utilities, states, and program implementers to design effective HPWH programs. It emphasizes reducing first-cost barriers, increasing consumer awareness, and engaging the supply chain. The guide also highlights the role of HPWHs in providing DR and grid support.

Administered by the New Buildings Institute, the Advanced Water Heating Initiative (AWHI) is a national market transformation effort aiming to catalyze a rapid transition to HPWHs by shaping policies, building demand, bringing products to market, and educating the supply chain.[77] Entities participating in the AWHI include building owners, utilities, federal agencies, state and local governments, manufacturers, engineers, installers, advocates, researchers, and building industry professionals from across the U.S.

Additionally, the U.S. Climate Alliance, a coalition of 25 states and territories, has committed to deploying 20 million heat pumps, including HPWHs, by 2030. This initiative supports decarbonization, job creation, and equitable access to clean energy technologies.

Table 3 compares the proposed CalMTA product definition with DOE requirements, ENERGY STAR specifications, and the NEEA HPWH program.

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[77] Advanced Water Heating Initiative. https://www.advancedwaterheatinginitiative.org.

Table 3. Comparison of MTA product characteristics to selected other HPWH standards and programs

Product Characteristic	**CalMTA**	**DOE**	**ENERGY STAR**	**NEEA**
HPWH units included	120-volt integrated, split 240-volt integrated, split	Standards required for all HPWH product types on and after 5/6/2029	120-volt integrated 240-volt integrated Split-system	120-volt integrated, split 240-volt integrated, split
Nominal storage volume	≤ 120 gallons	≥ 20 to ≤ 120 gallons	None specified	≤ 119 gallons
UEF standard/ specification	2.20 (120-volt integrated) 3.30 (240-volt integrated) 2.20 (split-system)	On and after 5/6/2029: 2.3 (≥20 and ≤55 gal) 2.5 (>55 and ≤120 gal)	2.20 (120-volt integrated) 3.30 (240-volt integrated) 2.2 (split-system)	Does not use UEF but must be ENERGY STAR certified
FHR standard/ specification	≥ 45 gallons per hour	No requirement	≥ 45 gallons per hour	High volume draw tests
Load shift	Future: AHRI 1430 certified	No requirement	Optional – expect to refer to AHRI 1430	Endorsement – EcoPort or AHRI 1430
Refrigerant	Future: GWP ≤ 10	No requirement	No requirement	No requirement
Warranty	≥ 6 years parts	Not specified	≥ 6 years parts	≥ 10 years parts

8 Product performance

The CalMTA team used EnergyPlus, DOE's open-source building simulation software, to model whole-building energy performance of HPWHs compared to baseline residential water heating technologies. The modeling adhered strictly to the California DEER prototype modeling framework published by CPUC on January 12, 2026.

Building on the energy modeling, the team conducted an avoided cost analysis using the CPUC's Avoided Cost Calculator and three cost test approaches: a societal cost test (SCT) with both base and high social cost of carbon assumptions, and a total resource cost (TRC) test. Both the energy modeling and avoided cost analyses evaluated seven installation scenarios comparing proposed HPWH and baseline technologies, as shown in Table 4.

Detailed assumptions and methodologies for the energy modeling and avoided cost analyses are provided in Appendix B, Attachment 2.

Table 4. Summary of MTI product installation cases considered by energy modeling analysis

Case	Baseline Technology	Proposed Technology
1	Gas Storage Water Heater, 50 Gallon UEF = 0.68	Hybrid Integrated HPWH, 80 Gallon, UEF = 2.2, 120-volt
2	Gas Storage Water Heater, 50 Gallon UEF = 0.68	Hybrid Integrated HPWH, 50 Gallon, UEF = 3.3, 240-volt
3	Gas Storage Water Heater, 50 Gallon, UEF = 0.68	Hybrid Integrated HPWH, 80 Gallon, UEF = 3.3, 240-volt
4	ER Storage Water Heater, 50 Gallon, UEF = 0.92	Hybrid Integrated HPWH, 50 Gallon, UEF = 3.3, 240-volt
5	ER Storage Water Heater, 50 Gallon, UEF = 0.92	Hybrid Integrated HPWH, 80 Gallon, UEF = 3.3, 240-volt
6	Hybrid Integrated HPWH, 50 Gallon, UEF = 2.3	Hybrid Integrated HPWH, 50 Gallon, UEF = 3.3, 240-volt
7	Hybrid Integrated HPWH, 80 Gallon, UEF = 2.3	Hybrid Integrated HPWH, 80 Gallon, UEF = 3.3, 240-volt

8.1 Climate considerations

As mentioned, the CalMTA team's energy modeling analysis relied on DEER HPWH models developed for the California eTRM measures. These models assume water heaters are installed in unconditioned indoor spaces; therefore, all CalMTA analyses reflect this assumption.

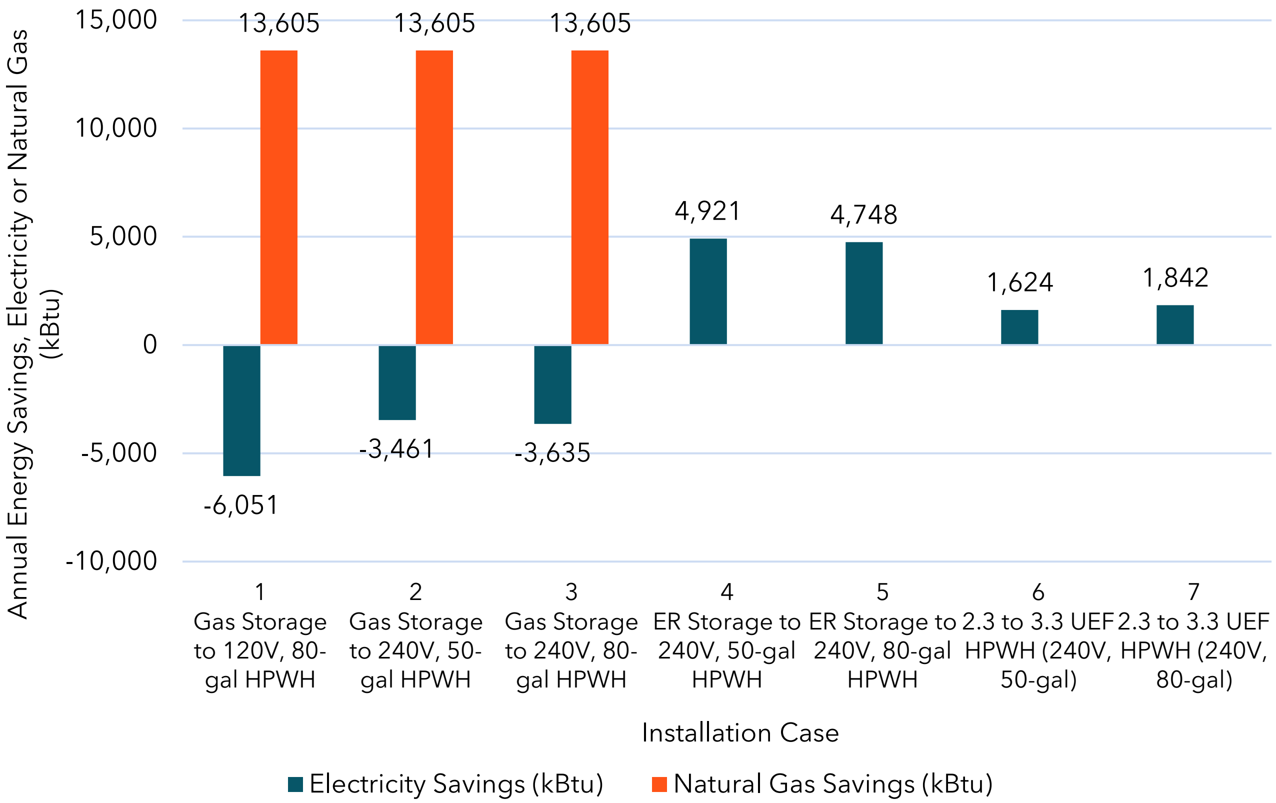
An unconditioned indoor space is the most common installation location type for a primary water heater in a California single-family home. According to 2020 Residential Energy Consumption Survey (RECS) data, approximately 47% of California single-family homes have their primary water heater located in a garage, while the remainder have their primary water heater located in a living space (22%), outside (22%), or in a basement (4%).[78]

To minimize computation time, the CalMTA energy modeling analysis focused on three of California's 16 climate zones (CZs), with each CZ selected to represent the typical service territory climate of the three major California utilities: CZ07 for San Diego Gas and Electric (SDG&E), CZ10 for Southern California Edison (SCE), and CZ12 for PG&E.

8.2 Energy savings

For each installation case, CalMTA's energy modeling analysis estimated annual electricity savings and annual gas savings as shown in Figure 3. Positive values represent cases where the proposed HPWH product consumed less energy than the baseline technology, while negative values represent cases where the proposed HPWH product consumed more energy than the baseline technology. Negative annual electricity savings result for Cases 1 through 3 because the proposed technology uses electricity while the baseline technology uses gas (i.e., no electricity). For Cases 4 through 7, average annual gas savings are not applicable because both the proposed and baseline technologies use electricity.

Figure 3. Annual electricity and gas savings by installation case



Note: Cases 1 through 6 assume a 50-gallon storage volume for the baseline technology, while Case 7 assumes an 80-gallon storage volume for the baseline technology.

8.3 Greenhouse gas emissions

GHG emissions savings were estimated using the CPUC avoided cost framework for natural gas consumption, electricity consumption, as well as refrigerant leakage. To estimate electricity- and natural gas-related GHG emissions savings, GHG emissions factors from the avoided cost workbooks were applied to the energy savings shape (i.e., hour-by-hour energy savings over a full year) modeled for each installation case. To estimate refrigerant-related GHG emissions savings, the refrigerant avoided cost calculator[79] was used assuming a HPWH unit with R-134a refrigerant.

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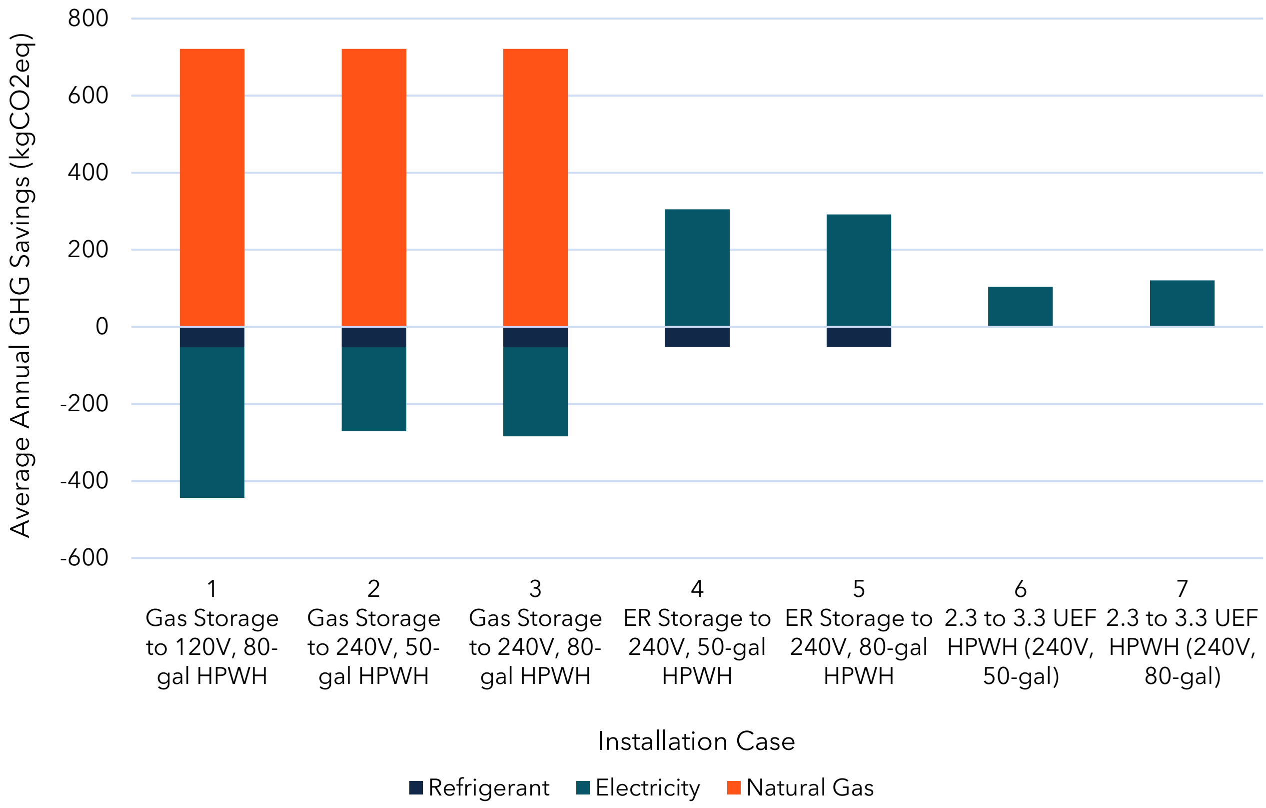
[79] Refrigerant Avoided Cost Calculator and Fuel-Sub Calculator Technical Guidance. n.d. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/building-decarb/deer_supporting_files_racc-fsc-technical-guidance-document_2024419_racc-fsc_technical_guidance.pdf.

Figure 4 shows the resulting average annual GHG emissions savings for each installation case broken down by source (refrigerant, electricity, or natural gas). Values reported are the average annual emissions savings from 2024 through 2054. While emissions factors for natural gas and refrigerant are constant across all years, GHG emissions from electricity consumption decrease over time due to a reduction in GHG intensity of the electric grid. Positive values/bars represent a reduction in GHG emissions, while negative values/bars represent an increase in GHG emissions. The sum of all values/bars across each installation case represents total reduction in GHG emissions.

Average annual total GHG emissions savings are positive in all installation cases, with the biggest savings achieved for fuel substitution cases (Cases 1 through 3) and the smallest savings achieved for swapping a less-efficient HPWH unit for a more-efficient model (Cases 6 and 7). Case 1 has 37% lower GHG savings compared to Cases 2 and 3 because it uses a 120-volt HPWH unit with a lower efficiency than the 240-volt HPWH unit (UEF of 2.2 compared to a UEF of 3.3). Of note, the average annual total GHG emissions savings for Case 1 is only 13% greater than the average of Cases 4 and 5, which both compare a 240-volt HPWH product to baseline ER storage water heater technology.

Figure 4. Annual GHG emissions savings by installation case



Note: Cases 1 through 6 assume a 50-gallon storage volume for the baseline technology, while Case 7 assumes an 80-gallon storage volume for the baseline technology.

8.4 Bill impacts

Energy efficiency measures using the same fuel will typically result in bill savings for consumers. Fuel substitution, however, can be more complicated due to the difference in price for electricity versus natural gas, also known as the spark ratio.[80] There is currently a relatively significant spark ratio in California, with electricity costing four times or more than natural gas for the same amount of energy.[81] Therefore, upgrading from a gas storage water heater to a HPWH product could result in higher utility bills depending on the efficiency of the existing unit, the HPWH product

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[80] The spark ratio is the cost to the customer of 1 kWh of electricity to the cost of 1 kWh of natural gas. This is a common metric for assessing the economic practicality of fuel substitution.

[81] U.S. Energy Information Administration. "California State Energy Profile Data." Accessed November 2025. https://www.eia.gov/state/data.php?sid=CA#Prices.

operation mode (i.e., HP only, HP+ ER, ER only, etc.) and the price difference between electricity and gas, while upgrading from an ER storage water heater to a HPWH product should almost certainly result in a reduction in utility bills for a consumer.

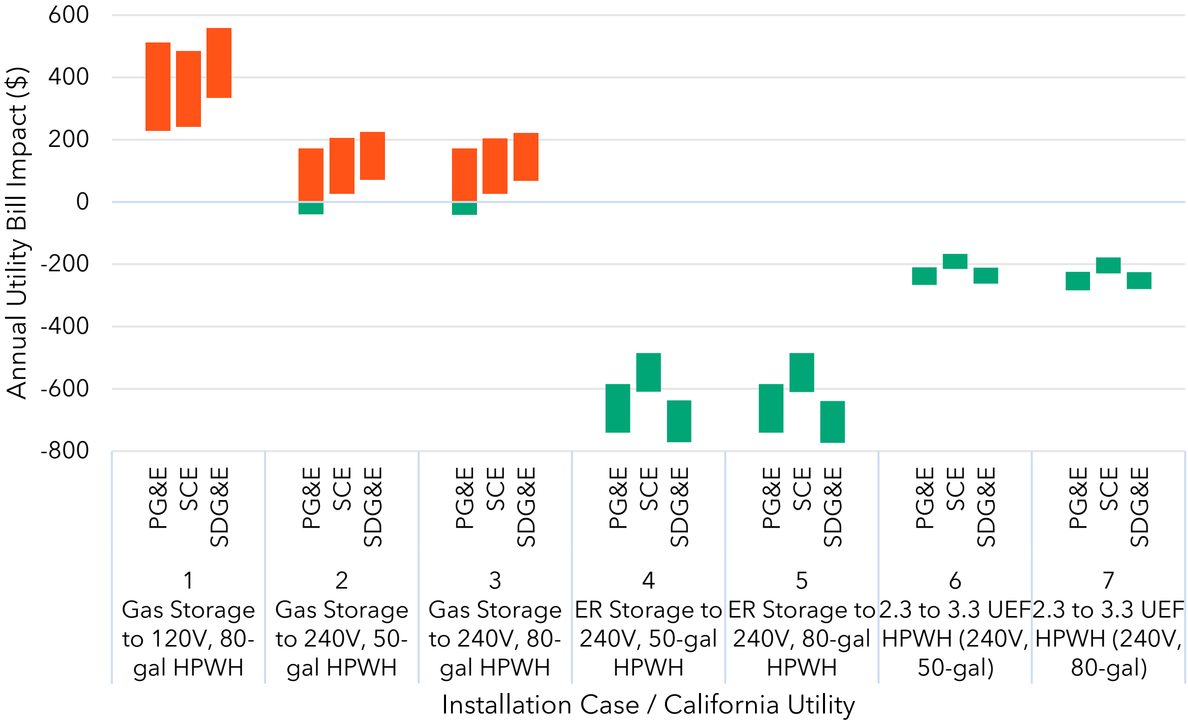
For CalMTA's bill impacts study, the team modeled annual bill impacts for a range of California electricity and natural gas rate structures. The team considered present-day TOU electricity rates, electric vehicle friendly electricity rates, fixed standard natural gas rates and fixed excess natural gas rates published by the three major California investor-owned utilities.

Figure 5 shows the annual utility bill impact (electricity and gas) ranges modeled for each installation case and utility. Negative values represent bill savings while positive values represent a utility bill increase. For Cases 1 through 3, the least favorable bill impact for each utility always occurs with a TOU electricity rate and a fixed standard natural gas rate (largest spark ratio), while the most favorable bill impact always occurs with an electric-friendly rate and a fixed excess natural gas rate (lowest spark ratio). For Cases 4 through 7, the least favorable bill impact always occurs under an electric-friendly rate, while the most favorable bill impact always occurs under a TOU electricity rate.

For installation cases where the baseline technology is an ER storage water heater or a hybrid integrated HPWH product (Cases 4 through 7), results consistently show utility bill savings for consumers switching to the proposed HPWH product. In contrast, for installation cases where the baseline technology is a gas storage water heater (Cases 1 through 3), results predominantly show utility bill increases for consumers switching to the proposed HPWH product. As mentioned, utility bill increases modeled for Cases 1 through 3 are primarily driven by California's significant spark ratio.

However, there are cases where replacing a gas storage water heater with a 240V HPWH product does not increase a consumer's utility bill (see Figure 5, Cases 2 and 3). Modifying installation case assumptions converts a substantial number of utility bill impacts from negative to positive and are discussed below.

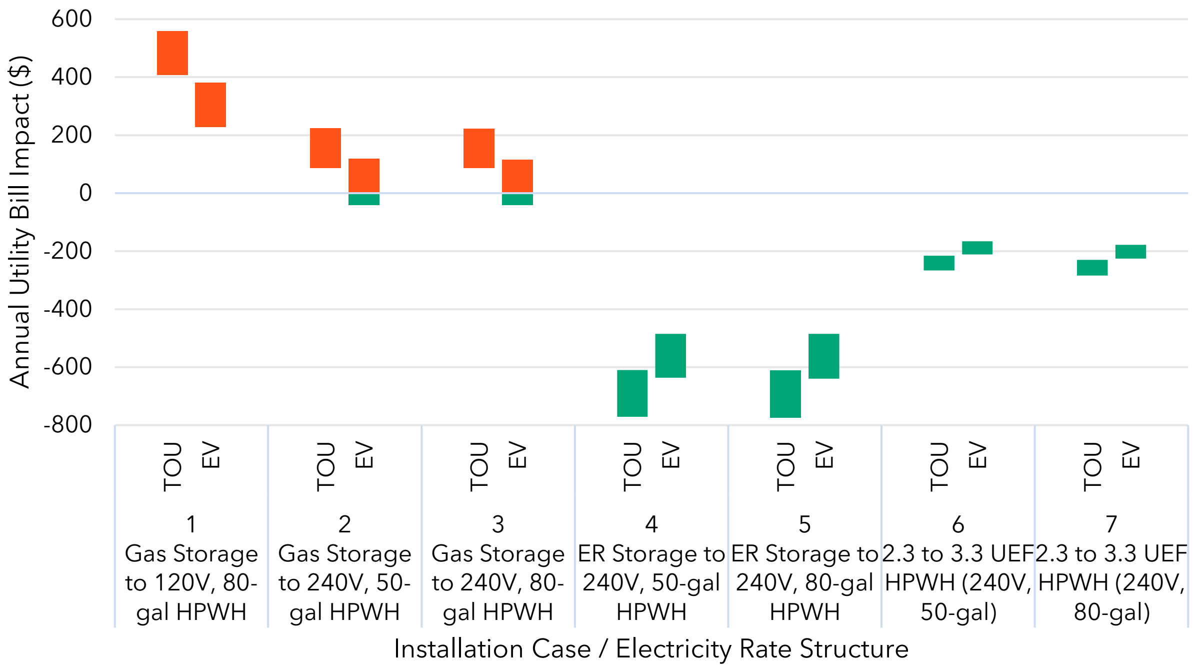
Figure 5. Modeled annual utility bill impact ($) by installation case and utility, all rate structures



Note: Cases 1 through 6 assume a 50-gallon storage volume for the baseline technology, while Case 7 assumes an 80-gallon storage volume for the baseline technology. Bars represent ranges of potential bill impact outcomes modeled across electricity and natural gas rate structures. Potential bill impact outcomes are based on a weighted average of single-family homes (77%), multifamily homes (19%), and mobile homes (4%) representative of California housing stock. Orange bars represent potential annual utility bill increases, while green bars represent potential annual utility bill savings.

Figure 6 shows potential annual utility bill outcome ranges for each installation case and electricity rate structure. In all installation cases, a friendly electricity rate decreases the absolute value of annual utility bill impact. This trend is favorable where annual utility bill increases are modeled under a TOU electricity rate (Cases 1 through 3). However, this trend is less favorable where annual utility bill savings are modeled under a TOU electricity rate.

Figure 6. Modeled annual utility bill impact ($) by installation case and electricity rate structure, all utilities



Note: Cases 1 through 6 assume a 50-gallon storage volume for the baseline technology, while Case 7 assumes an 80-gallon storage volume for the baseline technology. Bars represent ranges of potential bill impact outcomes modeled across utilities and natural gas rate structures. Potential bill impact outcomes are based on a weighted average of single-family homes (77%), multifamily homes (19%), and mobile homes (4%) representative of California housing stock. Orange bars represent potential annual utility bill increases, while green bars represent potential annual utility bill savings.

The CalMTA team also modeled utility bill impacts for low-income California residents eligible for the CARE program. Under the CARE program, qualifying consumers are eligible for a 20% discount on natural gas bills and a 30% to 35% discount on electricity bills.[82] Figure 7 Annual potential utility bill impact outcomes for each installation case, with and without CARE discounts

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[82] California Public Utility Commission (CPUC). “California Alternate Rates for Energy (CARE).” https://www.cpuc.ca.gov/consumer-support/financial-assistance-savings-and-discounts/california-alternate-rates-for-energy.

applied, are shown in Figure 5. For the CARE electricity discount, the CalMTA team used 30% for SDG&E,[83] 32.5% for SCE,[84] and 35% for PG&E.[85]

With CARE discounts applied, potential annual utility bill outcomes become more positive for Cases 1 through 3. However, application of CARE discounts diminish the absolute value of potential utility bill savings is decreased by the CARE electricity discount for Cases 4 through 7.

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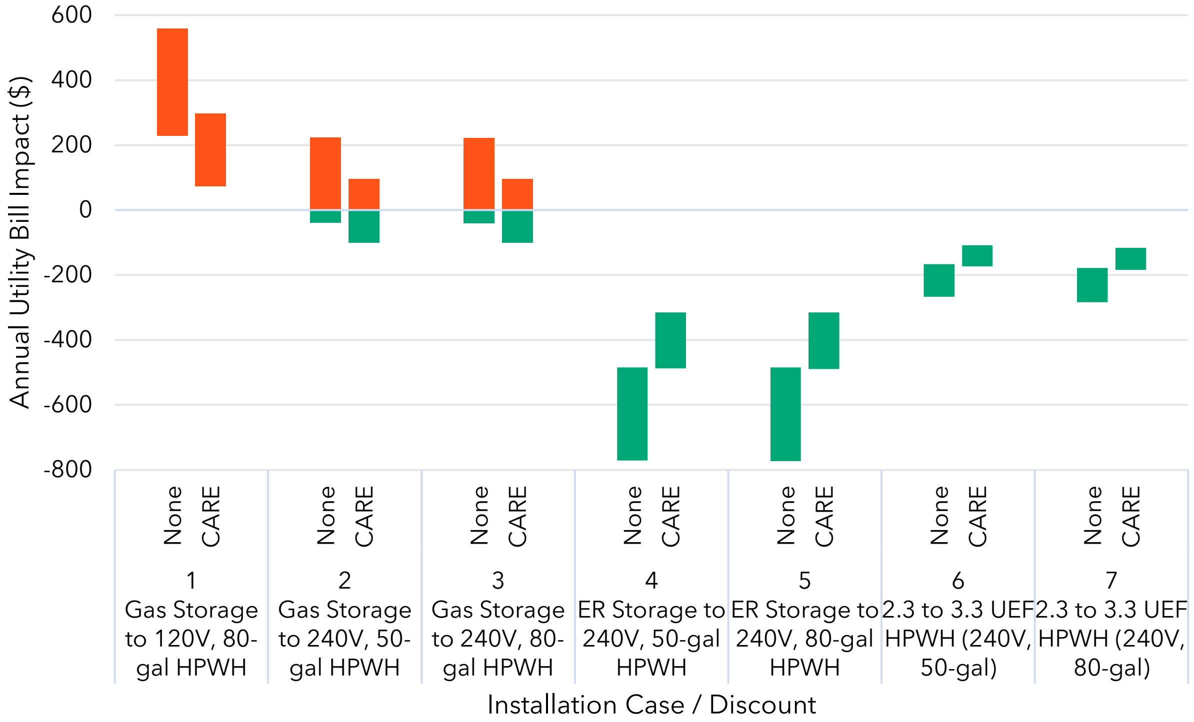
[83] San Diego Gas and Electric (SDG&E). "CARE and FERA Programs." https://www.sdge.com/residential/pay-bill/get-payment-bill-assistance/assistance-programs#overview.

[84] Southern California Edison (SCE). "CARE & FERA." https://www.sce.com/save-money/income-qualified-programs/care-fera.

[85] The CalMTA team could not find an exact CARE electricity discount percentage to use for PG&E. The bill impacts study assumed a 35% CARE electricity discount for PG&E because the other major utilities use the minimum and average percentage of the 30-35% range shown on the CPUC website.

Figure 7. Modeled annual utility bill impact ($) by installation case with CARE discounts applied, all utilities and rate structures



Note: Cases 1 through 6 assume a 50-gallon storage volume for the baseline technology, while Case 7 assumes an 80-gallon storage volume for the baseline technology. Bars represent ranges of potential bill impact outcomes modeled across utilities, electricity rate structures, and natural gas rate structures. Potential bill impact outcomes are based on a weighted average of single-family homes (77%), multifamily homes (19%), and mobile homes (4%) representative of California housing stock. Orange bars represent potential annual utility bill increases, while green bars represent potential annual utility bill savings.

To represent the change that customers may experience when buying a new HPWH unit, we also compared the change in utility bill impacts when replacing an existing gas storage water heater (UEF = 0.58)[86] to a new HPWH unit.

We also explored how higher efficiency HPWHs would impact utility bills. According to the ENERGY STAR HPWH product list, the majority of products on the market today are well above

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[86] U.S. Energy Information Administration. "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies." March 2023. https://www.eia.gov/analysis/studies/buildings/equipcosts/pdf/full.pdf.

the minimum Energy Star UEF requirements. For 120V HPWHs, we consider a UEF of 2.75 and 3.0, which represent 99% and 85% of the products on the ENERGY STAR certified products list, respectively.[87] For 240V HPWHs, we consider a UEF of 3.75 and 4.0 which represent 64% and 24% percent of ENERGY STAR certified products.[88]

Additional alternative scenarios also consider the application of CARE discounts.

Figure 8 and Figure 9 show how the alternative scenarios impact potential utility bill outcomes for Case 1 (replacing with a 120V HPWH product) and Case 2 (replacing with a 240V HPWH product), respectively. Data labels show the midpoint difference for potential annual utility bill outcome under three alternative scenarios versus the original installation case. Alternative scenario results are not shown for Case 3 since they are nearly identical the alternative scenario results for Case 2.

For Case 1, potential annual utility bill savings are sometimes possible when replacing an old (lower efficiency) gas storage water heater with a 3.0 UEF 120V HPWH product under CARE discount rates. For Case 2, potential annual utility bill savings become more likely when a higher efficiency 240V HPWH product replaces an old (lower efficiency) gas storage water heater under CARE discount rates.

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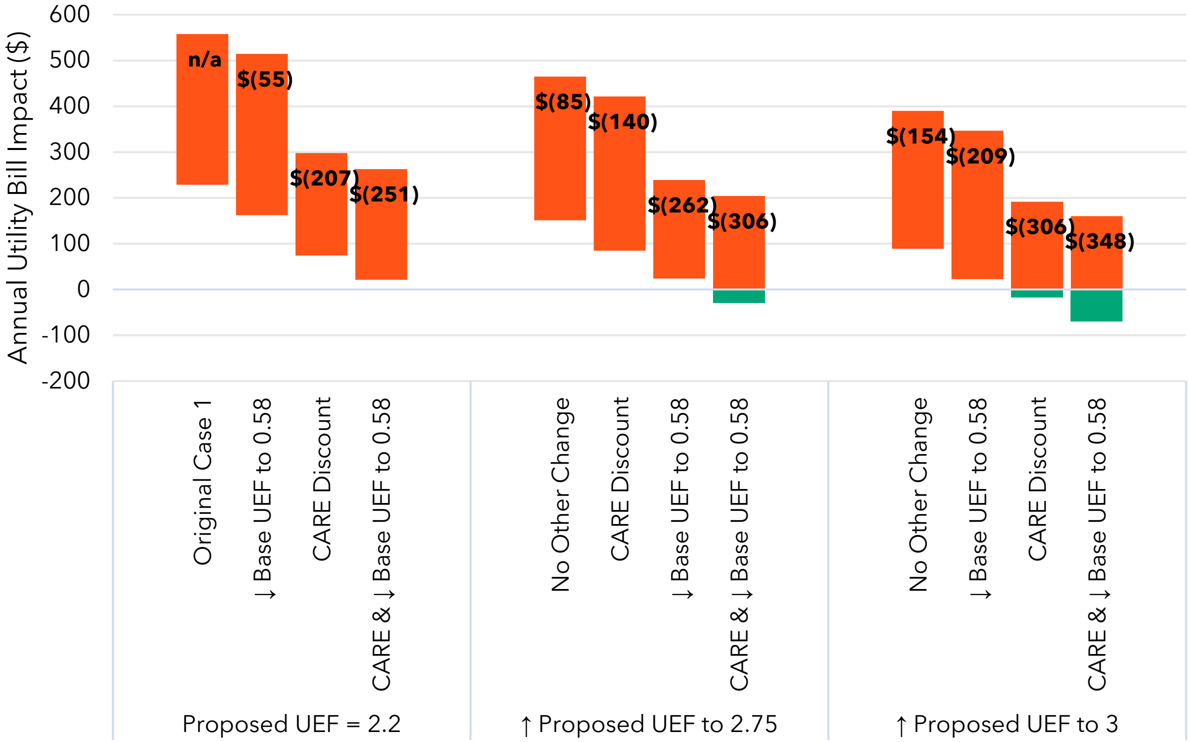
[87] Out of 72 120V HPWHs on the ENERGY STAR certified product list, 71 had a UEF of 2.75 or higher and 61 had a UEF of 3.0 or higher. https://www.energystar.gov/productfinder/product/certified-heat-pump-water-heaters/, Accessed, January 30, 2026.

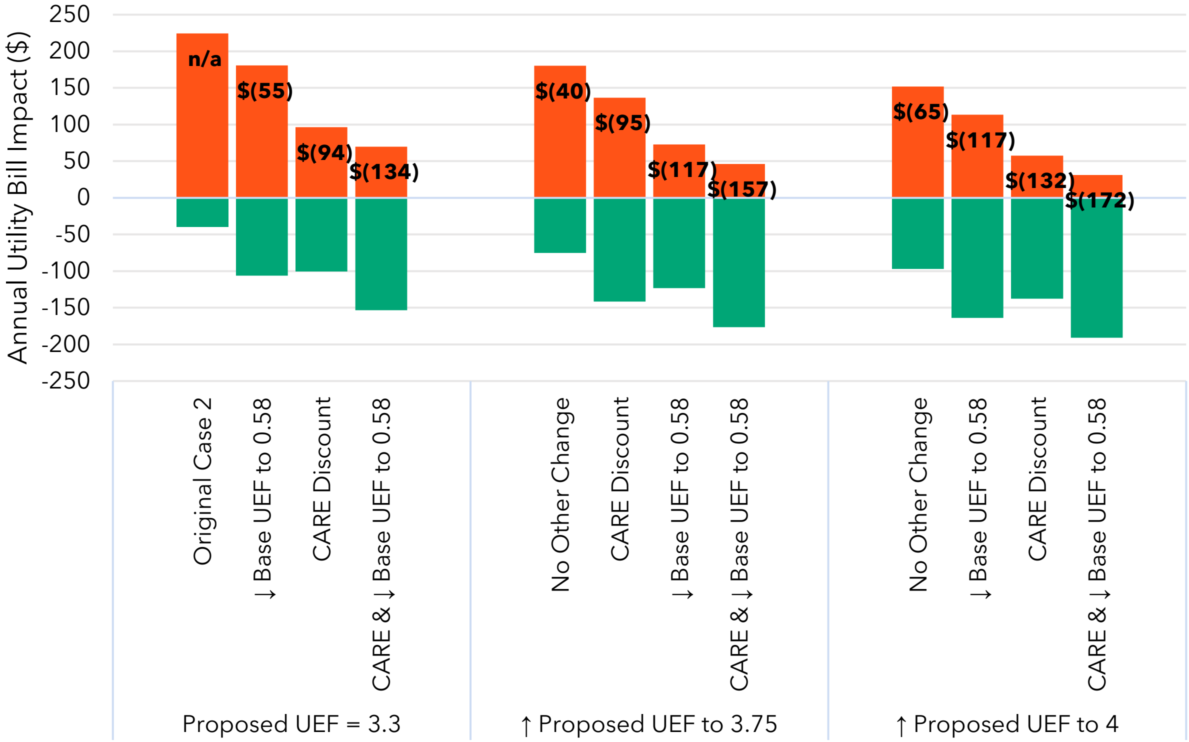
[88] Out of 534 integrated 240V HPWHs on the ENERGY STAR certified product list, 342 had a UEF of 3.75 or higher and 130 had a UEF of 4.0 or higher. https://www.energystar.gov/productfinder/product/certified-heat-pump-water-heaters/, Accessed, January 30, 2026.

Figure 8. Modeled annual utility bill impact ($) by alternative scenario for installation case 1, all utilities and rate structures



Note: Installation Case 1 is a 120V HPWH unit replacing a new baseline gas water heater. Bars represent ranges of potential bill impact outcomes modeled across utilities, electricity rate structures, and natural gas rate structures. Potential bill impact outcomes are based on a weighted average of single-family homes (77%), multifamily homes (19%), and mobile homes (4%) representative of California housing stock. Orange bars represent potential annual utility bill increases, while green bars represent potential annual utility bill savings.

Figure 9. Modeled annual utility bill impact ($) by alternative scenario for installation case 2, all utilities and rate structures



Note: Installation Case 2 is a 240V HPWH unit replacing a new baseline gas water heater. Bars represent ranges of potential bill impact outcomes modeled across utilities, electricity rate structures, and natural gas rate structures. Potential bill impact outcomes are based on a weighted average of single-family homes (77%), multifamily homes (19%), and mobile homes (4%) representative of California housing stock. Orange bars represent potential annual utility bill increases, while green bars represent potential annual utility bill savings.

CalMTA's utility bill impacts evaluation suggests that current ER storage water heater consumers may be most inclined toward HPWH unit replacements. In contrast, current gas water heater consumers may be deterred from a HPWH unit replacement by a potential increase in utility bills. With respect to low-income California residents, these trends generally remain the same, but the CARE discounts do help reduce the spark ratio and thus mitigate the chance of utility bill increases for current gas water heater consumers.[89]

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[89] The higher discount rate for electricity (30-35%) compared to gas (20%) under CARE rates can make fuel substitution more economically viable in some situations

8.5 Product reliability

Reliability is an important product characteristic critical to achieving a market transformation with HPWHs. According to consumer experience surveys conducted by TECH Clean California in partnership with Opinion Dynamics, HPWHs have failure rates comparable to heat pump HVAC systems, but they require less troubleshooting and fewer repairs than heat pump HVAC systems.[90] Installers or consumers that report issues with a HPWH product commonly cite aspects other than reliability as problems, like installation complexity, inadequate hot water recovery, compressor noise, and/or Wi-Fi connectivity.

Further, searches of the CPSC[91] and international OECD[92] recall databases return few safety-related incidents regarding HPWHs.

Unfortunately, quantitative reliability data for HPWHs is limited. Most HPWH product reliability reports rely on anecdotal evidence. For the reliability assumptions used in CalMTA's energy modeling and avoided cost analyses (e.g., effective useful life), see Appendix B, Attachment 2.

8.6 Avoided costs

CalMTA's analysis used the CPUC Avoided Cost Calculator, which provides a robust framework for evaluating the impact of fuel substitution and energy efficiency measures. The calculator estimates system-level utility costs of providing electric or gas on an hourly basis in $/kilowatt-hour (kWh) and $/therm. Avoided cost factors were multiplied by the modeled energy savings outputs to develop annual avoided costs for each installation case. The avoided costs were batched into three categories: energy benefits, grid benefits, and GHG benefits, which are the categories that are used for total system benefit (TSB) reporting in the MTI Plan.

The avoided cost benefit for each installation case in Table 4 was calculated over the period of 2024 to 2054. These hourly and annual values are used as an input to the market adoption and TSB modeling outlined in Appendix B. Figure 10 summarizes CalMTA's avoided cost analysis results by showing the average annual energy, grid, and GHG avoided costs of each installation

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[90] Steiner and Loomis, TECH Clean California Customer Experience Survey (Opinion Dynamics).

[91] U.S. Consumer Product Safety Commission. "U.S. CPSC Product Recall Database."

[92] Organization for Economic Co-operation and Development (OECD). "Global Recalls Portal."

case under the TRC test approach.[93] The results show average annual total avoided costs are greatest for Cases 1 through 3 (i.e., cases with baseline gas storage water heater technology) because of large average annual GHG avoided costs. Grid avoided costs are negative in Case 1 because electricity consumption is highest in this case, outweighing the natural gas grid savings.

A detailed description of how avoided costs were calculated for this report can be found in Appendix B, Attachment 2.

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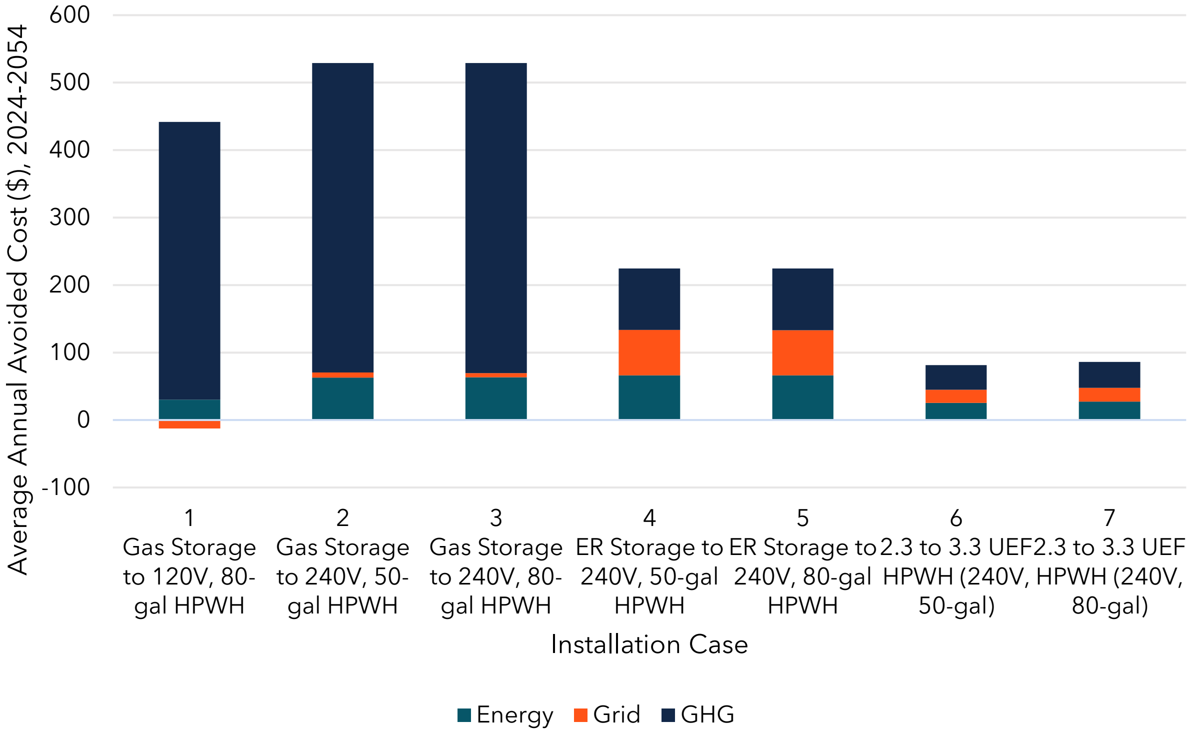
[93] The avoided cost factors are divided into three categories for simplification: "energy" includes the Energy factor from the electric model and the Market factor from the gas model. "Grid" includes Generation Capacity, Transmission Capacity, Distribution Capacity, Ancillary Services, and Losses from the electric model as well as Transmission and distribution from the gas model. "GHG" includes Cap and Trade, GHG Adder, GHG Rebalancing, and Methane Leakage from the electric model and Environment, Upstream Methane Leakage, Behind the Meter Methane Leakage, and Gas Air Quality Adder from the gas model. The values shown here are in nominal future dollars prior to discounting for total system benefit and cost effectiveness calculations. The details of the avoided cost calculations are covered in more detail in Appendix B.

Figure 10. Annual average avoided cost benefit by installation case, 2024-2054 (TRC test approach)



Note: Cases 1 through 6 assume a 50-gallon storage volume for the baseline technology, while Case 7 assumes an 80-gallon storage volume for the baseline technology.

8.6.1 Refrigerant avoided costs

In this MTI plan, the proposed technology, residential HPWHs, contain refrigerant in a direct expansion process, while the gas storage water heater and ER water heater baseline technologies do not contain refrigerant. Therefore, avoided cost estimates must include a negative benefit of the release of refrigerant from the HPWH system. The CPUC refrigerant avoided cost calculator (RACC)[94] uses refrigerant leak rates from CARB, which is 1% per year for HPWHs with 100% of the remaining refrigerant released at EOL. While in some cases refrigerant may be recovered at EOL, the RACC does not allow for this scenario.

Currently, 94% of the products in the TECH Clean California's HPWH qualified products list use R-134a as the refrigerant (GWP_{100} = 1,430). For this reason, Figure 10 reports avoided costs that

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[94] Refrigerant Avoided Cost Calculator and Fuel-Sub Calculator Technical Guidance.

assume R-134a as the refrigerant. Beginning in 2027, however, the CPUC will require all HPWHs incentivized by the TECH Clean California program to have a GWP_{100} less than 750.[95] This requirement makes it prudent to evaluate future versions of the product that use lower GWP refrigerants such as R-32 (GWP_{100} = 675) and carbon dioxide (R-744, GWP_{100} = 1). Using the standard calculations for HPWHs in the RACC calculation workbook (v3.1),[96] the CalMTA analysis calculated the total lifetime avoided cost for a HPWH unit using either of these lower GWP refrigerants.

Table 5 summarizes the lifetime avoided costs of a HPWH installed in 2024 with each refrigerant considered by the CalMTA team and includes a breakdown of costs by lifetime leakage and EOL release of refrigerant.[97]

Table 5. Lifetime refrigerant avoided costs

Refrigerant	GWP_{100}	Avoided Cost of Annual Leakage, NPV [2024$]	Avoided Cost of EOL Leakage, NPV [2024$]	Total Avoided Costs, NPV [2024$]
R-134a	1,340	-45.50	-181.55	-226.95
R-32	675	-21.43	-85.70	-107.13
R-744	1	-0.03	-0.13	-0.16

8.6.2 Potential benefits of load shifting

The current CPUC HPWH measure package does not include load shifting or DR, although this is planned as a future addition. The potential benefit of load shifting from an avoided cost perspective can be demonstrated by making simple adjustments to the heat pump and ER heating controls.

To demonstrate potential load shifting impact, the team modeled a single case using an 80-gallon 240-volt HPWH unit with a UEF of 3.3 in CZ12, with the single-family draw profile. The model increases HPWH unit setpoint from 57°C to 70°C from 3:00 PM to 5:00 PM, then turns off the

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[95] California Public Utility Commission (CPUC). Rulemaking 19-01-011 - Prohibition on High GWP Refrigerants in Appliances Incentivized by Building Decarbonization Programs. 2025. https://efiling.energy.ca.gov/GetDocument.aspx?tn=262498&DocumentContentId=99028.

[96] California Energy Data and Reporting System (CEDARS). "RACC-FSC_v3.1.xlsx." https://cedars.cpuc.ca.gov/deer-resources/tools/supporting-files/resource/2/history/.

[97] The refrigerant avoided costs come from the CPUC refrigerant avoided cost calculator, RACC-FSC_v3.1.xlsx. The HPWH product was modified to have a 20-year EUL to match the eTRM value.

HPWH product from 5:00 PM to 9:00 PM each day. Because of the high temperature load up, total annual electricity consumption for water heating increases from 1,311 kWh to 1,370 kWh (~5%); however, there is no electricity consumption during the peak period of 5:00 PM to 9:00 PM. This operation increases the average annual value from -$205.57 to -$168.30 for an average improvement of 18% or an avoided cost of $37.27 per year.

Average annual avoided cost could be further improved by optimizing the control scheme, increasing HPWH unit heat pump capacity,[98] and increasing water demand during peak periods. The example above uses a peak period between 5:00 PM and 9:00 PM, which is not currently a high-use period for water heating. Currently, in the single-family demand profile, there is 36% more hot water draw from 7:00 AM to 11:00 AM compared to 5:00 PM to 9:00 PM. However, increased electric demand during the morning may be more likely in the future as homes electrify, thus increasing water demand during peak periods.

9 Product plan

This section describes activities that may be undertaken during the execution of the MTI across various areas of the product, service, or practice.

9.1 Product development & technical matching to housing stock

9.1.1 Identify optimal installation scenarios for 120-volt HPWHs

Short-term actions

- Conduct a market assessment of plug-in HPWHs. Quantify the number of homes, especially low-income and multifamily units, that can electrify without panel upgrades.
- Perform equity-focused cost studies to quantify savings from avoiding panel upgrades.
- Develop a HPWH product expansion roadmap with manufacturers that matches California’s current technology gaps and housing needs.

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[98] The DEER 240-volt HPWH model has 1,230 W of heat pump capacity and 4,500 W of ER capacity. Models with a higher heat pump capacity can load up prior to peak more efficiently and optimize controls with a lower setpoint temperature without hot water run out. More details of the DEER HPWH models can be found in Appendix B, Attachment 2.

Long-term actions

- Maintain and update HPWH product expansion roadmap with manufacturers that matches California's current technology gaps and housing needs.
- Support state efforts to model HPWH energy and load shifting for 120-volt units.
- Assess lifecycle economic benefits for low-income and multifamily households by comparing plug-in 120-volt installations with panel-upgrade scenarios that could support 240-volt HPWH models.
- Pilot demonstrations of panel optimization technologies such as circuit-sharing and meter collar solutions to assess options to avoid panel upgrades.
- Study the feasibility of repurposing photovoltaic meter collars for appliance-level electrification.

9.1.2 Identify optimal installation scenarios for split-system HPWHs

Short-term actions

- Conduct secondary research to characterize current split-system HPWH product barriers and opportunities, focusing on known factors related to load shifting, commissioning, permitting, and trade certification.
- Evaluate the market for quick-connect refrigerant lines. Use modeling and secondary research to assess the impact of line set length and refrigerant charge levels on field performance.
- Monitor the NEEA Hot Water Innovation Prize program[99] for relevant developments.
- Review manufacturer manuals to understand refrigerant charge optimization practices.

Long-term actions

- Observe installation and conduct split-system HPWH system field studies to further evaluate installation issues or barriers and to assess in-field performance and user acceptance.

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[99] NEEA 2025 Operations Plan, April 2025, https://neea.org/wp-content/uploads/2025/05/2025-Operations-Plan.pdf

9.1.3 Facilitate harmonization of load flexibility protocols across HPWH products and utility programs

Short-term actions

- Standardize the CTA-2045-B communication protocol. Collaborate with manufacturers to identify and resolve compatibility issues with proprietary systems.

Long-term actions

- Explore embedded implementation of CTA-2045. Work with the CTA and manufacturers to revise protocol specifications.
- Evaluate conformance of field-installed systems with load shifting requirements.
- Research integration of HPWHs with smart home systems. Investigate middleware or APIs that enable platforms like Google Home and Alexa to interpret CTA-2045 DR signals.

9.2 Aggregate market and programs to build scale and momentum by submarkets

9.2.1 Short-term actions

- Update and maintain database of HPWHs on the market. Identify most important technology and features to track (e.g., size, amperage).
- Monitor and assess California AQMD activity and timelines regarding gas water heater zero-NOx requirements.
- Develop a dynamic tool that prioritizes advantageous HPWH product installation based on fluctuating variables, like current electric rates and local codes.
- Monitor electricity rates by utility, county, and locale.
- Monitor development of AHRI residential HPWH installation standard.
- Review historical market data on banned refrigerants to inform predicted market behavior and timelines in response to the Environmental Protection Agency's American Innovation and Manufacturing (AIM) act.[100]

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[100] U.S. Congress, American Innovation & Manufacturing Act of 2020, Pub. L. 116-260, div. S, § 103 (Dec. 27, 2020) (codified at 42 U.S.C. § 7675)

For retrofit market

- Develop a custom housing California housing stock database using existing datasets (e.g., Restock, residential solar maps) to identify and aggregate attributes that influence ease of adoption in the retrofit market (e.g., panel capacity, utility service area, presence of residential solar) specific to both environmental and social justice (ESJ) and non-ESJ communities.
- Utilize the database to create retrofit readiness profiles based on adoption-relevant attributes and leverage results to prioritize various targeted incentive programs and adoption initiatives.

For new construction market

- Determine needed research and cost analysis to encourage HPWH product installs in new builds.
- Investigate percent of new builds installing gas water heaters instead of HPWHs, focusing on trade-off metrics and factors influencing the decision to install gas.

9.2.2 Long-term actions

- Identify and prioritize technological advancements that facilitate rapid scale intervention, based on characteristics in the custom California housing stock database.
- Identify HPWH technology changes and external factors, like changes to electricity rates or solar installation, that could enable a household to move from a low priority to a high priority CalMTA target.
- Investigate the impact of efficiency tiers driving the adoption of premium technologies on up-front cost. Evaluate the potential for lower-cost units that preserve efficiency benefits using fewer premium components.
- Identify opportunities and partners to support HPWH-focused revisions to the CPC's FHR requirements.[101]

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[101] Cal. Code Regs. tit. 24, pt. 5, § 501.1(2)