Plug-in 120V Heat Pump Water Heater Measure Package Updates to California eTRM

Final Report

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Abbreviations and Acronyms

Acronym	Meaning
A	Amps
AC	Air conditioning
ACC	Avoided cost calculator
ADU	Accessory dwelling unit
AHRI	Air-Conditioning, Heating, and Refrigeration Institute
AR	Accelerated replacement
AHWI	Advanced Water Heating Initiative
Base Gal	Baseline gallon
Base UEF	Baseline uniform energy factor
BldgHVAC	Building HVAC
BldgLoc	Building location
BldgType	Building type
CA	California
CalTF	California Technical Forum
CEC	California Energy Commission
CET	Cost-effectiveness tool
CEDARS	California Energy Data and Reporting System
CO_2	Carbon dioxide

Acronym	Meaning
COP	Coefficient of performance
CPUC	California Public Utilities Commission
CZ	Climate zone
DAC	Disadvantaged communities
DEER	Database for Energy Efficiency Resources
DOE	Department of Energy
DX	Direct expansion
EE	Energy efficiency
EE-N	Electric-to-Electric without electrical resistance
EER	Energy-efficiency ratio
EE-Y	Electric-to-electric with electrical resistance
EF	Energy factor
ER	Electric resistance
ET	Emerging technology
EUL	Effective useful life
eTRM	The California electronic Technical Reference Manual
FHR	First-hour rating
FS	Fuel substitution
FSC	Fuel substitution calculator
FS-N	Gas-to-electric without electric resistance

Acronym	Meaning
FuelSub	Fuel substitution
FS-Y	Gas-to-electric with electric resistance
Gal	Gallon
GHG	Greenhouse gas
HP	Heat pump
HPWH	Heat pump water heater
HSPF	Heating seasonal performance factor
HTR	Hard-to-reach
HVAC	Heating, ventilation, and air conditioning
IOU	Investor-owned utility
kBtu/h	Thousand British thermal units per hour
kWh	Kilowatt-hour
MAT	Measure application type
MAEDbS	Modernized Appliance Efficiency Database System
Meas UEF	Measure UEF
MP	Measure package
NBI	New Buildings Institute
NC	New construction
NEEA	Northwest Energy Efficiency Alliance
NR	Normal replacement

Acronym	Meaning
PA	Program administrator
PG&E	Pacific Gas & Electric
PI	Program implementer
PTHP	Package Terminal Heat Pump
RACC	Refrigerant Avoided Cost Calculator
RASS	Residential Appliance Saturation Survey
RLAC	Refrigerant leakage avoided costs
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SEER	Seasonal Energy Efficiency Ratio
SFD	Single-family dwelling
SGIP	Self-Generation Incentive Program, a new funding initiative to become largest source of incentives in California
T20	Title 20 Appliance Efficiency Regulations
T24	Title 24 Building Energy Efficiency Standards
TAC	Technical advisory committee
TECH	Technology and Equipment for Clean Heating
TF	Technical Forum
TPM	Technology Priority Map
TRC	Total resource cost

Acronym	Meaning
TRM	Technical reference manual
TSB	Total system benefit
UEF	Uniform energy factor
V	Volt(s)
WH	Water heater

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Introduction

Plug-in 120-volt (120V) heat pump water heaters (HPWHs) are market-ready and proven to be an important new offering. It is estimated that 90 percent of water heater replacements occur on an emergency basis (NBI 2023). Without an easy, fast, and affordable replacement option, homeowners are likely to opt for replacement with natural gas water heaters, to match current water heater fuel type. The 120V low-power HPWH design can plug into existing wall outlets without expensive electrical panel upgrades or home rewiring often required for gas water heater (WH) replacements. A recent California-wide field study reported an average monthly energy-consumption savings of approximately 85 percent in comparison to the pre-existing natural gas water heater when normalized to kilowatt hour (kWh) (NBI 2023). The proposed new residential water heating electrification offerings described below will allow space and power-constrained households to decarbonize and help California meet its goal of installing 6 million heat pumps by 2030 (TECH n.d.). Currently, 93 percent of California's water heating stock is gas and propane WHs (Energy Solutions 2023). 120V HPWHs can help utilities, cities, and states meet decarbonization goals by targeting the retrofit market and emergency replacements. Because the 120V plug-in technology does not always contain an inefficient electric resistance element, the energy savings could be substantial, and the technology is expected to meet cost-effectiveness requirements. Current measure packages for fuel substitution already promote ”traditional” 240-volt (240V) HPWH systems. This project is aimed at developing measure package research for 120V HPWHs, which would help existing homeowners electrify water heating without major electrical upgrades while receiving incentives from the state.

The current HPWHs in the California Electronic Technical Reference Manual (eTRM) have uniform energy factor (UEF) requirements for eligibility. Since 120V HPWHs have smaller compressor sizes, the UEF for a majority of the tank sizes are lower than the eTRM eligibility criteria. However, since they do not have an inefficient electric resistance element (or have smaller size element), they are expected to save more energy.

This project will help create measure package offerings for the 120V HPWHs, allowing this category to be incentivized for residential customers. The technology provides a fast, convenient, and low-power option to replace their water heaters, alleviating costs, and the need for upgrading their electrical panel in power constrained homes. Including plug-in 120V HPWHs specific offerings within the eTRM residential HPWH measure packages will encourage these products to come to market, make incentives available for this technology, and assist utility programs in targeting hard-to-reach (HTR) customers and disadvantaged communities (DACs). For selected customers, it can also lower monthly utility bills (depending on rate structures).

Objectives

The objective of the project was to provide recommendations to include the 120V HPWHs offerings into the existing eTRM measure packages (MPs) and get incentivized. The project team researched and documented ways to reduce the UEF cap requirements and add additional savings values for this new class of solution.

Our research questions were:

1. What are the current residential HPWH eTRM requirements for eligible HPWHs? Do different 120V products meet the requirements?
2. What are the current minimum code requirements for UEFs?
3. Can the current UEF requirements for 120V HPWHs be reduced, or can additional savings be achieved?
4. How should recommendations for product types, building types, and market sectors be integrated into the existing eTRM to ensure that plug-in 120V HPWHs can be successfully offered? How should these recommendations differ from those for 240V HPWHs, to account for the unique characteristics and applications of 120V systems?

The project team also documented the installation first costs and looked at the technical feasibility and practical considerations of the technology.

The primary outcomes of this project were recommendations for updates to SWWH025-07 (Heat Pump Water Heater, Residential, Fuel Substitution) (CPUC 2024) and SWWH014-05 (Heat Pump Water Heater, Residential) (CPUC 2024) measures related to residential HPWHs. Members of the governing bodies, such as the California Technical Forum (CalTF), California Public Utilities Commission (CPUC), and Investor-Owned Utilities (IOU) stakeholders, will review these integrations for potential adoption.

When these updates are incorporated into the current eTRM and incentives are established, utility programs will be better positioned to target HTR and DAC customers. These programs may employ direct-install strategies or innovative approaches like fixed-cost and same-day installation services.

Methodology & Approach

To achieve the project objectives, the team conducted tasks as described in

Table 1.

Table 1: Summary of Project Tasks

Task Number	Description
Task 1	Research on 120V HPWH products, tank sizes, and their uniform energy factor (UEF) values
Task 2	Research on the current residential eTRM requirements, Title 24 (T24) California Building Energy Efficiency Standards, and Title 20 (T20) California Appliance Efficiency Regulations
Task 3	Analysis of additional savings using EnergyPlus and the effect of a UEF limit requirement reduction for 120V HPWHs[1]
Task 4	Fuel-substitution (FS) test and Refrigerant Avoided Cost Calculator (RACC) calculations
Task 5	Cost-effectiveness analysis
Task 6	Document measure package requirements
Task 7	Reporting

Product and Compliance Research

Tasks 1 and 2 involved comparing the UEFs of current products with those specified in eTRMs to ascertain whether the products and tank sizes meet the current UEF requirements outlined in these documents:

a. SWWH025-07, Residential Heat Pump Water Heater for fuel substitution[2]

b. SWWH014-05, Heat Pump Water Heater, Residential[3]

To accomplish this task, the project team employed a web-scraping approach to collect data on 120V HPWH products listed on the EnergyStar website[4]. Additionally, relevant product information

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[1] The initial scope included the use of a DEER calculator. However, the project teams' assumption that the DEER calculator would be the appropriate tool has been superseded by events. Specifically, the DEER water heater calculator will be discontinued for residential use in 2026, and the current version does not accommodate specific considerations for analyzing the 120V HPWH. Therefore, the new DEER2026 EnergyPlus water heater prototypes were used for this project instead of the DEER calculator. There are no expected cost or schedule changes as a result of this modification event.

[2] Heat Pump Water Heater, Residential, Fuel Substitution | ETRM (caetrm.com)

[3] Heat Pump Water Heater, Residential | ETRM (caetrm.com)

[4] https://www.energystar.gov/productfinder/product/certified-water-heaters/results

was extracted from the California Energy Commission (CEC) database[5], which provides a comprehensive list of HPWHs that comply with the state's energy-efficiency (EE) standards. These two sources ensure a comprehensive overview of the products in the market. The product information allowed a comparison of the actual product's UEF requirements with California's set standards and identify the extent to which the 120V HPWHs meet the eligibility requirements set in eTRM.

The project team also reviewed California (CA) T24 and T20 requirements on HPWHs and electric requirements in retrofits and new construction. The team used code requirements and code exceptions to document the measure packages for the eTRM updates.

Energy Savings Analysis

Based on the findings from Task 1 and 2, the project team analyzed the savings from installing 120V plug-in HPWHs compared against minimally code-compliant gas and electric HPWHs. The analysis involved two sets of offerings: considering replacing gas and electric baselines with 120V HPWHs, as well as versions with and without electric resistance (ER) elements. The project team has learned that, per CPUC direction, the Database for Energy Efficiency Resources (DEER) calculators will be discontinued for residential energy-savings calculations in 2026, and EnergyPlus models are being created to simulate residential WH measures. Thus, the project team used EnergyPlus to evaluate the energy savings of these potential 120V HPWHs to recommend them for the existing MPs. The baselines were consistent with the current MPs, which includes gas water heaters, ER water heaters, and HPWH for some larger tank sizes. The analysis scope included the three residential draw profiles for single family, multifamily, and double-wide mobile home, for all 16 climate zones. The simulations included both same size and upsizing from the baseline tank size, constrained by available space but used to alleviate first-hour rating (FHR) differences.

[5] https://cacertappliances.energy.ca.gov/Pages/Search/AdvancedSearch.aspx

Table 2 summarizes the parameters that were used for energy modeling.

Table 2: Proposed Energy Modeling Criteria[6]

Parameter	Baseline	Proposed
Climate Zone	1-16	1-16
Water Heater Type	Gas and electric water heater	120V HPWH, with and without electric resistance
Building Type	Single family, multifamily, mobile homes	Single family, multifamily, mobile homes
Demand Profile	Based on DEER2026	Based on DEER2026
Tank Size	30 to 80 gallons and instantaneous	40 to 80 gallons
UEF	0.59-3.00	2.75, 3.00, 3.3, 3.50
Space conditioning system	Unconditioned	Unconditioned

Fuel-Substitution Test

Task 4 involved conducting fuel-substitution calculations using the CPUC's Fuel Substitution Calculator (FSC) to confirm the offerings in the above proposed measure package passes the CPUC Fuel Substitution Test for total source-energy consumption and environmental impacts. Per Decision 19-08-009 Rulemaking 13-11-005 Decision Modifying the Energy Efficiency Three-Prong Test Related to Fuel Substitution, FS measures must pass the Fuel Substitution Test to be eligible for energy-efficiency (EE) incentives. The Fuel Substitution Test has two components: 1) the measure must not increase total source energy, and 2) the measure must not adversely impact the environment. The FS calculations were conducted using the RACC-FSC_v3.0 that was published on 04/22/2024 by the CPUC to confirm all measure offerings passed Part One and Two of the Fuel Substitution Test.

Cost-Effectiveness Analysis

The TRC team conducted a comprehensive cost comparison between 240V and 120V integrated HPWHs from three leading manufacturers: AO Smith, Rheem, and Ruud. The goal of the analysis was to identify and assess cost variations for WHs with similar storage tank capacities between the two voltage types.

For each manufacturer, the TRC team gathered cost data for water heaters with capacities of 40, 50, 65, and 80 gallons, ensuring consistency in tank size across both 120V and 240V models. To quantify the price differential, the team calculated the percentage change in cost between the 240V

[6] Refer to Appendix A for a comprehensive baseline and measure case comparisons.

and 120V WHs for each tank size. This allowed for a clear comparison of price variations between the two voltage options across different manufacturers.

Additionally, the project team averaged the costs for water heaters with the same storage capacity across all three manufacturers, providing a consolidated view of pricing trends based on tank size and voltage type. These averages offer a broader perspective on how costs vary across the market for different voltage configurations, helping to identify potential cost-saving opportunities.

Our analysis indicates that 120V WHs tend to be more expensive than their 240V counterparts across similar tank capacities for all manufacturers examined (AO Smith, Rheem, and Ruud). The increase in cost for the 120V models varies depending on the storage capacity and manufacturer, with an average increase of 20 percent for a 40-gallon tank, 28 percent for both 50-gallon tank, 20 percent for a 65-gallon tank, and 28 percent for 80-gallon tank. This cost increase for 120V models can largely be attributed to the integrated mixing valve that manufacturers have added to these units. The mixing valve increases the thermal capacity of the tank to allow for better performance in smaller tanks. However, it also contributes to a slightly higher price point for 120V HPWHs compared to their 240V models.

The project team ran cost-effectiveness analyses using the CPUC's Cost Effectiveness Tool (CET) for the new measure offerings by leveraging the existing SWWH025-08 and SWWH014-06 MP eTRM CET inputs export function. These MP CET input files were used as a starting point in order to minimize changes to the cost-effectiveness assumptions between the new 120V offerings and the existing 240V offerings. The CET input files were adjusted to use the energy savings and costs for all configurations of the 120V HPWH offerings for all climate zones (CZs) and residential building types. Since normal replacement (NR) and new construction (NC) measure application types would return the same cost effectiveness, only the NR and accelerated replacement (AR) measure application types were run using the calculator. Furthermore, the calculations were run assuming implementation in the program years 2024 or 2025 to be consistent with the currently published measure packages. Thus, the CET was run using the current DEER HPWH effective useful life (EUL) of 10 years, the 2022 avoided cost calculator (ACC) values, and a start year of 2024.

Documentation of Measure-Package Requirements

The project team documented measure-package requirements to create a separate category for the 120V HPWHs. This involved outlining the updated technical specifications (e.g., lower UEF values), installation standards, performance benchmarks, eligibility criteria for incentives, or other regulatory or operational requirements that would support the integration of 120V HPWHs within the existing MPs.

Our final task includes summarizing the findings from Tasks 1 through 6 to support future updates of the SWWH025-07(Residential HPWH for fuel substitution) and SWWH014-05 (HPWH, Residential) measures. The project team proposed changes to the measure packages under consideration and provided the opportunity for review and input by lead program administrator (PA) and other relevant stakeholders. The project team also involved CalTF staff and the lead PA for each measure package analyzed for this project. These stakeholders have been engaged to get their inputs on the scope of work and portfolio fit, and they provided advice, inputs, and data.

Market Overview

HPWH Market Challenges

Despite over 14.4 million residential WHs in the state and more than 7.5 million units being replaced annually —90 percent on an emergency basis — HPWHs struggle to increase their market share beyond 2.3 percent as of 2021 (NBI 2023). This analysis highlights key barriers to wider adoption of HPWHs in general, such as higher upfront costs, and installation challenges including space, ventilation, and condensation issues. Additionally, the lack of 240V electrical supply and a general unfamiliarity with 120V HPWHs among both installers and consumers discourage their adoption, leading them to favor traditional gas heaters, which represent 93 percent of the water heating market and 40 percent of gas consumption.

Residential HPWH Measure Package

Currently, the eTRM has two MPs for residential HPWHs. SWWH025-07 is a FS measure, where the measure case is defined as a HPWH that replaces a base case natural gas storage or instantaneous domestic hot water heater that meets the minimum federal code. The SWWH014-05 measure's base case is an ER storage water heater with a storage volume of 30, 40, or 50 gallons or a heat pump water heater with a storage volume of 60 or 75 gallons. Market penetration for these measures has shown significant growth, with around 12,000 installations since 2020 contributing to 158 million net lifecycle kWh[7]. Still, there are opportunities to further expand and optimize measure offerings. Despite accounting for approximately 3.5 percent of the total claimed net lifecycle kWh in the state, these measures have not yet fully captured the diverse range of HPWHs available in the market.

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[7] According to California Energy Data and Reporting System (CEDARS).

Table 3 summarizes the capacity and UEF of the two HPWH measure packages. There are no savings in Table 3 for 65 gal (2.91), 80 gal (2.91), and 80 gal (3.0) as these are heat pump baselines.

Table 3: Summary Existing HPWH Measure Package Description

Measure Package	Base Case Equipment Type	Base Case Capacity (Gal)	Base Case UEF	Measure Case Capacity (Gal)	Measure Case UEF
SWWH025	Storage	40	0.64	<45	3.3 - 3.75
SWWH025	Storage and tankless	30, 40, 50, high draw	0.6 - 0.81	>=45 to <=55	3.3 - 3.75
SWWH025	Storage	40, 50, 60	0.61 - 0.64	> 55 to <= 75	3.3 - 3.75
SWWH025	Storage	50, 60, 75	0.59 - 0.63	> 75	3.3 - 3.75
SWWH014	Electric storage	30, 40, 50	0.92	>=45 to <=55	3.3 - 3.75
SWWH014	Heat pump	60	2.91	> 55 to <= 75	3.3 - 3.75
SWWH014	Heat pump	75	3	> 75	3.3 - 3.75

120V HPWH Adoption Prospect

HPWHs operating at 120V offer flexibility in electrical configurations, with options for shared or dedicated circuits. Shared circuits are practical in environments with limited electrical capacity, while dedicated circuits are preferred where ample electrical infrastructure exists. The 120V HPWHs are ideal for low-medium hot water demand households and the fact that they often eliminate the need for electrical upgrades makes them a candidate for emergency replacements (NBI 2023). This study aimed to test the hypothesis that 120V HPWHs are expected to exhibit higher energy savings than their 240V counterparts due to their reliance on HP technology alone, as opposed to the addition of ER elements that increase recovery rates at the cost of efficiency. This efficiency advantage, however, comes with a trade-off in the form of a lower FHR, which can be addressed by increasing the storage volume or using a mixing valve. A cost comparison between high-efficiency 240V and 120V models from the same manufacturer showed a $500 premium for the 120V model (Casco 2023). Despite this, the 120V HPWH option could be more cost-effective when considering the significant expenses with upgrading electrical infrastructure for a 240V system.

The California 120V HPWH field validation program, involving the installation and monitoring of 32 units, revealed that 30 out of 32 customers were satisfied with the heaters (NBI 2023). The study documented that households saved between $800 and $15,000 compared to 240V HPWHs, primarily due to lower electrical modifications and quicker installation times, between four to seven hours. These water heaters emerged as a viable solution for emergency replacements, drawing only 4 to 6 amps of the rated 15 amps and consuming 85 percent less energy than gas or propane WHs. This study found that 30 percent of California homes, especially those under 2,000 ft^2 and built after the year 2000, could transition to electrification without significant upgrades. To address the identified barriers, the team recommends integrating 120V HPWHs into current incentive programs, advocating for dual trade licenses for installers, and designing new product types to overcome space limitations.

NBI (2023) further recommended supporting 120V HPWHs adoption through eTRM measure package updates. According to this study, the limitations of the existing MPs include eligibility restrictions, limited tank size options, and efficiencies (UEF). Additionally, plug-in models are not fully modeled, which limits their potential benefits, particularly in terms of demand control and connectivity options in the water heating savings calculator (Energy Solutions 2023). The NBI study specifically recommended the addition of new efficacy tiers to the SWWH025 and SWWH014 measure packages between UEF of 2.6 and 3.3, as well as an update to DEER Water Heater Calculator to include 120V HPWHs.

Building on the recommendations from the NBI study, our study found existing products available in the market with a UEF of less than 3.3 to be proposed for inclusion in the existing HPWH measure package as described below.

120V HPWH Product Research

This section presents an analysis of the current landscape of 120V residential HPWHs against the established eTRM requirements. A critical focus is given to the UEF, with a benchmark set at a UEF of ≥ 3.3 to determine minimum eligibility and efficiency compliance.

Compliance with TRM Requirements

The dataset, derived from the Energy Star database, includes (42) 120V HPWH products spanning eight different brands. The findings on compliance based on UEF values are as follows:

- Only eight products (19 percent) meet or exceed the benchmark of UEF ≥ 3.3.
- A significant majority, 34 products (81 percent) fall below the UEF requirement, highlighting a gap in market offerings for 120V HPWH that align with the TRM.

Additionally, the CEC created a database of appliances approved by the T20 standard called the Modernized Appliance Efficiency Database System (MAEDbS). The project team searched MAEDbS and found that there are 22 approved plug-in 120V HPWHs, but only three of the 22 meet the eTRM UEF requirements of 3.3 or greater (CEC 2021).

Compliance across Brands

Rheem, Richmond, and Ruud each offer a compliance rate of 33.33 percent, indicating that one-third of their 120V products meet the eTRM UEF threshold. Brands such as American, Lochinvar, Reliance Water Heaters, and State have yet to offer 120V products that satisfy the UEF ≥ 3.3 criterion.

Capacity and Efficiency Correlation

A review of tank capacities in relation to UEF ratings suggests a correlation between larger tank sizes and compliance. Non-compliant products have a lower average capacity (54 gallons) compared to compliant ones (65.5 gallons), indicating that higher-capacity models are more likely to meet the UEF standards.

Efficiency and Capacity Categorization

Table 4 categorizes 120V HPWH products from Energy Star and CEC databases, based on UEF and storage volume.

Table 4: 120V HPWH Product Efficiency and Capacity Bin

UEF	Storage Volume (gal)	No. of Products
2.8	36	4
3	37	4
3	46	14
3	82	6
3.2	68	6
3.3	59	4
3.5	72	4

The project team proposed four storage volume bins to apply different efficiency and capacity scenarios within the model. This enabled a detailed assessment of the energy savings that could be achieved by replacing with the proposed 120V HPWH products, in comparison to the more commonly used 240V models. Parameterized EnergyPlus models were developed in the DEER prototype framework using ModelKit. These water heater templates used performance curves developed for 120V units, and allow user inputs such as storage tank volume, coefficient of performance (COP), heat pump capacity, and electric resistance capacity. In order to make additional manufacturers and products eligible for incentives in the future, we modeled all the tank sizes and UEFs combinations shown in the following Table 5.

Table 5: Proposed 120V HPWH Product Efficiency and Capacity for Modeling

UEF	Storage Volume (gal)
2.75	40, 50, 65, 80
3.0	40, 50, 65, 80
3.3	40, 50, 65, 80
3.5	40, 50, 65, 80

Code Requirements

The project team reviewed California code requirements on HPWHs and electric requirements in retrofits and NC. The state has two sets of standards pertaining to HPWHs, including Title 24 on Building Energy Efficiency Standards and Title 20 on Appliance Efficiency Regulations. The only reference to a plug-in 120V HPWH in the 2022 Building Energy Efficiency Standards is a mention that a 120V HPWH may be installed in place of a 240V HPWH for new dwelling unit with one bedroom or less (CEC 2022). For new construction of single-family and multifamily homes greater than one bedroom, 240V WHs are prescriptively required under Title 24. However, this is not a mandatory requirement: Homes opting for the performance compliance path are not required to install 240V systems. Additionally, the 240V requirement does not apply to alterations in existing buildings, mobile homes, or homes with one bedroom or fewer. This distinction has been raised by the CPUC and it is important to note these specific conditions when considering prescriptive versus performance-based compliance. 120V plug-in HPWHs are a good option for less-than-one-bedroom single-family and multifamily homes, accessory dwelling units (ADUs), mobile home new construction, and replacement (alterations) of and existing WH unit.

The UEF is the metric for the EE of WHs, and UEF rating is determined by assigning a WH into one of four different categories of hot water usage — very small, low, medium, and high — and then evaluating its performance based on that usage. The higher the UEF value, the more efficient the heat pump WH. Table 6 summarizes the UEF requirements from Federal Standard for Water Heaters Regulated Under 10 C.F.R Section 430.32(d) and as specified in Title 20.

Table 6: Rated Storage Volume and Minimum UEF for Electric Storage Water Heater

Rated Storage Volume (gal)	Draw Pattern	Minimum UEF*
≥ 20 gallons and ≤ 55 gallons	Very small	0.8808 – (0.0008 x V_r)
≥ 20 gallons and ≤ 55 gallons	Low	0.9254 – (0.0003 x V_r)
≥ 20 gallons and ≤ 55 gallons	Medium	0.9307 – (0.0002 x V_r)
≥ 20 gallons and ≤ 55 gallons	High	0.9349 – (0.0001 x V_r)
> 55 gallons and ≤ 120 gallons	Very small	1.9236 – (0.00011 x V_r)
> 55 gallons and ≤ 120 gallons	Low	2.0440 – (0.0011 x V_r)
> 55 gallons and ≤ 120 gallons	Medium	2.1171 – (0.0011x V_r)
> 55 gallons and ≤ 120 gallons	High	2.2418 – (0.0011 x V_r)

*V_r = rated storage volume

Source: California Energy Commission

Table 6 and Table 7 show that the products reviewed from CEC and Energy Star product databases meet or exceed the Title 20 and federal code UEF requirements for UEF.

Table 7: 120V HPWH Product Efficiency and Capacity

120V Product UEF	120V Product UEF Storage Volume (gal)	Code Minimum UEF with Very Small Draw Pattern	Code Minimum UEF with High Draw Pattern
2.8	36	0.9	0.9
3	37	0.9	0.9
3	46	0.8	0.9
3	82	1.9	2.2
3.2	68	1.9	2.2
3.3	59	1.9	2.2
3.5	72	1.9	2.2

Product Costs

Table 8 summarizes baseline water heater costs. For baseline 30-, 40-, 50-, and 60-gallon gas storage and tankless WHs, the material cost and labor cost values were derived from SWWH025-07 measure package. For baseline 30-, 40-, and 50-gallon electric storage water heaters, the material cost and labor cost values were derived from the SWWH014-05 measure package.

Table 8: Baseline Water Heaters Costs

Water Heater Type	Material Cost	Labor Cost
Storage natural gas water heater, 30 gal, UEF = 0.6	$758.49	$368.54
Storage natural gas water heater,40 gal, UEF = 0.64	$818.58	$387.98
Storage natural gas water heater, 50 gal, UEF = 0.63	$1,090.33	$409.45
Storage natural gas water heater, 60 gal, UEF = 0.61	$1,090.33	$433.59
Storage natural gas water heater, 75 gal, UEF = 0.59	$2,290.97	$491.08
Tankless natural gas water heater, high draw, UEF = 0.81	$1,062.06	$409.08
Electric storage water heater, 30 gal, UEF = 0.92	$619.91	$348.24
Electric storage water heater, 40 gal, UEF = 0.92	$708.79	$383.1
Electric storage water heater, 50 gal, UEF = 0.92	$797.67	$383.1

Table 9 presents the installation costs for 120V HPWHs across various storage volumes and UEF ratings. The costs shown reflect typical installation scenarios that include material and labor costs but exclude additional expenses such as electrical upgrades, conduit installation, or wiring modifications back to the electrical panel and new breakers. This is because the installation complexity can vary significantly depending on the home's electrical infrastructure. For simplicity, no difference in cost is assumed between products with or without ER, as the primary cost drivers remain consistent regardless of this feature.

Table 9: 120V HPWH Costs for Cost Effectiveness Test

Storage Volume (gal)	UEF	Installation Cost
40	2.75	$3,710
40	3.00	$3,710
40	3.30	$3,710
40	3.50	$3,820
50	2.75	$4,490
50	3.00	$4,490
50	3.30	$4,490
50	3.50	$4,640
65	2.75	$5,140
65	3.00	$5,140
65	3.30	$5,140
65	3.50	$5,320
80	2.75	$6,440
80	3.00	$6,440
80	3.30	$6,440
80	3.50	$6,680

For additional reference, the project team also reviewed the measure case cost of a 120V HPWH from a field study report of plug-in HPWHs (NBI 2023), in which 32 sites installed 120-volt HPWHs. In that study, the cost of 120V HPWHs with mixing valve equipment ranged from $2,350 for a 50-gallon to $3,040 for an 80-gallon unit. The cost of 120V HPWHs is higher than other conventional WHs, partially due to the integration of the thermostatic mixing valve in the 120V option, which costs around $25 Table 10 presents the average cost of the 120V HPWHs in that study, excluding retailer discounts and utility incentives.

Table 10: 120V HPWH Product Costs

Water Heater Type	Material Cost	Labor Cost	Electrical Upgrade Cost
120-Volt Heat Pump Water Heater	$2,673	$2,658	$31

Savings Analysis

The project team summarized the number of measures and number of runs in total as follows. Each run was simulated in 16 climate zones and three building types.

- Baseline runs (11 total):
  - Electric storage WHs in five storage volume categories with federal minimum efficiency.
  - Gas storage WHs in five storage volume categories with federal minimum efficiency.
  - Gas instantaneous WH with federal minimum efficiency.
- Measure runs (32 total):
  - 120V HPWH in four storage volume capacities, four UEF categories, and with/without ER backup heat.

The project team summarized the findings of the savings analysis as follows:

- Table 11 shows the average gas savings, electric savings, and penalty for both measures.

Table 11: Average Gas and Electric Savings

Measure	Average Gas Savings (Therms)	Average Electric Savings/Penalty (kWh)
SWWH014-07	N/A	835
SWWH025-05	138	-1,290

- The 240V and 120V models have the same general consumption patterns with respect to CZ and building types.

- Table 12 shows that, for measure SWWH014-07, the 120V model has 13 percent reduced electric savings[8] compared to the 240V model. For measure SWWH025-05 the electric penalty for the 240V HPWH is 20 percent less than the 120V HPWH.

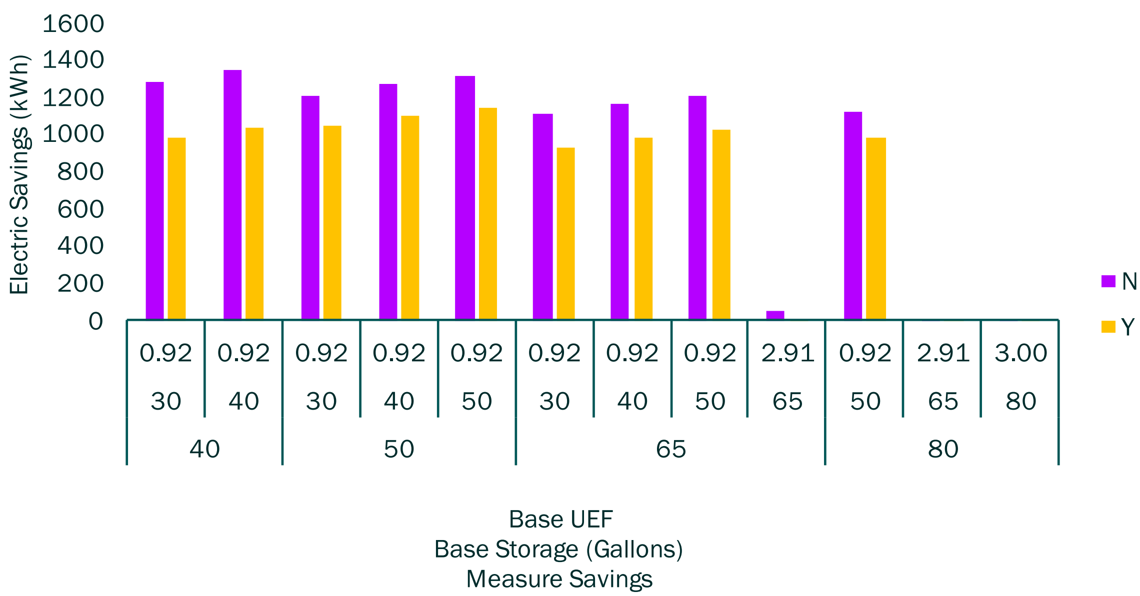
Table 12: Average Increase or Decrease in Electric Savings

Measure	120V (kWh)	240V (kWh)
SWWH014-07	835	961
SWWH025-05	-1,290	-1,034

- 120V units without ER backup perform similarly to 240V units, on average.
- The 120V offerings with ER show considerably less savings or larger electric penalty.
- Many 120V HPWHs with low UEFs have negative savings for larger sizes that use HPWH baselines.

Average kWh Savings for SWWH014

Figure 1 shows the average kWh savings for SWWH014 120V HPWH residential measures at a UEF of 3.5. The graph indicates minimal savings for larger capacity measures when using HPWH baselines.



[8] This is an average value based on 120V models with and without electric resistance.

Figure 1: Average kWh savings for SWWH014 HPWH residential measure (3.5 UEF).

Legend:

N = 120V residential HPWH offerings without electric resistance

Y = 120V residential HPWH offerings with electric resistance

Figure 2 compares the savings for 120V residential HPWH with and without ER to 240V residential HPWH with ER. Results show that savings are lower for the plug-in HPWH with ER, and about the same for plug-in units without ER. The 240V results are from a separate SWWH014 run, and not all modeling inputs are directly aligned.

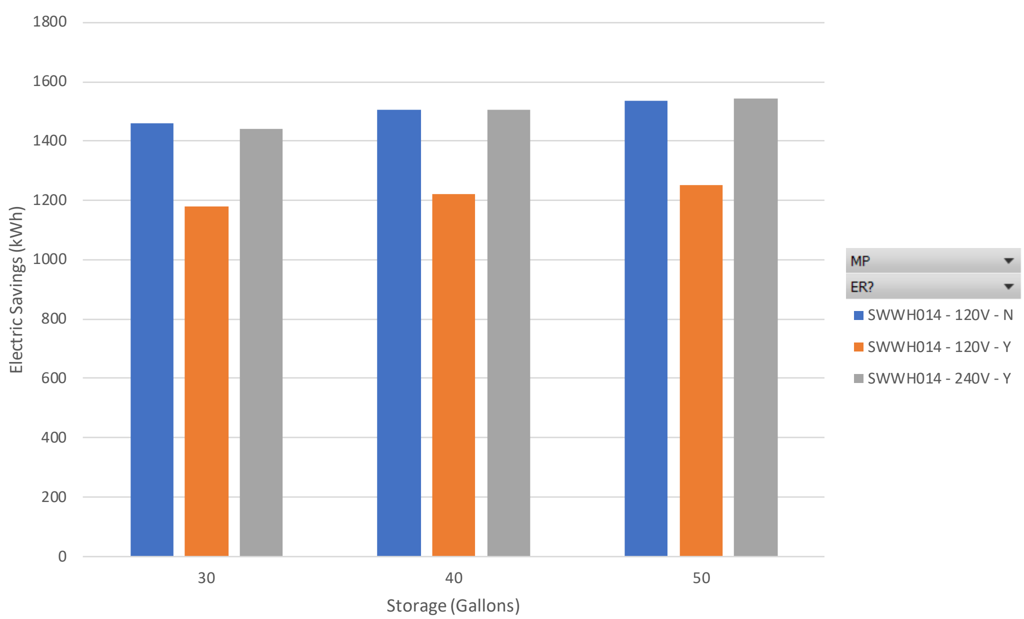


Figure 2: Comparison of kWh savings for SWWH014 240V, 120V with electric resistance, and 120V without electric resistance (3.5 UEF).

Legend:

ER = Electric resistance

N = 120V and residential HPWH offerings without electric resistance

Y = 120V and 240V residential HPWH offerings with electric resistance

MP = Measure Package

Average kWh and Therms Savings for SWWH025

Figure 3 shows the average electric savings for the fuel substitution measure of SWWH025 for 120V HPWHs. The natural gas savings are not impacted by a change in measure case.

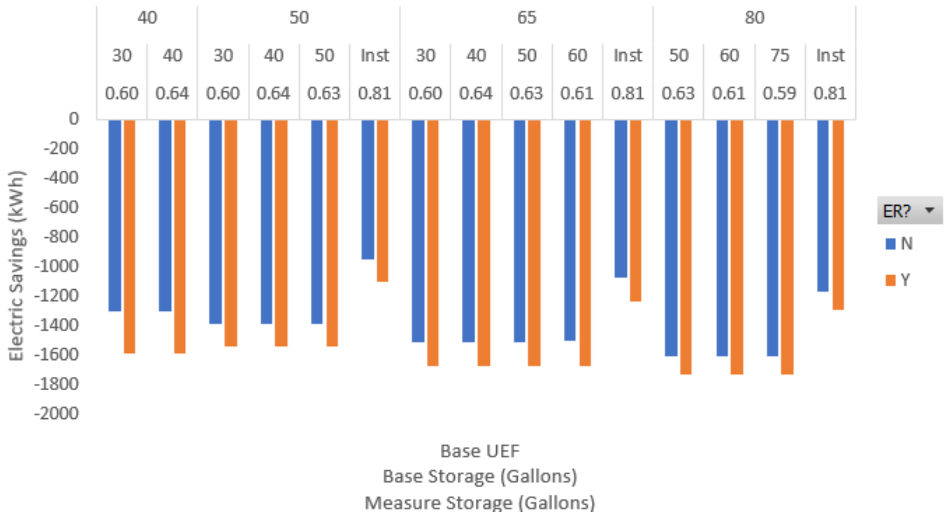


Figure 3: Average kWh savings for SWWH025 HPWH residential fuel-substitution measure.

Legend:

ER = Electric resistance

N = 120V residential HPWH offerings without electric resistance

Y = 120V residential HPWH offerings with electric resistance

Figure 4 shows that the relationships between the 120V and 240V models for this FS measure are similar; however, the 120V models with electric resistance demonstrate higher electric penalties.

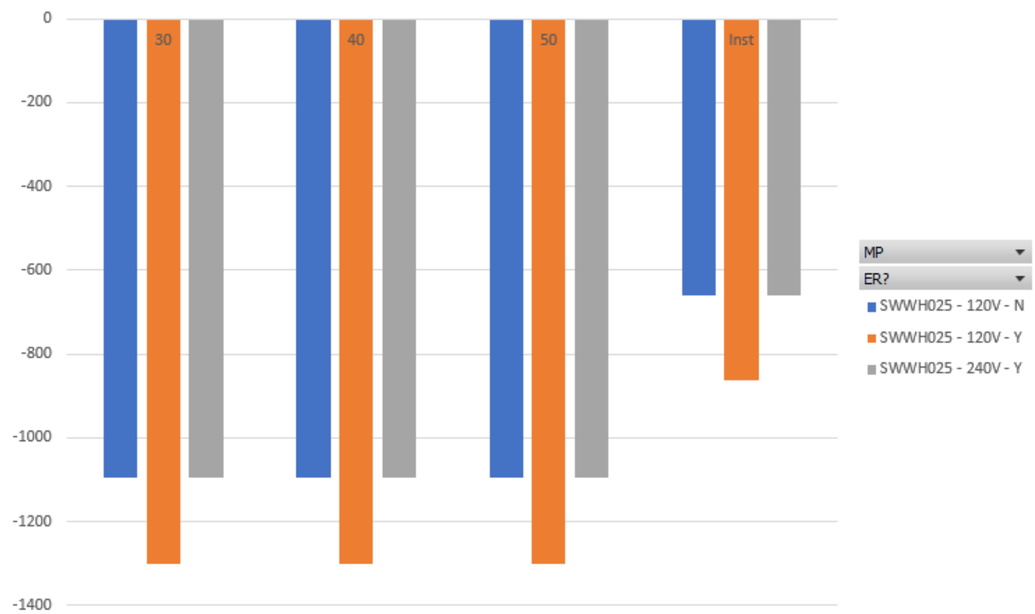


Figure 4: Electric penalties for SWWH025 HPWH residential fuel-substitution measure.

Legend:
ER = Electric resistance
N = 120V residential HPWH offerings without electric resistance
Y = 120V and 240V residential HPWH offerings with electric resistance
MP = Measure Package

Fuel Substitution & Refrigerant Impact

Fuel Substitution Test

Using Methodology & Approach described above, the project team confirmed that **all measure offerings passed part one and two of the Fuel-Substitution Test.**

Non-Energy Impacts

CPUC's Resolution E-5152 requires IOU PAs to report refrigerant leakage avoided costs (RLAC) for all EE measure claims involving adding (not replacing) equipment that uses refrigerant. The RLAC must be determined using the CPUC RACC, which has undergone significant changes and is now integrated into the FSC under RACC-FSC_v3.0, published on 04/22/2024. Table 13 shows the unit refrigerant avoided cost calculations outputs.

Table 13: Refrigerant Avoided Cost Calculations Outputs

Measure Description	Unit Refrigerant Costs (USD)
Heat pump water heater, consumer style, any gal, replacing consumer natural gas water heater (NR, NC, AR)	$258.28
Heat pump water heater, consumer style, any gal, replacing consumer electric resistance water heater (NR, NC, AR)	$258.28
Heat pump water heater, consumer style, any gal, replacing consumer heat pump water heater (NR, NC)	$0.00
Heat pump water heater, consumer style, any gal, replacing consumer heat pump water heater (AR)	$0.46

These summaries ensure compliance with FS and refrigerant impact regulations, confirming the measures' efficiency and environmental benefits.

Cost Effectiveness Test (CET)

In this CET analysis, the Total System Benefit (TSB) and Total Resource Cost (TRC) ratio are critical metrics used to evaluate the cost-effectiveness of new 120V plug-in HPWH measure offerings. The TSB represents the total value of the benefits accrued from the implementation of the measure over its lifetime, while the TRC ratio compares the total costs to these benefits. This analysis leveraged the CPUC's CET tool to assess how various factors — such as tank size, UEF ratings, building type, and climate zones — impact these measures' cost-effectiveness and system benefits. The following charts, unless otherwise specified, focus on a single category: residential (Res) for building type, normal replacement (NR) for measure application type, and excludes electric resistance (ER) measures.

Total Resource Cost (TRC)

Figure 5 compares the TRC ratios across four categories: electric-to-electric without electric resistance (EE-N), electric-to-electric with electric resistance (EE-Y), gas-to-electric without electric resistance (FS-N), and gas-to-electric with electric resistance (FS-Y). The median TRC ratio for gas-to-electric in both scenarios is higher than that of the electric-to-electric categories. This indicates better cost-effectiveness in the fuel-substitution scenario. The FS-N category exhibits the highest median TRC ratio and less variability, which suggest greater consistency in cost-effectiveness. FS-Y shows a similar pattern but with slightly more spread. Both electric-to-electric categories show lower median TRC ratios, and the case without electric resistance (EE-N) has the broadest range, indicating a wider variation in cost-effectiveness outcomes. These results suggest that **FS case is generally** more cost-effective than the EE conversions, with ER having a small effect on performance in both substitution types.

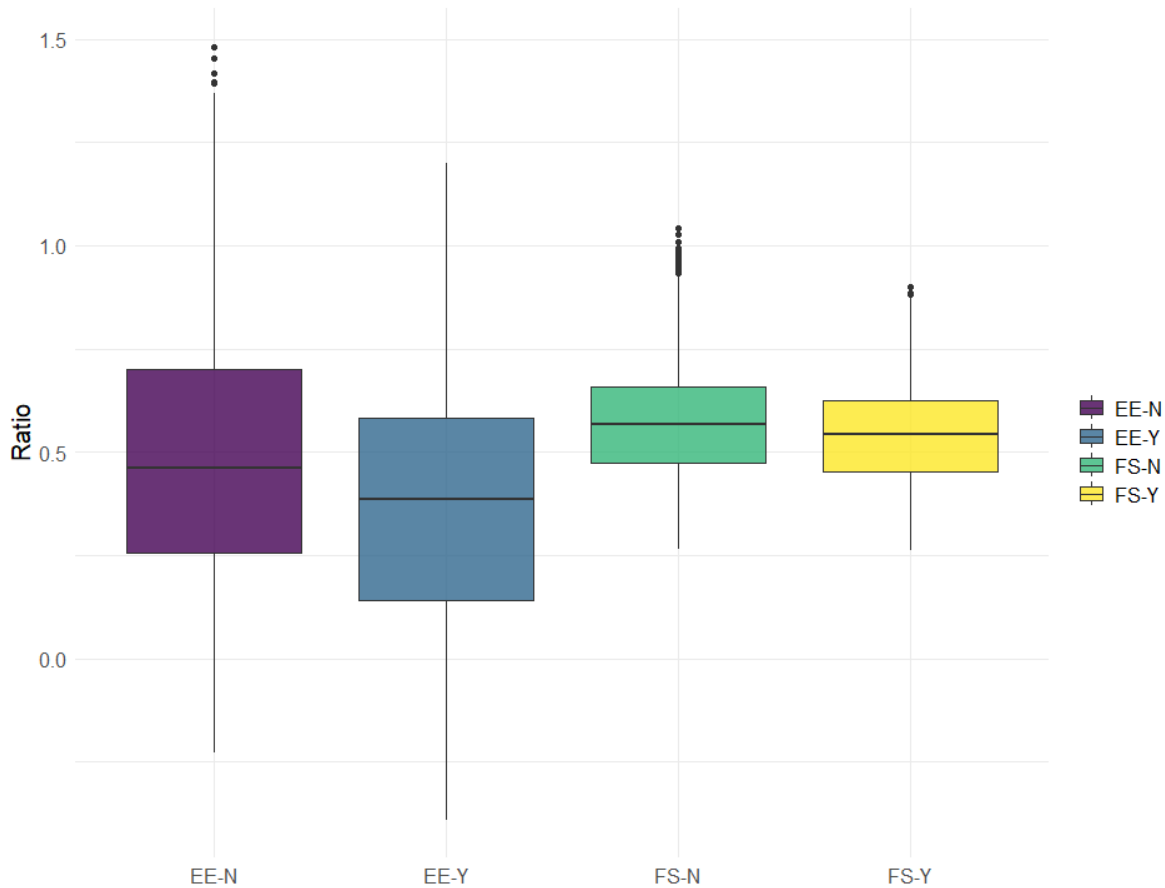


Figure 5: TRC ratio by fuel substitution and electric resistance.

Total Systems Benefits (TSB)

Figure 6 shows comparison between TSB across the same four categories as described in the previous Total Resource Cost (TRC) section. The FS-N category exhibits the highest median TSB, with a wider range of benefits and several high outliers exceeding $1,000, which indicates significant energy savings potential. The FS-Y category also performs well but has a slightly lower median and a narrower distribution compared to FS-N, which suggests fewer outliers in performance. Both EE categories show lower median TSB values, with EE-N performing slightly better than EE-Y. The results highlight that **FS scenarios offer significantly greater TSBs than EE scenarios do, and the absence of ER tends to provide higher benefits within each substitution type.**

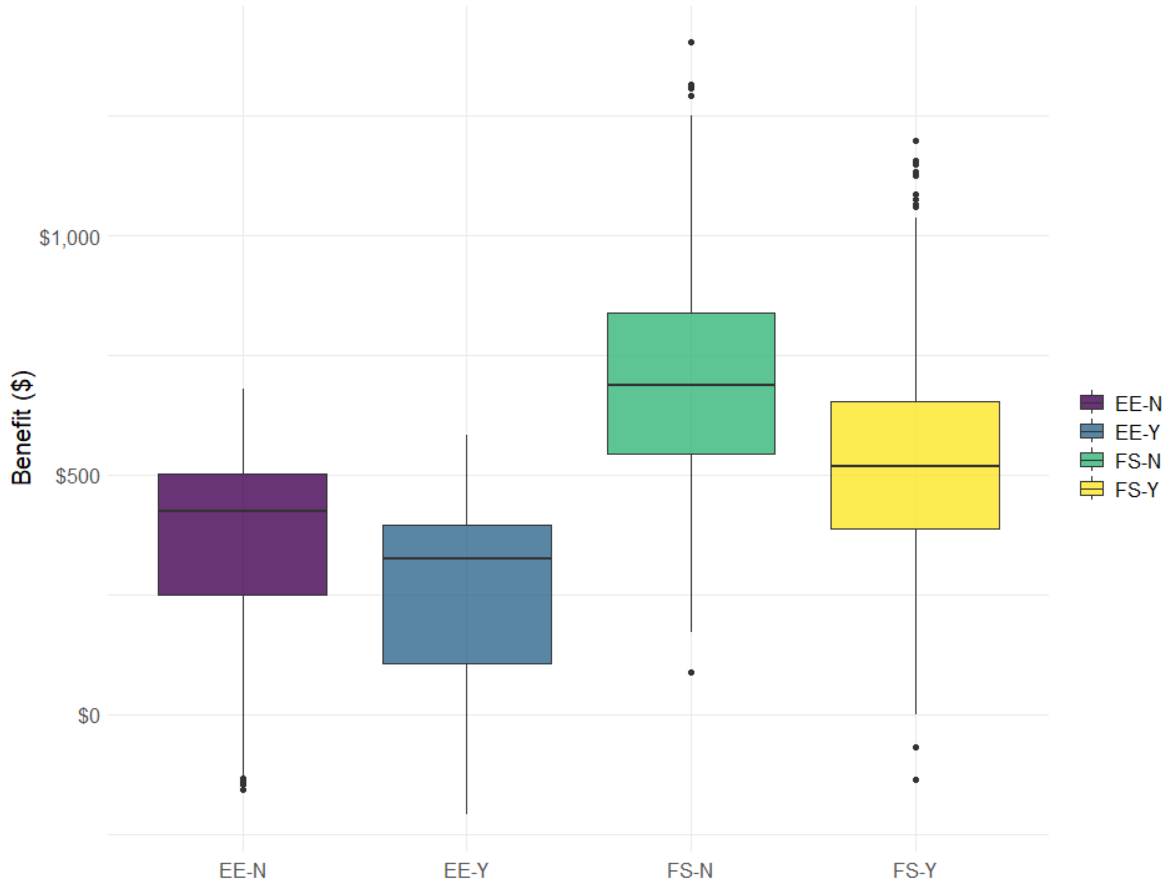


Figure 6: TSB by fuel substitution and electric resistance.

HPWH Relationships between TRC and TSB

This section presents the 120V HPWH relationships between TRC and TSB. For a simplified visualization, the graphs and analysis will compare systems with the highest UEF rating (3.5, represented in teal) and the lowest (2.75, in peach).

Energy-Efficiency Case

In the electric-to-electric case, Figure 7 shows that most HPWH systems are not cost-effective, with most data points falling below the TRC ratio of 1.0. The TSB is also relatively low, with most values concentrated below $500. Systems with higher efficiency (UEF 3.50) perform somewhat better in terms of the TSB compared to the lower efficiency (UEF 2.75), but still struggle to reach the cost-effectiveness threshold of 1, except for some systems with smaller tank sizes (40 gallons). Overall, this scenario indicates limited economic and energy savings potential for electric-to-electric substitutions, particularly for lower-efficiency systems.

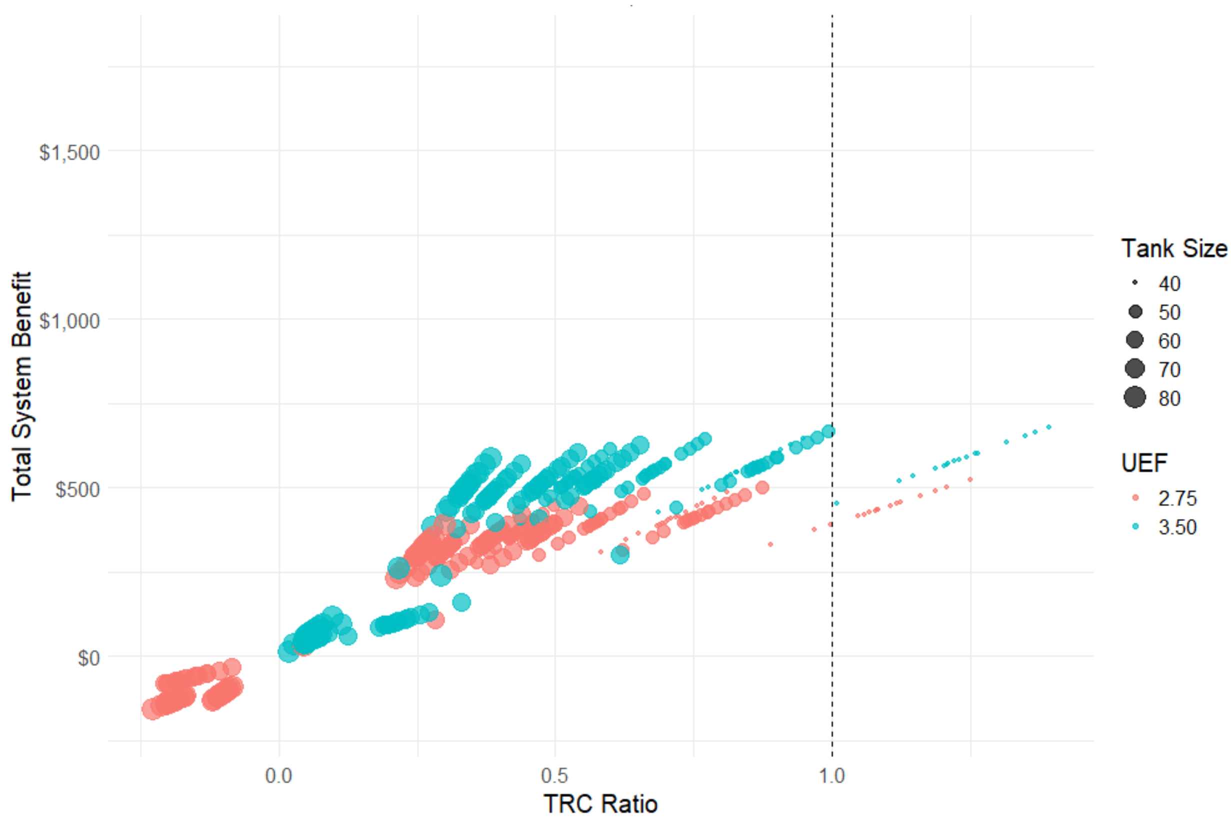


Figure 7: HPWH relationship between TRC and TSB by UEF and tank size, energy-efficiency case.

Fuel Substitution Case

Figure 8 shows that HPWHs with a UEF of 3.50 outperform those with a UEF of 2.75 in terms of both cost-effectiveness and overall system benefits. The higher-efficiency systems consistently show a greater likelihood of being cost-effective and deliver higher TSB. Lower UEF systems, particularly at 2.75, tend to underperform especially with smaller tank sizes, and may not provide sufficient benefits to justify their costs in many cases. More specific findings from the graph are listed in the following:

- TSB: HPWHs with a UEF of 3.5 tend to have higher TSB values overall compared to systems with a UEF of 2.75, with many points exceeding $1,000. This demonstrates that higher efficiency units deliver greater overall benefits.
- TRC: Only one system is above the TRC threshold of 1.0, the one with small tank size (40 gal) and high UEF (3.50). The data points representing UEF 3.50 systems are generally more clustered around higher TRC ratio compared to the systems with UEF of 2.75.

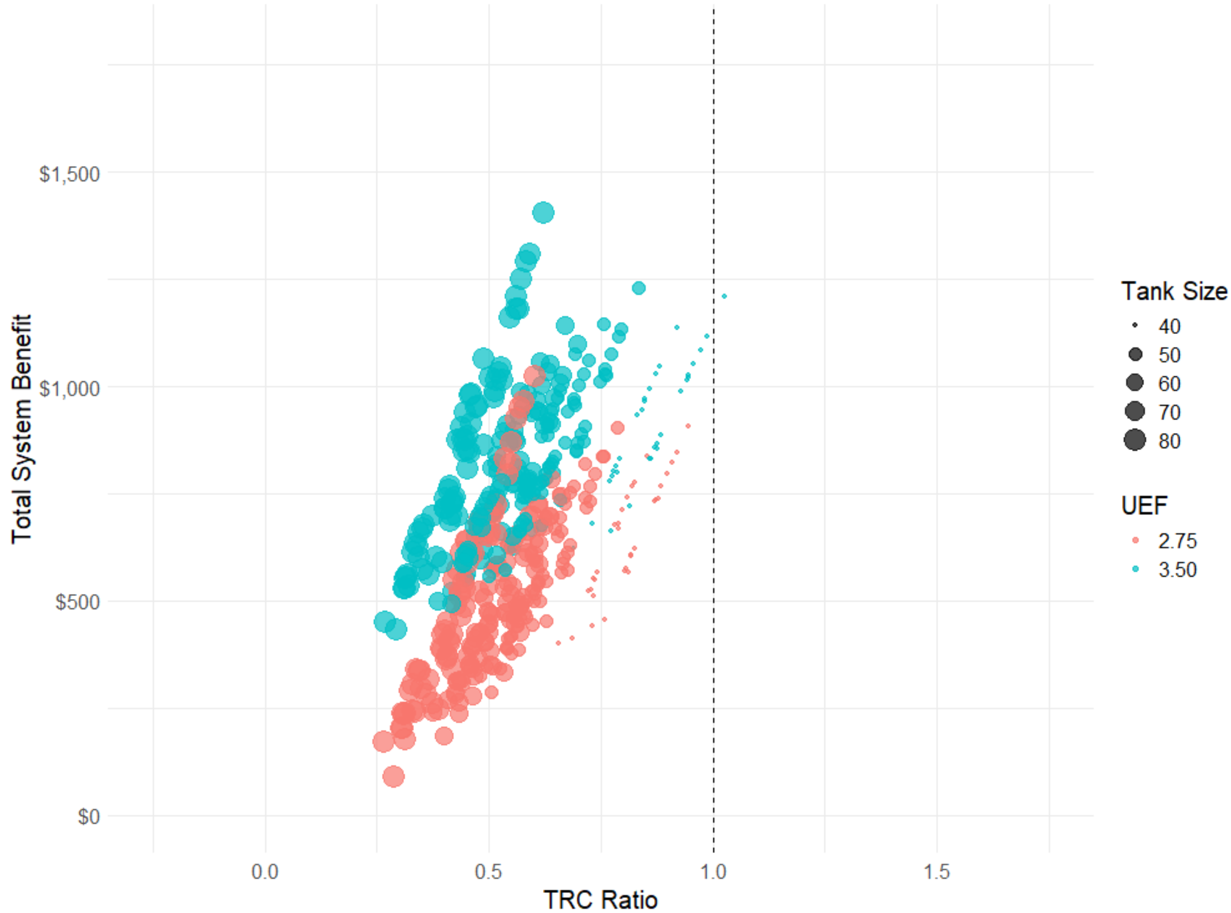


Figure 8: HPWH relationship between TRC and TSB by UEF and tank size, FS case.

TRC and TSB by Tank Size

This section summarizes the relationship between tank size and the TRC ratio and TSB for both EE and FS measures. The following graphs provide a comparison of cost-effectiveness and system benefits across a range of baseline and measure case tank size combinations (measure gallon–baseline gallon). The analysis shows that smaller tank sizes generally provide the highest cost-effectiveness and system benefits, while larger tank replacements tend to exhibit lower or even negative outcomes, particularly for EE measures.

Figure 9 shows the average TRC ratio by tank size for both EE and FS measures. The data shows that smaller tank sizes, particularly 40 to 50 gallons, tend to have higher TRC ratios with 40-g (gallon) replacing 40-g baseline achieving TRC of over 1 for the EE case. Larger tank sizes, especially those exceeding 65 gallons, demonstrate lower TRC ratios, with many values below 0.6 and even negative cost-effectiveness for some EE cases. The reason for low or negative TRC ratios for EE combinations with baseline tanks exceeding 65 gallons is that the baseline for 65- and 80-gallon electric systems are HP offerings that have close or higher UEF values than the measure case 120V systems.

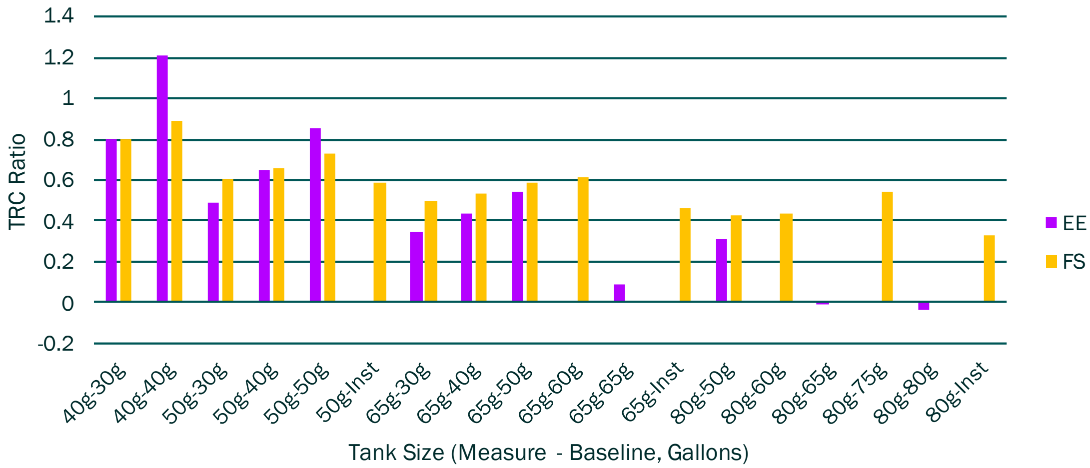


Figure 9: Average TRC ratio by tank size.

Figure 10 presents the average TSB by tank size for both EE and FS measures. Unlike the TRC ratio case, the TSB values for FS measures and electric resistance baselines generally trend upward as baseline tank sizes increase. This is due to higher thermal losses experienced in less efficient baseline storage tanks, which result in greater savings for FS measures as tank sizes increase. While smaller tank sizes typically show higher TSB values for heat pump baselines, this trend does not hold for electric resistance baselines, where larger tanks lead to higher overall system benefits due to the increased potential for energy savings. As a result, both TRC and TSB rise with increasing baseline tank sizes in these cases.

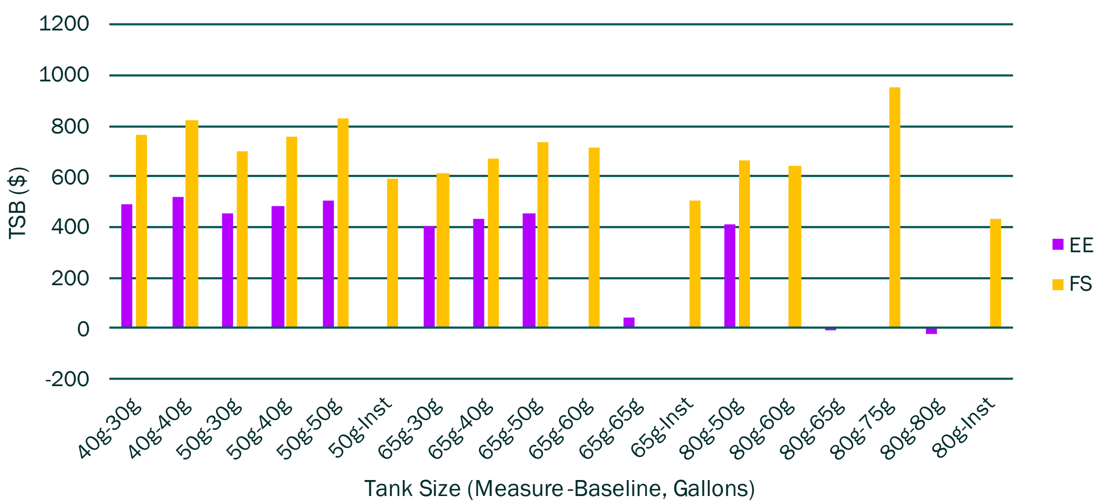


Figure 10: Average TSB by tank size.

TRC and TSB by UEF

This section explores the relationship between UEF and the TRC ratio as well as the TSB for both EE and FS measures. The results help to assess how the efficiency of 120V HPWHs, as represented by UEF, affects their cost-effectiveness and system benefits. Overall, higher UEF values lead to improved cost-effectiveness and system benefits for both EE and FS measures, with FS measures consistently offering better performance in terms of both TRC and TSB across all UEF levels.

Figure 11 shows the average TRC ratio by UEF for both EE and FS measures. As the UEF increases, the TRC ratio tends to improve for both types of measures. FS measures consistently outperform EE measures across all UEF levels. FS measures show TRC ratios between 0.56 and 0.60, while EE measures show TRC ratios between 0.38 and 0.53. This suggests that while both EE and FS measures become more cost-effective with higher UEFs, FS measures maintain a better overall cost-effectiveness.

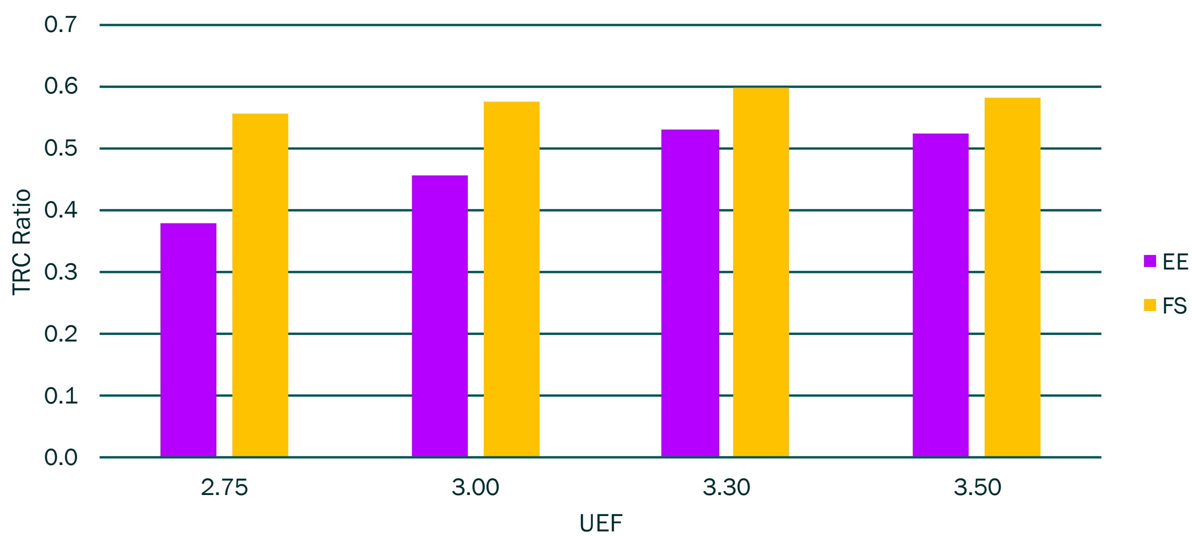


Figure 11: Average TRC ratio by UEF.

Figure 12 presents the average TSB by UEF for both EE and FS measures. The TSB results show a positive trend as UEF increases, with FS measures consistently providing higher system benefits compared to EE measures. At UEF levels of 3.30 and 3.50, FS measures achieve TSB values exceeding $750, while EE measures reach around $400 at the same UEF levels. Lower UEFs (2.75) show significantly lower TSB for both measures, particularly for EE, which falls below $300. These findings indicate that higher-efficiency WHs (those with higher UEFs) deliver greater societal benefits, particularly in the FS measures.

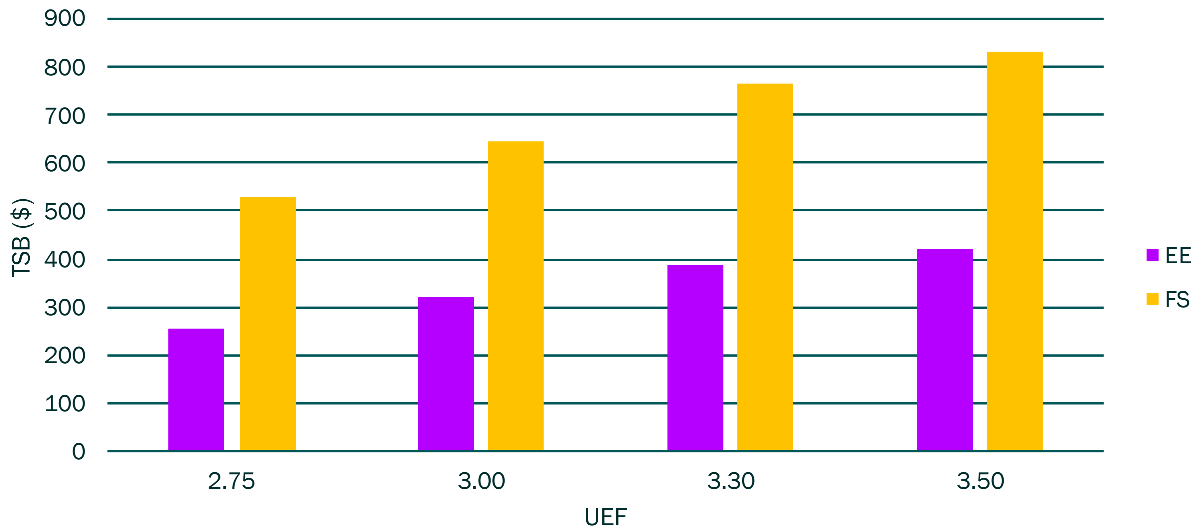


Figure 12: Average TSB by UEF.

TRC and TSB by Building Type

This section explores the relationship between building types and the TRC ratio as well as the TSB for both EE and FS measures. By analyzing these building types — mobile (DMo), multifamily (MFm), residential (Res), and single family (SFm) homes — the results provide insights into the building type that offers the most favorable outcomes for each measure. Overall, FS measures are consistently more cost-effective and deliver greater societal benefits than EE measures across all building types (Figure 13). SFm homes shows the highest performance, while DMo shows the lowest. This relationship is likely due to greater hot water demand in the SFm homes with typical large home size and more occupants as compared to DMo homes, which creates a larger opportunity for both energy savings and system benefits when upgrading to more efficient systems.

Figure 13 shows the average TRC ratio by building type for EE and FS measures. Across all building types, FS measures outperform EE measures. SFm has the highest TRC ratio, with FS measures of 0.59 and EE measures of 0.49. DMo show the lowest TRC ratios, with FS measure of 0.54 and EE measure of 0.40.

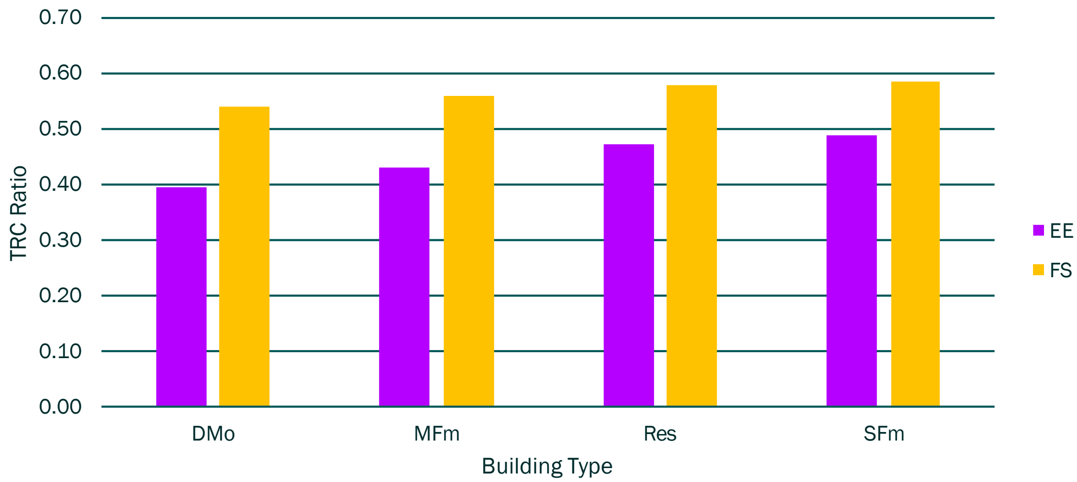


Figure 13: Average TRC ratio by building type.

Figure 14 presents the average TSB by building type for EE and FS measures. Similar to TRC ratio relationships, FS measures deliver consistently higher TSB values across all building types, with SFm showing the highest benefits, more than $700. On the lower end, DMo shows the smallest TSB values, particularly for EE measures, at less than $300.

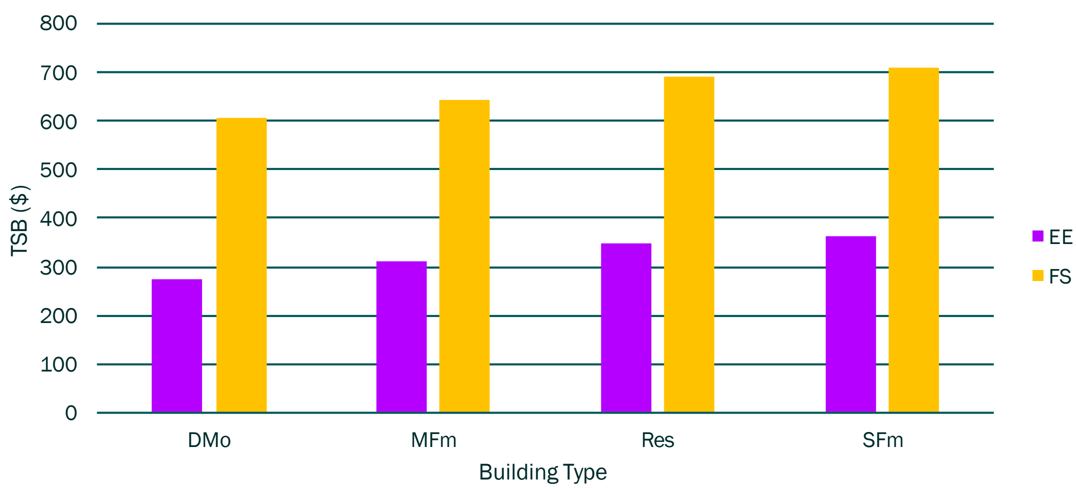


Figure 14: Average TSB by building type.

TRC and TSB by Climate Zone

This section provides a summary of the relationship between different CZs and the TRC ratio as well as the TSB for both EE and FS measures. In general, FS measures consistently show higher cost-effectiveness and system benefits than EE measures across all CZs. CZ 1 achieves the highest TRC and TSB values, while CZ 15 exhibits the lowest savings for both cases. CZ 1 is the coldest CZ in

California, and CZ 15 is the warmest. This relationship between CZ,TRC, TSB is likely due to the temperatures of the incoming domestic water supply temperatures for each CZ and its impact on the temperature rise needed from the WHs.[9]

Figure 15 displays the average TRC ratio by climate zone for both EE and FS measures. FS measures outperform EE measures across all CZs. FS maintains a higher TRC ratio between 0.49 and 0.66, while EE measures have a lower range between 0.37 and 0.59.

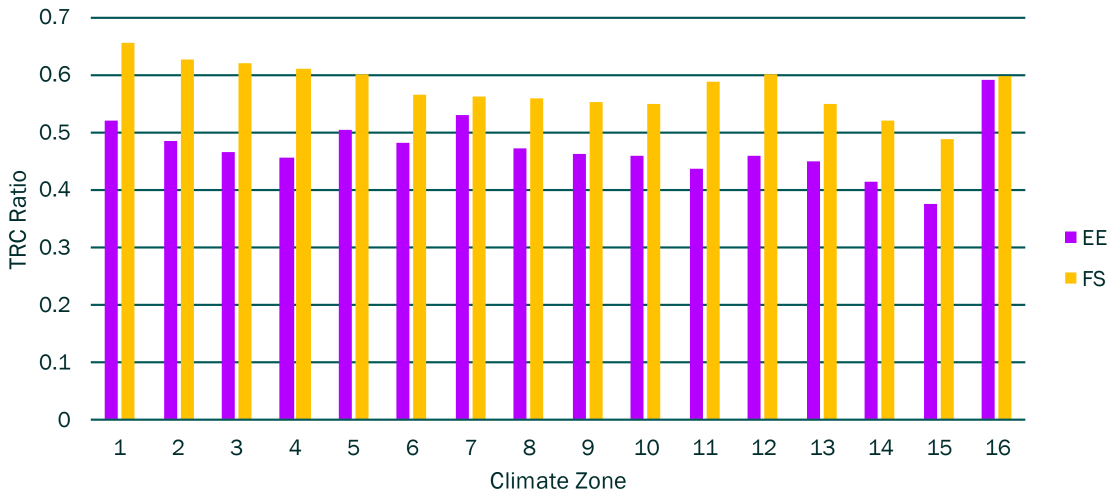


Figure 15: Average TRC ratio by climate zone.

Figure 16 presents the average TSB by CZ for both EE and FS measures. FS measures show considerably higher TSB across all climate zones compared to EE measures. CZ 1 achieves the highest TSB values of over $900 for the FS case, while CZ 16 achieves the highest TSB values for the EE case, at $438.

[9] The load in the colder climate zone will be slightly higher due to higher losses and lower ground water temperature. However, the HPWH is located in an unconditioned space which will have lower ambient temperatures, and therefore lower efficiency. This efficiency degradation is more significant for a HPWH than gas or electric resistance. This penalty doesn't apply when comparing two HPWHs in an EE measure. For example, comparing climate zone 16 to 12, the electric resistance water heater in CZ16 uses 3% more energy due to higher load and storage losses, but the HPWH uses 5% more energy in CZ16 due to lower efficiency. Thus, the savings are lower in CZ16. Comparing two HPWHs, the baseline and proposed systems both use about 5% more energy in CZ16, so the savings are higher.

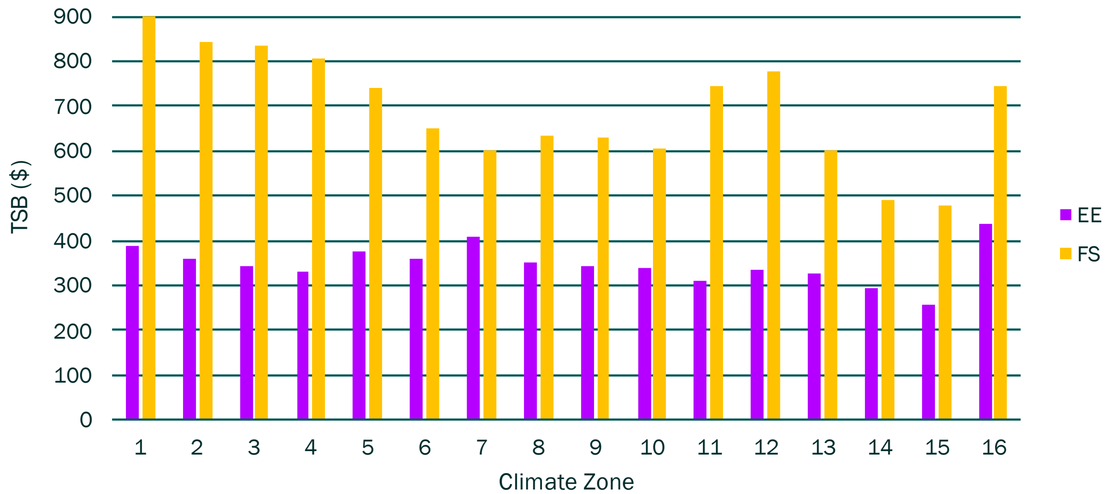


Figure 16: Average TSB by climate zone.

Stakeholder Engagement

The project team met with SCE, San Diego Gas and Electric (SDG&E), CLEAResult, and Energy Solutions to discuss our initial findings and to seek feedback on the measures, UEF requirements, modeling methodology, where the envisioned offerings would be most effective, and potential barriers.

- Feedback included a discussion noting that the EnergyStar UEF requirements are 2.2, while the measures are 3.3. Suggestions included making it clear that the modeling criteria baseline is coming from the code requirements listed in DEER, that our modeling of adding in master mixing valves is correct, and that the FHRs will be different for models that do or do not have ER.
- When discussing the best path for incentives, stakeholders suggested considering midstream programs to assist in higher market penetration especially for emergency scenarios. The stakeholders suggested that midstream retail would be a good option, such as having the 120V plug-in models discounted at major retailers like Home Depot. We also discussed that it would be helpful to include the 240V models in these midstream retail programs.
- Potential barriers discussed included timely availability, which is lacking for some products. Once orders increase, shipping might improve. To determine how to replace gas units, feedback included increasing the volume of 120V plug-in models one to two sizes greater than their gas counterparts. For example, if the existing unit is a 30-gallon gas water heater, the replacement unit should be either a 40 or 50-gallon 120V plug-in model. Sediment buildup was mentioned as a concern, and we noted that this is not in the current measure but could be considered.

After the analysis was updated, the project team followed up with SCE and SDG&E to discuss the specific measures to include. Three key decisions that impact the implementation of 120V systems under SWWH025 and SWWH014 included:

- Excluding new construction for 120V systems from energy efficiency measures due to code requirements.
- Omitting the 65- and 80-gallon baseline offerings as these resulted in negative savings
- Adding options with and without electric resistance to provide flexible choices within the measure package.

Measure Package Eligibility Considerations

This section outlines recommendations for updating SWWH025 and SWWH014, aiming to support the successful inclusion of 120V plug-in HPWHs in the measure package update to ensure product offerings are cost-effective and feasible.

- **Measure offerings:** The 120V HPWH systems should be included as a distinct product category due to their unique market potential and installation ease. These units are particularly suitable for retrofit applications where minimal electrical upgrades are required. Their distinct feasibility and cost-effectiveness impacts are well suited for measure offerings that are separate from the existing heat pump water heater offerings.
- **Electric resistance:** To ensure easier implementation, ER and non-ER HPWH offerings should remain separate. This is driven by significant differences in savings and cost-effectiveness based on the CET results. Segregating these offerings will allow for better tracking and clearer eligibility criteria for customers and will facilitate smoother program implementation.
- **Measure application types:** Due to their reduced electric upgrade costs, 120V HPWH measures should target existing homes. Therefore, the team recommends adding these offerings under the NR and AR measure application types. Furthermore, following feedback from SCE and SDGE, we suggest 120V HPWH measure offerings be excluded from NC measure application type in the SWWH025 and SWWH014 packages, due to code requirements for new construction that mandate 240V HPHW systems in buildings that need to comply with Title 24. This exclusion will not significantly impact the fuel-substitution strategy, as these measures primarily target existing buildings and retrofits.
- **Tank size:** Although some tank sizes performed better than others, the project team recommends that all 120V HPWH tank sizes be offered in the measure package. This will provide maximum flexibility to installers and end users to select the appropriate tank sizes for their application. This is particularly important for 120V HPWHs that will have a lower heating output than existing gas systems and will need to upsize their storage capacities in order to provide similar FHRs to meet existing loads. We also recommend that 65- and 80-gallon electric baseline equipment not be offered since they require HP baselines and confer negative or no savings.

- **Building Type:** 120V HPWH systems are most advantageous for homes with electrical constraints as these buildings can benefit most from the plug-and-play nature of 120V systems. This situation can pertain to any home or building type, and the project team recommends that all building types be offered in the measure package. Of particular note are multifamily dwelling units, which may have infrastructure constraints due to many homes in a single building, and mobile home buildings in parks with constrained infrastructure.
- **Market type:** The focus for 120V HPWH measures should be on retrofit and FS markets, specifically targeting homes transitioning from natural gas to electric water heating systems.
- **Installation standards:** The unique characteristics of 120V HPWHs should be reflected in installation standards that emphasize plug-and-play deployment and retrofit flexibility. This includes incentivizing installers to adopt best practices for replacing existing gas systems without requiring panel upgrades or extensive electrical modifications. The installation location should prioritize areas where free heat can be recovered, such as laundry rooms, or other areas with waste heat. While there may be limited flexibility in changing locations for retrofit scenario, in cases where the storage tank size needs to be increased due to the upgrade, the water heater may need to be relocated. In such scenarios, any new location should provide adequate space for ventilation and comply with manufacturer guidelines regarding air volume requirements.

Conclusion

This research has demonstrated that 120V plug-in heat pump water heaters (HPWHs) offer energy and cost savings, particularly due to their flexibility in terms of reduced need for electrical infrastructure upgrades. These advantages make 120V HPWH systems a valuable addition to existing measure packages. We have also identified key eligibility considerations, which should be incorporated into the measure package updates to ensure proper implementation and maximize potential savings.

A key contribution of this research is providing a clear path for the measure package development team to integrate the savings and cost data from our analysis into updates for SWWH025 (Residential Heat Pump Water Heater for fuel substitution) and SWWH014 (Heat Pump Water Heater, Residential). These findings confirm that 120V HPWH systems (UEF of 2.6 and greater), which are relatively new to the market, address an important gap by offering a cost-effective, easily deployable solution for residential water heating.

Based on our modeling and analysis, we recommend incorporating these systems into the eTRM, leveraging the modeled savings and recommendations around eligibility considerations. This inclusion will help utilities and stakeholders maximize savings and support efforts to target hard-to-reach and disadvantaged communities with innovative approaches such as fixed-cost, same-day, emergency replacement installation programs.

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Appendix A: Energy Saving Results

The full energy savings results are attached in "ET23SWE0074_Final Report_Appendix A_Energy Saving Results.xlsx".

Full tabular data is available in the "All Savings" sheet. The following nine sheets show graphs of EE and FS electric (kWh) and gas (therms) savings by CZ, efficiency (UEF), and storage volume (Gal). For example, the sheet "EE kWh x CZ" tab shows energy-efficiency measure electricity savings by CZ.