Residential Heat Pump Water Heating

Market Transformation Advancement Plan

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

Contents

List of Abbreviations

Abbreviation	Definition
AWHI	Advanced Water Heating Initiative
BMA	Baseline Market Adoption
CalMTA	California Market Transformation Administrator
CARB	California Air Resources Board
CBECC-Res	California's Building Energy Code Compliance Software
CE	Cost-Effectiveness
CEC	California Energy Commission
CET	Cost-Effectiveness Tool
CPUC	California Public Utilities Commission
EIA	Energy Information Administration
ESA	Energy Savings Assistance
ESJ	Environment and Social Justice
ESRPP	ENERGY STAR Retail Products Platform
EUL	Effective Useful Life
FDI	Flow-down Incentives
GHG	Greenhouse Gases
HEEHRA	Home Electrification and Appliance Rebates
HOMES	Home Investment Partnership Program
HPWH	Heat Pump Water Heater
HVAC	Heating, Ventilation, and Air Conditioning
IMC	Incremental Measure Cost
IOU	Investor-Owned Utility
MPI	Market Progress Indicator
MR	Market Research
MT	Market Transformation
MTAB	Market Transformation Advisory Board
MTI	Market Transformation Initiative
NEEA	Northwest Energy Efficiency Alliance
PAC	Program Administrator Cost
PG&E	Pacific Gas & Electric

RECS	Residential Energy Consumption Survey
ROI	Return on Investment
RPR	Repeat Purchase Rate
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SME	Subject Matter Expert
TSB	Total System Benefit
TMA	Total Market Adoption
TA	Technology Assessment
TRC	Total Resource Cost
UEI	Unit Energy Impacts
WE&T	Workforce Education and Training

Initiative Name:	Residential Heat Pump Water Heating
Lead Name:	Katie Teshima, Program Manager Alexis Allan, Strategy Manager
Date:	September 17, 2024

1 Purpose

This Advancement Plan summarizes available information and essential research activities for the proposed Market Transformation Initiative (MTI) that CalMTA recommends advancing from Phase I: Concept Development into Phase II: Program Development. It represents the stage gate deliverable illustrated in Figure 1 that describes the scope of work for research, testing, and stakeholder engagement that will be needed during Phase II to develop a full MTI Plan for approval by the California Public Utilities Commission (CPUC) for Phase III: Market Deployment. The initial research efforts outlined in this Advancement Plan will inform the long-term potential of this technology before CalMTA recommends whether to advance this Market Transformation (MT) idea further. All MT Advancement Plans are reviewed by the Market Transformation Advisory Board (MTAB) and the public before they are finalized by CalMTA. This Advancement Plan contains:

1. Key characteristics of the MT idea (e.g., description, target market, initial MT theory, etc.).
2. Identified gaps in knowledge that need to be filled before an MTI Plan could be written for CPUC approval.
3. Budget and work plan for activities in Phase II that will fill the knowledge gaps.

Figure 1: MTI Development Documents by Phase

Additional information on CalMTA and the MTI development process can be found at https://calmta.org.

2 Executive summary

This section summarizes the Market Transformation concept opportunity, the problem it is trying to solve, strategies that are likely to drive market change, and the sustained change in the market we are expecting to see.

For the past 15 years, residential heat pump water heaters (HPWH) have been available as an energy-efficient alternative to standard gas and electric resistance water heating equipment. Despite being two to three times more efficient than conventional options, HPWHs have yet to achieve widespread adoption and represent less than 1% of the water heaters sold in California.[1]

While future changes in federal standards may accelerate the adoption of HPWHs, the typical 15-year lifespan of conventional water heaters puts any efficiency savings created by such standards that much farther away. To wait on assumed progress not only squanders possible savings, it underestimates the extent of market transformation required. Enhancing market penetration and acceptance of HPWHs now will help minimize grid burden, support the adoption of upcoming standards, enable the installation of more efficient electric units, and replace failing gas water heaters before the new standards take effect. This approach will also ensure that Environmental and Social Justice (ESJ) markets benefit, and it will maximize the efficiency and grid connection of installed HPWHs, driving long-term market transformation.
HPWHs face several market and organizational barriers, including:

- Complex and crowded California landscape with differing programs
- Low manufacturer return on investment (ROI)
- High installation and equipment costs with complex installations
- Potential for higher operating costs for those moving from natural gas water heating
- Low consumer awareness of the products and low interest in investing time in contemplating their water heaters
- Installers are reluctant to promote HPWH and are not convinced of the business case for HPWHs

There are multiple opportunities to overcome these barriers, which include:

- Coordinating with current California programs applicable to HPWH adoption (TECH, California Heat Pump Partnership, PG&E WatterSaver, SCE Smart Shift Rewards etc.)
- Federal codes and standards accelerating the deployment of heat pump technology

[1] Daigle, Brian and David, Andrew. Residential Heat Pump (Hybrid) Water Heater Market, Production, and Trade. Executive Briefings on Trade. United States International Trade Commission. February 2022. https://www.usitc.gov/publications/332/executive_briefings/ebot_residential_heat_pump_hybrid_water_heaters.pdf

- California Air Resource Board (CARB) work reducing pollutants and possible limitations on sales of combustion equipment
- Leveraging ENERGY STAR's label and heat pump water heater program to create awareness and acceptance of the technology
- National energy efficiency and market transformation advocates
- Deployment of programs like the Home Investment Partnership Program (HOMES), High-Efficiency Electric Homes Rebate Act (HEEHRA) and Equitable Building Decarbonization increasing market activity and incentives

In addition to broader market-level strategies, CalMTA will work specifically on product cost and accessibility, community relationship building, and workforce education and training (WE&T) among other priorities determined during ESJ stakeholder collaboration. CalMTA will be designing a shared approach with ESJ stakeholders to further refine our understanding of the barriers and create a pathway to widespread adoption.

Considering the number of preexisting incentive programs, for this MT idea CalMTA would leverage the collective work of state and national programs through three primary activities: program partner identification and outreach, collaborative Statewide HPWH Strategic Plan development, and strategic plan execution and monitoring. The CalMTA team also plans to bolster our technical understanding and utilize existing technical research to inform our approach. CalMTA's preliminary analysis finds that this MT idea has an estimated Total System Benefit (TSB) of $3.1 billion over the 20-year lifecycle of the initiative.

As envisioned by CalMTA, the majority of residential water heaters installed in any given year will be grid-enabled HPWHs by 2035. This MT idea will equitably accelerate the pace of change, reduce market confusion on the direction and tactics of California's water heater work, and decrease overall costs required to move California's residential water heating stock to heat pump technology.

3 Product, service, or practice definition

This section describes the preliminary understanding of the initiative's technology, service, or practice, its benefits, and any existing codes, standards or policies that governs it. Some parts of this definition may not be fully known at this point and will be solidified through further research and studies outlined in the following sections.

Most residential HPWHs utilize air-source technology where heat from the surrounding air is transferred to water using a vapor compression cycle. Because heat pumps transfer heat instead of creating heat, they are far more efficient than conventional electric and gas water heaters. Since HPWHs are all-electric, they significantly reduce emissions compared to gas water heaters.

Most residential HPWH products are "hybrid" models that include both a heat pump and electric resistance heating elements for backup heating. These heating elements improve recovery times in periods of high hot water demand, but they draw significantly more power than the heat pump; therefore, it is important for HPWHs to be sized, installed, and controlled to minimize the use of resistance backup during periods of high demand on the electricity grid.

The technology focus of this MT idea includes grid-connected 120V and 240V electric, air-source HPWHs less than or equal to 120 gallons with standardized connectivity and controls to support electric load shifting.

4 Market Transformation theory and opportunity

4.1 Market opportunity

This section describes the market context, Market Transformation concept, and opportunity.

Residential HPWHs represent a substantial grid and energy efficiency benefit to California's housing stock and are a necessary technology foundational to achieving the state's decarbonization goals. In California specifically, between public and investor-owned utilities (IOUs), the CPUC, California Energy Commission (CEC), and community choice aggregator programs, an estimated more than 30 programs target residential HPWHs. A deeper exploration into other entities and programs would potentially uncover additional efforts. The numerous California programs and national efforts targeting this technology are focused on product advancements, lowering equipment and installation costs, training, awareness building, incentive programs, removing barriers and garnering acceptance with several efforts focusing specifically on ESJ communities.

Existing efforts by California Air Resources Board (CARB) and state and federal standards and state codes efforts are ongoing and underway, providing an opportunity for CalMTA efforts to harness market momentum in support of these efforts.

Despite the multitude of existing HPWH energy efficiency and decarbonization efforts and that major manufacturers have had commercially available product for nearly 15 years, the market has been slow to adopt the technology. Less than 1% of water heaters installed annually in California are HPWHs.[2] This lack of adoption showcases that many remaining market barriers impede the

[2] Daigle, Brian and David, Andrew. Residential Heat Pump (Hybrid) Water Heater Market, Production, and Trade. Executive Briefings on Trade. United States International Trade Commission. February 2022. https://www.usitc.gov/publications/332/executive_briefings/ebot_residential_heat_pump_hybrid_water_heaters.pdf

acceptance and adoption of HPWHs, and that an opportunity exists to partner with the various programs to potentially increase the scale and speed of adoption.

Given the quantity of HPWH programs in a market so fraught with barriers, there is an opportunity for CalMTA to develop an HPWH MT idea that focuses on creating and supporting a cohesive and collaborative Statewide HPWH Strategic Plan. This MT idea would unite the collective horsepower of these individual efforts by identifying collaborative forces, cooperating on research efforts, ensuring the technology meets the needs of California residents, and removing structural market barriers to jointly accelerate HPWH adoption while reducing resource requirements.

To accomplish this, CalMTA will segment this work into the three primary activities highlighted below.

Program partner identification and outreach
The identification and outreach process will focus on identifying and documenting programs and organizations ripe and necessary for HPWH collaboration and coordination, leveraging existing relationships, and market characterization research. Once program partners are identified, CalMTA will conduct outreach and convene partners to solicit engagement in the design of a collaborative Statewide HPWH Strategic Plan to tackle the residential HPWH while aligning with California's statewide and policy goals.

Collaborative Statewide HPWH Strategic Plan development
CalMTA will establish a collaborative of program partners to facilitate a process and host summit(s) to jointly establish a multi-year Statewide HPWH Strategic Plan. Throughout this collaborative process, CalMTA will facilitate efforts to align on market barriers, develop coordinated market interventions to overcome them, identify areas in need of additional research, negotiate and establish clear roles and responsibilities across programs, and create a shared logic model and ongoing coordination approach. The Statewide HPWH Strategic Plan designed in partnership with program partners will inform CalMTA's role in future work and the design of the full MTI Plan.

CalMTA envisions a long-term collaborative Statewide HPWH Strategic Plan that will:

- Identify short-term and long-term goals with program partners while creating a shared sense of roles and responsibilities to amplify results and avoid duplicating efforts
- Prioritize efforts and align tactics with manufacturers, national efforts, and other market actors
- Align and identify appropriate product tiers or specifications and product needs to support California's long-term goals
- Identify shared market and program risks and create coordinated mitigation approaches
- Ensure the benefits of HPWHs are prioritized and recognized in ESJ communities

- Pool resources and explore statewide awareness/acceptance building campaigns leveraging common messaging and tactics; common approaches and strategies to overcome installer acceptance; workforce development needs; product development; localized code and installation barriers; etc.
- Develop and sustain market conditions to support the supply chain in readying for the federal standard requiring the majority of electric storage water heaters transition to heat pump technology
- Align programmatic and market transformation efforts with California's codes and standards efforts and CARB

Strategic Plan execution and monitoring

Creation of the Statewide HPWH Strategic Plan, developed in collaboration with program partners, will be completed in Phase II of the MTI. Phase III will shift focus as efforts are envisioned to center on the execution and ongoing monitoring of the Statewide HPWH Strategic Plan. The execution efforts will include deploying the intervention strategies, coordination and management of efforts identified with program partners and prioritized by CalMTA, monitoring the plan's success, facilitating ongoing engagement with program partners to assess performance, and identifying needs for the plan to evolve.

The goal is not to replicate or replace the organizations and programs already doing good work in California on HPWHs. The intention is to unify the efforts across the state and fill gaps on activities not currently being addressed that are identified as mission critical for greater acceptance and accelerated adoption of HPWHs.

4.2 Target market

This section defines the sector(s) this product, service or practice is intended for. The target market may be adjusted based on the results of the research conducted in Phase II of the initiative.

Residential single- and multi-family new and existing construction and the supply chain and program partners that serve these sectors.

4.3 Key market barriers

This section captures a high-level overview of perceived barriers which limit adoption of the technology in this market. These barriers will be verified, during Phase II, through the work defined in Section 6 of this document.

Key market barriers for this MT idea have been broken into two categories as described below.

Organizational Barriers – Barriers CalMTA will be attempting to overcome with its coordinated state-wide strategy and include:

- Complex and crowded California landscape with differing programs
- Low manufacturer ROI

Market Barriers - Those CalMTA assumes to exist, based upon experience and existing research, that will be further refined based upon CalMTA collaborative efforts and the Statewide HPWH Strategic Plan design. These include:

- High installation and equipment costs
- Potential for higher operating costs for those moving from natural gas water heating
- Consumers have low awareness and low interest in water heaters
- HPWHs require additional education and training for installers and the supply chain, something traditional equipment has not required, and therefore there is limited interest in training or an existing infrastructure to leverage.
- Installers are reluctant to promote HPWH and are not convinced of the business case for HPWHs
- Complex installations in comparison to existing equipment

4.4 Points of leverage and strategy interventions

This section describes the points of leverage and strategic interventions that are envisioned at this early stage that could be utilized to achieve the transformed market end state. The next research phase of this MT idea will help the team test and refine assumptions.

The HPWH market offers several key points of leverage building upon program partner efforts, which include:

- Northwest Energy Efficiency Alliance (NEEA) has been actively engaged in transforming the residential water heating market since 2009, establishing and maintaining a product specification that is leveraged nationally and recognized by water heater manufacturers.
- New Building Institute's Advanced Water Heating Initiative (AWHI) is a national collaborative focused on building demand and educating the supply chain.
- ENERGY STAR's label and heat pump water heater program can be leveraged to create awareness and acceptance of the technology.
- Energy efficiency retail platforms, like the ENERGY STAR Retail Products Platform (ESRPP) and programs operated by the California IOUs (like Southern California Edison's online marketplace) could help create awareness and demand.
- ENERGY STAR Manufacturer's Action Council and its representatives can be leveraged to engage manufacturers and develop innovative solutions to drive adoption of HPWH in California.
- TECH Clean California, a CPUC statewide program aimed at accelerating adoption of clean space and water heating technology, and accompanying The Switch is On campaign will be key points of leverage for contractor- and consumer-facing education and promotion of statewide incentives.

- California utility partners, community choice aggregators, community-based organizations, and public utilities. These partners are currently operating HPWH programs and CalMTA can learn from their efforts, research, and results. We will explore partnership opportunities to braid the individual work of these organizations with a larger statewide effort.
- CalNEXT program team and expertise will be leveraged to compare and inform research projects exploring for duplication of efforts and looking for areas where our work can build off each other.
- Energy Savings Assistance Program (ESA) is a statewide program that provides no-cost weatherization services to low-income households. The program aims to help customers conserve energy and save money.
- Low-Income Weatherization Program is the only program of its kind in CA that focuses exclusively on serving low-income households with solar PV and energy efficiency upgrades at no cost providing an opportunity to couple program with HPWH.
- California Energy Commission efforts and deployment of the HEEHRA, HOMES, and Equitable Building Decarbonization program include support for HPWH and will be considered as part of the initiatives overarching strategy.
- California codes, standards and legislative efforts aimed at moving the market to heat pump technology.
- CARB zero-emission efforts and proposed sales prohibition on most residential combustion appliances.
- Recently passed federal standard requiring HPWH for the majority of electric applications can be leveraged to ready the supply chain and increase comfort with the technology while readying the market for broader adoption.

4.5 Environmental & social justice

This section describes the initiative's targeted equity approach and summarizes the initiative's potential intervention strategies to advance equity, benefit environmental and social justice communities and develop workforce development, education, and training (WE&T).

As part of CalMTA's long-term strategic plan development process for HPWH, ESJ leadership will be an integral part of the strategic planning process to ensure that the specific barriers and needs of the ESJ communities are reflected. CalMTA will ensure the plan builds and prioritizes equity, ESJ, WE&T and reflects the communities stakeholders serve. As a collective statewide effort, CalMTA and stakeholders will review and align on ESJ community approaches and identify roles and responsibilities collaboratively. Potential approaches include:

- Identify available incentives, and strategies to establish a low to no cost offering for HPWHs in ESJ communities while accounting for possible bill impacts.
- Identification of resources, tools, and collaboration efforts needed to establish effective community relationships that drive equitable adoption of HPWHs in ESJ communities.

- Leverage or design an approach to create opportunities for building an educated, well-trained workforce in ESJ communities prioritizing creating greater diversity amongst trade allies, companies, and job placement.
- Evaluate U.S. Department of Housing and Urban Development (HUD) water heater regulations for manufactured and mobile homes and compare to current HPWH form factors to identify gaps.

Preliminary outcomes associated with these approaches include:

- Statewide strategic planning process includes ESJ stakeholders and includes explicit strategies to ensure equity and mitigate risks to ESJ communities.
- Market uptake by ESJ communities is similar to other communities with similar characteristics.
- Installers from ESJ communities are engaged in and make commitments to HPWH workforce development activities.
- Installers serving ESJ communities see HPWHs as a profitable business opportunity as much as those that serve higher-income communities.

4.6 Market vision/end-state

This section describes the vision of the end state for what the transformed market will look like because of the initiative's work.

When successful, this MTI will equitably accelerate the pace of adoption, reduce market confusion on the direction and tactics of California's water heater work, and decrease overall costs required to move California's residential water heating stock to heat pump technology. By 2035 the initiative aims to create the market dynamics to ensure the majority of new residential water heaters installed are grid enabled HPWHs, that customers understand what to expect from this technology in their homes, and that the supply chain values and adopts HPWHs as a prioritized segment of their business.

4.7 Key market assumptions

This section describes key market assumptions for the State of California that are assumed when determining the market vision/end state.

The following market assumptions inform this MT Advancement Plan:

- Code efforts continue to advance the new construction market towards requiring heat pump water heaters.[3]

[3] 422.3(A) California Energy Code Requirements for Heat Pump Water Heaters, Electric Cooktops, Electric Clothes Dryers and Their Readiness in Single-Family Buildings. https://up.codes/s/california-energy-code-requirements-for-heat-pump-water-heaters-electric-cooktop

- The majority of existing residential water heaters are fueled by natural gas.[4]
- Manufacturers and supply chain partners would appreciate and be motivated by coordinated efforts where possible.
- Supply chain is established, and grid-enabled product is available throughout distribution and retail channels.
- Coordinated efforts would decrease the total cost to the state by braiding funds aimed at similar efforts (i.e. consumer messaging, supply chain engagement, research activities, training).

4.8 Diffusion and "lastingness" mechanism

At some point, the market will continue to transform, even when the initiative's investments have ended. This section describes the market mechanism that will continue to move the technologies' transformation forward, after CalMTA's exit, to achieve the end state described above.

This MT idea will build and support a Statewide HPWH Strategic Plan with program partners and execute a coordinated statewide approach to accelerate the acceptance and adoption of HPWHs. These efforts will create the market momentum and scale needed to support the upcoming federal standard and ensure product acceptance, price and installation are no longer barriers to adoption in support of for California's advancing state codes, standards, and climate goals.

4.9 Conceptual Logic Model

Conceptual logic models include high-level barriers and opportunities that inform the draft interventions, as well as expected outcomes and long-term impacts. The proposed market characterization, product assessment, and pilots conducted in Phase II will verify this logic model's assumptions and draft interventions. Once this work is completed in Phase II, CalMTA will develop a more refined and formal logic model for Phase III: Market Deployment.

Given the unique nature of this MT idea and the coordinated effort that will take place to collectively build a Statewide HPWH Strategic plan identifying shared barriers and strategic interventions a logic model will be developed and shared in the next phase of our work.

As mentioned above we expect to design the logic model during Phase II based on the research described in Section 6 and the program partner activities described above. This Phase II research will inform the development of an evaluation plan that includes clearly defined market progress indicators, the data sources for tracking those, and the expected timeframe for realizing market transformation progress.

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[4] Title 24, Part 6 Fact Sheet for Residential Domestic Hot Water, EnergyCodeAce, https://energycodeace.com/download/35088/file_path/fieldList/FactSheet.Res-DHW.2019-010320.pdf

While Phase II research is needed to fill information gaps before we can establish clearly defined market progress indicators (MPIs) and measurement plans, Table 1 shows our current thinking on likely MPIs, and some of the possible associated data sources.

4.10 Measuring market outcomes

This section identifies a few preliminary market progress indicators (MPIs) for the initiative. A more comprehensive set of MPIs and equity metrics will be established during the development of a more refined and formal logic model for Phase III: Market Deployment.

Table 1. Possible MTI Market Progress Indicators and data sources

Preliminary Outcome	Possible Market Progress Indicator	Possible Data Sources
Coordinated Statewide HPWH Strategic Plan Executed	Program administrators signed on to strategic plan	Program materials
Ongoing CA Program Collaboration	Program administrators signed on to strategic plan, Program administrators participating in collaboration	Program materials and Program Stakeholder interviews
Engaged and growing installer network	Installer Network Size/Plumbers and HVAC contractors offering HPWH	Installer surveys
Improved and simple customer purchase experience	Installer HPWH conversion rates, customer purchase/install experience	Installer surveys, HPWH purchaser surveys
Customer aware of eligible rebates/credits	Customer awareness	Customer/general population surveys, HPWH purchaser surveys
Consistent messaging and centralized resources for customers and supply chain	Customer awareness, installers and manufacturers are aware, engaged, using resources	Program materials, customer/general population surveys, installer surveys, manufacturer interviews
HPWH becomes more cost-competitive	HPWH price/incremental cost compared to equivalent units	Secondary product research or shelf-stocking
Accelerated adoption of HPWH	HPWH sales	Sales or shipment data
Manufacturers view HPWH product line as viable and	Manufacturer attitudes	Manufacturer interviews

Preliminary Outcome	Possible Market Progress Indicator	Possible Data Sources
profitable; experience a return on investment		

In addition to the preliminary market progress indicators shown in Table 1, CalMTA is working to develop metrics specifically focused on equity and WE&T. Although additional, ongoing engagement will be required to establish the most appropriate equity indicators and metrics of measurement, Table 2 shows our preliminary thinking on possible equity metrics.

Table 2. Possible MTI equity metrics and data sources

Preliminary Outcome*	Possible Equity Metric	Possible Data Sources
Installers serving ESJ communities see HPWHs as a profitable business opportunity as much as those that serve higher income communities	Size of ESJ installer network promoting HPWH vs. broader installer network promoting HPWH	Installer survey, zip code mapping to identify installations in ESJ regions/communities
Market uptake by ESJ communities is similar to other communities with similar characteristics	Market share in ESJ communities vs. other communities	Installer survey, customer survey, Residential Appliance Saturation Study, ESRPP sales data, Energy Information Administration (EIA) Residential Energy Consumption Survey (RECS) data
Statewide strategic planning process includes ESJ stakeholders, and includes explicit strategies to ensure equity and mitigate risks to ESJ communities	Program administrators of programs targeting ESJ communities are present in planning process and signed on to strategic plan Strategies for risk mitigation exist in plan, strategies executed	Statewide strategic plan document, program implementation documentation
Installers from ESJ communities engaged in and make commitments to HPWH workforce development activities	% of ESJ installer network engaged in workforce development	Installer surveys

*See environmental & social justice approach in Section 4.5.

5 Gap analysis

This section describes the most critical data/information needs to be gathered through phase II to make sure the Market Transformation Initiative is viable and to create the MTI plan. Section 6 will provide more information on how we are going to gather this data.

The CalMTA team estimates that there are currently over 30 programs supporting HPWH adoption in California. The team has compiled a matrix of programs and sponsors, but comprehensive information about the barriers impeding HPWH uptake in the residential market is still needed. There are also knowledge gaps surrounding the details of the program offerings as well as California stakeholder perspectives on barriers that the statewide HPWH Strategic Plan could address through new intervention strategies.

In Phase II, CalMTA will fully explore the existing residential HPWH program and policy landscape. Further, Phase II research and stakeholder engagement activities will gauge the appetite for a statewide approach to HPWH transformation among influential groups and players and build on the existing experience and expertise of historical programs to inform the MTI's interventions. Phase II activities will also involve customer and market actor research to inform a market characterization, but the specific research needs will be developed with stakeholder input and after a detailed review of the completed and active HPWH market research to ensure the research does not duplicate the many efforts already underway. Research timelines, and the subsequent MTI Plan itself, will be developed to reflect the expected completion dates of existing efforts, where known.

One critical focus of the Phase II research will be development of a robust baseline market adoption (BMA) forecast. BMA forecasting will be particularly challenging for this MTI given the large number of existing and pending programs, such as HOMES and HEEHRA, and the collaborative nature of the MTI. Because a collaborative statewide approach will - by definition - result in "co-created" impacts, Phase II efforts will include development of a carefully delineated plan to evaluate MTI influence. Given the likelihood that a majority of incremental units in the first several years will receive local and/or federal program incentives, the evaluation plan may need to consider an MTI-specific attribution approach – for example, an approach similar to what California uses to assess codes attribution.

From a technical perspective, CalMTA will identify and address enduring HPWH technical concerns through its own research and by leveraging ongoing and upcoming research activities through CalNEXT and other programs. The goal of this research is to address product size and potential hot water runout concerns when replacing conventional gas and electric water heaters with HPWHs. Additionally, with 120V HPWHs on the market and new federal standards, the team will monitor HPWH design modification, selling price, installation costs, and replacement rates compared to today's HPWHs. Finally, CalMTA will leverage CalNEXT and other HPWH emerging technology and market transformation programs to learn more about 120V HPWH performance.

Of interest are hot water recovery rates, reducing the need for back-up electric resistance heating, and assessing installer and customer experiences with 120V HPWHs.

6 Research and program development plan

6.1 Technology assessment

This section describes any assessment that might be needed to prove the viability of the technology, service, or practice the initiative is targeting. Table 3 summarizes what and why the information is needed to complete the planning phase of the initiative and how the information will be collected. Table 4 summarizes the budget per task and the time it will take to complete the task. The budget does not include staff time.

Although HPWHs have been commercially available for over 15 years, most efforts have focused on removing technical barriers to replacing existing electric water heaters. In California, it is estimated that nearly 90% of water heaters are fueled by natural gas.[5] Technical barriers to transitioning gas storage and gas instantaneous water heaters to HPWHs include fuel switching panel capacity logistics and cost, HPWH size constraints, and HPWH performance hurdles.

- Fuel switching panel capacity - Many homes that currently use gas for space and water heating do not have the electric service required for HPWHs, especially 240V HPWHs. In these cases, installing a HPWH requires adding a circuit to an electric panel, upgrading the electric panel, or in some cases, upgrading the electric supply to the home. All electric panel upgrades add cost and time to the HPWH installation, making HPWH installation very difficult in emergency replacements, which are roughly 50% of water heater replacements.[6]
- Size constraints – Integrated HPWHs are typically taller than conventional gas and electric water heaters since the heat pump is on top of the unit.[7] Additionally, since HPWHs cannot heat water as quickly as gas storage water heaters, storage volume is often increased to ensure hot water availability. Installers often size replacement HPWHs to 1 to 2 sizes larger than the water heater that they are replacing (i.e., a 40-, 50- or 65-gallon tank is replaced with a 50-, 65- or 80-gallon tank, respectively).
- Performance hurdles – Integrated HPWH performance is negatively impacted by poor air flow and low room temperatures. When not installed properly, back-up electric resistance

[5] Title 24, Part 6 Fact Sheet for Residential Domestic Hot Water, EnergyCodeAce, https://energycodeace.com/download/35088/file_path/fieldList/FactSheet.Res-DHW.2019-010320.pdf

[6] Energy Star Water Heater Market Profile, Department 2009, https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/Water_Heater_Market_Profile_Sept2009.pdf

[7] An integrated heat pump water heater includes heat pump(s), electric resistance element(s), and a storage tank in a single unit.

heaters in the unit kick in, increasing electricity use, reducing energy efficiency, and increasing operating costs.

- Recognizing there are many efforts and organizations funding research to understand HPWH technical barriers, the CalMTA team plans to bolster our technical understanding and leverage existing technical research to inform our approach for replacing gas water heaters with HPWHs. CalMTA has submitted the following research questions to CalNEXT for evaluation in its 2025 program to ensure efficiency use of resources: 1) optimizing HPWH recovery performance, 2) assessing technologies that can effectively operate across all California climate zones, and 3) understanding fuel switching panel capacity of residential homes.

The CalMTA team identified the following technology assessment (TA) research objectives to address critical technical knowledge gaps and to inform the MTI strategy. The interviews and literature reviews that will be conducted with Market Research (MR) are described in Table 5.

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

a. Document and identify gaps in current HPWH sizing practices.
b. Identify and analyze effective HPWH sizing approaches.
c. Review how California building code impacts HPWH first hour rating and sizing expectations / restrictions.

TA 2. Leverage CalNEXT and other California and national programs to assess and evaluate performance solutions for HPWHs as replacements for gas water heaters in all California climate regions.

a. Determine the best approach for characterizing HPWH recovery.
b. Evaluate how heat pump capacity, tank set point temperature, and other variables impact HPWH recovery.
c. Evaluate opportunities for decreasing HPWH reliance on back-up electric resistance heaters.
d. Evaluate form factor and performance of prototype HPWHs with different refrigerants to increase heat pump operating window.

TA 3. Monitor HPWH design changes, cost (first cost and operating costs), and replacement rates.

a. Develop trust and ongoing communication with HPWH manufacturers.
b. Compare HPWH replacement rates (how often product failures result in replacement) and warranty claims with similar products (i.e., gas and electric storage water heaters, heat pump mini splits).
c. Develop a HPWH cost scenarios forecast through 2035.

TA 4. Assess electric panel electrification readiness in California homes to identify and target HPWH replacements in residences with low expected fuel-switching costs.

a. Mine historical home electric panel specification data by home vintage, municipality or zip code, and other characteristics to be determined.

b. Evaluate historical data, TECH Clean California home electric panel data, data from the 2023 CPUC fuel substitution study, and data from the CalNEXT HPWH Technology Focused Pilot to identify residences with low expected fuel-switching costs.
c. Identify home electric panel data gaps and develop an approach for collecting additional data to support targeted gas to HPWH replacement.

Table 3. Summary of technology assessment activities

Technology Assessment (TA) Research Objective	Phase II Research Task					Deliverable(s) Informed by Research	Related Market Research
	Literature & Existing Data Review	Ongoing Expert Engagement	Energy Modeling & Engineering Calculations	Lab Testing or Product Tear Down	Field Study		
TA.1: Evaluate Current 120V and 240V HPWH Sizing Practices	✓	✓	✓			Baseline Product, Product Technical Characterization, MTI Plan	MR.1
TA.2: Leverage CalNEXT and Other Programs to Assess and Evaluate Performance Solutions for HPWHs	✓	✓				Product Technical Characterization, MTI Plan	
TA.3: Monitor HPWH Design Changes, Cost (first cost and operating costs), and Replacement Rates	✓		✓			Baseline Product, Product Technical and Cost Characterization, MTI Plan	MR.3
TA.4: Assess Electric Panel Electrification Readiness in California Homes	✓	✓	✓			Home Electrification Readiness, MTI Plan	MR.3

Table 4. Summary of technology assessment needs, cost, and estimated timeline

Technology Assessment Task	Schedule (Estimated Weeks)	Estimated Cost	Deliverables Informed by this Task
(1) Literature & Existing Data Review	Weeks 1 - 18	$50,000	Baseline Product, Product Technical Characterization, Cost Characterization, Home Electrification Readiness, Electric Demand Forecast, MTI Plan
(2) Ongoing Expert Engagement	Weeks 15 – 35	$50,000	Baseline Product, Product Technical Characterization Cost Characterization, Home Electrification Readiness, MTI Plan
(3) Energy Modeling & Engineering Calculations	Weeks 15 -35	$165,000	Baseline Product, Product Technical Characterization, Cost Characterization, Home Electrification Readiness, MTI Plan
Total Estimate:		**$265,000**	

6.2 Market research

This section describes the market research needed to inform the MTI planning. The objective of the proposed research, the methods by which the research is conducted and how the results of the research will be use are shown in Table 5. Table 6 summarizes the budget per task. The budget does not include staff time.

The CalMTA team identified the following Market Research (MR) objectives to fill critical knowledge gaps in the market and inform the MTI strategy:

MR 1. Understand the existing state and federal HPWH program and policy landscape, barriers, and opportunities.

a. Create a comprehensive inventory of CA and federal programs or policies, features, and forecasted impacts.
b. Engage stakeholders to gather perspective on key barriers and opportunities for coordination across programs, regions, stakeholders, target markets. Where possible, gather lessons from other jurisdictions with successful HPWH programming outside of California.
c. Assess program stakeholders' perspectives on a statewide collaborative entity and perceptions on needs and valuable intervention strategies.
d. Assess leverage points for the MTI from a policy and regulatory perspective and document upcoming codes and standards, CA legislation and proposals (such as the upcoming CARB space and water heating rulemaking), funding vehicles for electrification, and low GWP refrigerant regulations to understand their implications on the market and opportunities for MTI interventions.

MR 2. Leverage completed and ongoing market research, evaluation, and R&D efforts.

a. Document/analyze available market insights, reports, and data from programs and CA market studies and determine gaps for CalMTA research.

b. Understand existing and upcoming research and development efforts on HPWH technology in key product design areas.

MR 3. Characterize the baseline market conditions, develop market baseline forecast and evaluation plan for incremental impact.

a. Quantify current market saturation of HPWHs in the residential sector through surveys and a review of existing research and quantify market share as a portion of total water heater sales through the acquisition of sales or shipment data. Explore proportion of sales of HWPHs by efficiency levels if available.
b. Segment the residential market by building type, segment (new construction vs. existing) and water heater type to inform market adoption potential and strategy.
c. Generate a baseline forecast of total market sales of HPWH, as well as program-incented units and IRA-incented units as a subset of total market (the baseline market adoption).
d. Update incremental cost estimates and forecasts.
e. Characterize the products on the market (voltage, system types, sizes, features, and price) and assess availability (stock and lead times).

MR 4. Characterize the supply and demand side market.

a. Characterize the supply chain and create a supply chain map
b. Conduct installer and customer surveys and develop journey maps for both.
c. After Research Objective 2 is addressed, develop more specific research topics for market actor and consumer research.

Market Research Methods: To inform the above Market Research Objectives, the team will execute the following Market Research Tasks: secondary research and data analysis, program stakeholder and manufacturer interviews, and market actor and customer surveys. The team will also collect CA program administrator data on HPWH rebates and forecasted units, identify a data source for comprehensive market sales, and create a statewide database to compile this information and track market movement and impacts of the MTI. Finally, the team will host a CA HPWH Program Summit(s), and invite program stakeholders to discuss/share common barriers and opportunities. CalMTA will also use the Summit as an opportunity to disseminate findings from preliminary research to stakeholders, gather additional intelligence and spur discussion on innovative approaches and interventions.

Table 5. Market research objectives, tasks, and deliverables

Market Research (MR) Objective	Phase II Research Task						Deliverable(s) Informed by Research
	Secondary Research and Data Analysis	Program Stakeholder Interviews	Manufacturer Interviews	Market Actor and Customer Surveys & Journey Mapping	CA HPWH Summit(s)	HPWH Program Database, Market Adoption & CE Forecasting	
MR.1: Understand the Existing HPWH Program and Policy Landscape in CA; Barriers, and Opportunities	✓	✓			✓		MTI Plan, Market Characterization
MR.2: Leverage Completed and Ongoing Market Research, Evaluation, and R&D Efforts	✓	✓	✓				MTI Plan, Market Characterization
MR.3 Characterize the Baseline Market Conditions, Develop Market Baseline Forecast and Evaluation Plan for Incremental Impact	✓	✓	✓	✓		✓	Baseline Market Adoption Forecast, Impact and Cost-Effectiveness Forecast
MR.3a: Quantify current market saturation of HPWH in the residential sector and quantify market share as a portion of total water heater sales	✓		✓	✓		✓	
MR.4: Characterize the Supply and Demand Side Market	✓	✓	✓	✓	✓	✓	MTI Plan, Market Characterization, Impact and Cost-Effectiveness Forecast

Table 6. Market research task, estimated cost, and estimated timeline

Market Research Task	Schedule (Estimated Weeks)	Estimated Cost	Deliverables Informed by this Task
(1) Secondary Research and Data Analysis	Weeks 1-8	$92,000	Market Characterization, BMA Forecast; Impact and CE Forecast, MTI Plan
(2) Program Stakeholder + Subject Matter Expert (SME) Interviews	Weeks 4-16	$34,000	Market Characterization, BMA Forecast, Impact and CE Forecast, MTI Plan
(3) Manufacturer Interviews	Weeks 12-18	$29,000	Market Characterization, BMA Forecast, MTI Plan
(4) Market Actor and Customer Surveys and Journey Mapping	Weeks 12-40	$228,000	Market Characterization, BMA Forecast, Impact and CE Forecast, MTI Plan
(5) CA HPWH Collaboration Effort and Summit(s)	Weeks 20-45	$180,000	MTI Plan, Market Characterization
(6) HPWH Program Database	Weeks 20-60	$89,000	BMA Forecast, Impact and CE Forecast
Total Estimate		**$652,000**	

The market research activities will conclude with an estimation of base year saturation and market share of the MTI technology.

The technology and market research activities described in this plan will inform an updated forecast of market adoption and development of Phase II TSB and cost-effectiveness estimates. These revised estimates will be developed upon the completion of the market characterization and will be submitted as part of the full MTI Plan.

6.3 Strategy Pilots

This section describes any potential intervention strategies that need to be tested during the Phase II development of this initiative and how conducting the pilot can inform the MTI's business case.

CalMTA has determined that the Residential Heat Pump Water Heating MTI requires additional research and development before a detailed strategy pilot may be recommended. The market and technology research above will help will determine if a pilot is needed and its scope. If CalMTA determines a strategy pilot is necessary, it will submit documentation for public comment and review.

7 External program review and stakeholder engagement

This section identifies a few key program stakeholders CalMTA needs to coordinate with as we determine the MTI viability and develop the MTI plan. This list is a subset of a larger list and more stakeholders will be identified to coordinate with during Phase II.

As is standard practice in Phase I of our MTI development process, CalMTA conducted initial analysis to identify areas of potential overlap, leverage, and opportunities for collaboration between the Residential HPWH initiative and existing programs or organizations focused on this market segment. While working closely with the wide range of California programs addressing this market segment will be a critical piece of the MTI's implementation, CalMTA will prioritize coordination with the following representative stakeholder groups as we conduct the activities identified in this Advancement Plan.

Recognizing the complex network of residential HPWH market activities in California and nationwide, we look forward to refining and expanding CalMTA's stakeholder engagement plan for this MTI as we proceed with our strategic planning efforts and market research. Many of these stakeholders, especially California programs like TECH Clean California, will be important members of the collaborative formed to support this MTI as well as our statewide strategic planning process.

Table 8. Summary of key external stakeholders

Program – Organization/ Stakeholder Segment	Coordination Approach
Statewide Codes & Standards Advocacy Programs	Continue ongoing series of coordination meetings to understand partners' current work and/or upcoming activities related to this technology and market segment. Provide relevant information and insight to support the standardization of product performance and efficiency metrics.
CalNEXT and Electric Program Investment Charge (EPIC) Program	Review existing research findings and conduct 1:1 outreach to the team's SMEs to understand questions and areas of future research. Maintain regular cadence of meetings to share research plans and explore for overlap and cost-sharing opportunities. Submit research ideas through CalNEXT Request for Ideas process.
TECH Clean California	Clarify roles and responsibilities to ensure CalMTA's work adds value to the market and is positioned for success.

Program – Organization/ Stakeholder Segment	Coordination Approach
	Establish regular cadence of communication and information-sharing mechanism to provide a comprehensive local and national market understanding.
NEEA Hot Water Solutions	Review relevant research to identify best practices and lessons learned from a successful HPWH market transformation initiative in the Pacific Northwest. Identify opportunities to leverage concurrent efforts to drive greater market alignment and impact.
New Building Institute AWHI	Identify opportunities to support and ensure alignment on AWHI's work to influence building codes, educate trade allies, inform local government planning, and develop awareness-building materials for HPWHs.
CEC	Monitor and engage with CEC team to understand approach to HEEHRA, HOMES, and Equitable Building Decarbonization program design and deployment. Identify opportunities to leverage these programs and involve CEC team in strategic planning and coordination opportunities.
The Switch is On	Leverage this campaign, which also serves as an aggregator for available HPWH incentives, as a channel for building increased market awareness and understanding.
CARB	Closely monitor CARBs and other California air quality standards targeting the phaseout of combustion equipment by 2030. Efforts will be included in Strategic Planning process and inform CalMTA assessment of a market transformation opportunity for HPWH.
Statewide programs	Leverage and identify opportunities to support the many existing programs offering incentives on residential HPWHs, including: • Golden State Rebates, the statewide midstream program offering residential HPWH instant rebates. • PG&E WatterSaver and SCE Smart Shift Rewards aimed at mitigating increased bills when switching to HPWH • The CEC-administered HOMES, HEEHRA programs, funded through the Inflation Reduction Act, which will support whole house energy efficiency retrofits and electric appliance rebates for low-and-moderate income households. • Income-qualified home electrification programs like ESA portfolio or the future CEC Equitable Building Decarbonization Program. • As we explore opportunities with multifamily buildings in our target market, the ESA Multifamily Whole Building programs (north and south).

Program – Organization/ Stakeholder Segment	Coordination Approach
	• As we explore opportunities with new construction as part of our target market, the CEC Building Initiative for Low-Emissions Development (BUILD) Program and California Electric Homes Program as well as the IOUs, statewide California Energy-Smart Homes Program.

In Phase II, we will define an approach for convening the administrators and implementers of these programs to support a Statewide HPWH Strategic Plan for accelerating residential HPWH market growth. Ongoing coordination with critical program teams will help CalMTA avoid duplication of efforts, facilitate mutually beneficial information/data-sharing, and identify key leverage opportunities to enhance each other's work in this market segment.

8 Potential risks & mitigation

Table 9 describes potential risks, the assumed severity, and how we plan to track and mitigate the risk if needed.

Table 9. Hypothesized MTI risk review

Initiative Risk	Severity	Mitigation Approach
Lack of value proposition for HPWH stakeholders to invest time/resources to coordinate with CalMTA.	High	Conduct 1:1 outreach meetings to better understand gaps and opportunities for CalMTA. Leverage MTI Plan approval process showcasing commitment and support of this MTI to encourage and motivate partners to participate. Explore mechanisms to ease burden of collaboration leveraging virtual and in-person meeting approaches located in various communities/territories of California. Develop a compelling business case, showing that we can be more effective collectively compared to separately.
Key decision makers are missing from CalMTA discussions, resulting in limited impact.	High	Engage program decision makers early in the process to create buy-in. Ensure decision makers are included and set the stage for organization-to-organization collaboration and coordination. Maintain regular meeting and communication cadence to showcase progress and value.

Initiative Risk	Severity	Mitigation Approach
Customer experience and purchasing decision remains challenging, preventing adoption.	High	Map existing customer journey to better inform MTI strategy. Develop customer personas to understand unique customer purchase path and barriers to adoption. Leverage collaborative efforts to develop an approach aimed at centralizing customer resources and messaging. Create shared customer feedback opportunities. Leverage market partner messaging and approach to amplify programmatic efforts.
Market is not prepared for and rejects California codes, standards and/or legislative efforts aimed at moving the market to heat pump technology.	High	Leverage market relationships to understand response pre and post legislation and closely monitor how the market is responding in real time. Work with supply chain partners to pivot tactics/strategies to address barriers prior to legislation taking place Explore and advocate for cost neutralization approaches targeting parody in price for installation and operation Create and/or leverage existing statewide sales data collection mechanism to track sales and monitor "work arounds" Work closely with regulatory organizations to understand monitoring and enforcement mechanism. Leverage market size of California to encourage market actors to partner on cost neutralization and training efforts, specifically targeting necessary pivots to installer business models and sales tactics
Fragmented HPWH market creates gaps in data, leading to misinformed program decisions.	Medium	Create flexible approach to data plan by identifying multiple trusted data sources. Create data sharing agreements with partners. Leverage California's market size and collaborative efforts to negotiate data agreements/exchange with market partners/actors.
ESJ-specific challenges are not meaningfully	Medium	Engage ESJ stakeholders early and often in the process.

Initiative Risk	Severity	Mitigation Approach
addressed and are not incorporated into this MTI.		Create multiple pathways for ESJ community inclusion in program logic model ensuring specific ESJ outcomes. Involve ESJ program partners in collaborative strategic planning exercise and ongoing collaboration activities. Allocate budget for ESJ-specific activities and tie to specified objectives and outcomes.
Manufacturer fatigue.	Medium	Create coordinated communication and engagement approach in partnership with program partners. Explore for opportunities to align program requirements. Align product modification requests across stakeholders, both in and outside of California to improve coordination. Leverage manufacturer experiences to inform statewide approach and engage manufacturing community in design of innovative approaches for HPWH channel. Engage HPWH manufacturers in conversations and working groups to better understand manufacturing decision making processes.
Product performance issues arise with 120V and 240V HPWHs.	Medium	Create mechanism through collaborative efforts to create consistent message to market actors/partners. Develop coordinated statewide mitigation approach with partners; create streamlined communication to manufacturing and supply chain community. Determine timeline for product improvements and market deployment.
Gas water heater sales increase as low NOx requirements near effectiveness date.	Medium	Monitor market sales and supply chain experience and adjust plan accordingly. Socialize the risk to partners to encourage their program plans and budgets recognize potential risk.
Duplication of efforts with other HPWH programs and initiatives.	Medium	Conduct regular stakeholder meetings to better understand gaps and opportunities for CalMTA, minimizing the potential to overlap.
Policies mandate HPWHs for single family homes,	Low	Leverage existing stakeholder relationships and program partners to understand the market's response.

Initiative Risk	Severity	Mitigation Approach
negating the need for an MTI.		Consult expert advice and recommendations from CalMTA program administrator and advisory board. Develop exit and/or transition strategy in the case that a Residential HPWH MTI is deemed no longer necessary.
Air quality board mandates drive market to less expensive, less efficient water heaters.	Low	Monitor market sales and supply chain experience and adjust plan accordingly. Socialize the risk to partners to encourage their program plans and budgets recognize potential risk.

9 Budget, timing, and expected results

Table 10 summarizes the budget estimate to complete the technology assessment, market research, and strategy pilot as described in Section 6.

Table 10. MTI Advancement Plan budget summary

Section	Estimated Cost $
Technology Assessment	
(1) Literature & Existing Data Review (Weeks 1-18)	$50,000
(2) Ongoing Expert Engagement (Weeks 15-35)	$ 50,000
(3) Energy Modeling & Engineering Calculations (Weeks 15-36)	$165,000
Market Research	
(1) Secondary Research and Data Analysis (Weeks 1-8)	$92,000
(2) Program Stakeholder + SME Interviews (Weeks 4-16)	$34,000
(3) Manufacturer Interviews (Weeks 12-18)	$29,000
(4) Market Actor and Customer Surveys and Journey Mapping (Weeks 12-40)	$228,000
(5) CA HPWH Collaboration Efforts and Summit(s) (Weeks 20-45)	$180,000
(6) HPWH Program Database Creation and Analysis (Weeks 20-60)	$89,000
Total	**$917,000**

Figure 2 in this section shows a rough timeline of this phase's activities to develop the MTI Plan.

Figure 2. Overall timeline/schedule of activities

Activity	Duration (Weeks)	Timeline (Months)														
Technology Assessment		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1) Literature & Existing Data Review	Weeks 1-18															
(2) Ongoing Expert Engagement	Weeks 15-35															
(3) Energy Modeling & Engineering Calculations	Weeks 15-36															
Market Research																
(1) Secondary Research and Data Analysis	Weeks 1-8															
(2) Program Stakeholder + SME Interviews	Weeks 4-16															
(3) Manufacturer Interviews	Weeks 12-18															
(4) Market Actor and Customer Surveys and Journey Mapping	Weeks 12-40															
(5) CA HPWH Collaboration Efforts and Summit(s)	Weeks 20-45															
(6) HPWH Program Database Creation and Analysis	Weeks 20-60															

Table 11 shows a rough estimate of the initiative should it advance to the Market Deployment phase and what the high-level estimates initiative results would be.

Table 11. Initiative market deployment budget & expected results

Initiative Cost ($)	>25 million	Meaningful movement in the HPWH market will require significant investment in technology, equity, and market readiness among other priorities.
Initiative Timeline (Years)	> 10 years	Given consumer's low interest in water heaters, high penetration of gas water heaters and increased cost and installation challenges, transforming the market will take time.
Expected Results	TSB: $3.099 billion TSB Energy: $272 million TSB Grid: -$45 million TSB GHG: $2.872 billion	Preliminary analysis shows that a Residential HPWH MTI could result in substantial emissions reduction, central to achieving state decarbonization goals.

*See Appendix A, Table A13. Stage 2 Preliminary Lifetime TSB Estimate – HPWHs.

About CalMTA

CalMTA is a program of the California Public Utilities Commission and is administered by Resource Innovations. We work to deliver cost-effective energy efficiency and decarbonization benefits to Californians through a unique approach called market transformation. Market transformation is the strategic process of intervening in a market to create lasting change by removing market barriers or exploiting opportunities, accelerating the adoption of identified technologies or practices. CalMTA-developed market transformation initiatives also aim to advance state goals on demand flexibility, workforce development and equity. Learn more at www.calmta.org.

Appendix A: Market forecasting and cost-effectiveness modeling approach

HEAT PUMP WATER HEATER

The information provided in this appendix summarizes the approach and methodologies used for the preliminary estimation of market adoption, total system benefit (TSB), and cost-effectiveness during Stage 2 scoring. The target markets, product definition, or other criteria may have shifted during the development of the advancement plan. The information contained in this appendix will be updated at the end of Phase II as part of the MTI Plan development to ensure the estimates better reflect the most current MTI design.

Market transformation initiatives (MTIs) generate energy savings and related benefits by accelerating and increasing market adoption of energy-efficient technologies and practices. Estimating the energy impacts and cost-effectiveness of MTIs requires developing a market forecasting model that uses a set of inputs based on well-documented sources, methods, and assumptions.

This appendix provides an overview of the technology and market characteristics of the MT idea involving the heat pump water heater (HPWH) as adopted in Stage 2 of the MTI lifecycle. The summary of model outputs covers the estimates of the benefits and cost-effectiveness of the MT idea. As we learn more about the market through additional research in Phase II of the MTI lifecycle, we will refine and update our approach and this document.

A.1 MTI overview

Table A1 summarizes the HPWH MT idea product definition and market characteristics adopted in Stage 2 of the MTI lifecycle. MTIs typically evolve over time based on market research and experience.

Table A1. MTI product definition and market characteristics

MTI Lifecycle Phase	Stage 2
Product Definition	A HPWH efficiently extracts heat from the surrounding air to warm water, providing high energy efficiency compared to traditional electric resistance or gas water heaters. In Stage 2, the product definition considered a unitary design, where the heat pump and water storage tank are seamlessly integrated into a single appliance. This streamlined approach simplifies installation and minimizes heat loss during water transfer.

Addressable Market Segments	Existing single-family homes, as defined by the EIA RECS 2020: homes either detached from any other house or attached to one or more other houses (e.g., duplex, row house, or townhome), built before 2025.[8]
Baseline Installation Conditions	Gas Water Heaters[9]

A.2 Adoption forecasting model

This section outlines the team's approach to forecasting the adoption of HPWHs from 2025 to 2045 in the addressable market segments in California's residential sector. To begin, we projected the BMA of the technology, which considers current and expected market trends, technological advancements, and regulatory factors, assuming no intervention by CalMTA. Next, we forecasted the total market adoption (TMA), which assumes interventions by CalMTA to address market barriers. Finally, the incremental adoption (TMA minus BMA) is input into analysis to estimate cost-effectiveness and TSB.

Inputs

Table A2 lists the key assumptions used to forecast the adoption of HPWH by the California residential sector.

Table A2. Assumptions used in forecasting model

Category	Variable	Assumptions	Notes
Forecasts of Units of MTI technology	Number of units of HPWH per household (ω)	2020: 1 2045: 1	Based on median ownership of water heaters in 2020 per EIA RECS 2020
	Effective Useful Life (EUL)	10 years*	California Electronic Technical Reference Manual
	Proportion of repeat buyers at end of life (RPR)	75%	
Timing of MTI Initiation, Rollout, and Impact Realization	Start year for initiation of CalMTA MTI	2025	
	Number of years for design and finalization of CalMTA initiatives	2	

[8] The Stage 2 analysis included existing single-family households. In Phase II, we will consider expanding the scope of the analysis to incorporate multi-family residences and potential adoption in the new construction segment.

[9] For simplicity, for the Stage 2 analysis, we considered only gas water heaters which were used by 87% of single-family homes in 2020 per EIA RECS 2020. In Phase II, we will also consider electric water heaters.

Annual market share of HPWH in the single-family residential water heater replacement market	2023	3%*	Based on ENERGY STAR sales data for the United States[10]
	2030	BMA: 33% TMA: 50%	
	2045	BMA: 45% TMA: 90%	

*We will review and update assumptions related to effective useful life (EUL) and base year market share in Phase II to reflect recent research.

The following sections discuss the sources and methods used to estimate product saturation, market size, and market growth (with and without the MTI).

Base-year population and saturation

The team used the EIA RECS 2020 (U.S. Energy Information Administration 2023) to develop estimates of the number of single-family households in California (Table A3). EIA calibrated the 2020 estimates with 2020 Decennial Census counts and 2019 American Community Survey estimates.

Table A3. EIA RECS 2020 estimated number and type of California households

	Single-Family Houses		
Description	Detached from any other house	Attached to one or more other houses (e.g., duplex or townhome)	Total households
Number of Households (millions)	7.58	0.98	8.56

For Stage 2 preliminary forecasts, we assumed that there was no growth in the number of households from 2020 to 2023.

Based on our analysis of EIA RECS 2020, we find that around 87% of the single-family households in California (7.1 million) have natural gas and propane water heaters, while around 12.6% have electric water heaters.

Vintage of current water heaters

Table A4 summarizes the base year saturation of water heaters in single-family households in California, disaggregated by vintage. The table is based on an analysis of EIA RECS 2020 data and informed the BMA and TMA estimates. These national estimates are for reference only.

[10] Unit Shipment and Sales Data. Energy Star. Undated. https://www.energystar.gov/partner_resources/products_partner_resources/brand-owner/unit-shipment-data/archives

Table A4. Main water heater age distribution in single-family households in 2020

Vintage Category of current Water Heater	Assumed Average Age in 2023	California		United States	
		# of single-family households (millions)	Proportion	# of single-family households (millions)	Proportion
Less than 2 years old	1 year	1.26	14.7%	13.48	16.0%
2 to 4 years old	3 years	1.44	16.8%	16.70	19.8%
5 to 9 years old	7 years	2.70	31.6%	25.47	30.1%
10 to 14 years old	12 years	1.86	21.8%	16.29	19.3%
15 to 19 years old	17 years	0.58	6.8%	6.93	8.2%
20 or more years old	22 years	0.71	8.3%	5.65	6.7%
Notes: Source: EIA RECS 2020 Question: "About how old is your main water heater? Your best estimate is fine." For simplicity, CalMTA only considered the "main" water heater and did not include additional water heaters owned by around 5.5% of single-family households in California.					

Methodology

To develop the preliminary Stage 2 forecast of the adoption of HPWHs, CalMTA developed a retirement schedule for existing water heaters in California based on their vintage and assumed EUL. Subsequently, we made assumptions about the proportion of households who will transition to HPWHs upon the retirement of their current water heater.

Baseline market adoption forecast

For the Phase I forecasting model, the following equation summarizes the team's approach to forecast the number of HPWHs adopted in any given year:

$$y_t = Retire_t^{BMA} \times \rho_t^{BMA} + y_{t-EUL} \times RPR \times \omega$$

Where:

y_t = annual adoption in t in terms of units of the MTI technology
$Retire_t^{BMA}$ = number of units of existing water heaters retired in year t in BMA
ρ_t^{BMA} = market share of the MTI technology in the replacement market in year t in BMA
RPR = repeat purchase rate of the MTI technology
EUL = expected useful life of the MTI technology in years
y_{t-EUL} = MTI technology adopted in year $(t - EUL)$ and retired in year t
ω = number of units of MTI technology per household

Retirement of current water heaters ($Retire_t^{BMA}$)

Instead of assuming that all water heaters of a given vintage are retired in a single year (see Table A5) employed a statistical distribution to model water heater retirement over several years. This approach assigns each vintage a retirement start year and a retirement end year, as shown in

Table A5. Within this timeframe, we assumed a uniform statistical distribution for retirements,[11] where the probability of a water heater from a specific vintage retiring is considered equal across each year between the start and end years. This statistical approach provides a more realistic representation of water heater retirement patterns compared to a single-year assumption. It acknowledges the variability in water heater lifespans and avoids an unrealistic "cliff effect," where all units retire at once. Using the average vintage in Table A5 and the assumed retirement schedule, we computed the average age at retirement for a given vintage.

Table A5. Assumptions for retirement schedule of current water heaters for BMA forecast

Vintage Category of current Water Heater	Retirement Start Year	Retirement End Year	Avg age at retirement completion
Less than 2 years old	2030	2047	17 years
2 to 4 years old	2028	2045	17 years
5 to 9 years old	2024	2041	17 years
10 to 14 years old	2023	2040	21 years
15 to 19 years old	2023	2030	21 years
20 or more years old	2023	2027	24 years

Replacement by HPWHs (ρ_t^{BMA})

CalMTA developed the following estimates of the annual market share of HPWHs in the market for water heater replacement by single-family households (Table A6).

Table A6. Assumed HPHW market share for BMA forecast

Year	Annual Market Share
2022	3%
2030	33%
2045	45%

The 2022 market share is based on ENERGY STAR-qualified product shipment data for HPWHs in 2022 for the entire United States.[12] In Phase II, we will use secondary research to refine estimates of the total market size for water heating in the residential sector in California.

The shares in 2030 and 2045 are the team's assumptions informed by current sales of HPWH in the residential markets in countries with strong government interventions to remove market

[11] The team considered a Weibull statistical distribution to model equipment retirement/phase-out to capture the nonlinear nature of failure rates over time. In Phase 2, we will revisit the approach used to model equipment failures.

[12] Unit Shipment and Sales Data. Energy Star. Undated. https://www.energystar.gov/partner_resources/products_partner_resources/brand-owner/unit-shipment-data/archives

barriers. Based on estimates of sales of HPWH to residential markets in France and Japan in 2021 by the European Commission (Lyons et al. 2022), and the team's assumptions of size of residential water heater market based on extrapolation of trends in the United States, it is estimated that HPWH have a share of around 10% in France and 29% in Japan.

The assumed annual shares were also informed by California's goal of installing 6 million heat pumps (both space conditioning and water heating) by 2030.[13,14] The assumed market share of HPWH to single-family homes in this report results in cumulative adoption of around 450,000 units (Figure A1 below) and an equivalent market saturation of 5% of single-family households in BMA. This assumption may be considered consistent with California's goal based on some simplifying assumptions of relative share of Heat Pumps in space conditioning and water heating market.

The assumptions were also informed by recent growth in sales of HPWH in the United States – from 52,000 units in 2016 to 104,000 units in 2020 - highlighting their potential.[15] The assumptions will be revisited in the next stage of the project.

In Phase II, we will revisit these assumptions based on inputs from subject matter experts and stakeholders and re-develop the Baseline Market Adoption forecast.

Total Market Adoption forecast

This section focuses on the Stage 2 adoption forecast for the MTI in California with targeted interventions to address market barriers and opportunities. While the specifics of these interventions remain undetermined, we considered the potential increase in adoption resulting from them. The forecasting methodology for TMA was consistent with the methodology used by the team to forecast BMA, and adoption in year t is written as follows:

$$y_t = Retire_t^{TMA} \times \rho_t^{TMA} + y_{t-EUL} \times RPR \times \omega$$

Where:

y_t = annual adoption in t in terms of units of the MTI technology

$Retire_t^{TMA}$ = number of units of existing water heaters retired in year t in TMA

ρ_t^{TMA} = market share of the MTI technology in the replacement market in year t in TMA

Other terms are as defined in the prior equation for BMA.

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[13] Governor's Letter to CARB. Office of the Governor of the State of California. July 22, 2022. https://www.gov.ca.gov/wp-content/uploads/2022/07/07.22.2022-Governors-Letter-to-CARB.pdf

[14] CEC 2022 IEPR: 2022 Integrated Energy Policy Report Update (ca.gov)

[15] Daigle, Brian and David, Andrew. Residential Heat Pump (Hybrid) Water Heater Market, Production, and Trade. Executive Briefings on Trade. United States International Trade Commission. February 2022. https://www.usitc.gov/publications/332/executive_briefings/ebot_residential_heat_pump_hybrid_water_heaters.pdf

The TMA forecast applies estimates of annual sales and assumptions similar to those used for the BMA forecast. However, inputs for the TMA forecast differ from BMA in two specific ways. First, we assume an accelerated retirement schedule for current water heaters (Table A7). Second, we expect that a higher proportion of households will adopt HPWHs instead of gas water heaters upon retirement of their current water heater (Table A8).

Retirement of current water heaters ($Retire_t^{TMA}$)

As shown in Table A7, based on the assumed retirement schedule, we computed the average age at retirement for a given vintage.

Table A7. Assumptions for retirement schedule of current water heaters for TMA forecast

Vintage Category of current Water Heater	Retirement Start Year	Retirement End Year	Avg age at retirement completion
Less than 2 years old	2030	2041	14 years
2 to 4 years old	2028	2039	14 years
5 to 9 years old	2024	2035	14 years
10 to 14 years old	2023	2034	18 years
15 to 19 years old	2023	2027	19 years
20 or more years old	2023	2027	24 years

Replacement by HPHWs (ρ_t^{TMA})

CalMTA developed the following preliminary estimates of the annual market share of HPWHs in the market for water heater replacement by single-family households (Table A8) for 2030 and 2045. We assumed linear interpolation for the intervening years.

Table A8. Assumed market share of HPWHs for forecast with MTI interventions

Year	Market Share with MTI Interventions
2022	3%
2030	50%
2045	90%

Similar to the BMA forecast, in Phase II, we will revisit these assumptions and re-develop the Market Adoption forecast.

Incremental Market Adoption (TMA – BMA)

Incremental market adoption in any given year is the difference between the number of units adopted in TMA and the number of units adopted in BMA.

$$y_t^{Incremental} = y_t^{TMA} - y_t^{BMA}$$

Where:

$y_t^{Incremental}$ = Incremental annual adoption in time t that may be attributed to CalMTA interventions.

Outputs

In this section, we summarize the preliminary BMA and TMA forecasts for existing single-family households. We used the following equation to estimate the cumulative adoption units:

$$\sum_{t=2025}^{2045} y_t^{BMA} \text{ and } \sum_{t=2025}^{2045} y_t^{TMA}$$

Baseline Market Adoption forecast

We forecasted a cumulative adoption of 2.9 million units by existing single-family households over the forecast horizon in the absence of CalMTA interventions. This forecast includes repeat sales of HPWH at the end of the life of the technology.

Total Market Adoption forecast

We forecasted a cumulative adoption of 5.1 million units by existing single-family households over the forecast horizon in the presence of CalMTA interventions.

Incremental adoption

We calculated incremental market adoption, in terms of number of units of the HPWHs, as the difference between TMA and BMA for 2.1 million units. Table A9 shows the incremental adoption as allocated to the baseline installation conditions.

Table A9. Stage 2 HPWH – incremental adoption

Segment	Technology	Baseline Condition	Incremental Market Adoption (Million Units of HPWHs)
Existing Single-Family	Heat Pump Water Heater	Gas Water Heater	2.12

A.3 Cost-Effectiveness Model

Evaluating cost-effectiveness and determining the net benefit for an MTI requires the appropriate application of the outputs from the market forecasting model, initiative costs, incremental measure cost (IMC), avoided cost, load shape, and unit energy impacts (UEI). This application of inputs considers the baseline installation conditions, baseline and efficient technologies, fuel types, target sector, and costs incurred by all stakeholders in the MTI implementation. Moreover, MTI costs and benefits change over time, due to factors such as EUL, regulatory policy, electricity and gas rates, and initiative funding.

Currently, California Energy Data and Reporting System's Cost-Effectiveness Tool (CET) is the official publicly available tool to evaluate energy efficiency programs in California. The CET can be used to evaluate programs from all utilities, and climate zones, using approved 8,760 load shapes, and defined avoided costs. However, since analysis for this MTI involved custom 8,760

load shapes not currently supported by CET[16], we developed an in-house Excel-based cost-effectiveness tool versatile enough to handle all the MTIs for CalMTA.

Inputs

The cost-effectiveness model uses the following inputs to assess cost-effectiveness and develop TSB estimates. TSB is a representation, in dollars on an annual basis, of the lifecycle energy, ancillary services, generation capacity, transmission and distribution capacity, and GHG benefits of the market transformation initiative. We applied the inputs according to the formulas listed in the Methodology section below.

Incremental adoption

We developed incremental market adoption of HPWHs for residential single-family households projected to replace their existing gas water heating equipment with HPWHs between 2025 and 2045. The MTI considered the existing equipment as shown in Table A10.

Table A10. Installation conditions

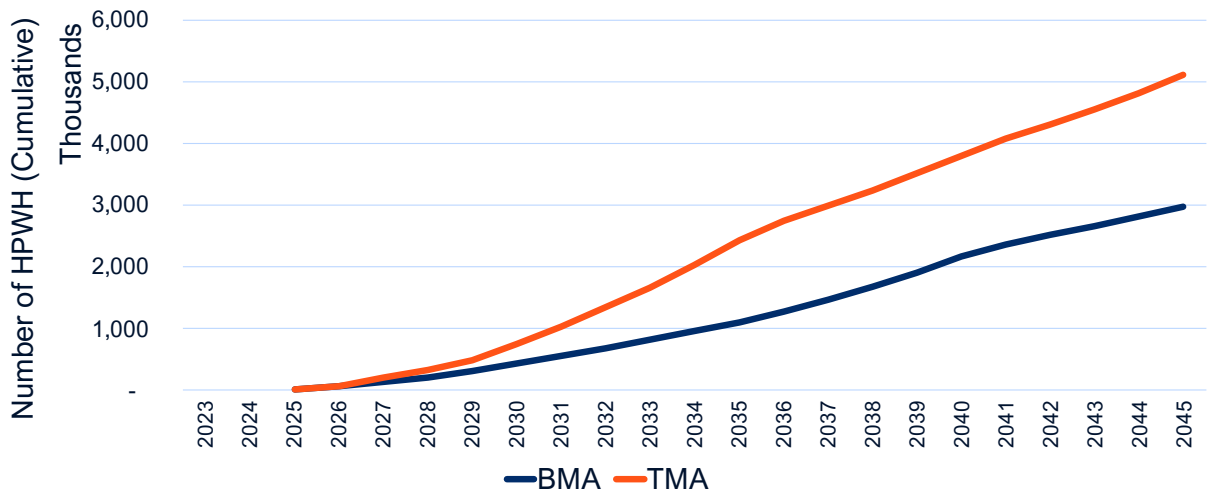
Sector	Decision Type	Baseline Equipment Types	Efficient equipment
Single-Family	Accelerated Replacement (AR), Normal Replacement (NR)	Gas water heater	Heat pump water heater with load-shift enabled

We applied incremental adoption to the MTI for the duration of the EUL of HPWHs. For example, if 80,000 units were projected to be installed in 2027, these units contributed to the model for 10 years (EUL for HPWHs), combined with HPWHs introduced in the following years. Figure A1 illustrates cumulative market adoption by year.[17]

[16] The CalMTA team used the CBECC-Res single family 80-gallon HPWH with Title 24 Joint Appendix (JA)13 enabled load shift capabilities to represent the MTI water heater prototype because it modeled load shift benefits of connected HPWH.

[17] For Phase II research, we will incorporate updated EUL values.

Figure A1. Cumulative adoption of HPWH by year



Initiative costs

Initiative costs are related to the implementation of the MTI. This includes flow-down incentives (FDI) and non-incentive costs, such as administration, research and evaluation, marketing, and other related costs. Initiative costs are applied over the length of the MTI from 2025 to 2045.[18] Initiative costs are used to determine the Total Resource Cost (TRC) test and Program Administrator Cost (PAC) test. In the PAC test, all initiative costs are included. Initiative costs are discounted to determine the net present value of the initiative.

Incremental Measure Cost

The team conducted secondary research to develop estimates of incremental costs. To determine these cost estimates, we researched currently available products for residential gas water heaters and HPWHs in California stores like Home Depot.

After determining the average costs for products currently in the market, we extrapolated the costs into future years by subtracting 2% of the first-year incremental cost from each subsequent year, to represent anticipated reduction in case costs relative to the baseline incremental cost. We assumed in Stage 2 that IMC would decrease over time due to economies of scale (that is, the price of the efficient technology becomes cheaper over time, as production volume increases) and move closer to the price of the baseline technology. The Stage 2 analysis also assumes that inflation would equally impact both the base and proposed cases and therefore did not update IMC estimates for inflation. In Phase II, we will conduct additional analysis to refine incremental cost estimates for the forecasting period. The IMC in the first year of adoption for households replacing gas water heaters with an HPWH was $912.

[18] Flow down incentives refer to incentives provided to midstream or upstream market actors that flow down to the customer and reduce customer costs.

The team included IMCs in the TRC test, along with non-FDI costs for each year and each installation condition. IMCs in the TRC test are discounted to determine the net present value of the initiative.

Avoided costs

Avoided costs are defined as the marginal costs that the state would avoid in any given hour through lower energy consumption. The electric avoided costs include cap and trade, GHG adder, GHG rebalancing, energy, generation capacity, transmission capacity, distribution capacity, ancillary services, losses, and methane leakage. The gas avoided costs include transmission and distribution, commodity, nitrogen oxides, carbon dioxide, and methane emissions.

The team developed avoided costs using the Avoided Cost Calculator (2022) for three utilities: Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E). We developed avoided costs based on a single HPWH for the installation condition from 2025 to 2052 in each utility's territory. Avoided costs include energy, grid, and GHG benefits for electric and gas fuels. Because the MTI will result in market impacts outside the IOU service territories, we also estimated avoided costs for "other" non-IOU territories.[19]

Avoided costs are used to determine the TSB, as well as TRC and PAC ratios. We applied avoided costs to the incremental adoption for PG&E, SCE, SDG&E, and "other" utilities for each installation condition in each year. We then summed and discounted these benefits to the first year of the MTI to determine the TSB. TSB is identical to the benefits used in TRC and PAC.

Load shape

Load shape is defined as the hourly probability of activity for the HPWH and is based on a set of variables including equipment runtimes, operating characteristics, and other factors, such as occupancy patterns. We developed the load shape using California's Building Energy Code Compliance Software (CBECC-Res) and applied it to the avoided costs and UEIs on an hourly basis for each year.

Unit Energy Impacts

The team developed annual consumption estimates for a gas water heater and a HPWH. We used single-family prototype to develop the baseline model (modeled in CBECC-Res 2022) with an

[19] Since the MTI is implemented for California as a whole, avoided costs for PG&E, SCE, and SDG&E only do not fully represent the entire state. For the Stage 2 (Phase I) analysis, we included a separate category, "other," to represent the other utilities in California, developed through population proportions and utility territory maps. Specifically, we overlayed the utility territory maps with county boundaries and assigned an appropriate proportion of the county's population to the respective utility. We developed avoided costs for the "other" category by applying population-weighted average avoided costs for the three utilities. After discussion with the CPUC, we agreed to remove benefits estimated for non-IOU territories from the Phase II cost-effectiveness calculations.

instantaneous gas water heater typical of new construction and replacement products used over the last decade. We then updated the model to use an 80-gallon HPWH with Title 24 Joint Appendix (JA) 13 enabled load shift capabilities, representing the proposed technology design. The average annual electric savings for the installation condition were -812 kWh per HPWH. Average annual gas savings were 107 therms for an average of $351.21 in total avoided cost across all cases.

Table A11. Unit Energy Impacts

Installation Condition	Average Annual Electric Savings	Average Annual Gas Savings
Single-Family Gas Water Heater	-811.82 kWh	107.47 therms

The team applied these UEIs to the load shape and avoided costs to determine the TSB generated by an HPWH adopted because of the MTI.

Methodology

The team took a systematic approach to developing the cost-effectiveness model that began by determining all the necessary model inputs and outputs for the MTI, further described below.

Determine input values

MTI cost-effectiveness inputs are broken down into six inputs: market adoption, UEIs, initiative costs, load shape, avoided costs using the 2022 ACC, and IMCs. Each of these inputs is developed using product and market definitions documented by the MTI team and must have consistent units of analysis. For example, MTIs can be defined in terms of a single unit of equipment, household, whole building, or square feet. All inputs must be developed accordingly and converted into the same units.

UEI inputs for Stage 2 consist of the three largest California utilities: PG&E, SCE, and SDG&E, and the "other" category representing other utilities in California. Therefore, each installation condition for any MTI has four sets of utility-specific UEIs. The model pairs UEI inputs with an 8,760 hourly load shape appropriate for each MTI technology that estimates how likely an end user will use the equipment in any given hour of the year.

All inputs must also be applied on a yearly basis, constrained by the EUL and the MTI lifetime. These inputs will be reviewed during Phase II and updated as appropriate. The Phase I analysis includes these EUL and lifetime assumptions for HPWHs:

- MTI lifetime = 20 years (2025 to 2045)
- EUL = 10 years

For incremental market adoption and initiative costs over the course of the MTI, we used three assumptions:

- 2025 and 2026 are initiative design years. Thus, incremental adoption begins in 2027.

- Though there is no incremental adoption in 2025 and 2026, the MTI is still operating; therefore, we allocate non-incentive related initiative costs to 2025 and 2026.
- For this MTI, there were no flow-down incentives.

Determine required outputs

After developing the inputs, the team developed and reported the outputs needed for cost-effectiveness. We applied a discount rate of 6% to discount outputs to the first year of the MTI to account for the time value of money. For the Phase II analysis, we will update this assumption and apply the discount rate based on the ACC. There are three outputs for reporting on the MTI: TSB, the TRC ratio, and the PAC. The team evaluated the TSB, TRC, and PAC for each of the two installation conditions for the MTI, determining the total for TSB, TRC, and PAC.

After collecting the required inputs and outputs, the team developed an Excel model that used all of the inputs, operated an hourly (8,760) based analysis, and reported the discounted values of both installation conditions and MTI-level TSB, TRC, and PAC.

Table A12 lists the terms (based on the CET) used by the Excel model to determine the TSB, TRC, and PAC.

Table A12. Cost-effectiveness model parameters

Terms	Description	Units
Terms	**Description**	**Units**
ElectricBenefits	Net Benefits generated through electric savings from ACC	Dollars/kWh & Dollars/kW and associated GHG avoided costs
GasBenefits	Net Benefits generated through gas savings from ACC	Dollars/Therms and associated GHG avoided costs
OtherBenefits	Benefits generated through non-electric or gas savings. Stage 2 analysis incorporated refrigerant benefits only.	Dollars per unit
NumberOfUnits	Incremental adoption	HPWHs
Net kWh	Net to Gross Ratio of the measure used to standardize other benefits to Electric and Gas benefits	NTG Ratio (Assumed to be 1 for this analysis)
MarketEffectsBenefits	Measure benefits generated through market forces	Dollarized Market Effects (assumed to be 0)
RefrigerantBenefits	Measure benefits generated through refrigerant savings	Dollars/unit
ElectricSupplyCost	Costs incurred in the supply of electricity	Dollars/kWh & Dollars/kW
GasSupplyCost	Costs incurred in the supply of gas	Dollars/Therms
MarketEffectsCosts	Costs incurred through market forces	Dollarized Market Costs (where present)

UnitRefrigerantCosts	Costs incurred through refrigerant losses. Stage 2 analysis incorporated refrigerant costs only.	Dollars/Unit
TRCCost	Costs associated with the TRC test	Dollars (Initiative Admin/Marketing/Evaluation and Incremental Measure Costs)
PACCost	Costs associated with the PAC test	Dollars (Initiative Admin/Marketing/Evaluation and Flow-Down Incentive Costs)

Total System Benefit

TSB is a function of the inputs described in earlier sections. For the HPWH MTI, we disaggregated TSB into three components: energy, grid, and GHG benefits (categorized as refrigerant and non-refrigerant). We used the following CET-based formula to determine TSB:

$$(ElectricBenefits + GasBenefits$$

$$+ NumberOfUnits * (Net\ kWh + MarketEffectsBenefits) * RefrigerantBenefits)$$

$$- (ElectricSupplyCost + GasSupplyCost$$

$$+ NumberOfUnits * (Net\ kWh + MarketEffectsCosts) * UnitRefrigerantCosts)$$

Cost-effectiveness ratios

Total Resource Cost

The TRC test compares the lifecycle benefits that the MTI will deliver to the costs associated with achieving those benefits from the perspective of the MTI administrator and the participant. Net benefits, initiative costs (not including FDIs), and IMC were used to determine TRC. The non-FDI initiative costs are summed together with the IMC and discounted in respect to the period of the MTI's implementation. The discounted net life cycle benefits for each installation condition are divided by the sum of the respective discounted IMC and non-FDI Initiative costs. This installation condition-specific TRC is weighted by its respective adoption total and summed with the other installation condition-specific TRC to determine the MTI TRC. Below is the CET-based formula used by the tool to determine TRC.

$$(ElectricBenefits + GasBenefits + OtherBenefits) / TRCCost$$

Program Administrator Cost

The PAC test compares the lifecycle benefits that the MTI will deliver to the costs associated with achieving those benefits from the perspective of the MTI administrator. Net benefits, and Initiative costs (including FDIs) were used to determine PAC. The initiative costs are discounted in respect to the period of the MTI's implementation. The discounted net life cycle benefits for each installation condition are divided by the sum of the initiative costs to determine PAC. This

installation condition specific PAC is weighted by their respective adoption totals and summed to determine the PAC. Below is the CET-based formula used by the tool to determine PAC.

$$(ElecBenefits + GasBenefits + OtherBenefits) / PACCost$$

Outputs

Total System Benefit (TSB)

Table A13 shows the preliminary TSB estimates, disaggregated for energy, grid, and GHG impacts.

Table A13. Stage 2 preliminary lifetime TSB estimate – HPWHs

Idea Name	TSB ($M)	Energy ($M)	Grid ($M)	GHG Non Refrigerant ($M)	GHG Refrigerant ($M)
Heat pump water heaters	3,099	272	-45	2,748	124

As shown in Table A13, the Phase I model estimates that this HPWH MTI will generate approximately $3.1 billion in lifetime TSB. The largest share of the benefit can be attributed to mitigated refrigerant and non-refrigerant GHG emissions, with an estimated $2.872 billion in TSB. The smallest share of the TSB is driven by negative grid benefits, with -$45 million in TSB. Finally, energy benefits driven by savings related to electricity and natural gas reductions generate nearly $272 million in lifetime TSB.

Cost-effectiveness ratios

The team developed preliminary TRC and PAC ratios of 2.19 and 81.48, respectively, for the MTI.

A.4 Phase II – Refined TSB and cost-effectiveness estimates

The CalMTA team will conduct additional market and technology research on HPWHs during Phase II of the MTI, as described in the Advancement Plan. Based on that research, we will refine TSB and cost-effectiveness estimates for the MTI. These refined estimates and their detailed methodology and assumptions will be included as part of the MTI Plan required for MTI advancement to Phase III. The MTI Plan will also include an evaluation plan and a data collection plan to support ongoing evaluation.

A.5 References consulted for Appendix A

Source #1. U.S. Energy Information Administration. Residential Energy Consumption Survey 2020 (RECS 2020): Consumption and expenditures technical documentation (Report No. DOE/EIA-0324(2020)). U.S. Department of Energy. 2023.

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