2024 Water Heating Technology Priority Map

Final Report

ET24SWE0010

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[1] Tim Minezaki is no longer with Energy Solutions, he is now at the San Francisco Public Utilities Commission, we thank him for the contributions to this Water Heating Technology Priority Map in 2024.

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Abbreviations, Acronyms, and Glossary Terms

Acronym	Meaning
ATWHPs	Air-to-Water Heat Pumps
CEC	California Energy Commission
CEC-EPIC	California Energy Commission - Electric Program Investment Charge
CPUC	California Public Utilities Commission
DER	Distributed Energy Resource
DOE	Department of Energy
DR	Demand Response
DWH	Domestic Water Heating
EE	Energy Efficiency
EPA	Environmental Product Agency
ET	Emerging Technology
ETCC	Emerging Technology Coordinating Council
FDAS	Flexible Demand Appliance Standards
FHR	First Hour Rating
GHG	Greenhouse Gas
GWP	Global Warming Potential
HP	Heat Pump
HPPH	Heat Pump Pool Heaters
HPWH	Heat Pump Water Heater
HVAC	Heating, Ventilation, and Air Conditioning
IDSM	Integrated Demand-Side Management
IOUs	Investor-Owned Utilities
kW	Kilowatts

Acronym	Meaning
MFHPs	Multi-Function Heat Pumps
NEB	Non-Energy Benefits
NEEA	Northwest Energy Efficiency Alliance
NEEP	Northeast Energy Efficiency Partnerships
PV	Photovoltaic
SB-49	California Senate Bill 49 (2019-2020): flexible appliance standards
SCE	Southern California Edison
SDG&E	San Diego Gas and Electric
SGIP	Self-Generation Incentive Program
SME	Subject Matter Expert
TAC	Technical Advisory Committee
TECH	Technology and Equipment for Clean Heating
TPM	Technology Priority Map
TSB	Total System Benefit
U.S.	United States
VRF	Variable Refrigerant Flow
WH	Water Heating

Glossary	Meaning
Technology Category	One of six broad technology categories (e.g. Whole Buildings, HVAC, Water Heating (WH), Plug Loads, Lighting, Process Loads).
Technology Family	Functional grouping that provides description of program role, opportunities, barriers.
Research Initiatives	New initiative in place of both subgroups and knowledge indices
Research Initiatives Key	Visual aid explaining if each research initiative is at a level of high understanding, research in progress, immediate needs, or future research needs.
High Understanding	Projects have run in this technology category, overall, the market is comfortable with this technology category, and it is well known.
Research In Progress	CalNEXT projects are currently running regarding this technology category.
Immediate Needs	There is a need to learn about this technology and there may not be any CalNEXT projects taking place at this time.
Future Research Needs	If the technology is not on the immediate horizon and requires further understanding and research before being fully developed.
Definitions	Narrative to provide additional clarification on the technology family scope.
Opportunities	Description of potential impacts and potential research areas.
Barriers	Description of key barriers and potential barriers research.
CalNEXT Role	Describes general level of engagement by CalNEXT SMEs. *Note: Roles will change as research is completed.*
Lead Collaborate Observe	“Lead” - CalNEXT expects to take on most or all of the work and cost burden. “Collaborate” – CalNEXT is interested in collaborating and co-funding projects. “Observe” – CalNEXT will track progress but encourage external programs to take lead in unlocking these opportunities.
CALNEXT Priority	Communicates expected level of focus by CalNEXT SMEs. *Note: Priorities will change as research is completed.*

Glossary	Meaning
High	“High” - CalNEXT SME team has highlighted this technology family as having high impacts within the Technology Category.
Medium	“Medium” - CalNEXT SME team determined this technology family has moderate overall impacts within the Technology Category.
Low	“Low” - CalNEXT SME team has highlighted this technology family as having low relative impacts within the Technology Category.

Introduction

The Technology Priority Maps (TPMs) provide the CalNEXT Program a framework to externally communicate priorities of the program, clearly define the central focus areas of the program, and assist with project screening. They will document the impact potential, programmatic research needs, and market readiness of all technology families across each of the end-use technology areas. The TPMs will drive product ideation and inform project selection. This Final Report covers the revision process for the 2024 Water Heating TPM.

2024 TPM Key Changes

Table 1 shows how content from the 2023 TPM technology families appears under new technology family headings. In this 2024 revision, there are instances where several 2023 technology families have been dispersed into various 2024 technology families, as shown below by the number of arrow pathways.

Table 1: Technology Priority Mapping

2023 TPM Technology Families		2024 TPM Technology Families
Residential-Duty Water Heaters		Unitary Electric Water Heaters and Single-Family Split Systems
Commercial-Duty Water Heaters		Residential Multifunction Heat Pumps
Alternative Design Strategies		Commercial Multifunction/Combination AWHPs
Pool Heaters & Residential Pool Pumps		Commercial Domestic Hot Water System Design
		Pool Heaters & Residential Pool Pumps
Considered under HVAC or Whole Building TPMs		Commercial Hydronic Heat pumps (cross-listed with HVAC)
Legend:	Major content overlap	Minor content overlap

The prior revision of the Water Heating TPM in 2022 included a significant reorganization of the technology families and subgroups to improve the clarity and reflect significant changes in the market landscape, compared with the time at which the previous TPM was developed. The 2023 Water Heating TPM revision aimed to improve the clarity of program priorities for prospective participants by making updates to the current technology families and adding new technology families as appropriate. The Water Heating category has undergone significant changes relative to that of other technology areas. Notable drivers include state-administered incentive programs targeting the heat pump market and the passage of the Inflation Reduction Act (IRA) of 2022, which continues to provide additional market support over the next decade in the form of tax credits. Additionally, the continued need for programs to transition to the Total System Benefit metric has implications for demand flexibility. These changes were reflected in different ways in the 2023 TPM update.

As for the 2024 TPM update, the CalNEXT Program Team built on existing processes for this TPM update. This year, the project team incorporated a stronger outreach push to ensure feedback, directly targeting deemed measure stakeholders from Southern California Edison (SCE), San Diego Gas & Electric (SDG&E), DNV, CLEAResult, California Market Transformation Administrator (CalMTA), and the California Technical Forum (Cal TF). The process this year started with the reformation of the Water Heating Technology Priority Map Subject Matter Expert (TPM SME) team, with representatives from each of the program team partners: VEIC, AESC, TRC, UC Davis, and Energy Solutions. The Water Heating SME team represents members that collectively support an aray of energy efficiency and integrated demand-side management (IDSM) programs, using technologies covered by the Water Heating TPM as well as members who support the California IOUs. The team met four times between February and April of 2024 to revise this draft Water Heating TPM. The SME team worked through a number of layout changes at the start of this revision process which can be seen below in the narratives of the Final Report. These visual changes will help stakeholders to quickly see the topics of highest interest and progress on each. The end goal is a simplified picture for the TPM that allows easier use and better connectedness across domains. For example, for the Unitary Electric Water Heaters initiative named “120V Residential” four icons indicate status in four areas. The first two—Performance Validation & Market Analysis—are technology-driven, and the next two—Measure Development & Program Development—are market-driven. These icons show progress for the research initiative across four stages: high understanding, research in progress, immediate needs, or future research needs. When a submitter or viewer views the table, the icons point to which type of projects are most needed. The changes provide a visual summary of the most important topics within a given technology family and record the current state of progress. To date, the majority of research projects take place within a handful of technology families, which was a large driver in how the technology families were chosen in 2024.

Table 2. Icons and their meanings

Icon	Meaning
	High Understanding
	Research In Progress
	Immediate Needs
	Future Research Need

One additional feature specific to this Water Heating TPM (and the HVAC TPM) is the development of two cross-listed technology families. This development was made to better orient and provide consistency between the two TPM categories and address an emergent system and design need: air-to-water heat pumps which can be deployed to provide both space conditioning needs normally under the HVAC TPM and domestic and service water heating needs found under the Water Heating TPM. The structure of these cross-listed topics was developed to ensure strong coordination among CalNEXT activities. Those two technology families are named: (1) residential multifunction heat pumps and (2) commercial hydronic heat pumps. These two technology families are structured slightly differently to account for the differing needs by market, as they differ in both size and complexity. Residential multifunction heat pumps are anticipated to be sold as a package of features (e.g. thermal storage, hydronic heating, cooling, hot water). That is contrasting with commercial systems, which appear heavily custom-engineered as a collection of components (heat recovery chillers, air-to-water heat pumps, service water controls, thermal storage) which need to be sized, integrated, and controlled together to support large-scale building electrification.

Overall, the changes made in this 2024 TPM aim to focus on increased technology transfer broadly across the portfolio, allowing the CalNEXT team to defined new measures of interest and illustrate its efforts to bring them to the portfolio. These changes should put greater focus on shorter-term activities, like measure packages to support expansion of the existing resource acquisition programs. Even for longer-term investments, the new visual format will provide more tactical guidance to what type of research is needed to better progress different technologies to the ultimate goal of portfolio savings.

Stakeholder Feedback

TPM Advisory Committee Outreach

The TPM Advisory Committee outreach began in April 2024. Stakeholder feedback was requested via email using a Word document of the technology family narratives that are listed below in Table 2. Any further stakeholder feedback conducted is incorporated in this Final Report.

Table 3: TPM Advisory Committee Outreach

Organization
2050 Partners
CalTF
CalMTA
CLEAResult
DNV
SCE
SDG&E

This outreach conducted allowed advisory members to provide candid feedback, providing written comments and suggestions via a collaborative Word document hosted on Microsoft SharePoint. Suggestions were reviewed by the TPM coordinator, the Water Heating SME team, and incorporated into the Revised 2024 Water Heating TPM section below. A detailed table of the changes made can be found in the Appendix of this report labeled, "Advisory Committee Feedback & Resolution Matrix."

Unitary Electric Water Heaters and Single-Family Systems

CalNEXT Role: Lead | CalNEXT Priority: High

Definition

Energy-efficient, load-shifting capable, electric HPWHs are designed to meet the hot water demands of residential households or small businesses. HPWHs pull heat from the surrounding environment and transfer it into the water inside the tank. HPWHs typically run off electricity and deliver hot water two to five times more efficiently than electric resistance, standard gas water heaters, or fossil fuel fired water heaters. Larger unitary systems such as 12 kW integrated heat pump water heaters for commercial applications are included.

Research Initiatives

Research Initiatives	Performance Validation	Market Analysis	Measure Development	Program Development
120V Residential	High Understanding	Immediate Needs	Immediate Needs	Immediate Needs
120V Commercial	Research In Progress	Research In Progress	Future Research Need	Future Research Need
240V Unitary	High Understanding	High Understanding	High Understanding	Immediate Needs
Split Systems and Small Form Factor	Immediate Needs	Immediate Needs	Immediate Needs	Immediate Needs
Low-GWP Refrigerant	Immediate Needs	Future Research Need	Future Research Need	Future Research Need
Connectivity & Load Shifting	Immediate Needs	Future Research Need	Immediate Needs	Future Research Need

KEY High Understanding   Research In Progress   Immediate Needs   Future Research Need

Opportunities

Storage HPWHs are a critical residential building decarbonization strategy, providing a cost-effective, electric water heating solution for load reduction and shifting peak during carbon intensive utility periods. There is enormous potential for load shifting and shaping, load management, and the resulting GHG reduction from shifting the heating schedule to times when the electricity grid has a lower marginal emissions rate and cost to operate.

Additional performance validation, measure and program development is necessary to accurately assess impacts and adoption pathways of split systems, 120V unitary, and solar-assisted models, as well as trends in upsizing storage capacity and utilization of integrated or master mixing valves. Standardization of first hour ratings for HPWHs and installer training regarding appropriate design and installation best practices to account for recovery rates of different HPWH solutions will be necessary to ensure satisfactory performance for all residential users.Significant gains have been made in developing best practices guides for the sizing and installation of HPWHs, however, additional research is required to assess design solutions and applications in common recirculation pump designs found in many California homes.

Shifting to low-GWP refrigerants (e.g., CO_2) offers increased performance, higher water storage temperature capabilities and other direct greenhouse gas (GHG) emission benefits to eliminate the impacts of refrigerant leakage. To support the market shift, new low-GWP performance validation, especially at higher storage temperatures, accompanied by mixing valves, will be necessary to inform updates to measure and program development.

Planned zero-emission regulations on residential water heaters in the Bay area and statewide are based on reducing indoor exposure to combustion gases to households. The assessment and attribution of non-energy benefits (NEBs) such as health impacts from air quality and the development of innovative solutions for increasing equitable access to HPWHs are important for supporting an accelerated transition away from gas water heaters.

Upfront cost is the most significant barrier to HPWH adoption in the most common opportunity, emergency water heater replacements. Identifying opportunities for cost-compression of equipment and installation costs is necessary for equitable and scalable HPWH market development. In addition, assessing existing and new, innovative financing mechanisms, deployment interventions and behavioral programs is critical to establish a sustainable and sufficiently capitalized incentive and that enable accelerated adoption of HPWHs.

Replacement of electric resistance WH (seven percent of the California market) and the new construction (NC) market offer the quickest opportunities for market adoption and total system benefit. Program designs that support electric resistance to HPWH incentives and approaches and NC builder approaches are needed to support these market sectors.

Barriers

HPWHs face many barriers but these barriers are mostly due to market and installation practices, not shortcomings in the technology itself. HPWHs have installation challenges and operational features not found in common gas storage alternatives that can make fuel-switching challenging:

1. Cost-effectiveness of HPWH fuel substitution can be impacted due to high HPWH equipment and installation costs, current electrical and gas tariff structure and/or grid integration incentives.
    1. Plumbing contractors generally lack awareness of HPWHs and expertise in the design and installation, including the disposal of condensate, adequate airflow, and venting to ensure proper performance.
2. Electrical service or panel upgrades can be a significant cost barrier and may need load management strategies or deployment of 120V products to mitigate the expense of an upgrade.

3. Emergency replacements are the most common scenario for a new water heater installation in existing homes, which creates immediate cost, time and complexity barriers to conversion from conventional gas water heaters. Permitting processes and a need for a separate electrical contractor adds significant cost increases and delays in hot water restoration for the customer.
4. Split-incentive issues between property owners and rental ratepayers complicate the costs and benefits of HPWHs.
5. Space and noise issues can undermine the suitability of unitary HPWHs, requiring a smaller form factor or split designs or relocation.
6. The introduction of new low-GWP natural refrigerants will require reevaluating their performance, as well as addressing permitting barriers and perceptions of safety risks with local inspectors.
7. There is an absence of a savings claims infrastructure, including eTRM load shapes, rules for quantifying load shape benefits, rules for viable electric alternative (VEA) measures to replace gas appliances, and the coordination on refrigerant leak reduction efforts.

Related CalNEXT Projects

- Small Medium Business HPWH Emergency Deployments
- ET23SWE0020 - Emergency Replacement Heat Pump Water Heater Market Study
- ET23SWE0035 - Residential HPWH Market Study and Measure Gap Analysis
- ET23SWE0075 - HPWH Conversion Readiness Program Focused Pilot
- ET23SWE0074 - Plug-in HPWH Measure Package Updates to eTRM
- ET22SWE0056 - Increasing Heat Pump Water Heater Deployment
- ET22SWE0036 - Residential Water Heater Sizing Measure Package Support

Resources & Links

- CalNEXT projects were the main resources referenced in the development of this technology family work.

Commercial Domestic Hot Water System Design

CalNEXT Role: Lead | CalNEXT Priority: High

Definition

Domestic water heating (DHW) is among the largest end-uses poised for decarbonization. With all-electric heat pump water heater (HPWH) options, HPWHs have a higher efficiency than electric resistance alternatives and can achieve dramatic energy and greenhouse gas (GHG) savings, compared with natural gas alternatives. This group covers efficient, demand-flexible non-unitary DHW systems for non-residential applications (such as offices, hotels, healthcare, and food service) and multi-family applications. Hot water systems under this group may include a primary heat generation (e.g. heat pump), storage, distribution, pumping, valves, controls, temperature maintenance systems, heat recovery, and alternative heat sources (e.g. solar or geothermal).

Research Initiatives

Research Initiatives	Performance Validation	Market Analysis	Measure Development	Program Development
Split HPWH	Immediate Needs	Immediate Needs	Future Research Need	Future Research Need
Unitary HPWH	Immediate Needs	Immediate Needs	Future Research Need	Research In Progress
Load Flexibility Controls	Research In Progress	Research In Progress	Immediate Needs	Future Research Need
Dual Fuel Systems	Immediate Needs	Immediate Needs	Future Research Need	Future Research Need
Distribution System Optimization	Research In Progress	Immediate Needs	Immediate Needs	Future Research Need
Heat Recovery	Immediate Needs	Immediate Needs	Future Research Need	Future Research Need

KEY High Understanding | Research In Progress | Immediate Needs | Future Research Need

Opportunities

There are many different important targets of research, development, and market transformation across different technologies, designs, and market segments within this group, each with their own needs. These projects could be executed as field demonstrations, technology development, lab studies, market studies, modeling, market transformation tools, or novel program delivery mechanisms. The state of understanding and research needs may differ, based on design configuration (e.g. integrated, split, central, clustered), segment (e.g. education, hospitality, healthcare, office, food service, multifamily), or building vintage (i.e. new construction or retrofit).

Prospective studies may focus on:

1. Reducing DHW system energy use and improving efficiency, designing without backup or temperature maintenance electric resistance (such as return-to-primary configurations), and reducing the complexity of all-electric centralized HPWHs.
2. Innovative program designs that can bring benefits of HPWHs to disadvantaged communities.
3. Developing incentive programs for medium and large low-GWP commercial HPWH in non-residential and multi-family buildings. Innovative program designs to ensure the multiple value-streams of efficiency, decarbonization, and grid-integration are all actualized.
4. Demonstration of overseas HPWH technologies that use new low-GWP refrigerants and other form factors such as low-GWP integrated HPWH or 20 to 30-gallon integrated HPWHs for distributed point-of-use applications.
5. Installed cost and space requirements compression of HPWHs and storage tanks.
6. Field assessments and design of dual-fuel water heating systems to address the needs of high-load, rapid-recovery applications, such as existing commercial kitchens, relegating existing gas water heaters to back-up, trim, boost, or secondary to a primary HPWH.
7. Demonstration projects that utilize the cold air by-product of air-source HPs to supplementally cool conditioned spaces.
8. Demand flexibility controls demonstration and implementation guidance. Optimization of load flexibility controls to minimize energy costs and GHG emissions. Recommendations for streamlined onboard load shift programming for HPWH systems.
9. Automated, algorithmic load shift controls based on input parameters such as monitored system operation, system capacity, hot water loads, total building coincident electrical demand, and utility rates (real-time or fixed time-of-use).
10. New unitary commercial HPWH designs above12 kW that offer more versatility for application in existing buildings with features such as ducting options, additional operating modes that fully lock out the electric resistance operating mode for use upstream of existing heater, and integrated controls to optimize usage, cost, and GHG, based on time-of-use factors such as peak rate periods and utility flex alerts.
11. Bringing clarity to designers for cost-effective scenarios for drain water heat recovery and using recovered heat as a heat source reservoir for the heat pumps.
12. Incorporating integrated exhaust air or refrigerant heat recovery systems at the water heater or point-of-use equipment location.
13. Optimizing distribution systems through novel recirculation and load-matching control strategies such as automatic balancing valves, combined optimization of temperature modulation, variable speed pumps with integrated constant return temperature control or occupancy-based inputs, distributed isolating valves, and pipe insulation. Distribution system optimization will not only reduce the operating costs and energy consumption, but also reduce the necessary HPWH system size or temperature maintenance components.
14. Incorporating high-performance master mixing valves to increase thermal storage capacity and utilization, increase the tank water temperature stratification with continuous recirculation systems, and reduce recirculation loop heat losses through precise temperature control.

15. Innovative program pathways and strategies for supporting the remediation and upgrades of existing, recirculating DHW distributions systems (e.g. pipe insulation, pipe hangers, shower crossover repair, balancing, pump controls, etc.).
16. Improving system efficiency through clustered centralized systems that reduce pipe heat losses and improve water heater efficiency versus one large, centralized water heating and distribution system.
17. Enhancing energy density and load matching of solar thermal and photovoltaic (PV)-assisted water heater designs.
18. Increasing thermal energy storage density by using phase change materials for increasing renewable energy penetration and load flexibility.
19. Development of alternative techniques to mitigate legionella risk, enabling additional use cases for HPWH systems.
20. Innovative utility rate structures or dedicated metering to facilitate decarbonization by mitigating operating cost burdens on building owners.

Barriers

Commercial-HPWH systems are still in a nascent technological stage that continues to evolve. Existing gas-fired hot water systems comprise 85 percent of the installed base of commercial water heaters. Physical space, electrical infrastructure, and installed costs are major upfront barriers that have slowed HPWH adoption in retrofit non-residential and multifamily applications. Of particular concern are escalating operating costs and affordability, as the electricity-to-gas cost ratio per unit of energy is approaching 8:1, significantly higher than recent years. Other limitations include product availability of low-GWP four-season heat pumps, weight, and noise. Manufacturers and distributors have started to address the barriers of design complexity, installation, and commissioning through the development of factory-built and commissioned skid and packaged systems that can be scaled for a range of applications.

Researchers and design firms have developed better sizing tools to right size heat pumps for mitigating cost and space requirements in multi-family buildings, but similar tools are needed for many other commercial HPWH applications. Current health department sizing requirements do not address the use of HPWH systems in commercial kitchens and do not account for storage volume as a factor in sizing water heater capacities. Recirculation systems, although important to improve hot water delivery time and minimize water waste, can heavily impact water heater performance in central multi-family and commercial buildings. New programs have only begun to scratch the surface of addressing barriers to adopting commercial HPWHs.

Barriers to be addressed include:

1. Lack of diverse commercial-duty integrated heat pump products such as 120 to 200-gallon 120V HP HPWHs.
2. Lack of field performance data of various designs, configurations, and applications (including system reliability and cost-effectiveness).
3. Lack of easy-to-access case studies that span the diversity of buildings with commercial HPWHs (120V integrated, 240V hybrid integrated, indirect central HPWHs, and combined with complementing distribution strategies including point-of-use heaters, heat recovery, master mixing valves, balancing, etc.).

4. Regulatory barriers to R290 HPWH development and adoption.
5. Lack of statewide incentive programs for medium and large commercial HPWHs for businesses.
6. Lack of design tools to select, appropriately size, and model HPWHs outside of multifamily applications.
7. Minimal documentation and empirically determined hot water load profiles for various non-residential building types, important for developing sizing tools, design guidance, and regulatory updates.
8. Ways to streamline electrical panel upgrades to support HPWHs or using alternative technologies to minimize or eliminate the need for upgrades.
9. Lack of HPWH familiarity for building permitting authorities (and health departments).
10. Lack of coordination between trades (e.g., engineering design, electrical, and plumbing).
11. Lack of sector-specific knowledge in implementing HPWHs in disadvantaged communities (multi-family housing).
12. Changes in the tariff structure and/or grid integration incentives to mitigate cost-effectiveness concerns.
13. Lack of code readiness activities to support electric ready code requirements for all non-residential building types that utilize commercial water heaters.
14. Lack of demonstration, guidance, and simplified implementation procedures of dependable demand flexibility and load shifting controls.
15. Lack of trusted distribution system software tools and design guides.
16. Lack of trusted software tools and design guides to simplify solar hot water system designs.
17. Lack of consistency among code requirements related to hot water setpoint temperatures.
18. Lack of experience deploying drain water heat recovery, particularly with the variety of potential heat sources.
19. Lack of experienced practitioners who can bring quality commercial-HPWH systems to building owners.
20. Potential degradation of energy efficiency with improperly designed recirculation systems for large HPWHs.

Related CalNEXT Projects

- ET22SWE0017 - Commercial and Multifamily CO2 Heat Pump Water Heater Market Study and Field Demonstration
- ET22SWE0019 - Market Potential for Heat Pump Assisted Hot Water Systems in Foodservice Facilities
- ET22SWE0048 - Commercial Kitchen Hot Water System Design Guide
- ET22SWE0028 - Packaged Central CO2 Heat Pump Water Heater Multifamily Demonstration
- ET22SWE0046 - Restaurant Field Monitoring
- ET22SWE0047 - Master Mixing Valve Field Study

- ET24SWE0017 - Small Medium Business HPWH Emergency Deployments
- ET23SWE0057 - Overcoming Key Barriers to Electrification of Foodservice Hot Water in California
- ET23SWE0059 - CHPWH Unpressurized Storage Design Optimization
- ET24SWE0027 - Characterization of Central Heat Pump Water Heating Deployment in the Multifamily Market
- ET24SWE0029 - Multifamily Central Heat Pump Water Heater Field Study
- ET24SWE0030 - Central Heat Pump Water Heating Control Optimization

Resources & Links

- CalFlexHub - The California Load Flexibility Research and Development Hub (LBNL)
- EcoSizer - Commercial and Multifamily Building Sizing Tool (Ecotope)

Residential Multifunction Heat Pumps (cross-listed with the HVAC TPM)

CalNEXT Role: Lead | CalNEXT Priority: Medium

Definition

Residential multifunction heat pumps (MFHPs) use an efficient compressor system to serve both the space conditioning and water heating requirements of a household, typically configured as a primarily hydronic system. MFHPs can come in multiple formats: two-function, or combination heat pump systems, which serve space heating and water heating demands, and three-function MFHPs, which provide space cooling in addition.

Research Initiatives

Research Initiatives	Performance Validation	Market Analysis	Measure Development	Program Development
2-function: Water Heating & Space Heating	Research In Progress	Research In Progress	High Understanding	Immediate Needs
3-function: Hot Water, Space Heating & Space Cooling	Research In Progress	Research In Progress	High Understanding	Immediate Needs
Selection Guidelines	Immediate Needs	Immediate Needs	Future Research Need	Future Research Need

KEY High Understanding Research In Progress Immediate Needs Future Research Need

Opportunities

Residential MFHPs offer a novel pathway to decarbonization, providing an efficient alternative to existing gas fired equipment or to an arrangement of multiple heat pumps (HPWH and a packaged central heat pump). MFHPs can potentially replace space heating, space cooling, and water heating with a single system, depending on the configuration and design. MFHPs have the potential to provide much higher total system benefits, by extending the benefits of thermal storage to space heating (and potentially space cooling). In addition, the single heat pump may free up a home's electrical panel capacity for other electrification uses and could be deployed with lower overall refrigerants than current heat pump practices.

MFHPs are relatively new to the US market, and, as a result, there are many opportunities to improve the understanding of their performance and impact on the residential sector. Opportunities for research include:

1. Laboratory testing of MFHPs to evaluate system performance in various applications.
2. Field demonstration/performance validation of MFHPs in new construction and existing building applications.

3. Market assessments of MFHP for California homes, including cost and requirements associated with an MFHP installation in new construction and existing buildings.
4. Assessing the potential TSB value of MFHPs (energy performance, demand flexibility, fuel substitution, and refrigerant emissions) compared with the efficiency of a single-function separate heat pump, HVAC, and water heating equipment.
    21. Assessing the bill impacts and customer economics of MFHPs (such as total costs of operation, operating costs under current rate structures, and increased value of load shed), compared with the efficiency of a single-function separate heat pump, HVAC, and water heating equipment.
5. Development of modeling tools to compare various MFHP types and guide program development and/or support early adopting market actors.
6. Assessing the workforce needs related to upselling practices to customers, comfort level of installation, and maintenance needs.
7. Validating customer comfort expectations and ensuring that proper hot water temperature and space temperatures can be met.

Barriers

As an emerging technology in the US market, there are many barriers to MFHP adoption that may be addressed. Understanding the performance of MFHPs in the context of US homes, the development of testing and installation standards, and the development of equipment selection guidelines are all necessary for understanding the efficacy of MFHPs in meeting California's decarbonization goals and encouraging MFHP use in California. Specific barriers include:

1. Absence of standardized testing procedures for MFHP evaluation.
2. Lack of MFHP product offerings compared to international markets, particularly those where hydronic heating is common.
3. Limited understanding of the capabilities of the MFHP system in managing occupant thermal comfort.
4. Absence of a standardized installation procedure and contractor/installer knowledge.
5. Absence of understanding of the efficiency of MFHPs compared to independent systems.
6. Need for a market assessment of MFHP for California homes, including the cost and requirements associated with new construction and retrofits.
7. Absence of MFHP modeling/design tools.

Related CalNEXT Projects

- ET22SWE0021 - Residential multi-function heat pumps: Product search
- Field assessment of residential three function heat pump performance
- ET22SWE0051 - Residential multi-function heat pump - heat exchanger improvement project
- ET23SWE0047 - 2023 Residential Multi-Function Heat Pump - Laboratory Testing
- ET23SWE0066 - 2023 Multi-Function Heat Pump - Lab Test Variable Speed
- ET24SWE0020 - Demonstration of "Combi" Air-To-Water Heat Pump

- ET22SWE0050 - Tech Evaluation of Air-to-Water Heat Pumps

Resources & Links

- CalFlexHub - Integrated Heat Pump for Residential HVAC and DHW with Hot Water Storage (Villara)

Commercial Multifunction/Combination AWHPs

CalNEXT Role: Lead | CalNEXT Priority: Medium

Definition

Commercial multifunction AWHPs serve water heating and space conditioning needs for multifamily or non-residential buildings. This multifunction category includes combination AWHPs that provide DHW and space heating only, as well as systems that provide space cooling. These systems use refrigerant to move thermal energy in air-to-hydronic distribution systems. They typically can provide two or three functions simultaneously.

Research Initiatives

Research Initiatives	Performance Validation	Market Analysis	Measure Development	Program Development
Combination: DHW and Space Heating	Immediate Needs	Immediate Needs	Future Research Need	Future Research Need
Two Function: DHW and Space Cooling	Immediate Needs	Immediate Needs	Future Research Need	Future Research Need
Multifunction: DHW, Space Heating and Cooling	Immediate Needs	Immediate Needs	Future Research Need	Future Research Need
Sizing Methodology	Immediate Needs	Future Research Need	Future Research Need	Future Research Need
Modeling and Software Tool Development	Immediate Needs	Future Research Need	Future Research Need	Future Research Need
Test Method Development	Immediate Needs	Immediate Needs	Future Research Need	Future Research Need

KEY High Understanding | Research In Progress | Immediate Needs | Future Research Need

Opportunities

Multifunction AWHPs that can provide multiple hydronic services to a building can address efficiency and decarbonization market needs across the California multifamily and non-residential sectors. Opportunities for emerging technology research include:

1. Laboratory applications testing and field demonstration of various multifunction AWHP systems in new construction and existing buildings.
2. Sizing tool development based on building load inputs and development of multifunction AWHP performance maps.

3. Modeling and software tool development to be validated with laboratory and field demonstration data.
4. Assessment of electrical infrastructure impacts, especially in retrofit applications. Will multifunction hydronic heat pumps reduce the need for electrical service or panel upgrades when decarbonizing existing buildings? Can a multifunction hydronic heat pump use existing chiller electrical service?
5. Studies on retrofitting existing buildings with variable flow refrigerant systems with multifunction hydronic heat pumps. In applications where VRF systems are failing, multifunction hydronic heat pumps may be a cost-effective decarbonization solution with lower refrigerant charges.
6. Assessment of benefits in space, cost, energy, peak power and GHG emissions, relative to decarbonization solutions that rely on separate heat pumps for DHW, cooling, and heating.
7. Thermal energy storage integration and quantification of the amount of energy available for load flexibility.

Barriers

There are several barriers to multifunction AWHPs that could be addressed through emerging technology efforts:

1. Manufacturers, researchers, programs, and regulators need standardized test methods of combination and multifunction HPs with native controls that mimic real world conditions and operation for all products and all configurations.
2. Multifunction AWHP efficiency may not be as high as separate heat pumps for DHW, cooling, and heating. This requires improved understanding of how controls, heat recovery, and system design can increase efficiency in AWHPs that simultaneously heat and cool.
3. Impacts on occupant comfort are not known. This requires improved understanding of controls, capacity, and system design that can maintain occupant thermal comfort (e.g. determining whether simultaneous water heating and space heating loads being met).
4. Multifunction AWHP technologies are more popular in international markets, particularly those in which hydronic heating prevails. More research is needed to understand and address the barriers to entry in the US market.
5. Load flexibility of multifunction AWHPs has not been explored. Controls that incorporate function switching, thermal energy storage (dedicated or DHW volume), and load up/shed require modeling, development, and testing.
6. Early adopter approaches are often custom-engineered, site-built systems. Packaged designs are needed for design, equipment, installation, and commissioning cost compression.

Related CalNEXT Projects

- ET23SWE0059 - CHPWH Unpressurized Storage Design Optimization
- ET24SWE0029 - Multifamily Central Heat Pump Water Heater Field Study
- ET24SWE0027 - Characterization of Central Heat Pump Water Heating Deployment in the Multifamily Market
- ET22SWE0017 - Commercial and MF CO2 based Heat Pump Water Heater Market Study and Field Demonstration
- ET22SWE0028 - Packaged Central CO2 Heat Pump Water Heater Multifamily Demonstration

Resources & Links

- CalNEXT projects were the main resources referenced in the development of this technology family work.

Commercial Hydronic Heat pumps (cross-listed with the HVAC TPM)

CalNEXT Role: Lead | CalNEXT Priority: Medium[2]

Definition

Commercial hydronic heat pumps serve space conditioning and service water needs for multifamily or non-residential buildings with large heating needs, such as a commercial kitchen or a large office building. These may be air-to-water heat pumps (AWHP) designed as boiler replacements or water-to-water heat pumps, such as heat recovery chillers, which can provide partial heating and cooling for facilities with simultaneous loads. This technology family is focused on advancements of the product itself.

Note: This technology family will not focus on the holistic system design or interoperability with other large components, which are spread across several technology families.

Research Initiatives

Key Initiatives	Performance Validation	Market Analysis	Measure Development	Program Development
Heat Recovery Chiller	Immediate Needs	Research In Progress	Research In Progress	Future Research Need
Air-to-Water Heat Pumps	Immediate Needs	Research In Progress	Research In Progress	Future Research Need
Software tool development to support product specification	Immediate Needs	Research In Progress	Immediate Needs	Future Research Need
Test Method Development & Validation	Immediate Needs	Research In Progress	Immediate Needs	Future Research Need

KEY High Understanding Research In Progress Immediate Needs Future Research Need

Opportunities

Hydronic heat pumps can provide multiple hydronic services to a building to address efficiency and decarbonization market needs across the California multifamily and non-residential sectors. Opportunities for emerging technology research include:

1. Laboratory applications testing and field demonstration of various multifunction AWHP systems in new construction and existing buildings.

[2] The Water Heating SME team would like to note that this is seen as a lower priority within the Water Heating TPM and has a heavier HVAC focus.

2. Measure development for heat recovery chillers and AWHPs to support partial or complete fuel substitution in large buildings.

3. Conducting cost benefit analysis of retrofitting existing buildings with VRF with hydronic systems.

Barriers

There are a number of barriers to hydronic heat pumps that could be addressed through emerging technology efforts:

1. While manufacturers have developed test procedures under AHRI 550/590, this test procedure has not been adopted by mandatory standards or voluntary standards, which limits the broad reach needed for this market adoption.

2. Load flexibility of multifunction AWHPs has not been explored. Controls that incorporate function switching, thermal energy storage (dedicated or DHW volume), and load up/shed all require data, modeling, development, and testing.

3. Early adopter approaches are often custom-engineered, site-built systems. Packaged designs are needed for design, equipment, installation, and commissioning cost compression.

Related CalNEXT Projects

- ET23SWE0028 - Market Characterization of Ultra-Low GWP Space Conditioning Heat Pumps for Commercial Buildings

- ET23SWE0048 - Commercial Air-to-Water HP Market Study

Resources & Links

- AHRI 550/590: 2023 Standard for Performance Rating of Water-chilling and Heat Pump Water-heating Packages Using the Vapor Compression Cycle

Pool Heaters and Residential Pool Pumps

CalNEXT Role: Lead | CalNEXT Priority: Low

Definition

Electric pool heaters for residential and non-residential pool markets; pool pumps and pool controls designed for the residential and non-residential pool market to increase efficiency, performance, and enable load shifting; and alternative strategies for pool heating and maintenance. The technology family will help support the development of all-electric codes and ease pool heating loads to improve grid resiliency.

Research Initiatives

Research Initiatives	Performance Validation	Market Analysis	Measure Development	Program Development
Hot Tub Heat Pump Pool Heater	Future Research Need	Future Research Need	Future Research Need	Future Research Need
Residential Heat Pump Pool Heaters	Future Research Need	Future Research Need	Future Research Need	Future Research Need
Commercial Heat Pump Pool Heaters	Future Research Need	Future Research Need	Immediate Needs	Future Research Need
Commercial Variable Speed Pool Pumping	Future Research Need	Future Research Need	Future Research Need	Future Research Need

KEY High Understanding Research In Progress Immediate Needs Future Research Need

Opportunities

Opportunities in this technology family will increase the efficiency with optimized equipment and designs, including optimized electrification of pool heating loads, pool operation controls and the incorporation of load shifting of electric pool loads. Prospective ET studies should include controls solutions, design guides, or demonstrations that address:

1. Projects that demonstrate the emergence of new technical innovations, such as smart controls, variable speed, hybrid units, low-temperature operability, and staggered start-up capability with heat pump pool heaters (HPPHs).
2. Projects that demonstrate electrification of pool heating loads as part of home electrification service assistance. Projects may include those that have homes with photovoltaic (PV) solar or plans for PV to be installed soon.
3. Projects that encourage HPPH or solar-assisted HPPH adoption in new home construction or newly constructed pools.

4. Innovative pool cover projects that encourage the consistent use of pool covers to enable the wider adoption of HPPH. Project could include novel methods to reduce the installation and maintenance costs of automated pool covers.
5. Innovative projects to address electrical system requirements when the existing pool heater uses natural gas.
6. Innovative applications of HPPH to provide heating to inground spas. Projects that demonstrate the utility of hybrid HPPH to provide spontaneous heating.
7. Innovative projects to demonstrate ability of electrical system to accommodate startup surges due to HPPH compressor operations. Accommodation of other emergent loads on the home electrical system such as heat pump and electric car charging.
8. Projects that demonstrate the load shifting potential for both pool heating and pumping in coordination with proposed flexible demand appliance regulations by the CEC.

Barriers

HPPH installation face opposition where high electric rates discourage the adoption of electric heating.

HPPHs lose heating capacity as temperatures decrease. While not a concern for spring, summer, and fall heating seasons, many climate zones within California present challenges to economical heating from HPPHs during the winter months, due to an increased heating load and decreased heating capacity.

Alternative hot water design strategies are an important approach to decarbonize many “hard-to-electrify” water heating scenarios. Emerging technology investments in this technology family can help bring greater awareness and highlight alternative decarbonization pathways.

Potential barriers studies should address:

1. Inconsistent design software
2. Ongoing practice to oversize heaters and pumps
3. Learning curve on pool heating operation with a HPPH, versus a gas-fired pool heater regarding set back temperatures.
4. Limitations based on health code requirements
5. Roof space for solar thermal competing with PV

Related CalNEXT Projects

- No previous CalNEXT projects found.

Resources & Links

- 2025 California Energy Code Swimming Pool and Spa Heating Final CASE Report.
- 2022 Cost-Effectiveness Study: All Electric and Solar Thermal Pool Heating
- Pool Heat Pump Design Strategies and Bay Area Resources
- A Pocket Guide to All Electric Retrofits of Single-Family Homes
- California Heat Pump Residential Market Characterization and Baseline Study

- CASE report
- The Reach Code report.
- Rudd heat pump pool heater
- CPUC Heat Pump market study
- Redwood energy report

Discussion

Following submittal of the 2024 Water Heating TPM, the Program Team will do the following:

- Update CalNEXT website with new 2024 Water Heating TPM.
- Launch email announcement through email outreach.
- Develop and submit Distribution Report.

Appendix A: Advisory Committee Feedback & Resolution Matrix (Incorporated in the Draft Report)

Table 4: Advisory Committee Feedback & Resolution Matrix

Technology Family	Section	Suggestion or Comment	Action Taken & Justification
All	Abbreviations, Acronyms, and Glossary Terms	Is this a universal list that will be kept as-is or modified for the final report?	No Action taken. These lists endeavor to include all acronyms used in this report or commonly used for water heating, as well as any concepts important for the TPM process, and suggestions are welcome.
All	2024 TPM Key Changes	Clarify if there was any engagement with Building Electrification/other fuel substitution measure stakeholders at SCE Other IOU engagement?	Yes, Technical Advisory Committee invitees included key IOU Building Electrification stakeholders. We welcome names of additional stakeholders for future outreach.
Unitary Electric Water Heaters and Single-Family Split Systems	Technology Family	Spilt System Water Heaters?	These are residential products that locate the heat pump/heat exchangers in a separate unit from the hot water storage tank. Removed “split” from family header but kept this term in the body of the section.
Unitary Electric Water Heaters and Single-Family Split Systems	Research Initiatives	Is ‘market analysis’ where you differentiate between Res and Com? If not, please clarify which research targets and which sector.	Generally, yes. Usage of products or product classes may shift between residential and commercial sectors over time as new markets consider these products.
Unitary Electric Water Heaters and Single-Family Split Systems	Research Initiatives	Split systems and small form factor for both 120V and 240V?	Correct, this initiative includes both voltages.
Unitary Electric Water Heaters and Single-Family Split Systems	Opportunities	120V unitary is not specifically listed in the table, assuming same as 120V residential?	Yes, unitary products are much more common than split, so categories not specifying this information are assumed to be unitary.

Technology Family	Section	Suggestion or Comment	Action Taken & Justification
Unitary Electric Water Heaters and Single-Family Split Systems	Opportunities	How do these relate to the table above. Upsizing storage capacity is contrary to small form factor. Mixing valves aren't mentioned.	Opportunities listed here apply to many of the research initiative listed above, but not everyone.
Unitary Electric Water Heaters and Single-Family Split Systems	Opportunities	How are these not currently standardized given the DOE test procedure requirements? Is FHR an appropriate metric for HPWHs?	The shift to HPs in water heating has disrupted the existing standard metrics. FHR should be used only. with caveats in considering HPWHs relative to other fuel types.
Unitary Electric Water Heaters and Single-Family Split Systems	Barriers	The process for quantifying the benefits due to load shifting needs to be finalized. Appropriate load shapes are needed to match typical prototype usage. Application of viable electric alternative (VEA) rules for existing fuel substitution measure packages must be established to responsibly phase out gas alternatives. Focus on refrigeration costs that are being added. How can risk of leaks and end-of-life discharge be mitigated so penalty is lessened.	Added barrier: "Absence of savings claims infrastructure, including eTRM load shapes, rules for quantifying load shape benefits, rules for viable electric alternative (VEA) measures to replace gas appliances, and coordination on refrigerant leak reduction efforts."
Residential Multifunction Heat Pumps	Barriers	Similar load shifting barriers to previous. Will there be EUL issues when combining technologies that need to be addressed?	Added barrier: "Absence of savings claim infrastructure, including eTRM load shapes, rules for quantifying load shape benefits, and resolution for conflicting effective useful life values."

Technology Family	Section	Suggestion or Comment	Action Taken & Justification
Residential Multifunction Heat Pumps	Opportunities	Wider potential for adoption of systems that provide space cooling as well vs. just space and DHW heating.	Agree but wanted there to be room in the program to look at combi systems (heating and DHW) as a potential area of interest for climates without cooling demand (i.e. CZ1)
Commercial Domestic Hot Water System Design	Barriers	This item is important; it needs to be collected in a way that it can be incorporated into new commercial energy plus prototype models.	Noted and being executed following the 2024 HVAC TPM Final Report submittal as a dissemination strategy, to be incorporated in the 2025 HVAC TPM revision process.
Commercial Domestic Hot Water System Design	Barriers	If quantifying combination of HPWH to also cool the space with by-product air; ensure that results are compatible with new Energy Plus prototypes.	Noted and being executed following the 2024 HVAC TPM Final Report submittal as a dissemination strategy, to be incorporated in the 2025 HVAC TPM revision process.
Commercial Hydronic Heat Pumps	Definition	Suggest including a literature review of existing case studies.	Noted and being executed following the 2024 HVAC TPM Final Report submittal as a dissemination strategy, to be incorporated in the 2025 HVAC TPM revision process.
Commercial Hydronic Heat Pumps	Opportunities	Investigate potential given limited applications that have simultaneous heating and cooling loads that take advantage of heat recovery chillers.	Noted and being executed following the 2024 HVAC TPM Final Report submittal as a dissemination strategy, to be incorporated in the 2025 HVAC TPM revision process.