2022 Water Heating Technology Priority Map

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Abbreviations, Acronyms, and Glossary of Terms

Acronym	Meaning
ACEEE	American Council for an Energy-Efficient Economy
BTU/h	British Thermal Unit/Hour
BUILD	Building Initiative for Low-Emissions Development Program
CEC	California Energy Commission
CEC-EPIC	California Energy Commission - Electric Program Investment Charge
CPUC	California Public Utilities Commission
CSLB	Contractor State Licensing Board
DER	Distributed Energy Resource
DOE	Department of Energy
DR	Demand Response
EE	Energy Efficiency
EPA	Environmental Product Agency
ET	Emerging Technology
ETCC	Emerging Technology Coordinating Council
FHR	First Hour Rating
GHG	Greenhouse Gas
GWP	Global Warming Potential
HP	Heat Pump
HPWH	Heat Pump Water Heater
HVAC	Heating, Ventilation, and Air Conditioning
IOUs	Investor-Owned Utilities
NEB	Non-Energy Benefits
NEEA	Northwest Energy Efficiency Alliance
NEEP	Northeast Energy Efficiency Partnerships

NYSERDA	New York State Energy Research and Development Authority
SB-49	California Senate Bill 49 (2019-2020): flexible appliance standards
SCE	Southern California Edison
SDG&E	San Diego Gas and Electric
SME	Subject Matter Expert
TAC	Technical Advisory Committee
TECH	Technology and Equipment for Clean Heating
TPM	Technology Priority Map
U.S.	United States
WH	Water Heating

Glossary	Meaning
Technology Category	One of six broad technology categories (e.g. Whole Building, HVAC, Water Heating, Plug Loads, Lighting, Process Loads).
Technology Family	Functional grouping that provides description of program role, opportunities, barriers.
Subgroups	Common examples to further describe each technology family.
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.
Emerging Technology Program (ETP) Role	Describes general level of engagement by CalNEXT SMEs. *Note: Roles will change as research is completed.*
Lead	"Lead" - CalNEXT expects to take on most or all of the work and cost burden.
Collaborate	"Collaborate" – CalNEXT is interested in collaborating and co-funding projects.
Observe	"Observe" – CalNEXT will track progress but encourage external programs to take lead in unlocking these opportunities.
ETP Priority	Communicates expected level of focus by CalNEXT SMEs. *Note: Priorities will change as research is completed.*
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.
Impact Factor	One of four broad impact areas (energy savings potential, demand flexibility potential, decarbonization potential, and other GHG impacts).
Impact Factor Ratings	A qualitative rating (High-Medium-Low) by the CalNEXT SME team on impact potential if technological advancements are made in key subgroups.
Knowledge Index	One of three types of knowledge areas (technical performance, markets, and program intervention) used to assess types of barriers studies necessary to obtain the stated impact potential.
Knowledge Index Rating	A qualitative rating (High-Medium-Low) by the CalNEXT SME team on the relative knowledge of most subgroups within a technology family. A higher rating means that the topic is well understood.

2022 Water Heating TPM

Water Heating Technology Category Overview

This category covers one of the most rapidly changing end-uses, as product availability, public funding, and the attention of energy efficiency (EE) and market transformation program efforts are converging to make changes in electric water heating. The decarbonization of water heating has been identified as an achievable and significant step toward California's overall decarbonization goals, and policies are changing to emphasize this end-use. These include the California Energy Commission's (CEC's) 2021 Integrated Energy Policy Report, the Flexible Demand Appliance Standards of SB-49, the CPUC's policies on fuel-switching EE measures and embrace of Total System Benefit (D 21-05-031 R. 13-11-005).

California's TECH and BUILD market transformation programs are working on the market transformation of water heating and identifying key barriers for CalNEXT to continue addressing. Water heater manufacturers have made key strides in HPWH product development, with recently introduced 110V products expanding the addressable market for residential HPWHs.

Unique Opportunities and Barriers

The electrification of water heating presents a key opportunity to build demand flexibility into this added electrical load: this make-or-break moment could result in either added stress on California's electric grid in the crucial evening hours or true success in bringing grid interactivity to the mass market. This TPM introduces a new technology family to focus on these issues.

Unitary HPWHs are relatively well-understood and have achieved some market success, but there are still important questions around performance of larger systems with heat recovery, mixing valves, and/or recirculation. CalNEXT can contribute to identifying and promoting best practices for commercial and multi-family HPWH systems.

Highlighted Priority Areas

Technology Family	Technology Subgroups	Definition	ETP Role	ETP Priority
Residential-duty water heaters	Unitary and Split-System heat pump water heaters for single family and individual multi-family dwelling units; low-GWP refrigerants for residential-duty heat pump water heaters;	Efficient, demand-flexible, electric water heating products designed to meet the hot water demands of residential households or buildings with similar water heating needs. This technology family will help meet the California Energy Commission's	**1-Lead**	1-High
Commercial-duty water heaters	Central heat pump water heater systems for multifamily, hotel/motel, food service, pools and commercial buildings; low-GWP refrigerants; dual-fuel water heaters;	Efficient, demand-flexible electric water heating systems for commercial applications (offices, pools, and food service) and multi-family residential (typically ≥5 dwelling units) applications.	**1-Lead**	1-High

Note: The Water Heating TPM primarily covers water heaters for domestic hot water systems (kitchens, bathrooms, and laundry) as well as that used in pool water heating. It does not cover hot water used in space heating systems which is covered by the HVAC TPM or for industrial process heating which is covered by the Process Loads TPM.

Residential-duty water heaters

(ETP Role: Lead, ETP Priority: High)

Key Factors

Energy Savings Potential: High
Decarbonization Potential: High
Demand Flexibility Potential: High
Other Emissions Impacts Potential: Low

Knowledge Index

Technical Performance: Medium
Market Understanding: Medium
Program Intervention: Medium

Subgroups (example technologies)

Unitary and Split-System HPWH for single family and individual multi-family dwelling units; low- Global Warming Potential (GWP) refrigerants for residential-duty HPWH.

Definition

Efficient, demand-flexible, electric water heating products designed to meet the hot water demands of residential households or buildings with similar water heating needs. This technology family will help meet the California Energy Commission's goal of installing at least six million heat pumps (HPs) by 2030.

Opportunities

HPWHs are a key strategy to building decarbonization by providing a cost-effective, all-electric water heating option, with significant electricity savings over resistance heating, with strong potential for demand flexibility.

Other greenhouse gas (GHG) emission benefits may be possible as the market shifts to low-GWP refrigerants, particularly as CO_2 split-systems are currently available. Refrigerant leakage from unitary systems is expected to be low.

Higher adoption of HPWHs in higher-income households due to upfront costs suggest special considerations of equity to ensure that non-energy benefits (NEBs) such as reducing indoor exposure to combustion gases and ability to participate in load flexibility programs benefit all ratepayers.

Manufacturer product improvements may be able to create new designs and recommendations to facilitate adequate airflow and/or venting, increase output, decrease unit size (for space-constrained scenarios), and address known electrical barriers (deploying 110V/120V products, load management to match electrical capacity).

Barriers

The technical performance of these products is generally well-known as there are mature testing and rating systems in place. The market is evolving as new products emerge, especially those which operate at 110V/120V electrical requirements. However, consumers and contractors will need targeted education as the default sizing metric of tank capacity is insufficient in comparing gas heaters and HPWH. Industry-wide transitions to first hour rating (FHR) or another metric to account for the lower British thermal unit per hour (BTU/h) ratings of HPWH will be necessary to ensure similar performance across products. Aside from this, HPWH have needs and features beyond the common gas storage alternatives that can make fuel-switching challenging:

1. Workforce training for the plumbing trades is needed to increase their adoption and knowledge of HPWHs in the residential market. Contractors will need to develop expertise to allow proper disposal of condensate, adequate airflow and venting to ensure proper performance, and expertise in electrical wiring without causing significant cost increases to the end-user. Electrical service upgrades can be a significant cost barrier and may need load management strategies or deployment of 110V/120V products to delay or mitigate the expense of an electric panel upgrade.
2. Currently, water heaters replacements are typically conducted in an emergency scenario and will need additional education and resources to end users such that these projects can be better planned by homeowners and landlords around space constraints and/or electrical capacity constraints (note: additional suggestions for market interventions are listed in the Grid Integration & Market Intervention technology family).

Commercial-duty water heaters

(ETP Role: Lead, ETP Priority: High)

Key Factors

Energy Savings Potential: High
Decarbonization Potential: Medium
Demand Flexibility Potential: Medium
Other Emissions Impacts Potential: Low

Knowledge Index

Technical Performance: Low
Market Understanding: Low
Program Intervention: Low

Subgroups

Central HP water heater systems for multi-family, hotel/motel, food service, pools and commercial buildings; low-GWP refrigerants; dual-fuel water heaters.

Definition

Efficient, demand-flexible electric water heating systems for commercial applications (offices, pools, and food service) and multi-family residential (typically ≥5 dwelling units) applications.

Opportunities

Water heating is among the easier end uses to decarbonize with an all-electric HP option, with much less energy consumption than an electric resistance water heater. HPWH present the potential for greater demand flexibility with appropriate system design due to the variety of system configurations (tank size, output), and draw patterns.

Overall, HP would likely increase other emissions due to refrigerant leakage, but that may be mitigated as there is an industry-wide transition to low-GWP refrigerants.

Prospective ET studies should focus on: (1) improving the efficiency of all-electric centralized HPWHs; and (2) lab and field assessments of dual-fuel water heating w/ gas-fired HP sources to address the lack of product solutions for high-load, rapid-recovery applications such as food service.

Barriers

Commercial-duty HPWH are still in a nascent technological stage that continues to change as the market evolves. Electrical infrastructure and installation limitations can prevent fuel-switching in retrofit applications with existing gas-fired hot water systems. New programs have only begun to scratch the surface of addressing barriers to adopting commercial HPWHs.

Potential barriers studies should address:

1. Lack of field performance data (including system reliability & cost-effectiveness).
2. Lack of design tools to select and appropriately size HPWHs outside of multi-family applications.
3. Lack of HPWH familiarity for building permitting authorities (and health departments).
4. Lack of coordination between trades (e.g., electrical & plumbing).
5. Lack of sector-specific knowledge in implementing HPWHs in disadvantaged communities (multi-family housing).

Grid Integration & Market Intervention

(ETP Role: Lead, ETP Priority: Medium)

Key Factors

Energy Savings Potential: High
Decarbonization Potential: Medium
Demand Flexibility Potential: Medium
Other Emissions Impacts Potential: Low

Knowledge Index

Technical Performance: Low
Market Understanding: Low
Program Intervention: Low

Subgroups

Distributed energy resource (DER) impacts of water heating; grid and utility integration for connected water heaters; financing mechanisms; deployment interventions; behavioral programs; etc.

Definition

Methods for realizing the promise of HPWH as a broadly adopted, turnkey, high-impact GHG reduction technology with the most positive (and least negative) impacts possible on hourly electric capacity and ramp-up issues.

Opportunities

This technology family will look to actualize the enormous (and growing) potential for load shift, shape, and shimmy: load management from scale of day to half-hour, and the resulting GHG reduction from shifting the heating schedule(s) to times when the electricity grid has a lower marginal emissions rate and cost to operate. These market interventions should look to ensure equitable access to the financial benefits as well as the associated NEBs.

Prospective ET studies should investigate (1) innovative program designs that can bring benefits of HPWHs to disadvantaged communities; (2) innovative program designs to ensure the multiple value-streams of efficiency, decarbonization, and grid-integration are all actualized; and (3) pilot demonstrations to validate emerging flexible demand appliance standards under CA SB-49 (Skinner).

Barriers

Current deployment barriers can embody multiple interventions: tariff innovation, demand response (DR) enrollment, control algorithm selection, equipment incentives, financing options, and custom design choices. The development of combined deployment solutions with ongoing demand program enrollment plus additional financing, permitting, and installation assistance should be prioritized.

Prospective ET studies should address:

1. Changes in the tariff structure and/or grid integration incentives to mitigate cost-effectiveness concerns.
2. Lack of customer & contractor education needed to ensure grid integration of HPWHs.
3. Lack of proven controls algorithms with robust industry acceptance for HPWHs.
4. Ways to streamline electrical panel upgrades to support HPWHs.
5. Ways to streamline the permitting process for HPWH installation and eliminate need for multiple contractor trades.
6. Market interventions necessary for rental ratepayers to see the benefits of HPWHs.

Alternative Design Strategies

(ETP: Lead, ETP Priority: Medium)

Key Factors

Energy Savings Potential: High
Decarbonization Potential: Medium
Demand Flexibility Potential: Medium
Other Emissions Impacts Potential: Low

Knowledge Index

Technical Performance: Low
Market Understanding: Low
Program Intervention: Low

Subgroups

Recirculation systems; heat recovery systems; external mixing valves; residential, commercial, and community-scale solar & geothermal water heaters.

Definition

Design strategies and alternative heat sources to optimize energy efficiency, water conservation and GHG benefits.

Opportunities

Opportunities in this technology family will increase demand flexibility through thermal energy storage and optimization of mixing valve and hot water distribution setpoints. Prospective ET studies should include software solutions, design guides, or demonstrations that address:

1. Bringing clarity to designers for cost-effective scenarios for drain water heat recovery.

2. Novel recirculation and load-matching control strategies such as combined optimization of temperature modulation, variable speed recirculation, and distributed isolating valves.

3. Enhancing energy density and load matching of solar thermal and PV-assisted water heater designs.

4. Identifying high-priority program opportunities for specific building or industry sectors with reliable, low-carbon intensity, cost-effective solutions.

5. Increased utilization of thermal energy storage for increasing renewable energy penetration and load flexibility.

6. Development of alternative techniques to mitigate legionella risk, enabling additional use cases for HPWH systems.

Barriers

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

Potential barriers studies should address:
1. Lack of trusted software tools & design guides to simplify large HPWH system.

2. Lack of trusted software tools & design guides to simplify solar hot water system designs.

3. Lack of consistency among code requirements related to hot water setpoint temperatures.

4. Lack of experience deploying of drain water heat recovery, particularly with the variety of potential heat sources.

5. Lack of experienced practitioners in alternative strategies.