March 1, 2022

A Specification for Residential, Commercial – Multifamily, and Industrial Water Heaters and Heating Systems
Advanced Water Heating Specification
Version 8.0

Effective Date: March 1, 2022 to July 15, 2024
AWHS Version 8.1 replaced Version 8.0

1.0 Introduction

This document succeeds the Northwest Energy Efficiency Alliance's (NEEA's) previous Advanced Water Heating Specification (AWHS Version 7.0). This version has been expanded to include commercial, multifamily, and industrial water heating systems in addition to residential water heaters. Notably, this version has no substantive changes to the residential water heater portion of the specification compared to Version 7.0.

Chapter 3—Commercial/Multifamily Water Heating Systems is in an initial draft phase, and NEEA welcomes feedback from experts on the proposed draft content. If you have feedback, please contact Geoff Wickes at NEEA: gwickes@neea.org.

1.1 Background

In the early 1980s, electric utilities in colder portions of North America introduced heat pump technology into the domestic water heating market (mostly in the residential market). Heat pump water heater programs have subsequently spanned three generations of technology and produced detailed measurements of technical performance and consumer acceptance. The experience gained from these programs yields definitive direction about key consumer needs as well as important technical and reliability criteria for proper application of this technology throughout a range of climates.

The ENERGY STAR® program released its first specification for residential water heaters in 2008, which included qualifying criteria for heat pump water heaters (HPWHs). ENERGY STAR included requirements for efficiency (EF 2.0 or better), capacity (first-hour rating 50 gallons), longevity (warranty ≥ 6 years), and electrical safety (UL 174 and UL 1995). While these requirements are important, the ENERGY STAR program did not address critical performance and comfort issues that have inhibited widespread adoption of HPWHs in colder climates. In 2009, several major manufacturers launched integrated HPWH units in North American markets that were ENERGY STAR-qualified but failed to address key performance issues. No *system-level* energy efficiency qualifications currently exist for commercial products in the ENERGY STAR program, just discrete components, e.g., the water heater.

While this specification initially focused on “Northern” climates (generally considered to be any location in International Energy Conservation Code (IECC) Climate Zones 4 or colder), it now provides a framework that extends to other climates. By prioritizing heat pump use over resistance elements, additional performance-related functionality, and consumer satisfaction, this specification and testing methodology will produce high efficiency water heating in all climates and in multiple configurations and building types.

The AWHS has evolved over time in response to changing federal test procedures and to accommodate an ever-changing market. Accordingly, the requirements have changed with different versions of the specification. All products previously qualified to an earlier version of the specification shall remain qualified even if subsequent requirements change. Any new products, subsequent to release of a new version of the specification, are subject to all new requirements. For an overview of the qualification process, refer to Appendix G.

Notable changes from Version 7.0 include, but are not limited to:

- Addition of commercial, multifamily, and industrial water heating systems to this version of the specification
- Additional Appendices to support commercial water heating

As mentioned earlier, the Residential portion of this specification has no substantive changes compared to Version 7.0. While the Residential section has been edited for clarity and organization, the requirements remain the same.

1.2 Purpose

This specification provides guidance to manufacturers and market actors interested in developing residential, commercial, multifamily, and industrial water heating products capable of providing high levels of consumer satisfaction and energy performance in a range of climates. The end goal of this effort is to ensure that the introduction of new generations of HPWH products will be as successful as possible to pave the way for HPWHs to become the standard product for all electric water heating markets. The specification also contains forward-looking Qualified Products List (QPL) tiers for which products may not yet exist. The purpose is not to require products be provided at any specific tier; instead, those future tiers are intended as guidelines for development of the specification over the next two to 10 years.

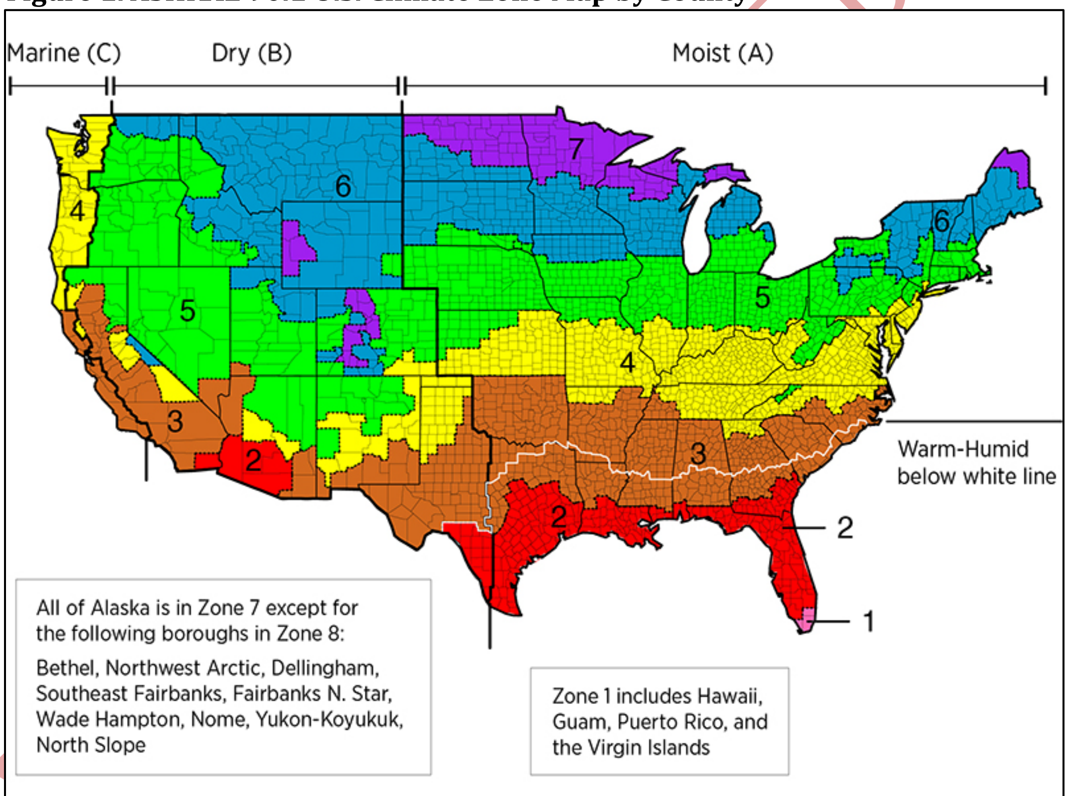
Utilities and other entities that invest in market transformation programs and/or incentives require reliable energy savings. Accordingly, this specification is also intended as a foundational document for utility program efforts that will work in partnership with manufacturers to accelerate market adoption of HPWHs for all main U.S. and Canadian climates. Using this specification will help to improve market acceptance, reduce the number of geographically-targeted SKUs for manufacturers, and ensure the expected savings materialize and are persistent on the grid.

This specification might also be referenced in the energy codes of states or jurisdictions wishing to establish higher efficiency standards in pursuit of energy and carbon reduction goals.

1.3 Climate

This specification is intended to ensure high performance in all main North American climates with a special focus on climates with 4,000 or more heating degree days and average ambient temperatures below 60°F. Heat pump water heaters rely heavily on the heat source and climate in which they are located, and these inputs have significant impacts on performance and energy efficiency. Applicable climate zones for this effort are based on zones developed by the International Energy Conservation Code (IECC).[1] These zones are also utilized by ASHRAE in standards and publications.

Figure 1. ASHRAE 90.1 U.S. Climate Zone Map by County



Source: *ANSI/ASHRAE/IES Standard 90.1-2019 -- Energy Standard for Buildings Except Low-Rise Residential Buildings*

[1] https://codes.iccsafe.org/content/IECC2021P1/chapter-3-ce-general-requirements

2.0 Residential Single Family (Unitary and Split-System) Water Heaters

This chapter covers the specification for residential heat pump water heaters.

2.1 Purpose of Residential Specification

This residential chapter of this specification addresses key topics that fall into three main categories:

- Performance—energy efficiency and savings, condensate management, freeze protection, user controls, reliability
- Comfort/satisfaction—sufficient hot water for customer needs, exhaust air, noise, ease of installation, serviceability
- Demand response—integration of technologies enabling water heaters to be used as thermal batteries or tools to shift load to provide additional value to the utilities and the electric grid

2.2 Residential Specification Scope

2.2.1 Residential Equipment Types/Definition

This Residential chapter of this specification covers the following types of electric, air-source, consumer heat pump water heaters of 119 gallons or less, and less than 6 kW:

- Integrated units—devices with the heat pump components and storage tank integrated into the same unit
- Split systems—units that separate the storage tank and the heat pump. The heat pump can be located outdoors in all climates.

"Consumer water heater" is defined in the Code of Federal Regulations 10 CFR 430.2. An electric heat pump water heater is defined as a water heater that uses electricity as the energy source, to power the compressor and all auxiliary equipment such as fans, pumps, controls, and any resistive elements. It is designed to transfer thermal energy from one temperature level—the source air—to another for the purpose of heating water, and is designed to heat and store water at a thermostatically-controlled temperature.

Related specifications cover additional product categories and subcategories, including:

- Plug-in heat pump water heater (120 volt space-constrained product)—a product addressing a special application need for some electric heat pump water heaters (see Appendix A)
- Gas heat pump water heater—products using gas as the energy source to drive the refrigeration cycle (see NEEA.org website for current version)

Other sections of this specification cover commercial and multifamily heat pump water heating products. Commercial systems are defined as serving more than four dwelling units or serving commercial loads needing more than a total of 119 gallons of storage volume and/or more than 6 kW of input power. Residential systems comprise units that serve a single dwelling or load and are below the commercial volume and heating capacity.

Products not covered by this specification include heat pump water heaters configured to "add on" to existing storage tanks and combination space + water heating systems.

2.2.2 Residential and Unitary Applications

This Residential chapter of this specification focuses on replacements for existing electric resistance storage water heaters and alternatives to new electric resistance water heaters. As such, storage tanks shall be configured to meet the installation and code requirements for typical electric resistance storage water heaters. Integrated units are generally applicable for (although not limited to) installation in conditioned spaces within the house and unconditioned or semi-conditioned spaces such as basements, garages, crawl spaces, and attics. Split systems can have the heat pump portion installed in any of the aforementioned spaces as well as in outside locations.[2]

2.3 Residential Product Tiers

Tiers are incorporated into this specification to recognize variations in product performance and supported installation applications. Throughout the Residential chapter of this specification, different product categories, e.g., integrated units or split systems, may have different requirements as applicable to their design and operation. Table 1 and Table 2 summarize the tier requirements for integrated units and split systems, respectively. The requirements are further detailed throughout this Residential chapter.

[2] For details, see NEEA's BetterBricks HPWH Technical Guides for Detached Single-Family New Construction and R-2 Occupancy (Low-Rise Multifamily New Construction)

Table 1. Integrated HPWH Product Tier Overview

	Minimum Cool Climate Efficiency (CCE)*	Minimum Features	Sound Levels**	Demand Response-Enabled?
Tier 1.0	2.0	• ENERGY STAR compliance • Freeze protection	dBA < 65	Optional
Tier 2.0	2.3	Tier 1 plus: • Minimal use of resistance heating elements (see Section 2.5.1) • Compressor shut-down/notification • 10 year warranty • Condensate management	dBA < 60	Optional
Tier 3.0	2.6	Tier 2 plus: • Simultaneous intake and exhaust ducting capabilities • Air filter management • Override and default mode behavior as per Section 2.6.1	dBA < 55	Required
Tier 4.0	3.0	Tier 3 plus: • Physical design or default controls that limit resistance element heating to less than upper 50% of tank	dBA < 50	Required
Tier 5.0	3.5	Tier 4 plus: • No resistance element usage in default	dBA < 50	Required

** See Appendix B.1.2 for details on Cool Climate Efficiency definition and calculation method.*
*** See Appendix D for details on Sound Level definition and calculation method.*

Table 2. Split-System HPWH Product Tier Overview

	Minimum SCOP*	Minimum Features	Sound Levels	Demand Response-Enabled?
Tier 1.0	2.1	• ENERGY STAR compliance • Freeze protection	dBA < 65	Optional
Tier 2.0	2.4	Tier 1 plus: • Minimal use of resistance heating elements (see Section 5.1) • Compressor shut-down/notification • 10 year warranty • Condensate management	dBA < 60	Optional
Tier 3.0	2.7	Tier 2 plus: • Override and default mode behavior as per Section 6.1	dBA < 50	Required
Tier 4.0	3.1	Tier 3 plus: • Physical design or default controls that limit resistance element heating to less than upper 50% of tank	dBA < 50	Required
Tier 5.0	3.6	Tier 4 plus: • No resistance element usage in default mode unless outside ambient air temperature is below -5°F	dBA < 50	Required

** SCOP (seasonal coefficient of performance) is a different variable from CCE. SCOP applies to split systems for which the heat pump is subject to outdoor air conditions (see Appendix B.4). The reference climate for the SCOP comprises a combination of the climates of five Pacific Northwest cities.*
*** See Appendix D for details on Sound Level definition and calculation method.*

2.4 Requirements for All Residential Units (Tiers 1.0 and above)

2.4.1 Standards Approval

The unit shall be approved by Underwriters Laboratories (UL), Electrical Testing Laboratories (ETL), CSA International (CSA), or an equivalent third-party agency to the applicable standards and have the ability to be installed in the U.S. and/or Canada.

2.4.2 ENERGY STAR Compliance

The unit shall meet ENERGY STAR criteria effective at the time of manufacture.

2.4.1 Freeze Protection Test

Applicable only to units circulating water to system components outside the heated house envelope or buffer space (i.e., circulating water to a heat exchanger that is in a location subject to freezing temperatures). If applicable, the unit shall pass the 24-hour power-off freeze protection test as specified in Appendix C. The test is designed to help ensure water heaters do not freeze during power outages. Manufacturers should clearly state in installation manuals how to install units to prevent freezing (in cold temperatures without an energized unit).

2.4.2 Cool Climate Efficiency (CCE)

The unit shall meet minimum Cool Climate Efficiency values for cool climate installations, under default (out of the box configuration) operating mode settings, according to Table 1. See Appendix B.1.2 for the Cool Climate Efficiency Test Procedure and corresponding calculation method.

2.4.3 Sound Levels

The unit shall not exceed maximum sound levels according to Table 1. for interior units. Exterior units must comply with local codes regarding noise. See Appendix D for Sound Pressure Measurement Test Method.

2.4.4 High Volume Draw Test

Units that allow electric resistance element operation in the default operating mode, under standard operating conditions, shall complete the high-volume draw test. Standard operating conditions are defined as the normal temperature operating range of the heat pump system. Products that qualify for Tier 5 do not need to undergo this testing nor do products that do not use resistance elements in the default operating mode under standard operating conditions. This test has no minimum or performance requirements. It is required as informational only and the results are to be submitted on the Product Assessment Datasheet (see Appendix N for an example).

2.4.5 OPTIONAL: Warm Climate Efficiency Test

This is a test to demonstrate performance in warm climates. Test results may be useful in demonstrating product applicability and expanding market reach in warm climates. See Appendix B.1.3 for the measurement details of this *optional* test. In lieu of a measurement, energy use may be extrapolated from lower temperature test results per the method suggested in Appendix B.1.3.

2.4.6 Installation Guidance

Installation guidance shall be provided so the unit is installed with adequate clearance for all airflow to and from the evaporator. The manual shall provide several possible configurations and/or installation scenarios to assist the installer.

2.5 Additional Requirements for Residential Tiers 2.0 and Above

2.5.1 Minimal Use of Electric Resistance Heating Elements

In default operating mode, units shall make minimal or no use of electric resistance heating elements in order to maximize energy savings potential. During the first draw of the U.S. Department of Energy (DOE) first-hour rating test,[3] the electric resistance heating element shall not be turned on until at least 66% of the tank's measured water volume has been withdrawn. Measured volume is defined as the actual storage volume of the unit under test, not the nominal rated tank volume.

[3] http://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=ap10.3.430_127.e&rgn=div9

2.5.2 Compressor Shut-Down, Notification

The unit shall provide notification to the consumer, at the unit itself through an indicator light, display, or similar, that the heat pump operation of the product has been disabled due to normal events, user-selected override, or product failure.

2.5.2.1 Normal, Temporary Event

The unit shall display that the heat pump is not currently operating if the compressor is temporarily disabled due to specific operational controls (e.g., low intake temperature or defrosting). The controls shall automatically restore compressor operation as soon as conditions return to allowable control parameters (e.g., return to minimum intake temperature or completion of the defrost cycle).

2.5.2.2 User-Selected Override and/or Power Failure

If the unit has a temporary, user-selectable heat pump override option, the unit shall provide a default override period of up to 72 hours before returning to the previously-selected operating mode (preferably to the as-shipped or better settings) except for 100% electric resistance. Upon power failure, the unit must return to the last mode the user had selected or in which the user was operating, unless new commands come in through the demand response port or the customer API.

2.5.2.3 Product Failure Alarm

The unit shall provide the following alarms to the consumer that the unit has a failure and requires service:

- Visual alarm—shall be visible without removal of panels and/or covers and have clear direction to the homeowner to take needed action to solve the problem.
- Audible alarm and/or electronic notification to homeowner via email, text message, phone app, or similar. If an audible alarm is used, the unit shall provide a homeowner acknowledgement feature that turns off the audible alarm. An audible alarm shall be at least 50 dBA at the location specified in Appendix D for measuring noise level on the HPWH.

The unit shall have a visual alarm and one or both of the following: audible or e-notification alarms.

2.5.3 Warranty and Service

The unit shall carry a warranty of a minimum of 10 years for all system parts as well as a minimum of one year for labor from date of installation.

2.5.3.1 Contact Information

The unit shall include clear information on how to obtain warranty service, replacement filters or other maintenance items, and technical support via a toll-free phone number clearly marked on the exterior of the unit regardless of the channel through which the product is sold.

2.5.4 Condensate Management

Condensate shall be drained away according to local plumbing codes and industry best practices.

2.5.4.1 Acceptable Condensate Piping

The unit shall include a minimum standard piping connection for condensate drainage of proper size to function for the life of the product under normal use (field installation materials to be provided by the installer for the connection). The manufacturer shall supply appropriate condensate piping specifications including piping diameter, length, allowable turns, slope, and acceptable termination for gravity drains and for condensate pumping in locations, such as basements, where gravity drainage is not possible. Instructions for the installer shall highlight the importance of correct condensate line installation practices and adherence to local plumbing code.

2.5.4.2 Condensate Overflow Shut-off and Alarm

Units shall include a safety switch to shut off compressor operation in the event of a blockage of the condensate removal system for any units installed in interior applications. An alarm (See Section 2.5.2.3) shall be activated to signal the need for service in the event of a compressor shut-off due to condensate drain failure.

2.5.4.3 Condensate Collection Pan and Drain Service

The condensate collection pan and drain shall be designed to require no regular maintenance or interaction by the consumer for the life of the product. In the event of a blockage, the pan and drain shall be designed to allow the consumer to be able to clear the drain with normal household tools and restore normal operation of the condensate line. Collection pan equipment and installation shall meet local code.

2.6 Additional Requirements for Residential Tiers 3.0, 4.0, and 5.0

2.6.1 Default Settings

The unit shall be shipped in the default operational mode used in demonstrating compliance with federal energy efficiency standards. Enhanced efficiency operational modes may be selected by the consumer during installation. Should a user initiate an override to a mode less energy efficient than the default condition, such selection will expire after a 72-hour period. Upon expiration, the appliance shall then automatically return to the mode previously selected by the user unless that mode was less efficient than the default, in which case it shall return to the default. The customer, technician, and/or installer shall have the ability to override the default setting. In the event of total power loss to the unit, upon restart, it shall revert to the last settings selected as long as it is not electric resistance only.

2.6.2 Intake and Exhaust Ducting

The unit may have a manufacturer-supplied, optional ducting kit to provide for simultaneous intake and exhaust air ducting ("ducting kit"), available from the same distribution/retail channels as the unit. See manufacturer's recommendations for ducting applications and solutions.

2.6.2.1 Ducting Hardware

The unit shall include all necessary flanges, collars, or other connections that are capable of directly connecting to common ducting products. Alternatively, manufacturer-supplied add-on ducting modifications may be used if they provide the same capabilities.

2.6.2.2 Minimum Flow Rate/Pressure Drop

The unit shall maintain necessary airflow to achieve the tested performance (CCE) when attached to the duct system. The manufacturer shall supply instructions for the ducting kit that show necessary installation requirements (e.g., maximum equivalent duct length at a given diameter) to maintain airflow.

2.6.2.3 Application Options

The unit shall be capable of operating with or without ducting installed. Manufacturers shall clearly identify which models are configured for which applications along with a clear description (e.g., parts list and drawings) of the appropriate layout/configurations and accessory parts necessary to meet the requirements for specific applications.

2.6.3 Air Filters: Routine Maintenance and Homeowner Notification

If any air filters are present, they shall be either 1) permanent, washable media or 2) replaceable, standard filters in shapes and forms obtainable at a typical hardware store. The unit shall provide visible notification to the homeowner of appropriate need to change, or service, the filter in order to prevent compromise of performance of the heat pump from reduced airflow. Recommendations are to be defined by the manufacturer.

2.6.4 Demand Response Features

Units shall be configured and shipped with the capability to respond appropriately to demand response, grid emergency, and efficiency messages over a standard communication protocol and hardware interface. Units shall have a communication port that operates in compliance with CTA-2045[4] (or equivalent open source modular interface standard) with specific demand response signals such as shed, end shed, etc. The communication port shall be easily accessible and allow for the plug-in of non-proprietary communication modules. The product shall revert to the user's previously-selected mode (or factory settings) after a demand response event. All CTA-2045 or equivalent open source modular interface functionality, including hardware and software, must be contained on the unit. A module or adaptor separate from the unit does not meet the requirement; it must be affixed in such a way that the average homeowner cannot remove it without special tools and/or significant effort. See Appendix F for further definitions and requirements.

[4] CTA-2045 has been newly renamed EcoPort.

2.6.5 Refrigerants

The current version of this specification does not require specific refrigerants to be used for any product. Future versions of this specification, especially for products at higher tier levels, may require refrigerants that have a lower Global Warming Potential[5] (GWP) than those typically used in current products (for example, future specifications may limit GWP to less than 100).

2.7 Additional Requirements for Residential Tier 4.0

2.7.1 Further Minimization of Electric Resistance Heating

The physical design, or default equipment controls, shall limit the electric resistance element heating to less than the upper 50% of the tank volume. This requirement applies only to operation within the standard operating range for the heat pump. If the temperature range is outside that at which the heat pump compressor can operate, use of resistance heat is permitted.

2.8 Additional Requirements for Residential Tier 5.0

2.8.1 No Resistance Element Usage in Default Mode

Integrated units shall not use electric resistance heat in the default operating mode. Split systems shall not use electric resistance heat in the default operating mode unless the outside air temperature is less than -5°F.

[5] https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

3.0 Commercial/Multifamily Water Heating Systems

This chapter covers the specification for commercial and multifamily water heating systems.

3.1 Purpose of Commercial Specification

The purpose of this specification is to ensure the repeatable and reliable design and installation of domestic hot water (DHW) HPWH systems, and to ensure these systems perform at the level of efficiency system designers expect. This is accomplished by creating a list of qualified HPWH product lines (Qualified Products List (QPL)) that designers, installers, and governing bodies can reference when designing, regulating, incentivizing, or comparing HPWH systems.

3.2 Commercial Specification Scope

This section of the specification addresses the performance of commercial and multifamily heat pump water heating systems. Commercial systems are defined by both product and application characteristics. For small unitary heat pumps serving single applications (whether the application is residential or small commercial), see the Residential Single Family chapter of this document. Commercial systems are larger units applied to multiple loads. Additional detail on the distinction between commercial and residential or unitary products follows.

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3.2.1 Commercial System Definition

This section of the AWHS 8.0 is applicable to all commercial building types, including multifamily, that utilize heat pump water heating technologies in a central domestic water heating plant application. Commercial systems are defined as those serving more than four dwelling units or serving commercial loads needing more than a total of 119 gallons of storage volume and/or more than 6 kW of input power. These systems can be unitary or split systems and can be configured several ways, discussed below in Section **Error! Reference source not found.**.

For the purposes of this specification, the following four major components are included in the commercial HPWH system:

1. Primary heating system: heat pump water heater(s)
2. Primary storage: hot water storage tank(s)
3. Temperature maintenance system (where applicable): Temperature maintenance storage tank(s),temperature maintenance heat source(s), hot water circulation pump and thermostatic mixing valve
4. Controls and sensors: either internal to the heating equipment or central controller

3.3 Commercial HPWH System Requirements

Heat pump water heater product manufacturers must complete and submit a Product Assessment Datasheet (PADS) that outlines compliance with the requirements in this section. A completed PADS must be submitted for each product line. Products submitted for inclusion in the Qualified Products List must be verified to have met the requirements in Sections 3.3.1–3.3.5, below.

3.3.1 General Requirements

Products shall meet the following requirements for inclusion on the Qualified Products List:

1. HPWH manufacturer shall provide a five-year parts warranty on the HPWH that commences on the HPWH system startup date or six months after the HPWH ship date, whichever is earlier.
2. HPWH manufacturer shall provide a one-year labor warranty for HPWH system troubleshooting, technical support, and parts replacement that commences on the HPWH system startup date.
3. HPWH system startup shall be performed by a manufacturer-authorized service provider.
4. HPWH system shall be capable of sending alarms or notifications to an off-site location if the following events occur:
    a. HPWH fails to start or is forced to shut off before the heating cycle is completed per the HPWH system sequence of operation
    b. Auxiliary electric-resistance heating is activated (excluding swing tank heater or defrost operation)

3.3.2 Standards Approval and Testing

1. The HPWH shall meet UL 1995 and or UL 60335-2-40 through testing by a Nationally Recognized Testing Laboratory (NRTL), Electrical Testing Laboratories (ETL), CSA International (CSA), or an equivalent third-party agency to all standards required by local and national code.
2. The HPWH system shall comply with the current version of the following codes:
    a. International Electrical Code
    b. National Electrical Code
    c. International Plumbing Code
    d. Uniform Plumbing Code
    e. International Mechanical Code
    f. All applicable health and safety requirements

3.3.3 HPWH Performance Data

Manufacturers shall submit performance data in alignment with the California Energy Commission's (CEC's) Joint Appendix 14: Qualification Requirements for Central Heat Pump Water Heater System standard (JA14). JA14 requirements are not part of this specification, but the performance data reported to the CEC will be utilized in Section 3.4 to model HPWH system efficiency. See Appendix G for the qualification process and details on submitting data.

3.3.4 Manufacturer-Provided Guidance

Manufacturers shall provide access to detailed HPWH system design and installation guidance that includes:

1. General summary of HPWH system operation
2. Detailed piping schematics that align with one or more qualified piping configurations listed in Section 3.3.5. Guidance that does not align with the qualified piping configurations will be subject to review during the PADS process.
3. Detailed performance specification for all components defined in Section 3.2
4. Requirements for additional ancillary HPWH system components, including but not limited to mixing valves, circulation pumps, wye strainers, balancing valves, check valves, and air vents
5. HPWH output heating capacity and storage sizing guidelines
6. Potable water quality, pressure, and flow considerations that affect DHW system piping design
7. Air source design considerations
8. Electrical specifications
9. Sound levels and sound testing method
10. Installation specifications and requirements
11. Maintenance requirements
12. Equipment operating manuals and warranty documentation
13. Sequence of operation

3.3.5 Qualified Piping Configurations:

Manufacturer-provided HPWH system piping schematics shall align with one or more of the following qualified piping configurations, as mentioned in Section 3.3.4 and illustrated in Figures 2 through 8.

1. Single-pass HPWH
    a. No hot water circulation, primary heat pump water heating only (**Error! Reference source not found.**)
    b. Hot water circulation returned to the primary storage (**Error! Reference source not found.**)
    c. Hot water circulation returned to a temperature maintenance tank in series w/electric resistance element, also referred to as a “swing tank” (**Error! Reference source not found.**)
    d. Hot water circulation returned to a temperature maintenance storage tank in parallel with multi-pass HPWH for reheat (**Error! Reference source not found.**)
2. Multi-pass HPWH
    a. Integrated HPWH, no hot water circulation (**Error! Reference source not found.**)
    b. Integrated HPWH, hot water circulation returned to primary storage (**Error! Reference source not found.**)
    c. Split-system, hot water circulation returned to the primary storage (**Error! Reference source not found.**)

Figure 2. Single-Pass Primary HPWH System without HW Circulation

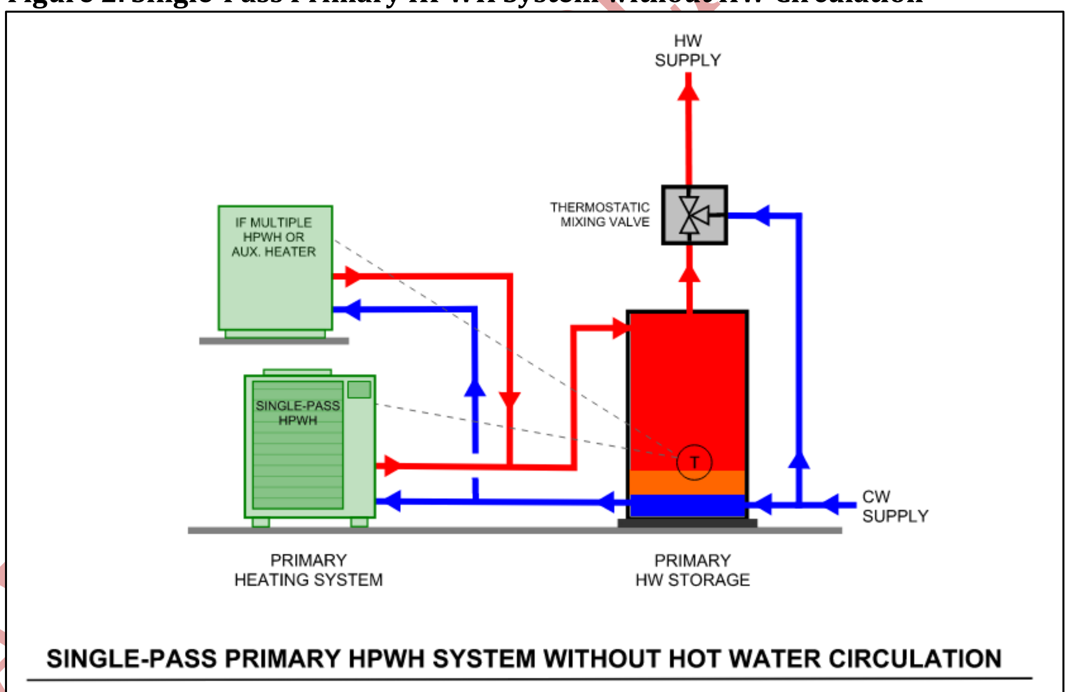


Figure 3. Single-Pass Primary HPWH with HW Circulation Returned to Primary Storage

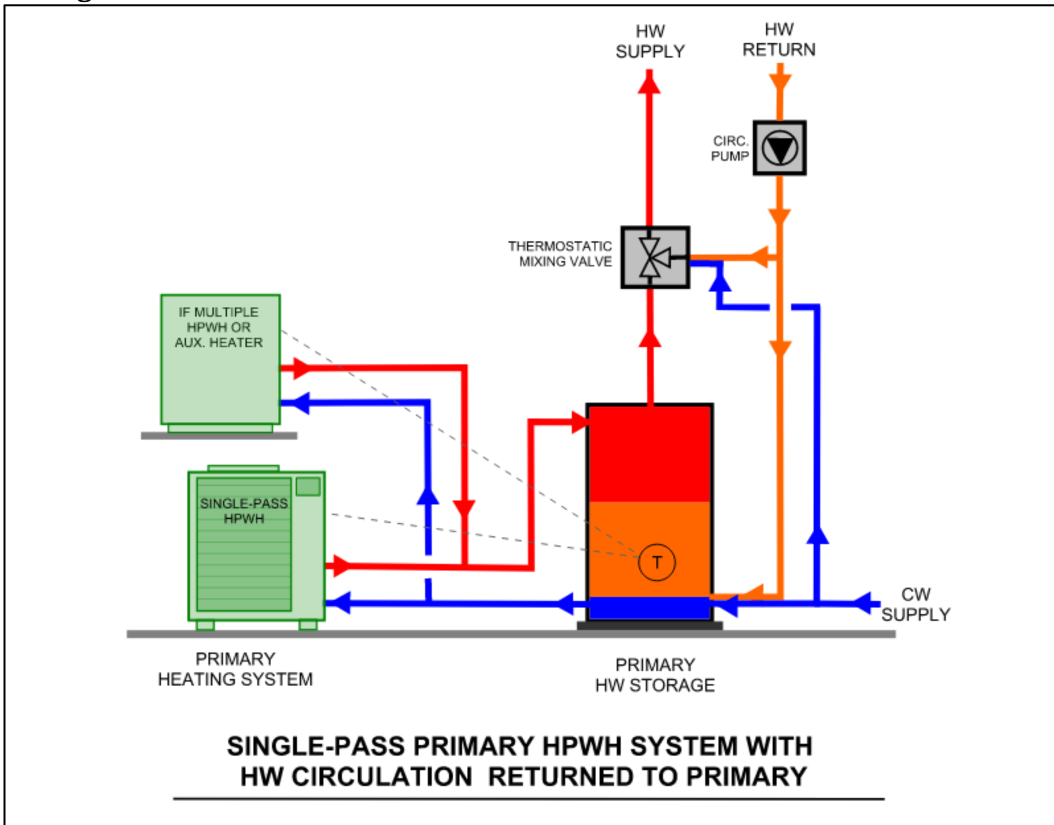


Figure 4. Single-Pass Primary HPWH with Series Temperature Maintenance Tank System (Swing Tank)

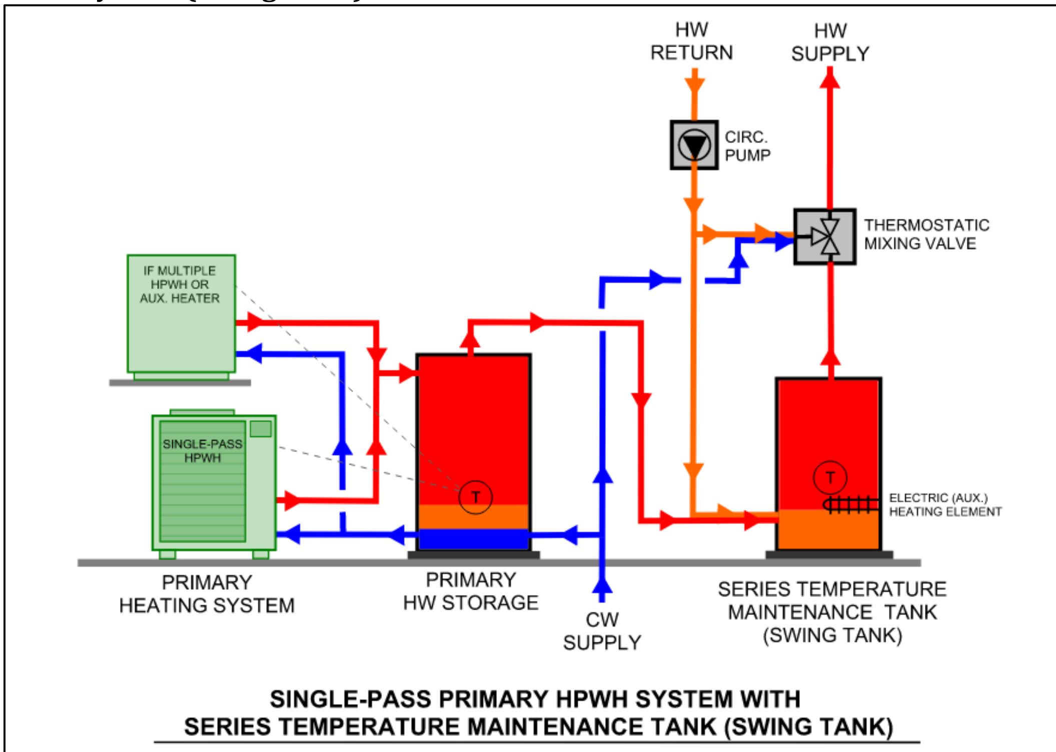


Figure 5. Single-Pass Primary HPWH with Parallel Temperature Maintenance Tank System

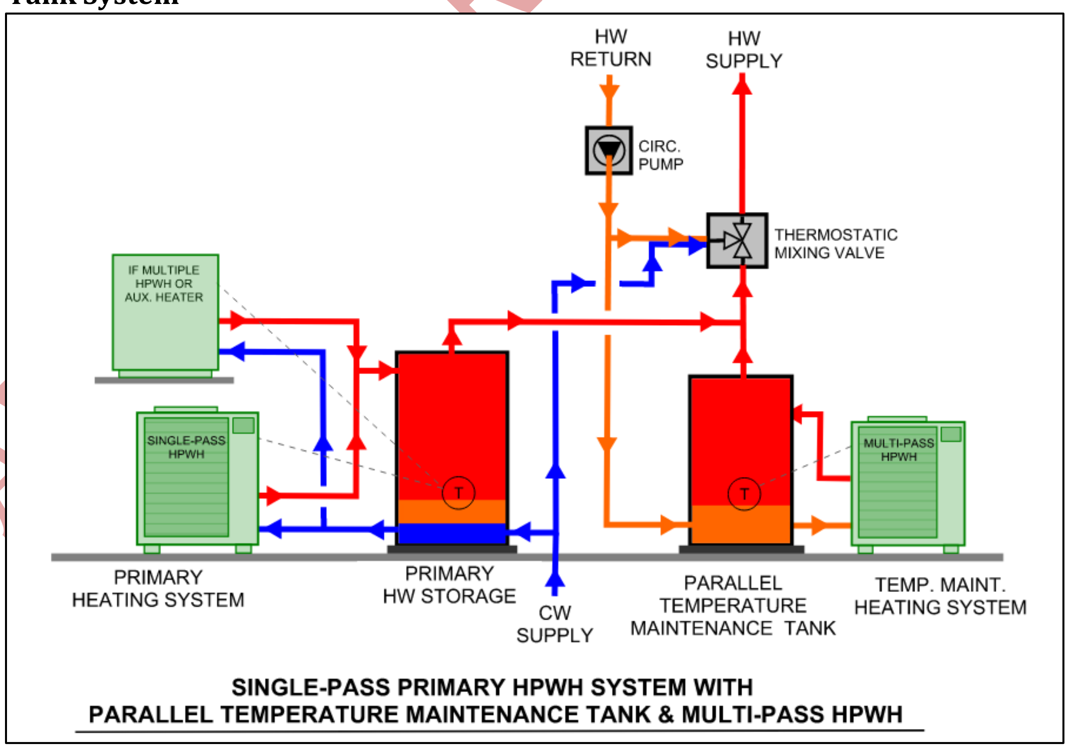


Figure 6. Multi-Pass Integrated HPWH System without Hot Water Circulation

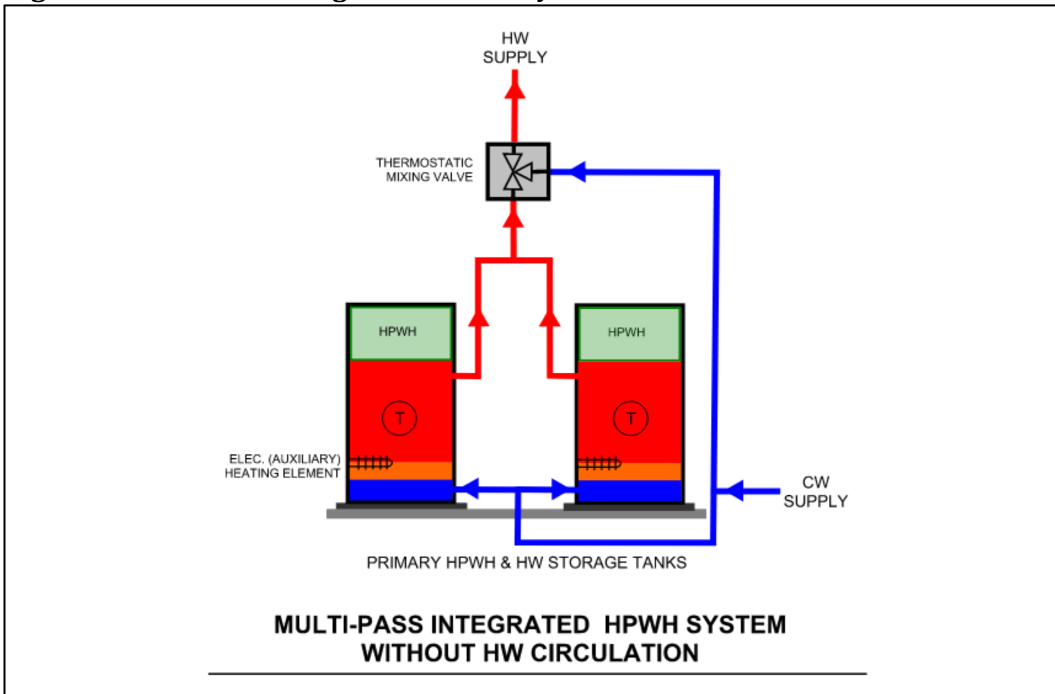


Figure 7. Multi-Pass Integrated HPWH System with Hot Water Circulation Returned to Primary Storage

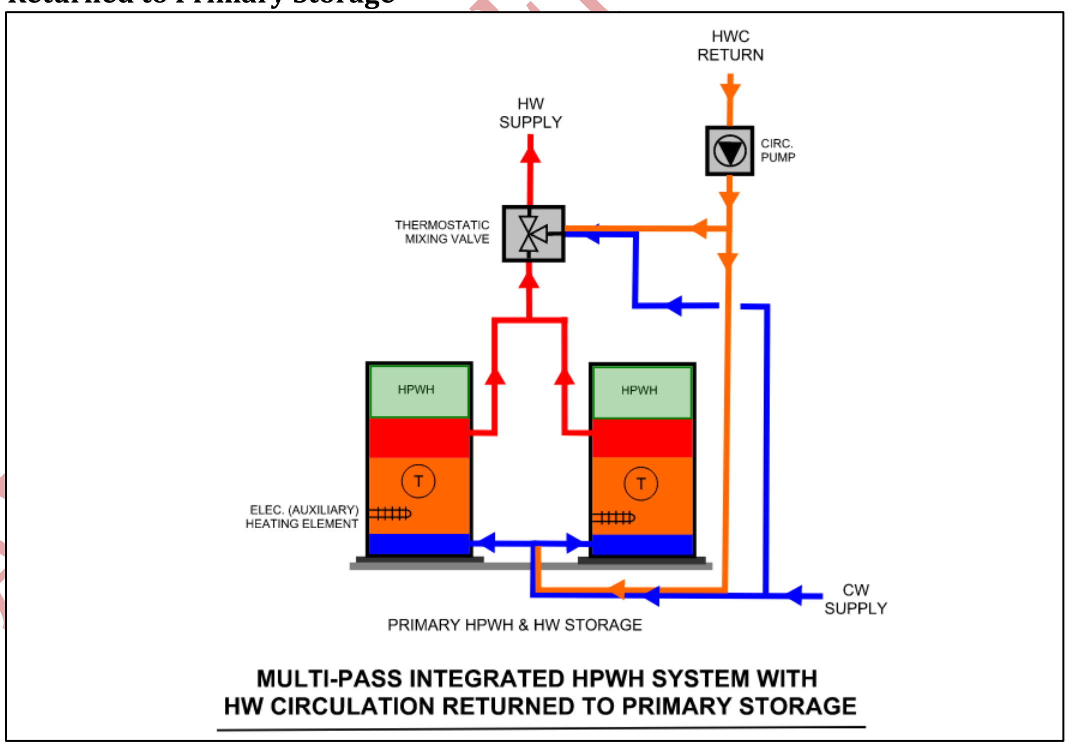
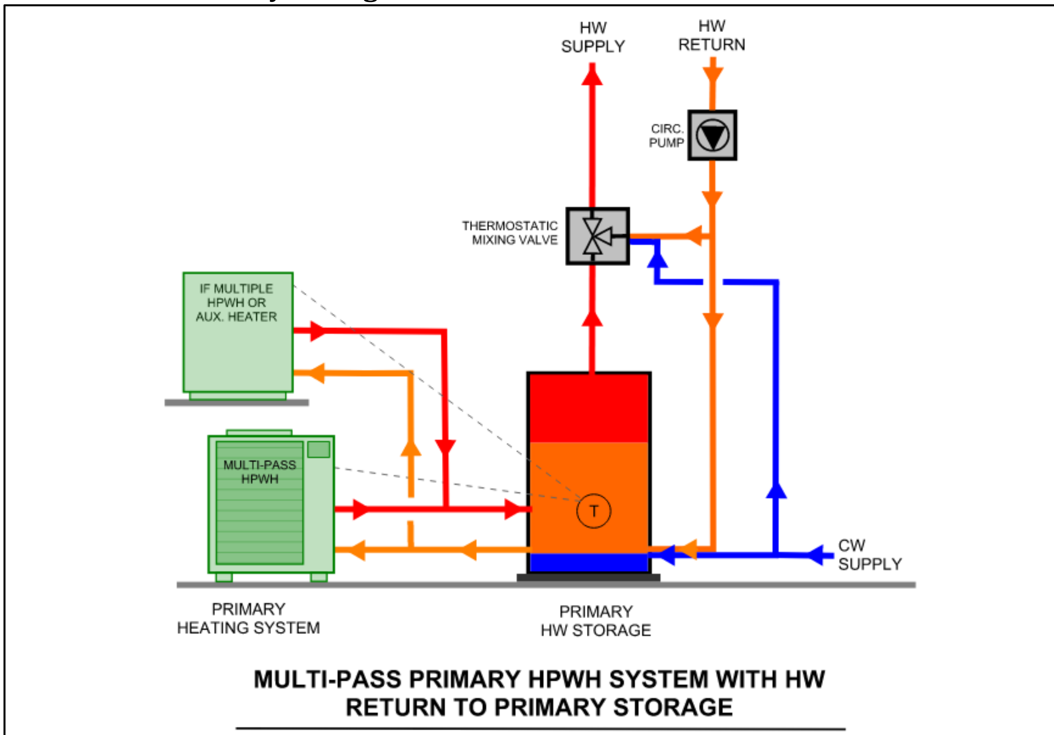


Figure 8. Multi-Pass Split-System HPWH with Hot Water Circulation System Returned to Primary Storage



3.3.6 Optional HPWH System Capabilities

The following capabilities are not required for inclusion of a product line on the Qualified Products List but can be incentivized or required by local codes as local context deems appropriate:

1. The HPWH shall have a CTA-2045 port (recently renamed EcoPort) and others.
2. Measurement and verification (M&V) equipment shall be installed on the HPWH system. See Appendix M for detailed requirements.

3.4 Modeled Commercial Multifamily System Performance

This section describes modeled HPWH system efficiency.

3.4.1 Commercial HPWH System Efficiency Modeling

Commercial HPWH system modeling software (Ecosim, created by Ecotope) simulates a one-year period of HPWH system operation on a minute-by-minute basis to predict an average annual system coefficient of performance (SysCOP). For each product line, the open-source (under the terms of the GNU General Public License[6] by the Free Software Foundation, version 3 or higher) Ecosim software provides an annual simulation for every combination of qualified piping configurations recommended by the manufacturer, 16 IECC climate zones relevant to the United States, and three different multifamily building prototypes.

Modeling is performed by AWHS administrators using the following manufacturer-submitted data:

- Manufacturer-recommended piping configuration(s) that align with one (or more) of the qualified piping configurations in Section 3.3.5
- HPWH performance and efficiency data outlined in Section 3.3.3

In combination with the following publicly-available data:

- Air temperature data representative of 16 IECC climate zones[7]
- Assumed DHW circulation heat loss equal to 100 Watts per apartment when applied to configurations with a DHW circulation loop, informed by multifamily DHW heat loss research[8]
- DHW usage profiles that represent four multifamily building prototypes used to define the range of multifamily building types[9]

The annual SysCOP predicted by the modeling of every combination of inputs are weighted and combined to estimate an average SysCOP for each product applied to each recommended configuration in each of four broader climate zones: hot, mild, cold, and extremely cold. These results are utilized to define the performance tier of a product on the Qualified Products List.

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[6] From the GNU License Notice: "This program is free software: you can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation, either version 3 of the License, or (at your option) any later version. This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for more details." See https://www.gnu.org/gnu/gnu.html for more information.

[7] Source: https://energyplus.net/weather or Wilcox, S. and W. Marion. 2008. *User's Manual for TMY3 Data Sets,* NREL/TP-581-43156. April 2008. Golden, Colorado: National Renewable Energy Laboratory.

[8] Kintner, P., and Larson, B. Literature Review of Multifamily Central DHW Distribution Losses. 2019.

[9] Source: TRC. 2019. *Multifamily Prototypes.* SCE PO4501068838. Rancho Cordova, California. Prepared for SCE.

3.4.2 Commercial HWPH System Efficiency Tiers

The SysCOP modeled for each configuration of each HPWH product line may qualify for one of four tiers in each of the four climate zones to which it is applied. The SysCOP required to qualify for each tier in each climate zone is shown in Table 3 below. Each product line's tier qualification is published in the Qualified Products List.

Table 3. HPWH System Efficiency Tiers

	Minimum SysCOP			
	Hot Climate (IECC Zones 1–2)	**Mild Climate (IECC Zones 3–4)**	**Cold Climates (IECC Zones 5–6)**	**Extremely Cold Climates (IECC Zones 7–8)**
Tier 1	1.75	1.50	1.25	1.15
Tier 2	2.25	2.00	1.60	1.50
Tier 3	2.75	2.50	2.25	2.15
Tier 4	3.50	3.00	2.75	2.50

3.5 Resources

- Manufacturers can access the Product Assessment Datasheets (PADS) using the following links:
  - Residential: https://neea.org/img/documents/Residential-Unitary-HPWH-Product-Assessment-Datasheet.xlsx
  - Commercial: https://neea.org/img/documents/Commercial-HPWH-Product-Assessment-Datasheet.xlsx

- The Qualified Products Lists can be accessed at the following locations:
  - Residential: https://neea.org/img/documents/Residential-Unitary-HPWH-qualified-products-list.pdf
  - Commercial: https://neea.org/img/documents/Commercial-HPWH-qualified-products-list.pdf

4.0 Industrial Water Heating Systems

This chapter covers the specification for industrial water heating systems—this is a placeholder for discussion of this technology. NEEA and the industry will work on this in future iterations.

4.1 Purpose of Industrial Specification

4.2 Industrial Specification Scope

4.2.1 Industrial System Definition

4.2.2 Industrial Applications

Appendices

Appendices A through N on the following pages detail information found earlier in this specification. Table 4 clarifies the types of HPWHs to which each Appendix applies.

Table 4. Appendix Titles and HPWH Specification Applications

Appendix	Title	Applies to Residential	Applies to Commercial	Applies to Industrial
A	Plug-In Heat Pump Water Heater Specification	Yes	No	
B	Test and Calculation Procedures	Yes	No	
B.2	Compressor Cutoff Temperature	Yes	No	
B.3	High Volume Draw Test	Yes	No	
B.4	Temperature Range Performance Testing—Split Systems	Yes	No	
C	Freeze Protection Test	Yes	No	
D	Sound Pressure Measurement Test Method	Yes	No	
E	Airflow Measurement	Yes	No	
F	Demand Response for Residential Water Heaters	Yes	No	
G	Qualification Process	Yes	Yes	
H	Disqualification, Tier Reassignment, and Requalification Process	Yes	Yes	
I	Commercial System COP Calculation Method	No	Yes	
J	Glossary	Yes	Yes	
K	Low GWP Refrigerants	Yes	Yes	
L	Demand Response for Commercial and Multifamily	No	Yes	
M	Measurement and Verification Requirements	No	Yes	
N	Sample Product Assessment Datasheet (PADS) Document	Yes	Yes	

Appendix A: Plug-In Heat Pump Water Heater Specification

Purpose

This specification presents requirements applicable to a water heater designed for electric supply-constrained locations—a "plug-in" heat pump water heater (HPWH). The plug-in water heater, designed for space-constrained installations (such as small closets, hallways, or dedicated locations) in some markets and applications, can be a good candidate to replace a gas-fired, atmospherically vented water heater. While some HPWHs currently on the market may be good fits for certain retrofit scenarios, this specification seeks to define criteria for installations where electrical modifications are needed to accommodate current HPWH models. Electrical constraints are twofold: (1) the existing water heater location may not have access to a dedicated 220V/240V circuit, and/or (2) the electrical panel may not be able to accept more circuits at the required ampacity. The specification makes use of certain criteria established in the Advanced Water Heater Specification (AWHS) by reference to reduce burden across multiple specifications.

Table 5. Plug-In HPWH Specification—Minimum Requirements

<table>
<tr><td>Electrical Constraints</td><td>Unit shall be able to operate on a shared 120 Volt / 15 Amp circuit.</td></tr>
<tr><td>Electrical Connections</td><td>Unit shall have a cord allowing plug-in to a standard 120V receptacle.</td></tr>
<tr><td>Space Constraints</td><td>To qualify as a "space-constrained" product, the unit shall
o fit within a space of 24" x 26" x 72" inclusive of drain pan and all plumbing connections, and
o be able to fit through an opening of minimum size as specified by the manufacturer and listed on the Qualified Products List.
If larger than these dimensions, the product will be listed without the space-constrained mark.</td></tr>
<tr><td>Energy Performance</td><td>
<table>
<tr><td></td><td>Product First-Hour Rating</td><td>Cool Climate Efficiency Requirement</td></tr>
<tr><td rowspan="2">Tier 1</td><td>≥ 51 gallons</td><td>CCE ≥ 2.4</td></tr>
<tr><td>< 51 gallons</td><td>CCE ≥ 2.2</td></tr>
<tr><td rowspan="2">Tier 2</td><td>≥ 51 gallons</td><td>CCE ≥ 2.6</td></tr>
<tr><td>< 51 gallons</td><td>CCE ≥ 2.4</td></tr>
</table>
</td></tr>
<tr><td>Sound Level</td><td>dBA < 55</td></tr>
<tr><td>Warranty</td><td>10 years parts, one year labor</td></tr>
<tr><td>Demand Response Connectivity (Optional)</td><td>CTA-2045 (EcoPort), or equivalent, and complying with the proposed California 2019 Title 24 requirements, JA13, for electric water heater demand management.</td></tr>
<tr><td>Documentation</td><td>Installation manual shall contain necessary references to NEC, UPC, and describe a list of approved installation locations and electrical connection scenarios.
Manufacturers are encouraged to create technical bulletins, or similar, to assist with installations in various installation locations and housing stock.</td></tr>
</table>

Additional minimum requirements from the AWHS are incorporated by reference:

- Section 2.4.2 – ENERGY STAR Compliance[10]
- Section 2.4.6 – Installation Guidance
- Section 2.5.4 – Condensate Management
- Section 2.6.3 – Air Filters: Routine Maintenance and Homeowner Notification

Testing Requirements

The following tests (in addition to the Department of Energy 24-hour Uniform Energy Factor (UEF) and first-hour rating tests) from the Advanced Water Heating Specification (AWHS) are required:

- CCE at 50°F ambient air / 50°F inlet water
- Compressor cutoff temperature
- Sound pressure measurement test

The following tests from the AWHS are *NOT* required:

- Northern climate delivery rating
- The freeze protection test is not required unless the HPWH circulates water outside of the hot water tank for purposes other than delivery to the house.

Reporting Requirements and Qualified Products List (QPL)

A list of products qualified to meet this specification will be initially maintained by the Northwest Energy Efficiency Alliance (NEEA). To qualify, manufacturers shall report the results by submitting a Product Assessment Datasheet[11] to NEEA (HPWH_Assessments@neea.org).

The Qualified Products List will contain a clear indication of whether the product fits the space constraint criteria. All products on the list will meet the electrical constraints. The QPL may also contain, but not be limited to, the following information: nominal volume, first-hour rating, CCE, UEF, and minimum opening required for installation.

[10] The first-hour rating requirement from ENERGY STAR will not be adopted for this spec. Discussions with ENERGY STAR are currently underway about how to align the requirements.
[11] A Product Assessment Datasheet specific to this specification is to be drafted. (The one currently linked contains more requirements than needed for this specification.)

Appendix B: Test and Calculation Procedures

This appendix contains the test and calculation procedures associated with the requirements set forth in the Advanced Water Heating Specification. The tests include the following:

- E_{50}—Efficiency based on the DOE 24-hour simulated use test, but at 50°F ambient air
- E_{95}—Efficiency based on the DOE 24-hour simulated use test, but at 95°F ambient air
- Compressor cutoff temperature
- High-volume draw test
- Freeze protection test (some units)
- Sound measurement
- Airflow measurement

B.1.1 Temperature Range Performance Testing—Integrated Units
Overview: Measure the performance of the heat pump water heater equipment over a range of ambient air operating conditions.

Definitions:
E_{95} – Efficiency based on the DOE 24-hour simulated test, but at 95°F ambient air
E_{67} – Uniform Energy Factor from the standard DOE 24-hour test, at 67.5°F
E_{50} – Efficiency based on the standard DOE 24-hour test, but at 50°F ambient air

1.0 Test Setup and Procedure
E_{67}: Follow standard DOE 24-hour test procedure (Section 6 of 10 CFR Pt. 430, Subpart B, App. E as published in Federal Register Vol. 79 No. 122, July 11, 2014)
E_{50}: Follow standard DOE 24-hour test procedure with the following adjustments:

- Ambient conditions shall be 50°F dry bulb, 43.5°F wet bulb (58% RH)
- Inlet water temperature: 50°F

E_{95}: Follow standard DOE 24-hour test procedure with the following adjustments (note this test is *optional*):

- Ambient conditions shall be 95°F dry bulb, 82°F wet bulb (40% RH)
- Inlet water temperature: 67°F

2.0 Calculation Method

Calculate E_{50} and E_{95} by following the procedure from the DOE 24-hour test (Section 6 of 10 CFR Pt. 430, Subpart B, App. E as published in Federal Register Vol. 79 No. 122, July 11, 2014) except substitute the respective ambient and inlet water temperature conditions. Retain the E_{50} and E_{95} values for documenting on the Product Assessment Datasheet.

B.1.2 Cool Climate Efficiency Calculation Climates (5-6)

Overview: Calculate a Cool Climate Efficiency (CCE) representative of water heater performance for equipment installed in semi-conditioned (e.g., basements, unheated utility rooms) and unconditioned (e.g., garages, crawl spaces) locations in cool climates.

Determining the CCE consists of lab measurement of efficiency at 67°F and 50°F (UEF and E_{50}), compressor cutoff temperature, and a temperature bin-based calculation procedure.

Definitions:

CCE—Cool Climate Efficiency as defined throughout this section

E_R—Efficiency for the HPWH operating in resistance-only heat mode (see Equation 8)

C_{cutoff} is the compressor cutoff temperature (see Appendix B.2)

Calculation Method:

The CCE utilizes a temperature bin weighted calculation.[12] The temperature bins for use in the CCE weightings are given in Table 6. Figure 9 two pages hence provides several graphical examples of the end result of the calculation.

Table 6. Temperature Bins[13]

j	T_j (°F)	f_j
1	77	0.021
2	72	0.121
3	67	0.124
4	62	0.131
5	57	0.132
6	52	0.141
7	47	0.121
8	42	0.096
9	37	0.071
10	32	0.040

The Cool Climate Efficiency is calculated as:

$$CCE = \sum_{j=1}^{10} E_j * f_j \quad (1)$$

where:

j is the bin number from Table 6

f_j is the fraction of hours for that bin

[12] The method is based on the Heating Seasonal Performance Factor (HSPF) method for space conditioning heat pumps.

[13] Tj gives the bin center. For example, the 62°F bin covers the 5-degree range 59.5°F to 64.5°F. "f" is fractional number of days per year in each of the temperature bins. The temperatures are daily averages for the dry bulb temperature in the buffer space. Climate data comes from TMY datasets of six cold climate cities (Boston, Chicago, Indianapolis, Minneapolis, Omaha, and Seattle). These temperatures are based on typical garage and unheated basement temperatures for houses in cold climates (weighting between garages and basement locations is 50/50). Temperature data are derived from simulated garage and unheated basement temperatures in different climates using SUNCODE (for garages) and SEEM (for basements) modeling tools. The garage scenario shares 1.5 of the walls with the house and 2/3 of the ceiling area. The other surface areas are exposed to the outside, attic, or ground. The garage area is 484ft^2 with two car doors. The outside walls are insulated to a nominal value of R-19. The basement scenario has a 1,344ft^2 basement with 7ft ceilings. As the basement is unconditioned, neither the basement walls nor the floor is insulated.

<u>E_j is determined in the following way:</u>

If *no* resistance heat is used in either the UEF or E_{50} test:

$E_j = (T_j – 50)*m_{CCE} + E_{50}$ (2)

where:

T_j is the bin temperature

m_{CCE} is the slope of the line connecting the two measured energy factors:

$m_{CCE} = (E_{67} – E_{50}) / (67.5 – 50)$ (3)

If resistance heat is used during the E_{50} test:

For bin temperatures <50°F:

$E_j = (T_j – 50)*m_{compT50} + E_{50}$ (4)

where:

j is the temperature bin below 50°F and

$m_{compT50} = (E_{50} – E_{R,Ccutoff}) / (50 – C_{cutoff})$ (5)

(the slope of the line connecting the measured E_{50} and $E_{R,Ccutoff}$ at the compressor cutoff temperature)

For bin temperatures ≥50°F and ≤67°F:

$E_j = (T_j-50)*m_{CCE} + E_{50}$ (6)

where:

j is the temperature bin at, or between, 50°F and 67°F and

m_{UEF} is as defined in Equation 3

For bin temperatures >67°F:

$E_j = E_{67}$ (7)

(the efficiency beyond 67°F is capped at the 67°F value)

where:

j is the temperature bin above 67°F

For equipment that limits heat pump operation within the range of temperatures covered in Table 6 (regardless of resistance heat use at other temperatures), the efficiency for those temperature bins shall be assigned a value of E_R, where E_R is based on resistance element-only operation and the measured heat loss rate of the tank obtained during the E_{67} test.

E_R is calculated for each temperature bin of resistance element-only operation as follows:

$$E_{R,j} = Q_{wtr}/(Q_{wtr} + Q_{stbdy,j}) \quad (8)$$

where:

Q_{wtr} is the energy input used to heat water over one day

Q_{stbdy} is the standby energy lost over one day

$$Q_{wtr} = m^* \, c_p * \Delta T \, / \, \eta_{elem} \quad (9)$$

where:

m is daily water mass corresponding to the draw pattern used in UEF test (either very low, small, medium, or high; 10, 38, 55, or 84 gallons; 82.4, 313.1, 453.2, or 692.2 pounds)

c_p is 0.998 Btu/lb°F (heat capacity of water at 96.5°F)

ΔT is 75°F (125°F set point temperature – 50°F inlet water temperature)

η_{elem} is 0.98 heating efficiency of electric element per DOE test procedure

$$Q_{stdby,j} = UA * (T_{tank} - T_j) * 24 \text{ hrs} \quad (10)$$

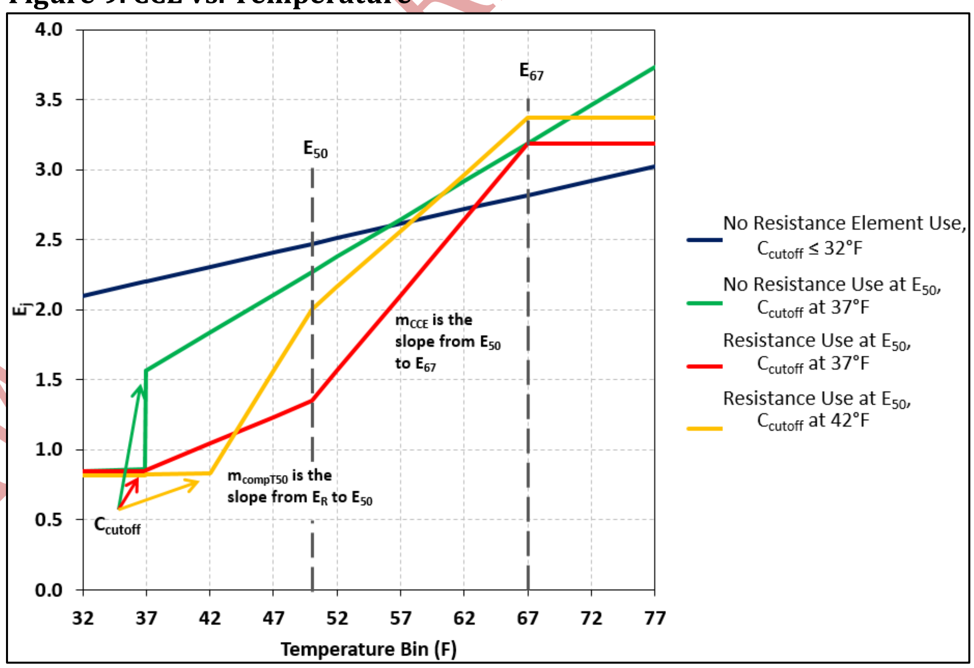
where:

UA is the measured tank heat loss rate (Btu/hr°F) from the E_{67} test

T_{tank} is 125°F (the tank set point temperature)

T_j is the bin temperature

Figure 9. CCE vs. Temperature[14]



[14] Note the CCE calculation procedure is designed to avoid giving undue benefit to using resistance elements at the 50°F condition. With the two test points used in the calculation, if no resistance element is used at 67.5°F but it is used at 50°F, the slope of the line connecting the two points will be artificially steep. An unduly steep slope leads to over-prediction of performance at temperatures above 67.5°F. Consequently, if resistance heat is used at 50°F but not at 67.5°F, the calculation procedure caps the predicted performance in the warmest temperature bins.

B.1.3. OPTIONAL: Warm Climate Efficiency Calculation (1-4)

The specification does not define a specific warm climate efficiency calculation; however, it provides the means with which to calculate one. The calculation may be useful in demonstrating product applicability and expanding market reach in warm climates. To estimate energy performance in warmer climates, use the temperature bin method analogous to calculating CCE. In that case, the procedure would be to use a temperature profile appropriate for the climate or installation of interest. Likewise, use the E_{95} test result, if available, and linearly interpolate performance for temperatures between that and the E_{67} result. If the E_{95} test result is not available, use the E_{50} and E_{67} results to extrapolate performance. The overall accuracy of the calculation is likely to be improved, compared to the extrapolation, if an E_{95} result is available.

Appendix B.2: Compressor Cutoff Temperature

Overview: A method to determine the low-end ambient temperature below which the compressor does not operate. The cutoff temperature is used within the Cool Climate Efficiency calculation. Determine the compressor cutoff temperature to within 5°F corresponding to the temperature bin centers in Table 6.

This is an *optional* test. A manufacturer may choose to self-report the compressor cutoff temperature, C_{cutoff}, and use that in the Cool Climate Efficiency calculation. If using the self-reporting method, and the reported temperature does not match one of the temperatures in Table 6, round the value to the nearest entry in the table. For example, 40°F shall be rounded to the 42°F bin and 39°F shall be rounded to 37°F bin.

If the compressor cutoff temperature is not known (i.e., the self-reporting method is not used), conduct the test as described here to ascertain that temperature.

1.0 Test setup

Set inlet water temperature, $T_{inlet\ water}$, to 50°F.

To start the test, establish normal water heater operation with the water heater outlet temperature at a set point of 125°F. Initiate a draw at 3gpm and withdraw a minimum of 10 gallons. More water shall be withdrawn if needed to achieve compressor cut-in. For example, a large capacity storage tank may require more water to be withdrawn to achieve a compressor cut-in depending on the water heater thermostat dead band.

2.0 Test procedure

The ambient conditions shall be varied as necessary to determine the cutoff temperature. To start, the ambient temperature shall be the closest temperature bin center to the cutoff temperature specified by the manufacturer. For example, if the specified cutoff temperature is 45°F, the test shall be started at 47°F (if specified temperature is 23°F, start at 22°F). If the compressor does not turn on in response to the draw at the first ambient condition, or fails to completely recover the tank with the compressor only, increase the ambient temperature by 5°F and repeat the test. Repeat this procedure until an ambient condition is achieved under which the compressor operates. All tests shall be conducted with an ambient RH of 60%. Record the lowest temperature bin in which the compressor operates. For purposes of Cool Climate Efficiency calculations, the compressor shall be assumed to operate over the entire temperature bin.

Appendix B.3: High Volume Draw Test

Overview: The High Volume Draw Test uses a demanding hot water draw pattern to reveal the conditions under which a unit may transition to electric resistance heating, which may either supplement or replace compressor heating. A significant goal of the AWHS is to provide electric utilities and hot water users with a product that maximizes energy savings over electric resistance water heaters. Any time resistance elements are used in hybrid water heaters, that savings is not realized. Energy savings vetting activities by the Regional Technical Forum[15] and field measurements by others[16] have demonstrated the need to better understand when resistance heating is used.

This test is intended to elicit electric resistance element use and may stress the capability of the water heater. The test output will be used to inform and calibrate predictions/ simulations of heat pump water heater energy use. The test is neither a simulated use test nor a direct rating test nor a representation of an average day; rather, its goal is to better inform when resistance elements are used. Consequently, the tank may run out of hot water during the test. This is an acceptable, even expected, outcome and testing should continue.

This test needs to be conducted only for equipment that uses electric resistance heating in its default operating mode under standard operating conditions. For equipment without resistance elements or without element use in default mode, this test is not required.

The draw profile is 18 hours long and contains three clusters of water draws. The test is conducted at 67.5°F ambient air and 58°F inlet water.

1.0 Test setup

Follow setup procedure for DOE tests (Section 5.2 of 10 CFR Pt. 430, Subpart B, App. E).

Verify water heater is in the default operating mode.

Use the draw pattern in Table 7 corresponding to the nominal tank size. If the nominal tank size is within two gallons of any of the tank sizes given in the table, use the closest size. If the water heater under test does not match any of the given tank sizes, calculate an appropriate draw profile scaled to the 50 gallon profile as follows: Divide the nominal tank size of the unit in question by 50 gallons and multiply each draw amount (in the 50 gallon profile) by that scalar. Do not change the flow rate; instead, change the draw duration. For instance, the first draw for a 55 gallon tank would be 5.5 gallons.

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[15] Regional Technical Forum *Heat Pump Water Heaters UES Measure* https://rtf.nwcouncil.org/measure/hpwh and RTF *Research Plan: Residential Heat Pump Water Heaters.* November 9, 2016. https://nwcouncil.app.box.com/s/ftk0313lkter7gw54pzq9nadfxg4l2q7.

[16] *Heat Pump Water Heater Model Validation Study.* Ecotope 2015. Prepared for Northwest Energy Efficiency Alliance. https://neea.org/resources/heat-pump-water-heater-model-validation-study

Table 7. High Volume Draw Test Pattern

Draw Cluster	Minute	Flow Rate (GPM)	Draw Amount (Gallons) by Nominal Tank Size					
			40	**50**	**60**	**65**	**70**	**80**
	0	3.0	4.0	5.0	6.0	6.5	7.0	8.0
	13	1.0	0.8	1.0	1.2	1.3	1.4	1.6
	43	1.0	0.8	1.0	1.2	1.3	1.4	1.6
	46	1.0	0.8	1.0	1.2	1.3	1.4	1.6
	49	1.0	0.8	1.0	1.2	1.3	1.4	1.6
1	54	1.0	0.8	1.0	1.2	1.3	1.4	1.6
	79	3.0	27.2	34.0	40.8	44.2	47.6	54.4
	95	3.0	4.0	5.0	6.0	6.5	7.0	8.0
	116	1.0	0.8	1.0	1.2	1.3	1.4	1.6
	165	1.0	0.8	1.0	1.2	1.3	1.4	1.6
	365	3.0	4.0	5.0	6.0	6.5	7.0	8.0
	377	3.0	4.0	5.0	6.0	6.5	7.0	8.0
	384	2.0	1.6	2.0	2.4	2.6	2.8	3.2
	412	2.0	1.6	2.0	2.4	2.6	2.8	3.2
2	445	2.0	1.6	2.0	2.4	2.6	2.8	3.2
	450	3.0	18.4	23.0	27.6	29.9	32.2	36.8
	463	2.0	1.6	2.0	2.4	2.6	2.8	3.2
	490	2.0	1.6	2.0	2.4	2.6	2.8	3.2
	690	3.0	3.2	4.0	4.8	5.2	5.6	6.4
	771	1.0	0.8	1.0	1.2	1.3	1.4	1.6
	775	1.0	0.8	1.0	1.2	1.3	1.4	1.6
3	784	1.0	0.8	1.0	1.2	1.3	1.4	1.6
	804	1.0	0.8	1.0	1.2	1.3	1.4	1.6
	813	1.0	0.8	1.0	1.2	1.3	1.4	1.6
	865	3.0	18.4	23.0	27.6	29.9	32.2	36.8
	881	3.0	3.2	4.0	4.8	5.2	5.6	6.4
End Test	1080							
		Total Gallons Drawn						
		Cluster 1	44.8	56.0	67.2	72.8	78.4	89.6
		Cluster 2	30.4	38.0	45.6	49.4	53.2	60.8
		Cluster 3	28.8	36.0	43.2	46.8	50.4	57.6
		Overall	104.0	130.0	156.0	169.0	182.0	208.0

2.0 Test procedure

Prepare the water heater for testing using the same initiation procedure as per the DOE 24-hour test.

Run 18-hour test using the appropriate scaled pattern from Table 7, recording all data.

Depending on tank size and controls, the hot water outlet temperature may drop below 105°F. This is an acceptable outcome for the test and testing shall continue.

3.0 Calculation and Reporting Procedure
Number of No-Electric Resistance Gallons:

Record the number of gallons drawn in each cluster, before the resistance element turns on, as follows: Note the minute in which the resistance element engages. Sum all the gallons drawn in the cluster prior to that minute and record as GC1, GC2, and GC3. Count the gallons only if the outlet water temperature is greater than or equal to 105°F. If no resistance element is used in the cluster, record as the total number of gallons drawn in the cluster. Retain for reporting on the Product Assessment Datasheet.

Appendix B.4: Temperature Range Performance Testing—Split Systems

Overview: This appendix, test method, and calculation procedure is in progress. Split-system HPWHs shall be tested over a range of outdoor ambient air temperatures to determine their energy performance. A draft test procedure is currently underway (*EXP10 - Load-Based and Climate-Specific Testing and Rating Procedures for Split System Air-to-Water Heat Pumps for Domestic Hot Water Service,* CSA Group, https://www.csagroup.org/standards/). When final, that test and rating procedure will be used within this specification. What follows is an outline of the current procedure.

The AWHS intends to require testing at the four conditions listed in Table 8. The test will consist of running the DOE 24-hour simulated use draw pattern at each set of conditions. An optional Temperature Operating Limit (TOL) is also included if the manufacturer wishes to measure and report an efficiency point below 5°F.

Table 8. Draft Testing Conditions for Split Systems

	Standard Outdoor Conditions			**Inlet Water**	**Indoor Ambient Conditions**
	Dry-Bulb Temperature, °F	Wet-Bulb Temperature, °F	RH (%)	Inlet Water Temperature, °F	Indoor Dry-Bulb Temperature, °F
A	5	2	30	42	67.5 ± 2.5
B	34	31	72	47	
C	68	57	50	58	
D	95	69	25	67	
L1	TOL	TOL-1		37	

In addition to the test procedure, seasonal coefficient of performance (SCOP) calculation procedures will determine annual efficiency levels in different climates. The SCOP is an entirely different quantity from CCE; SCOP applies to split systems where the heat pump is subject to outdoor air conditions. Broadly, the method will consist of calculating an efficiency for each test in Table 8 following the Uniform Energy Factor calculation method but substituting in appropriate temperature conditions. This will yield a COP at four distinct ambient temperatures: COP_A, COP_B, COP_C, and COP_D. An overall SCOP will then be calculated using a temperature bin approach similar to that used for the Heating Seasonal Performance Factor (HSPF) for air-source heat pumps.

The temperature bin profile for the SCOP calculation, sourced from Typical Meteorological Year 3 data,[17] is shown in Table 9. The draft reference climate for performance is a combination of the climates of five Pacific Northwest cities. The other climate temperature bin profiles are provided to aid in determining performance in other locations.

Test setup: Unit shall be tested with a 25ft standard length line set (if a manufacturer's system doesn't permit 25ft, it will be the maximum line length defined by the manufacturer). All supporting equipment including fans, pumps, line set insulation, and required heaters will be measured in total energy consumption for calculations.

[17] https://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

Table 9. Draft Temperature Bin Profile for Split-System SCOP Calculation

j	T_j (°F)	f_j - Fraction of Year in Given Temperature Bin for Each Climate						
		*Pacific Northwest**	Minneapolis	Seattle	Los Angeles	Houston	Boston	Atlanta
1	102	*0.000*	0.000	0.000	0.000	0.001	0.000	0.000
2	97	*0.003*	0.001	0.000	0.000	0.011	0.001	0.001
3	92	*0.005*	0.005	0.000	0.000	0.047	0.004	0.022
4	87	*0.010*	0.014	0.002	0.000	0.068	0.012	0.054
5	82	*0.019*	0.036	0.009	0.003	0.112	0.027	0.067
6	77	*0.029*	0.057	0.018	0.018	0.175	0.051	0.100
7	72	*0.045*	0.076	0.039	0.108	0.135	0.085	0.136
8	67	*0.064*	0.083	0.062	0.249	0.100	0.087	0.104
9	62	*0.096*	0.066	0.103	0.300	0.089	0.088	0.101
10	57	*0.135*	0.059	0.168	0.202	0.071	0.088	0.091
11	52	*0.143*	0.063	0.183	0.090	0.065	0.088	0.086
12	47	*0.133*	0.061	0.154	0.026	0.045	0.084	0.064
13	42	*0.121*	0.071	0.148	0.002	0.041	0.090	0.071
14	37	*0.086*	0.060	0.074	0.000	0.024	0.101	0.042
15	32	*0.057*	0.083	0.030	0.000	0.012	0.081	0.025
16	27	*0.030*	0.069	0.007	0.000	0.003	0.043	0.022
17	22	*0.013*	0.060	0.001	0.000	0.001	0.032	0.010
18	17	*0.006*	0.052	0.000	0.000	0.000	0.024	0.001
19	12	*0.002*	0.024	0.000	0.000	0.000	0.009	0.001
20	7	*0.001*	0.018	0.000	0.000	0.000	0.004	0.000
21	2	*0.001*	0.012	0.000	0.000	0.000	0.000	0.000
22	-3	*0.000*	0.015	0.000	0.000	0.000	0.001	0.000
23	-8	*0.000*	0.009	0.000	0.000	0.000	0.000	0.000
24	-13	*0.000*	0.004	0.000	0.000	0.000	0.000	0.000
25	-18	*0.000*	0.001	0.000	0.000	0.000	0.000	0.000
26	-23	*0.000*	0.001	0.000	0.000	0.000	0.000	0.000

* A combination of the climates of five Pacific Northwest cities are used in the reference climate for SCOP calculation and rating. The cities, and their weighting fractions, are: Portland (0.20), Seattle (0.40), Boise (0.25), Spokane (0.10), and Kalispell (0.05).

Appendix C: Freeze Protection Test

Overview: For units circulating water outside the hot water tank for purposes other than delivery to the house (i.e., to a heat exchanger for heating), test the water heater's ability to withstand adverse environmental events and still remain functional afterward as defined in 3.0 below.

1.0 Test setup

- The ambient air in which the water heater is located shall be maintained at 20°F dry bulb for the duration of the test.
- Set tank delivery water temperature set point to 125°F.
- Set equipment to the default operating mode.
- Inlet and outlet water lines shall be insulated to provide an R value between 4 and 8 h-ft^2-F/Btu for a minimum of two feet from the tank with 1" thick pipe insulation.

2.0 Test procedure

- Establish normal water heater operation: If the water heater is not operating, initiate a draw. Terminate that draw when equipment cut-in occurs. When the tank recovers and the heaters cut out, wait five minutes, then shut off all power to the water heater for 24 hours.
- After 24 hours, turn on power to the water heater and allow it to recover to the set point.
- Initiate a draw until the water heater compressor cuts in. Allow tank to recover to the set point.
- Shut off power to the water heater and inspect for damage.

3.0 Functionality

The water heater will have passed the test if all the following criteria are met:

- The compressor runs and the tank recovers after the 24-hour off period.
- There is no freezing or rupture of any water-related connections or components, including but not limited to heat exchangers, pumps, condensate lines, or other heat pump components aside from the standard plumbing connections required for a traditional electric resistance water heater.

Appendix D: Sound Pressure Measurement Test Method

Overview: A simplified, repeatable test to measure sound pressure level

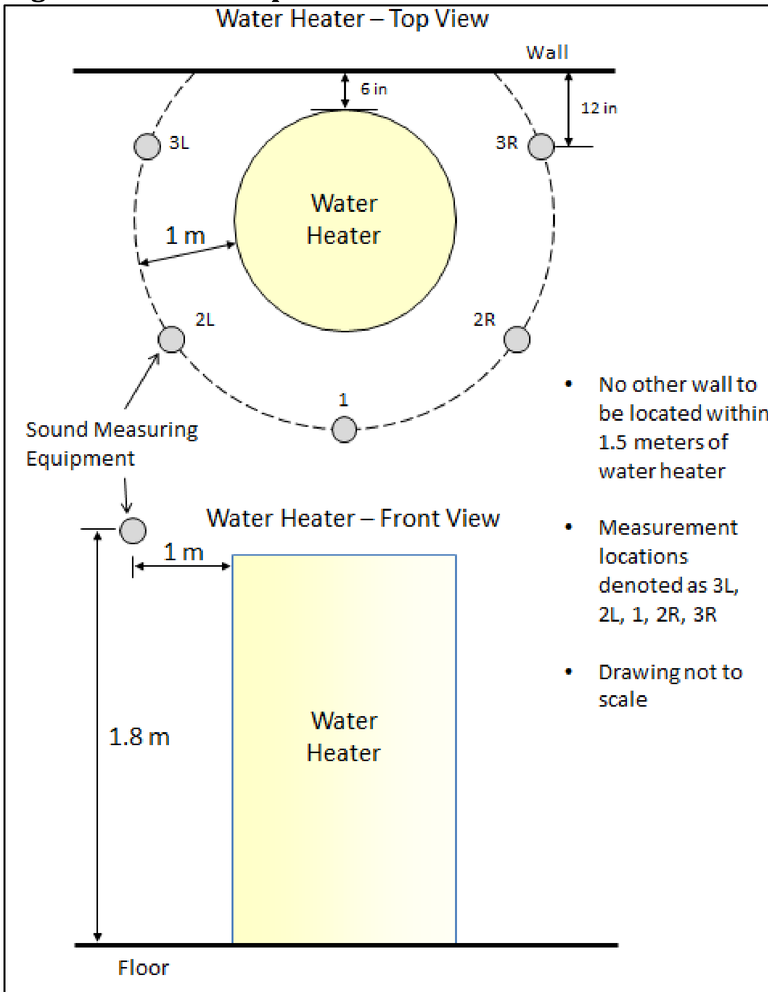
1.0 Test setup

- The testing room shall approximate a reverberation chamber. The approximate reverberation room is defined as follows: most surfaces are relatively hard—standard laboratory flooring materials such as concrete or linoleum, and cinderblock or drywall walls; the room need not be empty of other equipment, though other noise sources should be turned off. Efforts to dampen noise, such as applying anechoic tiles or baffles, shall not be performed. Measurements made in an anechoic or semi-anechoic style chamber are not valid. The test concept is to approximate a typical garage, basement, or house utility room.
- Place the water heater 6” away from one wall in the room.
  - All other walls or objects shall be at least 1.5 meters away from the water heater.
  - Ambient noise shall be at least 10 dBA less than the water heater being measured. For example, if unit under test is measured at 56 dBA, the ambient noise level may be < 46 dBA.
  - Unit shall be run without ducting attached for those units for which this is an option.
- Initiate normal water heater operation under an operating mode that uses all moving components simultaneously including, but not limited to, the compressor, fan, or pumps. Allow the unit to operate in this mode for one minute before proceeding and ensure that a steady state of operation is maintained during the entire sound measurement procedure.
  - Inlet water temperature shall be 58°F ±10°F
  - Ambient air conditions shall be 67°F ±18°F

2.0 Test procedure

- Measure the A-weighted sound pressure level:
  - At five points one meter distant from the water heater surface at a 1.8 meter height above the base of the water heater (see Figure 10). Points 3L and 3R should be 12” from the wall.
  - If the water heater has an airflow intake or exhaust flow path around the circumference of the equipment, position the unit, as follows, so the airflow is not directly aimed at a measurement point: aim the intake or exhaust between points (3L, 2L), (2L, 1), (1, 2R), or (2R, 3R). In no case should the flow path be directed between points (3L, 3R).
- Average all five measurements into a single sound value.

Figure 10. Test Setup for Sound Pressure Measurement



Appendix E: Airflow Measurement (Optional)

Overview: A test method for units with a ducting kit to measure and verify the airflow in a simulated duct system. This is an *optional* test provided for informative purposes only. A manufacturer may choose to self-report a product that meets the requirements of Section 2.6.2.2, in which case this test is not required. If it is unknown whether a unit conforms with Section 2.6.2.2 requirements, this test may be used.

The goal is to demonstrate whether the unit maintains 80% of the nominal airflow when attached to a duct system subject to 0.2" water column of total external static pressure (ESP). ESP is measured across the complete airflow path of the system. Conceptually, for exhaust ducting with a typical HPWH, this includes the filter at the air intake, the evaporator coil, the duct attachment kit, the exhaust duct itself, and an end cap. For dual-ducted systems, this could also include intake ducting and intake air grills.

Definition:

Nominal Airflow—the airflow across the evaporator at which the equipment is rated in the UEF test.

1.0 Test setup and procedure

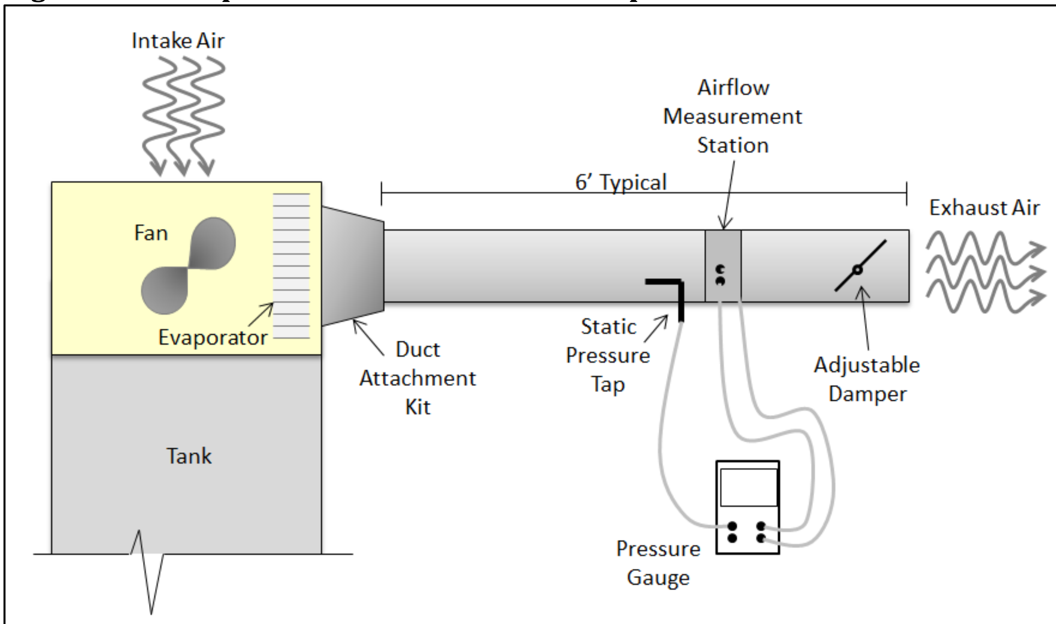
Each HPWH may have a unique airflow path and, therefore, measurement setup. The setup presented in Figure 11 is provided as one possible example.

- Attach ducting kit to airflow outlet.
- Attach an approximately 6-foot length of straight, round, sheet metal duct to the duct kit at a diameter matching the ducting kit outlet diameter.
- Install an adjustable damper at the outlet end of the duct.
- Insert an airflow measurement station and a static pressure tap in the middle section of the duct. Connect each to a pressure gauge.

2.0 Procedure

- Adjust damper position to increase ESP to 0.2" w.c. and record the airflow.
- Compare airflow at 0.2" w.c. to nominal airflow.
    - If airflow at 0.2" w.c. is at least 80% of the nominal airflow, the equipment passes the requirement.

Figure 11. Example Airflow Measurement Setup



Appendix F: Demand Response for Residential Water Heaters

ENERGY STAR® has completed a document delineating criteria for connected water heaters (see *ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters Eligibility Criteria, Version 4.0*),[18] which took effect in January 2022. This document defines a set of demand response messaging commands in its Appendix B; the AWHS shall support mapping of the commands defined in the document.

Demand Response Functionality Test Method

A test method to verify the product meets the demand response functionality requirements is currently being drafted by the Department of Energy. That method will be adopted by this specification. Refer to the "*Evaluation of Demand Response in Connected Water Heaters (in development)*" in *ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters Eligibility Criteria, Version 4.0* and—once it is completed and available—to the new standard AHRI 1430, *Demand Response for Electric Water Heaters.*

Products deploying CTA-2045 (newly renamed EcoPort), an existing, preliminary test procedure, may alternately be used to verify compliance with the requirements. That procedure, *ANSI/CTA-2045-B Water Heater Test Procedures: Information Exchange and Demand Response* is available here: https://www.epri.com/#/pages/product/000000003002016940/?lang=en-US.

The key elements of the standard are listed below:

	Characteristic	Requirement
1	Open Standard	A set of specifications, in draft or final form, that is available to any member of the public from a recognized standards development organization such as ANSI, CTA, IEEE, NEMA, AHRI, etc. (Nominal fee to cover administration cost of the standard's distribution allowed)
2	Physical Attributes	The appliance shall support a communication interface through a physical port or socket using an open standard that defines the physical and data link layers from a recognized standard development organization chosen according to Row 1 above. The specification shall define the socket dimensions, connector, pin configurations (power and data), and the serial data protocol used. To accommodate design of the appliance, the standard must specify the maximum dimensions of a communication device intended for use under the standard.
3	Security	The open specification shall specify information to be exchanged on a private serial communication bus between the appliance and a communication device attached to the appliance by the customer within the customer's premises. The security between the communication device and the grid will be managed by the company in control of the communication device, which is expected to use rigorous industry standard security measures throughout its platform.

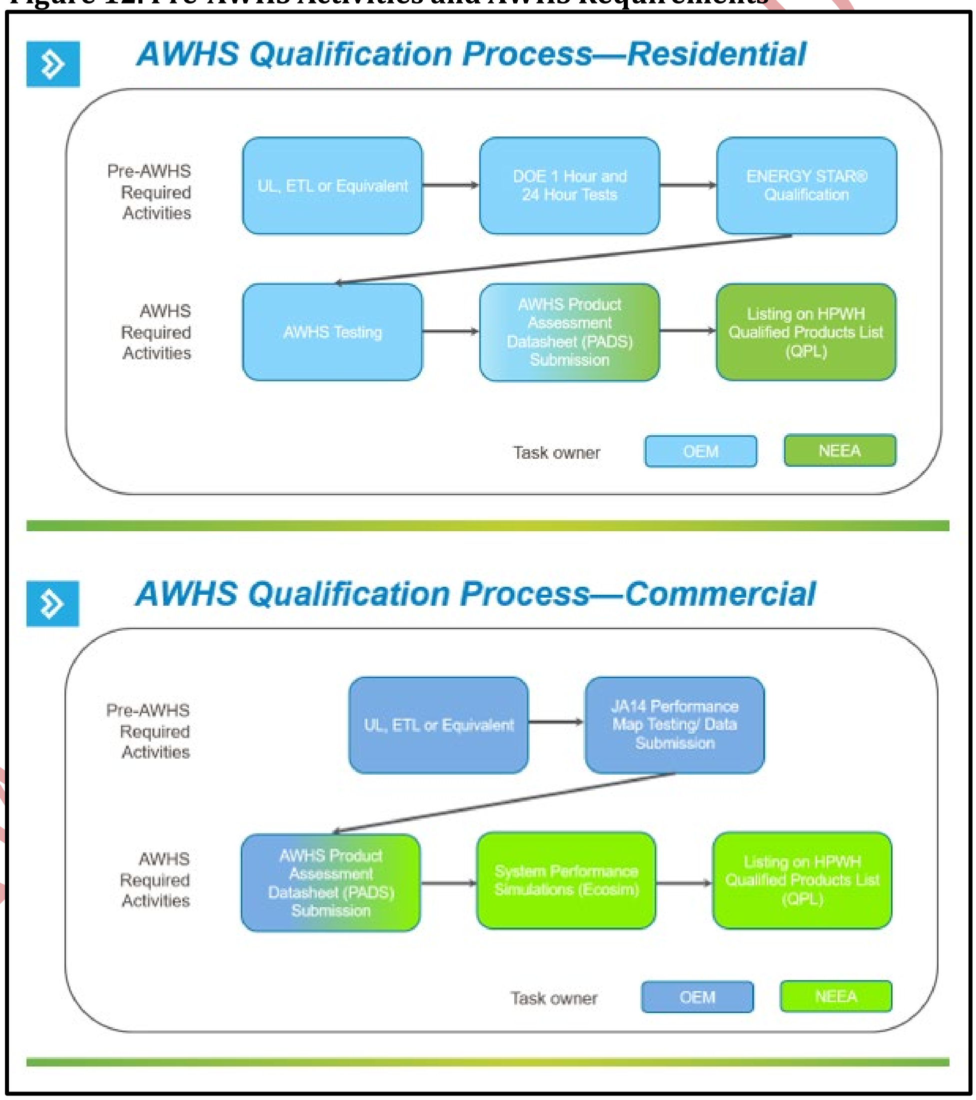
[18] https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.0%20Water%20Heaters%20Final%20Specification%20and%20Partner%20Commitments_0.pdf

	Characteristic	Requirement
4	Power Supply	Rules shall exist to govern the safe distribution of power from one device to another. Through the port, the appliance shall support power to the communication device at no less than 150 mW. If power is provided by AC line voltage, maximum continuous current shall be limited to 50 milliamps.
5	Roles	The standard shall define roles and rules that govern the exchange of information between an appliance and a communication device.
6	Interoperability	A method in the marketplace to demonstrate interoperability of the standard between an appliance and a communication device made by a different manufacturer must exist, e.g., a test harness specification provided by a third party such as OpenADR or GitHub, or an organization that provides services, without discrimination, to advance interoperability.
7	Data Link Layer	At a minimum, the data link layer must define/support the following attributes: 1. Data formatting 2. Data error detection, e.g., cyclic redundancy check (CRC) and ability to retry failed data exchange 3. Define a default exchange at minimum 19,200 bits/sec and have ability to negotiate other higher data rates 4. Ability to acknowledge, or note failure, by the appliance to understand and/or comply with an application command 5. Discovery: Ability of devices on both sides of the serial interface to support gaining information about the other device; information such as type of device, firmware used by the device, the application language used by the appliance, etc. 6. Power level available to the communication device 7. Ability to identify and exchange data using at least one and possibly many common application layer command language(s) 8. The specification must be written to support extensibility in recognition of the rapidly changing practices by grid operators to control electric usage in appliances designed for flexible operation. Future generations of the specification may require over-the-air upgrades. 9. Other services essential to data link layer standard
8	Interface Non-obsolescence	The service life of the communication standard and hardware, the physical port or socket, shall have an anticipated service life at least equal to that of the appliance itself.
9	Additional Communication Channels	The standard shall not define or restrict how information is exchanged by the appliance with other devices/entities other than on serial bus defined in the open standard. The standard shall allow a method of pass-through communications for USNAP 1.0, SEP 1.0, ClimateTalk, General IP, ECHONET Lite, KNX, LonTalk, SunSpec, BACnet at a minimum.
10	Customer Experience	The communication interface shall be installed on the appliance where the customer can access the port, even years after the purchase of the appliance, to install a communication device without undue effort or interference to the operation of the appliance.

Appendix G: Qualification Process

All the steps necessary for ENERGY STAR® qualification are required by the Advanced Water Heater Specification. A broad overview of the pre-AWHS activities and subsequent AWHS requirements are shown in the flow chart below (Figure 12). The original equipment manufacturer (OEM) is responsible for taking the water heater through preparation of the referenced AWHS Product Assessment Datasheet (PADS), at which point it is handed off to the managing agency (currently the Northwest Energy Efficiency Alliance (NEEA)). Testing may be conducted at any lab that the manufacturer is willing to stand behind and to sign off on the attestation in the PADS document. If all requirements are met, the product will be listed on the Qualified Products List (QPL). The QPL is updated as needed to keep current with products on the market.

Figure 12. Pre-AWHS Activities and AWHS Requirements



The qualification process for the Advanced Water Heater Specification begins when a manufacturer submits the Heat Pump Water Heater Product Assessment Datasheet to the managing agency (currently NEEA). The most current version of this datasheet, to be completed by the manufacturer, is under "Additional Resources" at https://neea.org/our-work/advanced-water-heater-specification.

Manufacturers are encouraged to perform their own Advanced Water Heater Specification testing (or modeling, if a commercial product) or facilitate it through any third-party EPA-recognized laboratory.[19] In the event the manufacturer does not perform this testing (and submits an incomplete assessment worksheet), qualification will be delayed until the managing agency or the manufacturer[20] performs the requisite testing.

Upon meeting all the requirements for qualification, a product will be added to the Qualified Products List and classified into the appropriate tier level. For the current list, and for a complete description of the current process flow for the qualification process, see "Additional Resources" at https://neea.org/our-work/advanced-water-heater-specification.

[19] See https://www.energystar.gov/index.cfm?fuseaction=recognized_bodies_list.show_RCB_search_form

[20] For situations in which the manufacturer's testing results are self-reported and validated by NEEA or its desigated managing agency

Appendix H: Disqualification, Tier Reassignment, and Requalification Process

This Appendix is divided into two sections: Residential (A) and Commercial (B). The managing agency (see below) may evaluate any product on the QPL at any time to ensure that the product meets the requirements of the Advanced Water Heating Specification. The evaluation may result in any of the following:

- A product may remain qualified to the specification at its current tier level.
- A product previously qualified to the specification may qualify for a different tier level.
- A product previously qualified to the specification may no longer qualify.

Grounds for disqualification or re-assignment of products to a different tier level may be uncovered through any of the following scenarios, or through other scenarios that may arise:

1. Lab re-testing of new units or versions of the product
2. Inspection of the product in the event that certain product features available at the time of initial qualification are no longer commercially available
3. Discovery of substantial differences between in-field performance and lab-tested performance (greater than 5%) through in-field testing. "Substantial" is here defined as having a material impact on the aggregate performance in the population of products under study, such that the product in aggregate no longer qualifies for the tier level under which it was qualified.
4. Observation of product safety issues in the field, or discovery of issues in lab or field testing
5. Challenge to Qualified Products
6. Challenge to modeled system performance values

A. Residential
For Residential water heaters, the Qualified Products List (QPL) managing agency is currently the Northwest Energy Efficiency Alliance (NEEA).

An entity (manufacturer, regulatory agency, advocacy group, or other party) may challenge the placement of a product on the QPL. This challenge event consists of the following:

- The party challenging the results contacts NEEA or the current QPL managing agency in writing that potential discrepancies in test results may exist.
- The managing agency notifies the challenged party in writing and coordinates a mutually agreeable testing lab for verification testing.
- Random units are pulled from distribution and sent to the testing lab.
- The full cost of doing the test (including procurement, shipping, and testing) shall be borne by whichever of the two entities is found in error.

In all the above scenarios, NEEA or the current managing agency will share the findings and other relevant information with the HPWH Program and Technical Workgroups, the challenging party (if applicable), and the challenged party for review. Upon review, NEEA or the current managing agency may decide to proceed with the disqualification/tier reclassification, or to proceed no further for reasons such as lab or field testing errors, insufficient confidence in testing results, or administrative errors in the testing process. NEEA or the current managing agency may request that the challenged party provide additional information, or participate in additional third-party testing, to determine the outcome; such information and/or findings would also be shared with the challenging party in the case of a third-party challenge.

All parties involved shall proceed in a confidential manner during and after the challenge event. NDAs will be in place with all parties involved at the onset of a disqualification process. No party is to disclose any information regarding the challenge or the involved product and/or parties. NEEA or the current managing agency may reveal only the challenge outcome or may choose to reveal additional information material to the challenge event.

Upon deciding to proceed with disqualification/tier-reclassification, NEEA or the current managing agency shall inform the challenged manufacturer and provide 20 days for a written response from the date of notice. NEEA shall share the written response (if any) with the HPWH work groups, gather feedback, make a final decision, and inform the challenged manufacturer and the challenging party of the decision. In the event that a previously qualified product is found to not meet specifications and/or the specified tier level, the product will be de-listed or relisted at a new tier level.

Once a product has been disqualified or assigned to a different tier level, the challenged manufacturer may petition for requalification or reassignment to the original tier level. The information provided in the petition (such as updated lab and field tests and/or manufacturing process or design changes) will be analyzed by NEEA or the current managing agency and shared with the existing incentive programs and/or technical work groups. At that point, a decision will be made and communicated to both the challenged and challenging parties.

B. Commercial

For commercial water heating systems, the QPL will be managed by NEEA. The process is similar to the Residential process above, except that lab testing is not required or possible; instead, commercial HPWH system modeling software (Ecosim, created by Ecotope) is used to determine performance. The biggest area for potential challenges resides in the underlying assumptions in the modeling software. Geography, amount of demand, and return temperatures will be the key variables. Modeling assumptions will be clearly defined in the product specification so that the “performance map data” are accurate to the location and installation.

In all the above scenarios, NEEA or the current managing agency will share the findings and other relevant information with the HPWH program and technical work groups, the challenging party (if applicable), and the challenged party for review. Upon review, NEEA or the current managing agency may decide to proceed with the disqualification/tier reclassification, or to proceed no further for reasons such as lab or field testing errors, insufficient confidence in testing results, or administrative errors in the testing process. NEEA or the current managing agency may request that the challenged party provide additional information, or participate in additional third-party testing, to determine the outcome; such information and/or findings would also be shared with the challenging party in the case of a third-party challenge.

All parties involved shall proceed in a confidential manner during and after the challenge event. NDAs will be in place with all parties involved at the onset of a disqualification process. No party is to disclose any information regarding the challenge or the involved product and/or parties. NEEA or the current managing agency may reveal only the challenge outcome or may choose to reveal additional information material to the challenge event.

Upon deciding to proceed with disqualification/tier-reclassification, NEEA or the current managing agency shall inform the challenged manufacturer and provide 20 days for a written response from the date of notice. NEEA shall share the written response (if any) with the HPWH work groups, gather feedback, make a final decision, and inform the challenged manufacturer and the challenging party of the decision. In the event that a previously qualified product is found to not meet specifications and/or the specified tier level, the product will be de-listed or relisted at a new tier level.

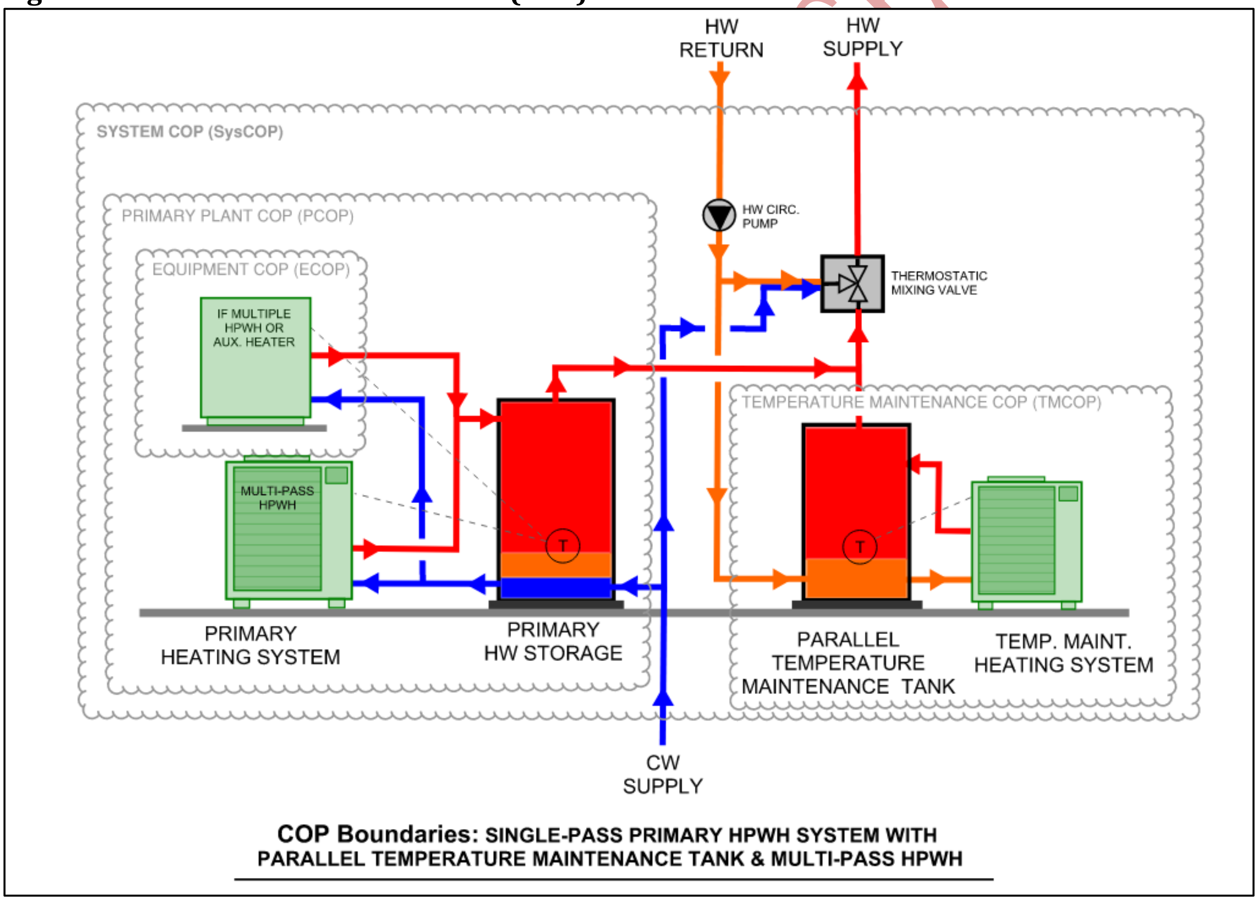
Once a product has been disqualified or assigned to a different tier level, the challenged manufacturer may petition for requalification or reassignment to the original tier level. The information provided in the petition (such as updated lab and field tests modeling and/or manufacturing process or design changes) will be analyzed by NEEA or the current managing agency and shared with the existing incentive programs and/or technical work groups. At that point, a decision will be made and communicated to both the challenged and challenging parties.

Appendix I: Commercial System COP Calculation Method

The commercial AWHS defines the following efficiency boundaries: the equipment COP (ECOP), primary plant COP (PCOP), temperature maintenance plant COP (TMCOP), and the system COP (SysCOP). Definitions of these coefficients of performance are included in the glossary section of this document. The SysCOP includes performance of connected equipment in the primary plant, equipment plant, and temperature maintenance tank.

The following diagram and formulas illustrate the coefficient of performance boundaries for a single-pass HPWH system with a parallel temperature maintenance tank. System performance of commercial systems is modeled using data from these calculations to analyze overall energy use of the system. The energy input to power the hot water circulation pump(s) and thermostatic mixing valve(s), when present, is not included in the SysCOP calculations but is shown below for illustrative purposes.

Figure 13. Coefficient of Performance (COP) Boundaries



$$\boldsymbol{DHW\ System\ COP} = \frac{\boldsymbol{E_{out}} + \boldsymbol{E_{loop\_loss}}}{\boldsymbol{E_{in\_primary}} + \boldsymbol{E_{in\_tm}}}$$

Where:

$$E_{out} = m_{use} * c_p * (T_{loop\_s} - T_{in})$$

$$m_{use} = m_{cold} + m_{cold\_2}$$

$$E_{loop\_loss} = m_{loop} * c_p * (T_{loop\_s} - T_{loop\_r})$$

T_{loop_s}: the temperature of hot supply water after the thermostatic mixing valve to the building HW fixtures

T_{in} : the temperature of cool makeup water entering the heat plant

T_{loop_r} : the temperature of the return water from the hot water circulation system back to the central domestic hot water heat plant

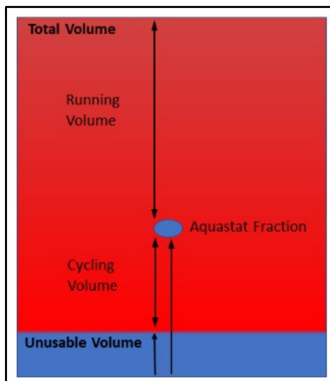
Appendix J: Glossary

Auxiliary or Backup Heating

A supplementary water heating system that provides continuation of hot water delivery in the event the HPWH is not functioning or is unable to supply sufficient hot water to meet current needs.

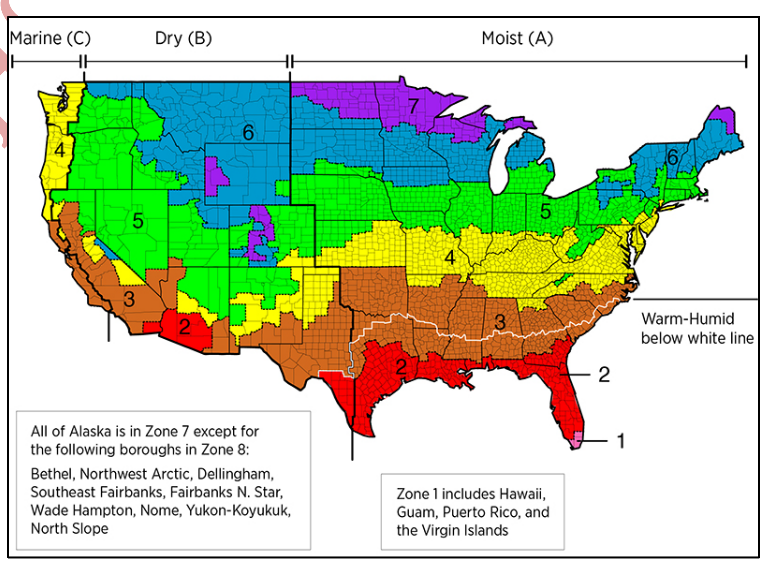
Aquastat Fraction

The point in the entire primary storage volume where the temperature trigger (aquastat) for cycling on the heat pump water heaters is placed. The default is to place this aquastat so that 40% of the primary storage (typically defined by the manufacturer or engineer) is used when the heat pump equipment is triggered to cycle on. This is controlled by the location of the aquastat port on the storage equipment that is being purchased.



Climate Zones

The eight U.S. climate zones are based on temperature, precipitation, and heating and cooling degree days. The eight zones are: hot-humid, hot-dry, mixed-dry, mixed-humid, marine, cold, very cold, and subarctic. (See map on the following page and in ASHRAE 90.1: https://www.ashrae.org/technical-resources/bookstore/standard-90-1)



Commercial Heat Pump Water Heating System (CHPWH)
Commercial heat pump water heating systems are defined as central domestic water heating plants serving more than four dwelling units or serving commercial loads needing more than a total of 119 gallons of storage volume and/or 6 kW of input power. These systems can be unitary or split systems and contain multiple equipment components to create a fully functioning system.

Custom Engineered System
This term describes a system that typically requires engineering design and support. It represents systems for which a single seller, distributor, or company supplies only the HPWH components without design specifications for the entire commercial HPWH system. In custom-engineered systems, an engineering team selects and specifies the components that make a CHPWH system, including the storage tank(s), temperature maintenance system, circulation pump(s), thermostatic mixing valve, auxiliary heaters, and storage tank controls.

Design Cold Water Temperature
This is the coldest water temperature supplied by incoming city water. Increasing this value means the HPWH has a lower temperature lift to the hot water supply temperature, and the required heating capacity will decrease.

EcoPort
New branded name for CTA-2045.

Ecosizer
The Ecosizer[21] is a free tool for sizing central water heating systems based on heat pump water heaters (HPWHs) in multifamily buildings. The tool is designed to support the building industry to adopt HPWHs to improve energy efficiency and reduce greenhouse gas emissions. The Ecosizer is also intended to provide educational information on central HPWH system designs to other stakeholders, for example to energy efficiency and building decarbonization advocates, program administrators and implementers, building science researchers, manufacturers, and policymakers.

Equipment Coefficient of Performance (ECOP)
This is the efficiency of each separate piece of equipment. For HPWH equipment, the ECOP varies with air and water temperatures.

21 https://ecosizer.ecotope.com/sizer/

Fully Packaged/Skid-Mounted

Fully Packaged / Skid-mounted—All-in-one package that can be shipped and installed as a complete solution to serve a specific number of occupants and/or dwelling units. At minimum, this includes the following components: the primary HPWH(s), the primary storage tank(s), the temperature maintenance system (when present), and a control system. The systems are designed, configured, and built up as a complete functional domestic hot water system.

Fully Specified Built-Up System

This term describes a fully specified package of parts, pieces, controls, and design assistance provided by a single seller, distributor, or company that comprises everything needed for a commercial HPWH system ("parts and smarts"). It includes the heat pump and specifications for the heat pump, allowable piping configuration, schematics, sequences of operations, and at a minimum, guideline specifications for all CHPWH system components that comprise a fully functional CHPWH system (HPWH(s), storage tank(s) temperature maintenance system, circulation pump(s), thermostatic mixing valve, auxiliary heaters, and controls). This follows the VRF model in which everything needed for a complex field-installed system is provided by a single manufacturer and designed to work together as a system.

Hot Water Storage Temperature

This is the set point temperature of the primary heat pump water heater, or the hottest temperature provided by the primary heat pump equipment.

JA14 (Joint Appendix 14)

The California Energy Commission's (CEC's) Joint Appendix 14 (JA14) to its Building Energy Efficiency Standards, specifically Title 24, Part 6, re: Qualification Requirements for Central Heat Pump Water Heater (HPWH) Systems.

Load Shift

This refers to the ability of the HPWH to turn off or minimize use to avoid electricity draw and reduce peak loading on utilities. The load shift function allows the user to block out part of the day when the heat pump water heaters will not run. The storage volume and heating capacity necessary to meet the load is sized similarly as in the primary system, but accounts for period(s) during which the heat pump water heaters will not run as requested by utility signals. This necessarily means that the storage volume must be higher so that the volume in the primary storage can provide the building occupants with hot water for the period when the heat pumps are prevented from running, and can meet any peaks after the end of the load shift period(s).

Multi-Pass Heating Cycle

A heat pump water heater equipment cycle in which water is heated to the storage set point temperature using multiple water passes through the refrigeration circuit. This typically generates a 10°F temperature lift for each cycle.

Number of Apartments
Total number of apartment units in the building. An increase in the number of apartments in a building will result in increased temperature maintenance losses for a given recirculation loop heat loss.

Parallel Temperature Maintenance Tank or Parallel Loop Tank
Single-pass heat pump water heaters are most efficient when heating cool city water to hot storage temperatures, whereas multi-pass equipment can still operate efficiently when incoming water temperatures are around 120°F. A parallel loop configuration is one strategy used to isolate the temperature maintenance task from the task of heating the primary storage. A parallel loop tank is an electric resistance element or a multi-pass heat pump that is piped in parallel with the primary system, specifically to handle the temperature maintenance load.

Parallel Primary Storage Tank Configuration
A storage tank configuration in which multiple tanks are piped in parallel to achieve a larger storage volume. The parallel primary storage tank configuration relies on equal flow through the parallel piping circuits for system balancing.

Primary Heating System—No Recirculation
This describes a system with equipment that operates only as a primary heating device, or heating the cool water from the city or main to the hot water storage tank set point.

Primary Plant Coefficient of Performance (PCOP)
PCOP represents the efficiency of the primary heating equipment. It incorporates losses from storage and energy use of any auxiliary or backup equipment. It is generally described as an average annual value.

Hot Water Recirculation Loop
This term represents the portion of the hot water distribution system where the water is circulated at a low constant or nearly constant flow rate to keep the water in the distribution piping near the end use fixtures at or near the delivery water temperature (typically 120°F).

Recirculation Loop Flow Rate
The recirculation loop flow rate is the rate at which a recirculation pump moves hot water through the distribution loop in gallons per minute.

Recirculation Loop Heat Loss
These are the losses associated with the recirculation loop expressed in watts/apartment unit. Previously-studied buildings show a median loss value close to 100W/apt, with a 25th percentile of ~66W/apt, and a 75th percentile of ~175W/apt. Ideally, building and plumbing design will minimize this load. This area of building science deserves additional research to better understand typical recirculation losses and how to minimize them.

Increasing the recirculation loop heat loss rate will increase the temperature maintenance load expected and thus increase the temperature maintenance heating capacity and storage volume.

Recirculation Loop Return Temperature
The recirculation loop return temperature is the temperature of hot water when it returns to the temperature maintenance plant. This variable is used along with the recirculation loop flow rate to calculate the recirculation loop heat loss rate.

Series Primary Storage Tank Configuration
A storage tank configuration in which multiple tanks are piped in series to achieve a larger storage volume. The hot outlet of the first tank is piped to the bottom of the second tank, and so forth.

Single-Pass Heating Cycle: Heats water to the storage set point temperature in a single water pass through the refrigeration circuit. It typically generates a 70°F to 100°F temperature lift in a single cycle.

Split-System Heat Pump
This is term in the industry to describe a heat pump that comes in (at least) two components. In traditional HVAC usage, it means that the compressor is located outside or detached from the storage tank (potentially in a remote location) and refrigerant and/or water is piped to an indoor tank or heat exchanger unit. Split systems for domestic water applications are defined as a heat pump water heater, controller, and storage tank not in a single packaged unit.

Storage Efficiency
This is the fraction of the primary storage volume that is filled with hot water at the storage temperature. The storage efficiency is used to check that the primary storage volume between the aquastat and the bottom of the effective storage volume is large enough that the primary HPWHs can cycle for at least 10 minutes without any hot water draws. Having a cycling volume greater than this minimum helps build a robust CHPWH system and adds some safety in the storage volume.

Supply Water Temperature
This is the water temperature supplied to the building occupants from the hot water system/plant. The default is set to 120°F, an industry standard. If aligning sizing efforts with CA Title 24 software, the temperature should be increased to 125°F.

Increasing the supply water temperature raises the reference temperature for the water occupants use. This will increase the storage volume as the hot water stored has less potential energy over the supply water temperature.

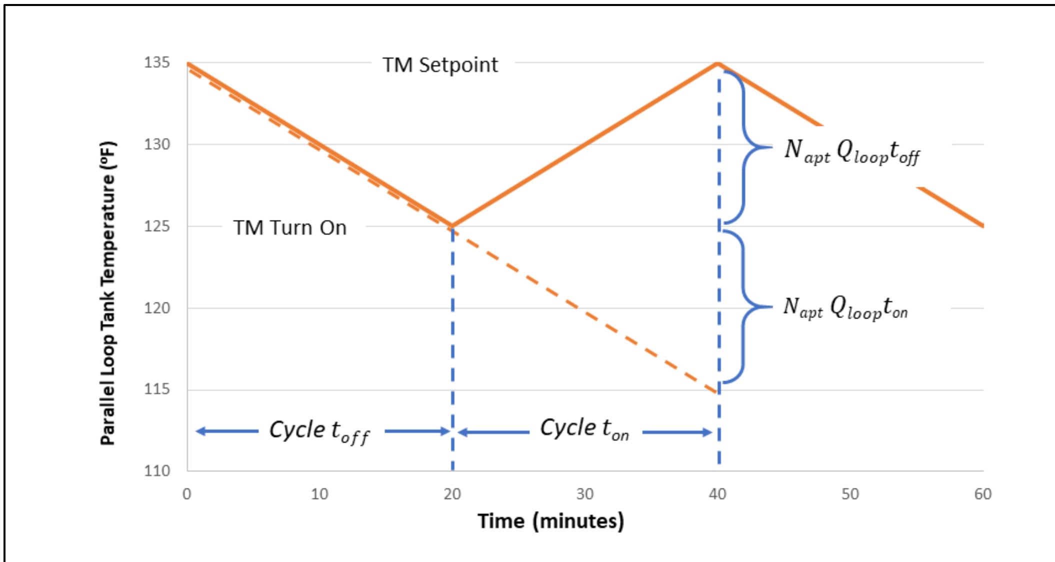
Swing Tank
A swing tank design is a proven technique to use the primary heat pumps to support the temperature maintenance load, while keeping the heat pump equipment isolated from the warm water returning from the recirculation loop. This design strategy is best suited for buildings with low temperature maintenance loop losses (< 60W/apt) and relies on increased storage volume (with tanks piped in series) to ensure storage stratification. Swing tank systems have an electric resistance element in the temperature maintenance tank as a backup safety factor. Sizing a swing tank system also means increasing the heating capacity and storage volume of the primary system. The temperature maintenance storage volume for the swing tank can be small.

System Coefficient of Performance (SysCOP)
This term represents the efficiency of the entire domestic hot water system—the combined efficiency of the primary plant and temperature maintenance plant. It includes all the heat energy put into the system to heat and maintain hot water over all the electrical energy used to heat and maintain hot water. SysCOP is typically described as an average annual value that accounts for climate conditions and entering and leaving water conditions.

Temperature Maintenance Coefficient of Performance (TMCOP)
This term represents the efficiency of the temperature maintenance system or the system that maintains the temperature of water in the hot water distribution piping at or near the supply water temperature. It incorporates losses from storage and energy use of any auxiliary or backup equipment.

Temperature Maintenance System
This is a system that maintains the temperature of water in the hot water distribution piping at or near the supply water temperature. Common practice in the industry is to circulate the hot water in the distribution piping at a rate that keeps the water near the supply water temperature of around 120°F. This term also includes heat trace or heat tape systems that utilize an electric resistance element attached to the HW distribution piping to maintain the water temperature near the supply water temperature.

Temperature Maintenance System/Set Point
This term, the temperature maintenance turn-on, and the one cycle off time are critical to sizing a multi-pass heat pump water heater system. The temperature maintenance set point is the temperature of the water serving the recirculation loop supply.
Increasing the temperature maintenance set point while holding the temperature maintenance turn-on temperature (at 125°F) will decrease the temperature maintenance tank volume as the stored energy density of the tank is greater.



Temperature Maintenance System Safety Factor
This is the safety factor of the temperature maintenance heater over the temperature maintenance load. A higher safety factor will increase the output of the temperature maintenance heater. If the safety factor were set to 1, the temperature maintenance heater and the temperature maintenance load would be in perfect balance.

Temperature Maintenance Turn-On
This term, the temperature maintenance set point, and the cycle off time are critical to sizing a multi-pass heat pump water heater system. The temperature maintenance turn-on is the temperature of the water that will trigger the temperature maintenance to begin a heating cycle—in other words, the lowest temperature to which the temperature maintenance tank should be allowed to drop. This cannot be less than the supply temperature.

Unitary System
A unitary system is sometimes referred to as an integrated system. This term is well-established to describe the common residential products that include the heater, tank, and controls all in one. Some manufacturers have added a large commercial unitary product, which shows that this term can span residential and commercial product categories.

Appendix K: Low GWP Refrigerants

The Advanced Water Heating Specification 8.0 does not take a position on Global Warming Potential (GWP) refrigerants. NEEA recommends consulting with the Environmental Protection Agency (EPA) and applicable local, state, and regional organizations for current recommendations on which refrigerants will be allowed for national and state agencies.

Appendix L: Demand Response for Commercial and Multifamily

ENERGY STAR® has finalized criteria for connected water heaters, which became effective in January 2022 (see *ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters Eligibility Criteria, Version 4.0*). This document defines a set of demand response messaging commands in its Appendix B; the AWHS shall support the mapping of the commands defined in this document in its criteria for connected water heaters as well.

Demand Response Functionality Test Method

A test method to verify the product meets the demand response functionality requirements is currently being drafted by the Department of Energy. That method will be adopted by this specification. Refer to the "*Evaluation of Demand Response in Connected Water Heaters (in development)*" in *ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters Eligibility Criteria Draft 1 Version 4.0*.[22]

Products deploying CTA-2045 (newly renamed EcoPort), an existing, preliminary test procedure, may alternately be used to verify compliance with the CTA-2045 standard. That standard, *ANSI/CTA-2045-B Water Heater Test Procedures: Information Exchange and Demand Response,* is available from the Consumer Technology Association's current standards work. The test method, protocol, and listing process will be available in Q1 2022 on the OpenADR Alliance webpage (TBD).

The key elements of the standard are listed on the following page.

[22] https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Draft%201%20Version%204.0%20Water%20Heaters%20Specification.pdf

	Characteristic	Requirement
1	Open Standard	A set of specifications, in draft or final form, that is available to any member of the public from a recognized standards development organization such as ANSI, CTA, IEEE, NEMA, AHRI, etc. (Nominal fee to cover administration cost of the standard's distribution allowed)
2	Physical Attributes	The appliance shall support a communication interface through a physical port or socket using an open standard that defines the physical and data link layers from a recognized standard development organization chosen according to Row 1 above. The specification defines the socket dimensions, connector, pin configurations (power and data), and the serial data protocol used. To accommodate design of the appliance, the standard must specify the maximum dimensions of a communication device intended for use under the standard.
3	Security	The open specification shall specify information shall be exchanged on a private serial communication bus between the appliance and a communication device attached to the appliance by the customer within the customer's premises. The security between the communication device and the grid will be managed by the company providing the communication device, which is expected to use rigorous utility industry standard security measures throughout its platform.
4	Power Supply	Rules shall exist to govern the safe distribution of power from one device to another. Through the port, the appliance shall support power to the communication device at no less than 150 mW. If power is provided by AC line voltage, maximum continuous current shall be limited to 50 milliamps.
5	Roles	The standard shall define roles and rules that govern the exchange of information between an appliance and a communication device.
6	Interoperability	A method in the marketplace must exist to demonstrate interoperability of the standard between an appliance and a communication device made by a different manufacturer, e.g., a test harness specification, test method, and protocol provided by a third party such as the OpenADR Alliance or GitHub, or an organization that provides services, without discrimination, to advance interoperability.
7	Data Link Layer	At a minimum, the data link layer must define/support the following attributes: 1. Data formatting 2. Data error detection, e.g., cyclic redundancy check (CRC) and ability to retry failed data exchange 3. Define a default exchange at minimum 19,200 bits/sec and have ability to negotiate other higher data rates 4. Ability to acknowledge, or note failure, by the appliance to understand and/or comply with an application command 5. Discovery: Ability of devices on both sides of the serial interface to support gaining information about the other device; information such as type of device, firmware used by the device, the application language used by the appliance, etc. 6. Power level available to the communication device 7. Ability to identify and exchange data using at least one and possibly many common application layer command language(s) 8. The specification must be written to support extensibility in recognition of the rapidly-changing practices by grid operators to control electric usage in appliances designed for flexible operation. Future generations of the specification may require over-the-air upgrades. 9. Other services essential to data link layer standard
8	Interface Non-obsolescence	The service life of the communication standard and hardware, the physical port or socket, shall have an anticipated service life at least equal to that of the appliance itself.
9	Additional Communication Channels	The standard shall not define or restrict how information is exchanged by the appliance with other devices/entities other than on serial bus defined in the open standard. The standard shall allow a method of pass-through communications for USNAP 1.0, SEP 1.0, ClimateTalk, General IP, ECHONET Lite, KNX, LonTalk, SunSpec, BACnet at a minimum.
10	Customer Experience	The communication interface shall be installed on the appliance where the customer or facility staff can access the port or equipment interface, even years after the purchase of the appliance, to install a communication device without undue effort or interference to the operation of the appliance.

Table 1. Communication and Discovery with CTA-2045-B*			
Function	**CTA-2045-B Message**	**CTA-2045-B Reference**	**Explanation and Requirement**
Verifying Connectivity	Outside Comm Connection Status Message	Table 8-2	Outside Comm Connection Status Message is a CTA-2045-B mandatory message. This recurring signal, sent from the communication module to the water heater, must be acknowledged, as it allows the water heater system to know that the attached communication module is successfully connected to a remote headend, or network server supporting the communication module, to know that the water heater system is present and connected.
System Type	Info Request—sent from the communication module to the water heater	Section 9.1.1 Section 9.1.1.1 (request) and Section 9.1.1.2 (response)	Info request sent from the communication module to determine the device type. Responses include electric resistance (0x0002) or heat pump water heater (0X0003). Also included in the info request response is the capability bitmap which indicates the support for advanced load-up (Bit6).
Operational State Query and Response	Operational State Query and Response Messages	Section 8.2.4	Operational state query and response enables remote systems to monitor the present state of the water heater system and to verify that curtailment events are acted upon and in effect. Responses include: 1. (State 0) Idle Normal—Water heater is not heating but is in a normal mode of operation. 2. (State 1) Running Normal—Water heater is in a Normal Operating Mode and the water heater is presenting heating (heat pump compressor or any heating elements are energized). 3. (State 2) Running Curtailed—Water heater is running a grid service mode of operation and the water heater is presently being heated. 4. (State 3) Running Heightened—Water heater is processing a load-up request and water is being heated. 5. (State 4) Idle—Water heater is in a grid service operational model and the water heater is not heating water. 6. (State 5) Water Heater Error—Device is malfunctioning. Recommended use: Failure of heat pump or element. 7. (State 6) Idle Heightened—Water heater is processing a load-up request and water is not being heated. 8. (State 12) Running Idle, Opted Out—Water heater is overridden and is consuming energy.
Energy Storage Capacity	Get Commodity Read —sent from the communication module to the water heater for energy storage info		Present Energy Storage/Take Capacity: The amount of grid energy that the end device can take now (watts or kWhs). Total Energy Storage/Take Capacity: Total amount of grid energy that can be absorbed by the device when it is at its lowest state of charge (watts).
Power/Demand	Get Commodity Read – sent from the communication module to the water heater for power consumption info		Electricity Consumed: The estimated power consumption in current conditions. Estimates can be made using the compressor power and/or the element(s) wattage.

**Note:* The table numbering in this Appendix is separate from that for the document as a whole.

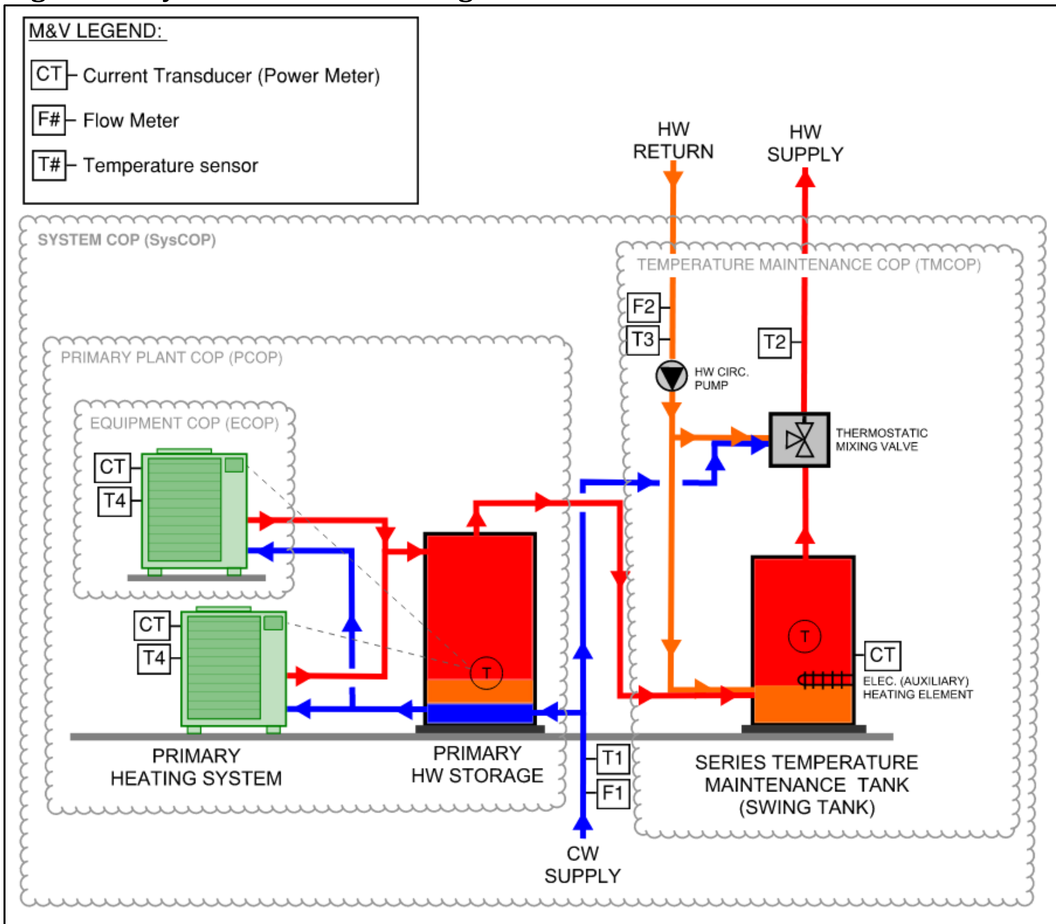
Table 2. Management with CTA-2045-B (Aligns with JA13)			
Function	**CTA-2045-B Message**	**CTA- 2045-A Reference**	**Usage and Purpose**
General Curtailment (Shed/Light Shed)	Shed (request) and Light Shed (request) and Basic Application ACK (response) Messages	Table 8-2	General curtailment directs the water heater to avoid using energy that the device otherwise would have used under normal operating conditions by using stored thermal energy in the tank to supplement. For heat pump water heaters and electric water heaters with resistive elements, the water heater shall avoid use of resistance elements during and immediately after the event unless user needs cannot be met. The water heater shall respond with an application "Acknowledge (ACK)," verifying receipt and support of the request.
Critical Curtailment (Deep Shed)	Critical Peak Event (request) (aka Deep Shed) and Basic Application ACK (response) Messages	Table 8-2	Critical curtailment directs the water heater to avoid using energy that the device would have used under normal operating conditions by using stored thermal energy in the tank to supplement up to a lower depleted level than for General Curtailment. For heat pump water heaters and electric water heaters with resistive elements, the electric resistance element may not be used. Heat pump-only operation is allowed. The water heater shall respond with an application "Acknowledge (ACK)," verifying receipt and support of the request.
Off Mode (Grid Emergency)	Grid Emergency (request) Full Shed/Off and Basic Application ACK (response) Messages	Table 8-2	Grid emergency directs the water heater to immediately, stop using energy for water heating when it is safe to do so. The water heater shall respond with an application "Acknowledge (ACK)," verifying receipt and support of the request.
Basic Load-Up	Basic Load-Up (request) and Basic Application ACK (response) Messages	Table 8-2	Basic Load-Up directs the water heater to use and/or store additional thermal energy that the device would not have used/stored under normal operation. Basic Load-Up allows the stored thermal energy to increase, within safety parameters set by the manufacturer, up to user set point.
Advanced Load-Up	Advanced Load-Up (request) and Basic Application ACK (response) Messages	Table 9-2	Advanced Load-Up directs the water heater to use and/or store additional thermal energy that the device would not have used/stored under normal operation. Advanced Load-Up allows the stored thermal energy to increase, within safety parameters set by the manufacturer, beyond user set point. This solution can leverage mixing valve technology.
Return to Normal Operation	End Shed/Run Normal Operation (request) and Basic Application ACK (response) Messages	Table 8-2	In the event an ongoing event is cancelled for any reason, the water heater shall return to normal operation. The water heater shall respond with an application "Acknowledge (ACK)," verifying receipt and support of the request resuming Run Normal operation.
Customer Override	Customer Override Message (initiated by the water heater) and Basic Application ACK Messages	Table 8-2	Customer override is sent by the water heater to notify that a customer override has occurred. Note: in accordance with the CTA-2045-A standard, the water heater shall send this message when override is first initiated and following incoming energy management messages while override is in effect.
Price Stream	Price stream of current and future prices	Table 9-2	Minimum of 10 time-price pairs representing the hourly look-ahead prices. Other pairs may be defined in the future.

Appendix M: Measurement and Verification Requirements (Optional)

The section establishes the minimum requirements for a Measurement and Verification (M&V) system when it is required by jurisdiction. The M&V system is intended to calculate and report the DHW system COP (SysCOP) and should meet the following requirements:

1. The following sensors and meters shall be provided:
    a. Temperature Sensors: ±1.0°F tolerance
        i. T1: Temperature of cold makeup water entering the DHW system
        ii. T2: Temperature of hot water leaving the thermostatic mixing valve
        iii. T3: Temperature of the hot water circulation return water
        iv. T4: Temperature of ambient air entering the HPWH evaporator coil (a local weather station is an acceptable alternative)
    b. Flow rate sensors/meters: ±1.0 GPM tolerance
        i. F1: Flow rate of cold makeup water entering the DHW system
        ii. F2: Flow rate of hot water circulation return water
    c. Current transducers and/or power meters
        i. Current transducers or power meters for each electrical equipment input
        ii. Accessory components or multiple HPWHs may be grouped on a single current transducer or power meter
        iii. When a dedicated temperature maintenance system is present, a dedicated current transducer or power meter must be provided to log input energy of the temperature maintenance system
2. Data shall be logged at one-minute intervals
3. Data shall be logged and stored for access for a minimum duration of six months
4. Project details including:
    a. Project location: state, city
    b. Occupancy demographics: building type, occupancy class, number of apartment units, number of full-time occupants
    c. System equipment specifics

Figure 14. System M&V Monitoring Points



Appendix N: Sample Product Assessment Datasheet (PADS) Document

Not available yet; under development for both Residential and Commercial HPWHs. Link will be added in updates to the NEEA website.

Manufacturers will be able to access the Product Assessment Datasheets (PADS) using the following links:

- Residential: https://neea.org/img/documents/Residential-Unitary-HPWH-Product-Assessment-Datasheet.xlsx
- Commercial: https://neea.org/img/documents/Commercial-HPWH-Product-Assessment-Datasheet.xlsx