Updated December 23rd, 2019

A Specification for Residential Water Heaters
Advanced Water Heating Specification

Formerly known as the Northern Climate Specification

Version 7.0

Effective Date: June 30, 2020

Background

In the early 1980s, electric utilities in colder portions of North America introduced heat pump technology into the residential water heating 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.

While this specification initially focused on "Northern" climates (generally considered to be any location in the International Energy Conservation Code 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.

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 a release of a new version of the specification, are subject to all new requirements. For an overview of the qualification process, refer to Appendix H.

Notable changes from version 6 include, but are not limited to:

- Renaming the Northern Climate Uniform Energy Factor (UEFnc) to Cool Climate Efficiency (CCE)
- Demand response enabled is required in Tier 3 and above
- Compressor cutoff temperature test made optional when data can be self-reported
- Optional warm climate test (95°F ambient) and calculation method added
- Northern climate delivery rating replaced in favor of a more informative, high-volume use test
- Airflow measurement test made optional
- Plug-In HPWH Specification added as an appendix (Appendix A)

1.0 Purpose

This specification provides guidance to manufacturers and market actors who are interested in developing products that not only meet ENERGY STAR criteria but are able to provide 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 the electric water heating market. The specification also contains forward-looking 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 a guideline for how the specification will develop in two to 10 years.

Utilities and other entities that invest in market transformation programs and/or incentives require reliable energy savings. Accordingly, the specification is also intended as a foundational document for utility program efforts that will work in partnership with manufacturers to accelerate market adoption of HPWH for any American 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 addresses key topics that fall into four 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
- Consideration of challenging installations – central locations with limited access to heat sources
- 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

2.0 Scope

2.1 Equipment Type. This specification covers the following types of electric, air-source, consumer, heat pump water heaters:

- 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)

Future versions of this specification will cover certain sizes of "commercial" heat pump water heaters that will generally have more storage and/or more output capacity than products currently covered. Nevertheless, current products may still be suitable for some commercial applications. Refer to the manufacturer's recommendations.

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 Applications. The focus of this specification is 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 space 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 are applicable for installation of the heat pump portion in all the aforementioned, plus at outside locations.

2.3 Climate. This specification is intended to ensure high performance in all climates. A special focus is on climates with 4,000 or more heating degree days and average ambient temperatures below 60°F. Meeting the minimum performance requirement in these climates ensures additional savings in all other climates in North America. The specification also provides a reporting provision for HPWH performance at warm temperatures, so efficiency can be understood in all climates.

3.0 Product Tiers

3.1 Overview. Tiers are incorporated into this specification recognizing variations in product performance and supported installation applications. Throughout the specification, different product categories, i.e., 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 elaborated throughout the specification.

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 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 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.*

Table 2. Split-System Product Tier Overview

	Minimum SCOP*	Minimum Features	Sound Levels Appendix B	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 quantity from CCE. SCOP applies to split-systems where the heat pump is subject to outdoor air conditions (see Appendix B.4). A blend of five Pacific Northwest cities was used as the reference climate for the SCOP.*
*** See Appendix D for details on Sound Level definition and calculation method.*

4.0 Requirements for All Units (Tiers 1.0 and above)

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 US and/or Canada.

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

4.3 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.

4.4 Sound Levels. The unit shall not exceed maximum sound levels according to Table 1. See Appendix D for Sound Measurement Test Method.

4.5 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 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).

4.6 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. There is no minimum or performance requirement for this test. It is required as informational only and the results are to be submitted on the Product Assessment Worksheet (see Appendix B.3).

4.7 OPTIONAL: Warm Climate 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.1.1 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.

4.8 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.

5.0 Additional and Optional Requirements for Tiers 2.0 and Above

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 DOE first-hour rating test,[1] 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.

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

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).

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.

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.

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

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.

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

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.

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

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 acquired by the installer for the connection). The manufacturer shall supply appropriate condensate piping specifications including piping diameter, length, allowable turns, 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.

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 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.

5.4.3 Condensate Collection Pan and Drain Service. The condensate collection pan and drain shall be designed to not require 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.

6.0 Additional Requirements for Tiers 3.0, 4.0, and 5.0

6.1 Default Settings. The unit shall be shipped in the default operational mode used in demonstrating compliance to 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.

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.

> **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.
>
> **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.
>
> **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.

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.

6.4 Demand Response Features. Units shall be configured and shipped with the capability of responding 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 (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. See Appendix G for further definitions and requirements.

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 (GWP) than those typically used in current products (for example, future specifications may limit GWP to less than 100).

7.0 Additional Requirements Tier 4.0

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, resistance heat may be used.

8.0 Additional Requirements Tier 5.0

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.

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. 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 heat pump water heaters (HPWHs) currently available 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.

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
○ fit within a space of 24” x 26” x 72” inclusive of drain pan and all plumbing connections, and
○ 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><th></th><th>Product First-Hour Rating</th><th>Cool Climate Efficiency Requirement</th></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. 1 year labor</td></tr>
<tr><td>Demand Response Connectivity (Optional)</td><td>CTA-2045, or equivalent, and complying with the proposed California 2019 Title 24 requirements, JA-13, for electric water heater demand management. To be revisited on next specification revision (likely 2021).</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.
It is strongly recommended that manufacturers 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 4.2 – ENERGY STAR Compliance[2]
- Section 4.8 – Installation Guidance
- Section 5.4 – Condensate Management
- Section 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

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 Worksheet[3] 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 product list may also contain, but not be limited to, the following information: nominal volume, first-hour rating, CCE, UEF, and minimum opening required for installation.

[2] The first-hour rating requirement from ENERGY STAR will not be adopted for this spec. Currently in discussions with ENERGY STAR about how to align the requirements.

[3] A Product Assessment Worksheet 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 Worksheet.

B.1.2 Cool Climate Efficiency Calculation

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.[4] The temperature bins for use in the CCE weightings are given in Table 3. Figure 1 two pages hence provides several graphical examples of the end result of the calculation.

Table 3. Temperature Bins[5]

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

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

[5] 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 is 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 1344ft^2 basement with 7ft ceilings. As the basement is unconditioned, neither the basement walls nor the floor is insulated.

The Cool Climate Efficiency is calculated as:

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

where:

j is the bin number from Table 3

f_j is the fraction of hours for that bin

E_j is determined in the following way:

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

$$E_j = (T_j - 50)*m_{CCE} + E_{50} \qquad (2)$$

where:

T_j is the bin temperature

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

$$m_{CCE} = (E_{67} - E_{50}) / (67.5 - 50) \qquad (3)$$

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

For bin temperatures <50°F:

$$E_j = (T_j - 50)*m_{compT50} + E_{50} \qquad (4)$$

where:

j is the temperature bin below 50°F and

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

(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:

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

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:

$$E_j = E_{67} \qquad (7)$$

(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 3 (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:

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

where:

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

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

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

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

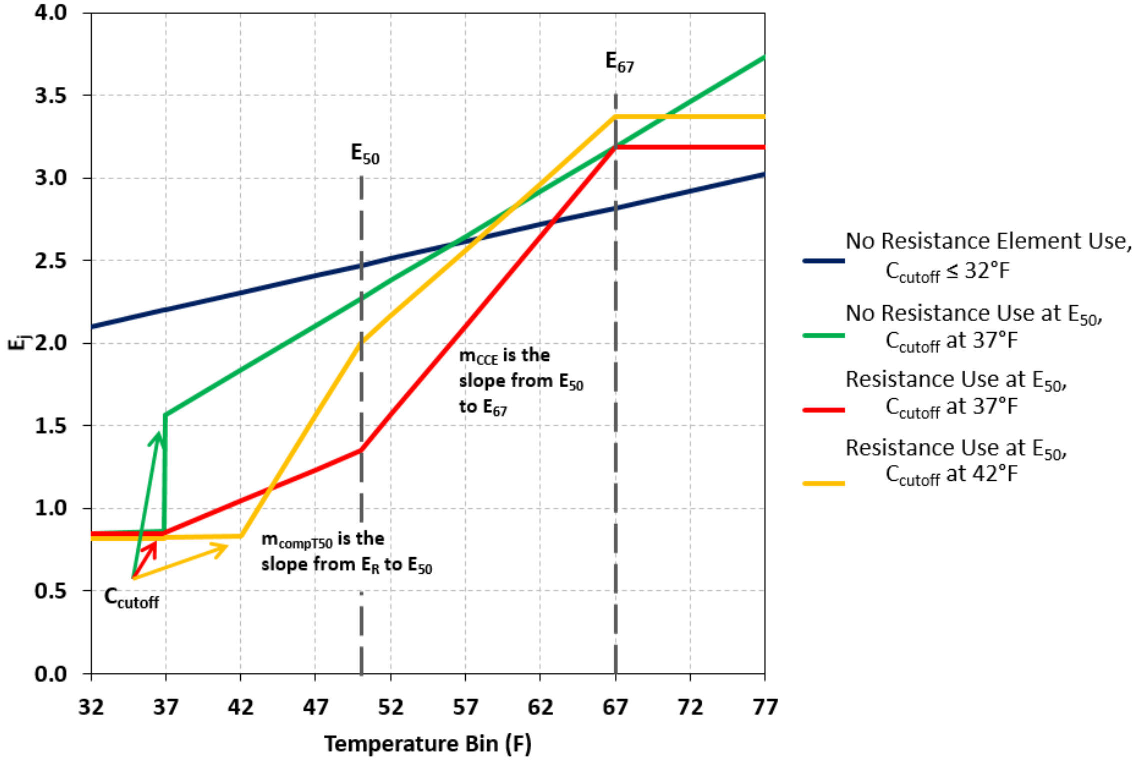
where:

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 1. CCE vs. Temperature[6]



[6] 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

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 3 or 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 3, 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[7] and field measurements by others[8] 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 3 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 4 corresponding to the nominal tank size. If the nominal tank size is within 2 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.

[7] 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.
[8] 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 4. High Volume Draw Test Pattern

Draw Cluster	Minute	Flow Rate (GPM)	Draw Amount (Gallons) by Nominal Tank Size					
			40	50	60	65	70	80
1	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
	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
2	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
	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
3	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
	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 4, 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 Worksheet.

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.

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

Table 5. 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, there will be seasonal coefficient of performance (SCOP) calculation procedures to 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 5 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,[9] is shown in Table 6. The draft reference climate for performance is a blend 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 25’ standard length line set. All supporting equipment including fans, pumps, line set insulation, and required heaters will be measured in total energy consumption for calculations.

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

Table 6. 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

**Blend of five Pacific Northwest cities used as 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 afterwards 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 2 feet from the tank with 1" thick pipe insulation.

2.0 Test procedure:

- Establish normal water heater operation: If water heater not operating, initiate a draw. Terminate that draw when equipment cut-in occurs. When the tank recovers and the heaters cut out, wait 5 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 apart 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

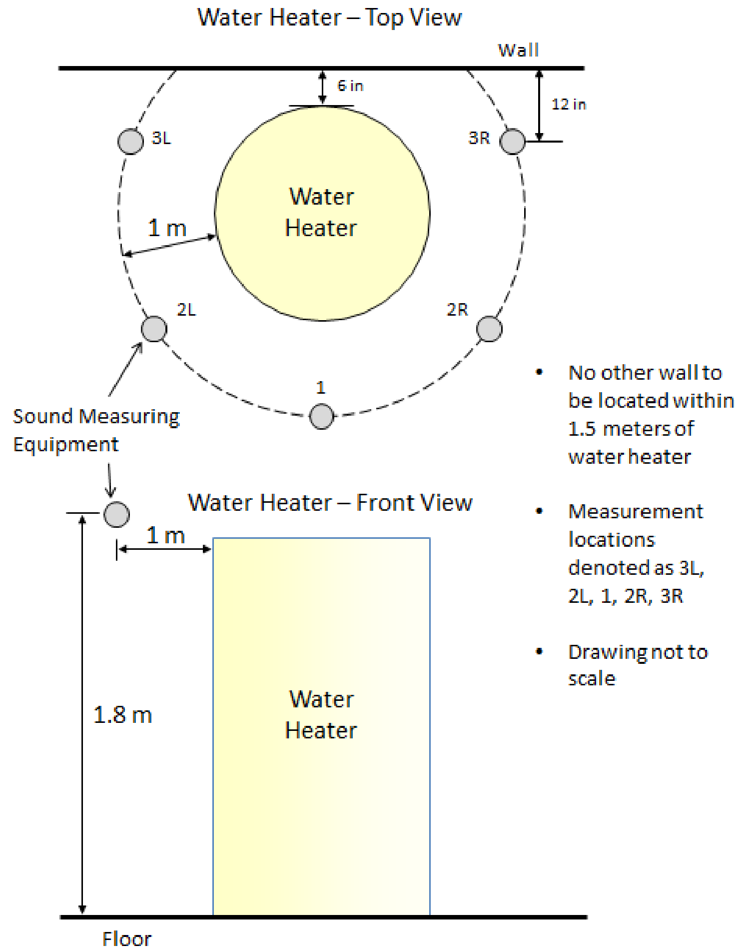
1.0 Test setup:

- 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 cinder block 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 less than or equal to 35dBA.
    - 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 1 meter distant from the water heater surface at a 1.8 meter height above the base of the water heater (see Figure 2). 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 2. Test Setup for Sound Pressure Measurement



Appendix E: RESERVED

Appendix F: Airflow Measurement - INFORMATIVE

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 6.2.2, in which case this test is not required. If it is unknown whether a unit conforms with Section 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.

Definitions:

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

1.0 Test setup and procedure

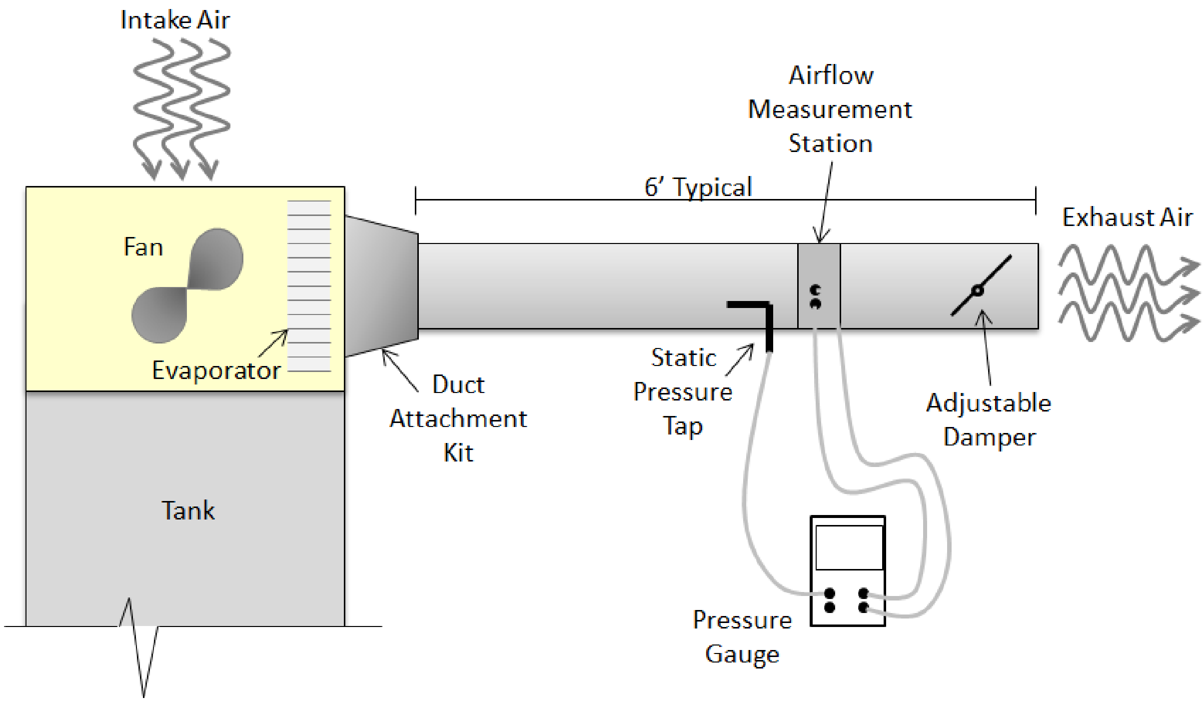
Each HPWH may have a unique airflow path and, therefore, measurement setup. The setup presented in Figure 3 is provided as one possible example.

- 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 3. Example Airflow Measurement Setup



Appendix G: Demand Response

ENERGY STAR is currently drafting criteria for connected water heaters (see *ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters Eligibility Criteria Version 3.3 Draft 1*).[10] This document defines a set of demand response messaging commands in its Appendix B; the AWHS shall support and 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 3.3 Draft 1*.

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

Equivalence
The meaning of **equivalence** to a modular communication port compliant with the current version of ANSI/CTA-2045 shall be defined by a communication specification with the following requirements from the perspective of the appliance:[11]

	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 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.

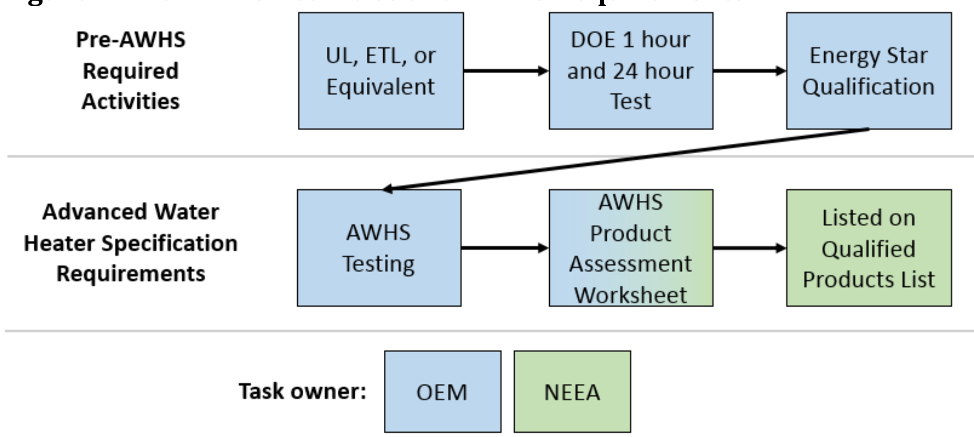
10 https://www.energystar.gov/sites/default/files/WH%20Draft%20V3%203_Connected_Spec%2004162019.pdf
11 "Appliance" is meant in the most general sense, namely a device that provides services or benefits to a person directly or indirectly.

	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 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 any common application layer command language 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 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 H: 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 4). It is the OEM's responsibility to take the water heater through preparation of the referenced AWHS Product Assessment Worksheet, at which point it is handed off to the managing agency (currently the Northwest Energy Efficiency Alliance (NEEA)). 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 4. 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 Worksheet" to the managing agency (currently NEEA) . The most current version of this worksheet is at https://neea.org/our-work/advanced-water-heater-specification.

Manufacturers are encouraged to perform their own Advanced Water Heater Specification testing or facilitate it through any third-party EPA-recognized laboratory.[12] 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 performs (if they are self-reported and validated by NEEA or its designated managing agency) 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 https://neea.org/our-work/advanced-water-heater-specification.

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

Appendix I: Disqualification, Tier Reassignment, and Requalification Process

The Qualified Product List (QPL) managing agency (currently the Northwest Energy Efficiency Alliance (NEEA)) may evaluate any product on the QPL at any time to ensure that the product meets the requirements of the Advanced Water Heater 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 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
   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. NDA's 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 Workgroups, 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.