

Consortium for Energy Efficiency **Residential Water Heating Initiative**



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This Initiative, the successor to the *CEESM High Efficiency Residential Gas Water Heating Initiative*, includes information on both gas and electric water heating as well as a revised strategy.

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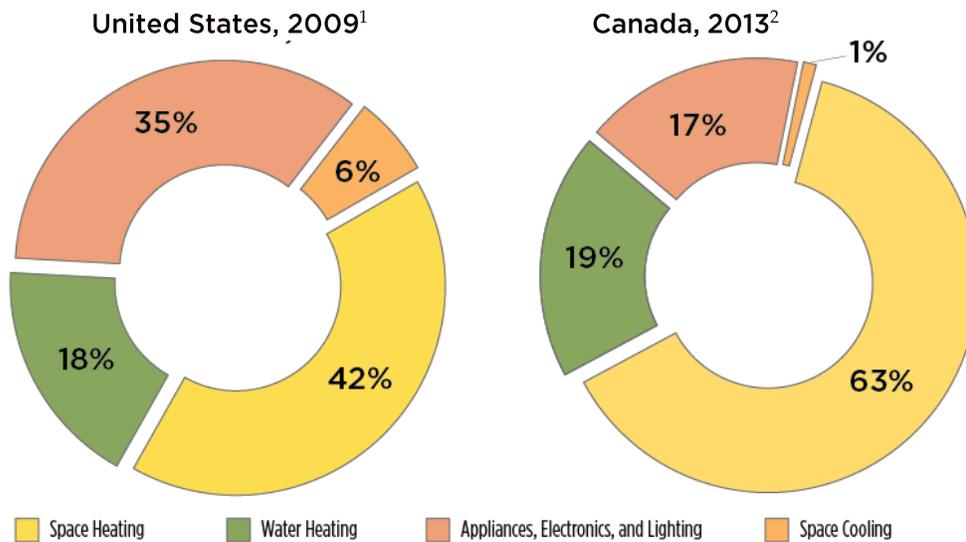
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1 Executive Summary

Water heating represents a major use of energy in North American homes with the potential for significant natural gas and electric savings. In the United States, water heating accounts for approximately 18 percent of all residential energy consumption; in Canada, water heating is estimated to be the second largest residential energy end use, accounting for roughly 19 percent of household energy consumption.

Figure 1. Residential Energy Consumption in Homes by End Use



The CEESM Residential Water Heating Initiative seeks to build a market for highly energy efficient water heating in North America by providing common definitions of efficient equipment and strategies for promoting uptake of these systems at scale. This version focuses on gas-fired storage, gas-fired tankless, and electric heat pump water heaters.

¹ Energy Information Administration, 2009. Residential Energy Consumption Survey, <https://www.eia.gov/consumption/residential/data/2009/>

² "Residential Secondary Energy Use (Final Demand) by Energy Source and End Use," Natural Resources Canada, <http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=HB§or=res&juris=00&rn=1&page=0>.

This Initiative takes the next steps in increasing adoption of efficient technology in the market by:

- Incorporating an expansive scope of efficient products ranging from gas-fired storage to gas-fired tankless to electric heat pump water heaters
- Addressing persistent market barriers related to stocking, distribution, sale, and purchase of efficient products
- Driving greater awareness as well as education regarding the benefits of efficient water heating systems across both key industry stakeholders and end users

As members adopt this initiative and align their programs, over time we expect an increase in the number of efficient water heaters manufactured and installed within the United States and Canada.

2 Initiative Approach

2.1 Initiative Scope

The CEE Residential Water Heating Initiative covers water heater products that use gas or electricity to heat potable water for use outside the heater upon demand. This includes the following product types:³

1. Storage type units designed to heat and store water at a thermostatically controlled temperature, including gas-fired storage water heaters with a nameplate input of 75,000 British thermal units (Btu) per hour or less containing more than one gallon of water per 4,000 Btu per hour of input and electric heat pump units with a maximum current rating of 24 amperes at an input voltage of 250 volts or less⁴
2. Instantaneous (or “tankless”)-type units that heat water but contain no more than one gallon of water per 4,000 Btu per hour of input with an input capacity less than or equal to 200,000 Btu per hour for gas-fired instantaneous⁵
3. Gas-fired storage “residential-duty” commercial water heaters that are designed to deliver hot water at a temperature less than or equal to 180°F with an input rate greater than 75,000 Btu per hour and not exceeding 105,000 Btu per hour, containing more than one gallon of water per 4,000 Btu per hour of input and storage volume less than or equal to 120 gallons and using a single phase external power supply for models requiring electricity⁶

The following products are excluded from eligibility:

- Electric resistance water heaters
- Add-on heat pump units
- Products tested to 10 CFR 431, Subpart G §431.106

³ Adapted from 10 CFR 430, Subpart A §430.2 *Definitions*
https://www.energy.gov/sites/prod/files/2014/06/f17/rwh_tp_final_rule.pdf

⁴ Ibid.

⁵ Ibid.

⁶ Adapted from 10 CFR 431, Subpart G §431.102 *Definitions*

- Combination space heating and water heating products

2.2 Initiative Goals and Strategies

This initiative seeks to encourage the manufacture, stocking, distribution, purchase, and installation of energy efficient water heaters through a combination of specifications and market approaches. Common technical specifications help drive greater market consensus around established elements that characterize efficient products. Binational coordination enables all stakeholders to promote shared definitions across multiple service territories. Consistent market approaches create further momentum by addressing persistent barriers through mutually agreed-on strategies that benefit from collective support and common implementation. Given the prevalent challenges associated with the adoption of efficient residential water heating products, CEE believes there is a need to deploy shared program tactics aimed at increasing the uptake of high performing models in the market.

The long-term goal of the Initiative is to increase the market penetration of energy efficient water heaters. This goal will be achieved when:

- Efficient equipment is readily available from manufacturers, wholesalers, and distributors
- Efficient equipment is promoted to consumers by plumbing contractors, builders, and retailers
- Efficient equipment is requested by customers
- Local, regional, and national codes and standards reflect increasingly efficient minimum requirements

The Initiative's primary objectives in pursuit of the long-term goal are to:

- Increase the number of efficient products available, measured by number of efficient models and brands sold (both at retail and through distributors)
- Increase the percentage of sales of efficient equipment, measured by number of efficient units purchased relative to the total number of units purchased
- Build a market of sufficient size to help achieve the scale of production that will allow manufacturers to offer efficient equipment at an attractive price to consumers, measured by price of qualifying models compared to other models over time
- Increase the number of plumbing contractors, builders, retailers, distributors, and wholesalers who promote efficient equipment, measured by program trade ally participation

3 Residential Water Heating Market

Water heating represents about 18 percent of US residential energy consumption, or about 4.6 quadrillion Btu of source energy annually.⁷ In 2015, 45 percent of homes in the US residential water heating market used electric water heaters, 48 percent used natural gas water heaters, and the remaining seven percent used other sources of water heating, including fuel oil, propane, wood, and

⁷ "Residential Energy Consumption Survey," US Energy Information Administration, accessed December 27, 2016, <https://www.eia.gov/consumption/residential/data/2015/hc/php/hc8.1.php>

solar.⁸ These fuel breakdowns vary by individual census regions across the country.

Figure 2. Fuel Used by Main Water Heating in US Homes, 2015⁹

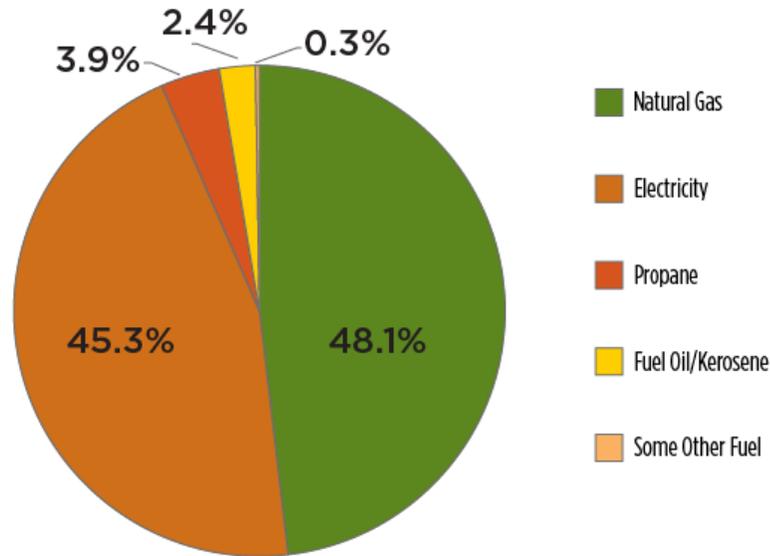
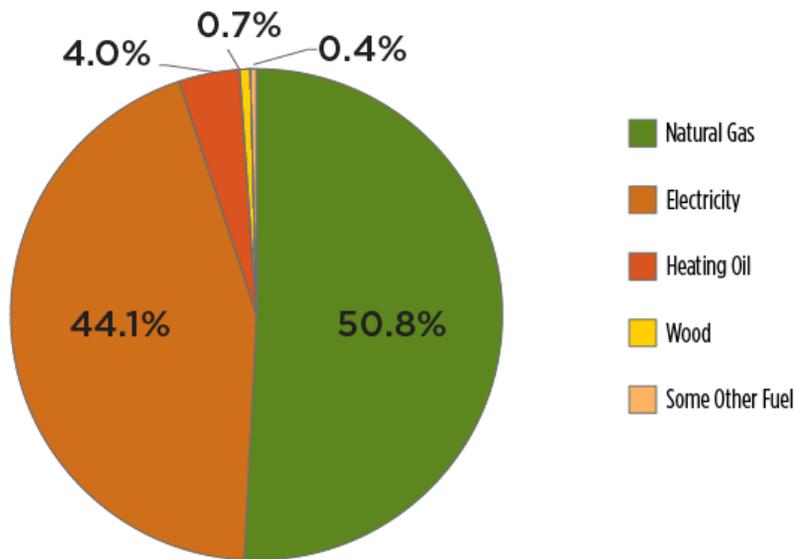


Figure 3. Fuel Used by Main Water Heating in Canadian Homes, 2014¹⁰



⁸ "Table HC8.1: Water heating in U.S. homes by housing unit type, 2015," 2015 Residential Energy Consumption Survey, US Energy Information Administration, accessed April 27, 2017, <https://www.eia.gov/consumption/residential/data/2015/hc/php/hc8.1.php>

⁹ Ibid.

¹⁰ "Residential Water Heating Energy Use and Water Heater Stock Share," Natural Resources Canada, Accessed November 2017, <http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=HB§or=res&juris=00&rn=17&page=0>.

Figure 4. Size of Main Water Heating in US Homes (Gas and Electric), 2015¹¹

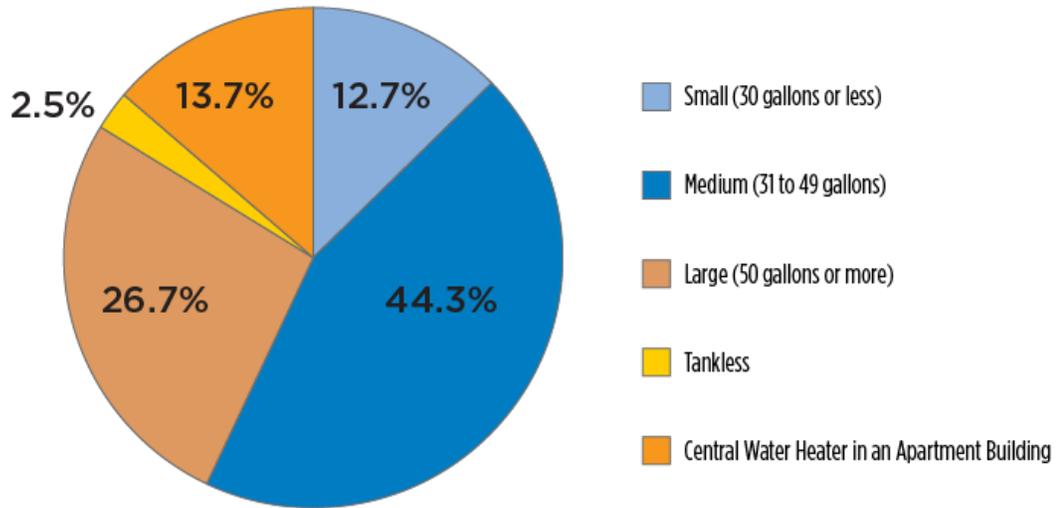
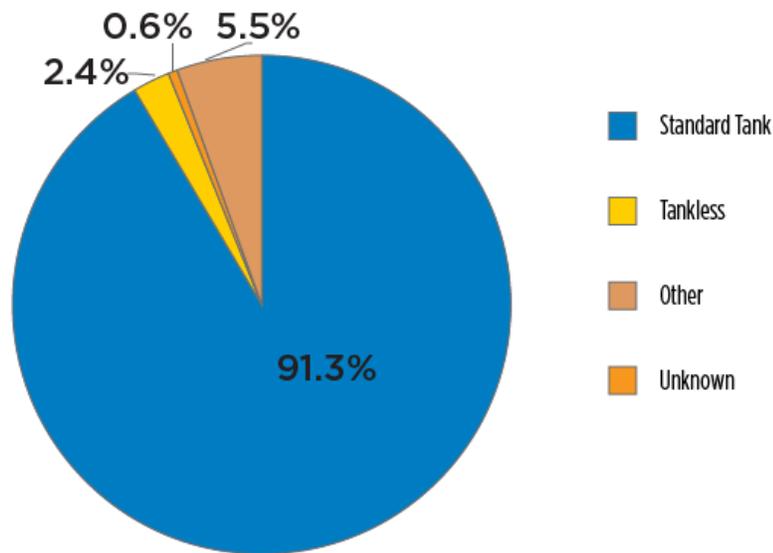


Figure 5. Size of Main Water Heating in Canadian Homes (Gas and Electric), 2011¹²

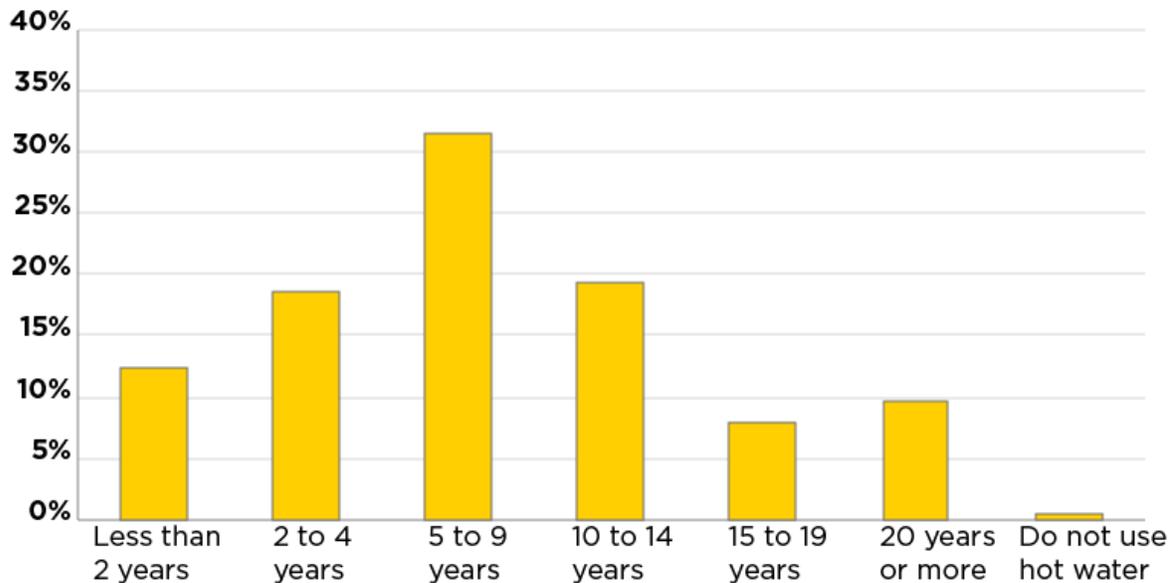


¹¹ "Table HC8.1: Water heating in U.S. homes by housing unit type, 2015," 2015 Residential Energy Consumption Survey, US Energy Information Administration, accessed April 27, 2017, <https://www.eia.gov/consumption/residential/data/2015/hc/php/hc8.1.php>.

¹² *Survey of Household Energy Use: Detailed Statistical Report. 2011*, Natural Resources Canada, 2011, <http://oee.nrcan.gc.ca/publications/statistics/sheu/2011/pdf/sheu2011.pdf>.

There are about 100 million installed residential water heaters in the United States, with roughly seven to eight percent of these replaced each year.¹³ The average life expectancy for gas water heaters is between four and 14 years and for electric water heaters, including heat pump water heaters, is 10 to 22 years.¹⁴ However, this number is highly variable, depending on factors such as water hardness and unit maintenance.¹⁵ About half of the water heaters in US homes as of 2010 were installed between 1990 and 2003.¹⁶

Figure 6. Age of Main Water Heater in US Homes¹⁷



¹³ “ENERGY STAR Water Heater Market Profile: Efficiency Sells,” US Department of Energy, September 2010, pg. 5, https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/Water_Heater_Market_Profile_2010.pdf

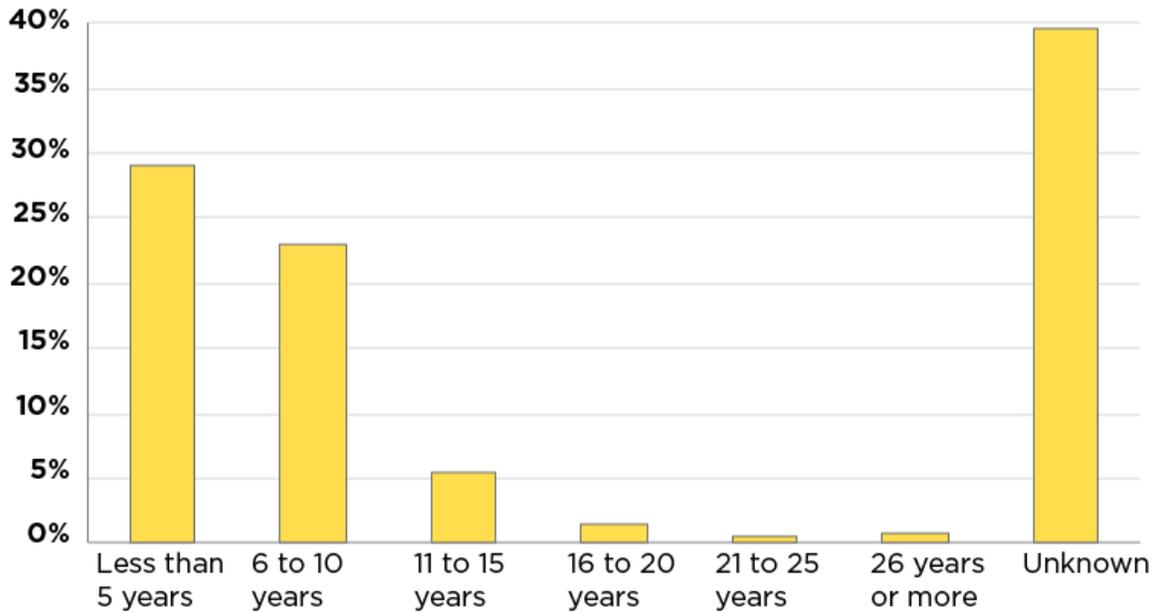
¹⁴ “Chapter 4. Residential Demand Module,” US Energy Information Administration, July 2017, pg. 6, <https://www.eia.gov/outlooks/aeo/assumptions/pdf/residential.pdf>

¹⁵ “2009 RECS Survey Data”

¹⁶ “ENERGY STAR Water Heater Market Profile: Efficiency Sells,” pg. 5

¹⁷ Maguire, Burch, Merrigan, and Ong, “Regional Variation in Residential HPWH Performance in the US,” National Energy Renewable Laboratory, 2014, <https://www.nrel.gov/docs/fy14osti/60295.pdf>.

Figure 7. **Age of Main Water Heater in Canadian Homes**¹⁸



Storage units dominate both the gas-fired and electric water heater markets, accounting for over 94 percent of the market share for water heaters in North America.¹⁹ Of the 9.8 million water heaters shipped in the United States during 2016, four million were electric resistance and 4.2 million were gas storage units. In 2013, approximately 397,000 tankless water heaters were sold, representing eight percent of all gas water heater sales; heat pump water heaters accounted for well under one percent of all sales in 2016, though those numbers have increased significantly since 2006.^{20,21} Canadian statistics from 2016 show shipments of 380,000 standard gas fired products, 602,000 standard electric units, and 39,500 tankless products, with 144,000 ENERGY STAR® gas products sold during that time.²² ENERGY STAR water heater shipment data of heat pump water heaters increased more than sevenfold between 2006 (roughly 2,000 units shipped) and 2009 (roughly 15,000 units shipped).²³

¹⁸ *Survey of Household Energy Use: Detailed Statistical Report. 2011*, pg. 100
<http://oee.nrcan.gc.ca/publications/statistics/sheu/2011/pdf/sheu2011.pdf>

¹⁹ Maguire, Burch, Merrigan, and Ong 2014, pg. 1

²⁰ “ENERGY STAR® Residential Water Heaters: Final Criteria Analysis,” ENERGY STAR, 2008, pg. 1,
https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/WaterHeaterAnalysis_Final.pdf

²¹ “ENERGY STAR® Unit Shipment and Market Penetration Report Calendar Year 2013 Summary,” ENERGY STAR, 2014.
https://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2013_USD_Summary_Report.pdf?7d29-cd97.

²² Canadian Institute of Plumbing and Heating Shipment analysis

²³ ENERGY STAR Water Heater Market Profile: Efficiency Sells, pg. 6

Figure 8. Storage Water Heater Shipments in the United States 2010-2017²⁴

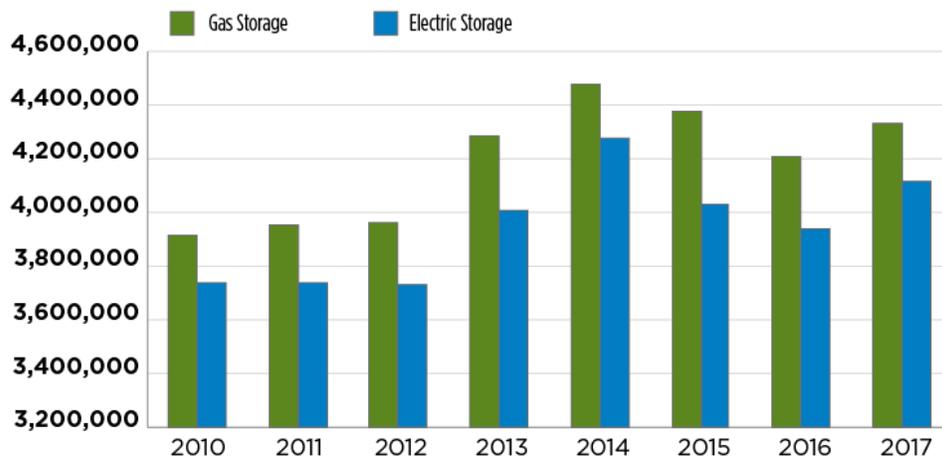
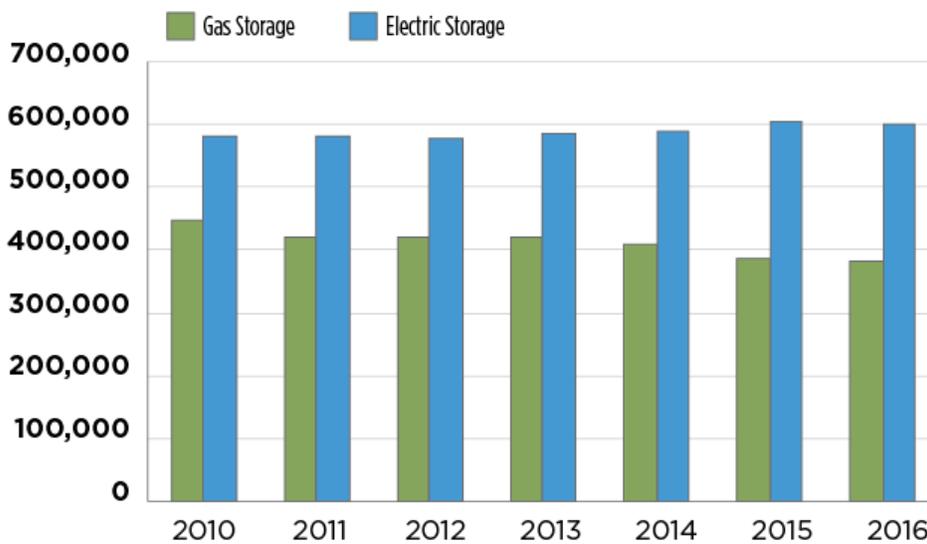
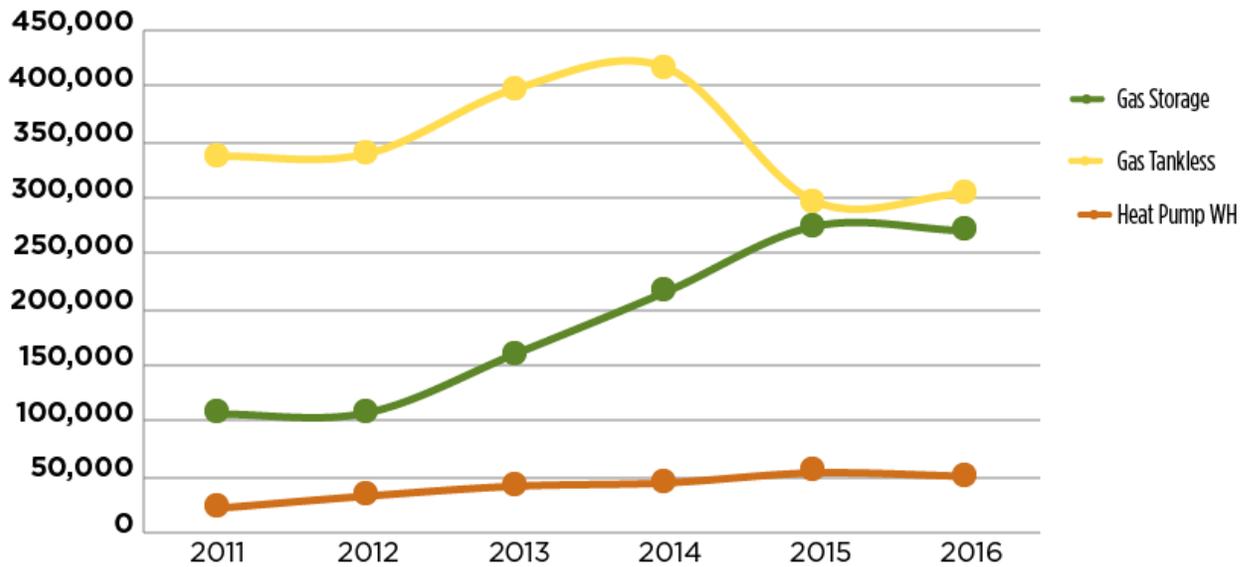


Figure 9. Storage Water Heater Shipments in Canada 2010-2016



²⁴ "Monthly Shipments," Air-Conditioning, Heating, and Refrigeration Institute, accessed February, 2018. <http://www.ahrinet.org/statistics>

Figure 10. ENERGY STAR Shipment Data 2010-2016²⁵

3.1 Natural Gas Equipment Market Overview

3.1.1 TECHNICAL INFORMATION

Storage water heaters are also commonly referred to as tank-type water heaters. The majority of gas-fired residential storage water heaters sold have an input of 75,000 Btu per hour or less and a rated storage volume from 20 to 100 gallons. They often have a glass-lined steel tank, foam insulation, a heat exchanger coil or flue running through the center of the tank, and a gas burner at the bottom of the tank. The water heater is activated when the gas burner is ignited. Combustion takes place in the burner when incoming air mixes with gas. The hot gases from the combustion process ascend through the flue or heat exchanger coil and transfer heat to the surrounding water in the tank. The heated water rises to the top of the tank and is then transferred through a hot water outlet to the tap.

Tankless water heaters are also commonly referred to as demand or instantaneous units. Gas-fired residential tankless units have a nominal input of between 50,000 and 200,000 Btu per hour and a rated storage volume of two gallons or less. Gas-fired tankless models are based on the same principles as a traditional storage water heater, but do not store water in a tank. The burner in tankless water heaters is activated when a minimum water draw occurs. Once a hot water tap is turned on and a flow sensor is triggered at the water heater, the burner begins to heat a heat exchanger. Cold water enters the unit and ascends through the heat exchanger, where heat is transferred to the water. Once the water reaches its set point temperature, it exits the unit ready for use.

²⁵ "Unit Shipment and Sales Data Archives," ENERGY STAR, Accessed November 2017, https://www.energystar.gov/index.cfm?c=partners.unit_shipment_data_archives.

Gas-fired heat pump water heaters are currently being developed and validated by the National Energy Technology Laboratory in partnership with the US Department of Energy. Other groups and entities are also researching this technology. Gas-fired heat pump water heaters have a potential energy factor of around 1.50 and may save over 40 percent more energy than other gas water heaters.²⁶ If fully deployed, it is estimated that this technology would save 0.45 quads of energy annually.^{27,28}

While these products are not explicitly included in the scope of the CEE Residential Water Heating Initiative at this time, energy efficiency program administrators have expressed significant interest in the development of commercially available gas heat pump products, including stand-alone models and combination products that provide both space and water heating. However, in order to promote these products, programs need significant confidence in their technical performance and customer satisfaction. In terms of performance, UEFs of over 1.0 would demonstrate the viability of gas heat pump technology as well as delivering significant energy savings over established baselines. Aspects of customer satisfaction would include reliable performance and product lifetime; these considerations are addressed in Section 4.1.4 of the Initiative.

Individual program administrators consider whether the potential benefits of a new technology outweigh the uncertainty of promoting a new class of products. Factors in this consideration may include credible third-party product testing, appropriate efficiency and safety certifications, familiarity with a manufacturer, and both modeled and demonstrated performance. Additionally, the optional criteria in the Initiative's Section 5.2.2 relative to freeze protection, installation guidance, and air filter maintenance and notifications may similarly apply to gas heat pumps. The presence of potential criteria related to sound levels would depend on the design and intended installation and purpose of the individual products; those intended for conditioned spaces would potentially call for sound level requirements.

3.1.2 PRODUCT SALES AND AVAILABILITY

Currently, the majority of residential gas-fired water heater sales in the United States and Canada are of minimum-efficiency storage models. Sales and availability of efficient units are in the minority, but all major manufacturers produce these units in significant quantities, with a variety of options to choose from in the market. While some retailers, distributors, and plumbers prominently feature and promote high efficiency products, there remain stocking limitations for high efficiency models, often leading to limited consumer options in emergency replacement scenarios.

²⁶ W. Goetzler, M. Guernsey, and M. Droesch, "Research & Development Roadmap for Emerging Water Heating Technologies," US Department of Energy, September 2014, https://energy.gov/sites/prod/files/2014/09/f18/WH_Roadmap_Report_Final_2014-09-22.pdf.

²⁷ "Gas-Fired Heat Pump Water Heater for Residential Applications," Stone Mountain Technologies, Inc., 2011, Slide 10, <http://aceee.org/files/pdf/conferences/hwf/2011/3B%20-%20Garra-brant.pdf>.

²⁸ "Residential Absorption Heat Pump Water Heater," US Department of Energy, accessed January 2, 2015, <http://energy.gov/eere/buildings/downloads/absorption-heat-pump-water-heater-0>.

3.2 Electric Equipment Overview

3.2.1 TECHNICAL INFORMATION

At this time the most common types of heat pump water heaters are electric models, which are intended as replacements for electric resistance water heaters, but a number of other types are currently being developed and tested. There are three overarching types of electric heat pump water heaters: add-on, split-system, and integrated or drop-in.

Add-on heat pump water heaters are heat pump units that are added to or coupled with an existing water heater. They can be situated next to or directly on the existing water heater. As the heat pump and original water heater are two separate units, if a problem arises with either the heat pump unit or the water heater unit, each can be replaced or repaired individually.^{29,30} Add-on heat pump water heaters use water-cooled condensers to transfer heat to the water heater tank.³¹ In addition to the water-cooled condenser, these units include an evaporator, compressor, and controls, and require that piping be installed from the HPWH to the electric water heater. Installation of piping can be costly, and there can also be additional costs and reliability concerns associated with the circulation pump. These types of HPWH are not currently covered under the ENERGY STAR or CEE specifications.

Split-system heat pump water heaters are heat pump units where a larger outdoor compressor is matched to an indoor storage tank. Integrated and add-on heat pumps typically draw heat from the interior of the space, often conditioned or semi-conditioned environments, while split systems draw from outside air.³² These systems work by having the heat in the ambient air pass through the evaporator and be absorbed by a refrigerant. The warm gaseous refrigerant is circulated in the system by a compressor, and as it passes through the compressor its pressure rises, as does the temperature. This hot refrigerant then passes through a heat exchanger to heat the water, which is finally pumped to the storage tank.³³ Tanks for these systems can be located as far as 50 feet from the outdoor compressor.

Drop-in or integrated heat pump water heaters are single units that can serve as direct replacements for electric resistance water heaters when in the proper location. They combine the water storage tank, controls, and system components in one package and do not require additional piping or water pumps, generally making them easier and quicker to install than other residential water heater

²⁹ Vincen Mei, Van Baxter, and Daniel Lamb, "Low Cost Heat Pump Water Heater (HPWH)," International Refrigeration and Air Conditioning Conference, 2006, Paper 796, Pg. 2 <https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1795&context=iracc>.

³⁰ Kenny Hart, "Is There a Heat Pump Water Heater in Your Future?" *ASHI Reporter*, July 2010, <http://www.ashireporter.org/HomeInspection/Articles/Is-There-a-Heat-Pump-Water-Heater-in-Your-Future-/1919>.

³¹ Hart, "Is There a Heat Pump Water Heater in Your Future?"

³² Bruce Sullivan, "CO2 Takes Heat Pump Water Heaters to the Next Level," Zero Energy Project, May 2017, <http://zeroenergyproject.org/2017/05/22/co2-takes-heat-pump-water-heaters-next-level/>.

³³ Martin Holladay, "Split-System Heat Pump Water Heaters," Musings of an Energy Nerd, Green Building Advisor, February 2016, <http://www.greenbuildingadvisor.com/articles/dept/musings/split-system-heat-pump-water-heaters>.

types. The evaporator is typically located on top of the unit. Manufacturers may position the condenser coils in one of three ways:^{34,35}

1. **Attached to outer tank wall** The condenser coils are attached to the outside of the tank and surrounded by a heavily insulated jacket to ensure that the heat moves into the water and not the room
2. **Submerged in tank** The condenser is submerged into the water of the tank in order to transfer heat
3. **Tank water pulled into condenser** The water is drawn out of the tank and into the heat exchanger, then returned to the tank

Additional heat pump water heater configurations and technologies are currently being developed and tested.

CO₂ heat pump water heaters have been available for a number of years and are most often found in commercial buildings, especially in Japan, Europe, and Australia. They have increasingly been adopted in residential building applications. This type of HPWH uses carbon dioxide as a refrigerant due to its low global warming potential. The US Department of Energy and Oak Ridge National Laboratory are currently working on a project to develop a CO₂ HPWH that meets ENERGY STAR criteria with a lower cost per unit. Current models can cost over \$6,000 before installation.^{36,37} These products are often split-system heat pump water heater types.

3.2.2 PRODUCT SALES AND AVAILABILITY

One hundred twenty-two ENERGY STAR qualified heat pump water heater models, produced by 15 different brands (many of these brands operate under the same three OEMs), were available in the United States as of December 2017.³⁸ The dimensions of these products range from 59.1" to 80.8" in tank height and from 21.5" to 26.7" in tank diameter.

The cost of individual products and the associated installation costs vary by region and home, based on individual project conditions. Furthermore, the capital cost for an HPWH may change in the future based on the pace of their adoption in the United States. The 2012 DOE estimate of the net installed cost

³⁴ Vincen Mei, Van Baxter, and Daniel Lamb, "Low Cost Heat Pump Water Heater (HPWH)," International Refrigeration and Air Conditioning Conference, 2006, Paper 796, Pg. 1 <https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1795&context=iracc>.

³⁵ Hart, Kenny, "Is There a Heat Pump Water Heater in Your Future?"

³⁶ "Residential CO₂ Heat Pump Water Heater," US Department of Energy, accessed January 2, 2015, <http://energy.gov/eere/buildings/downloads/co2-heat-pump-water-heater>.

³⁷ Kyle Gluesenkamp, "CO₂ Heat Pump Water Heater: 2014 Building Technologies Office Peer Review," Oak Ridge National Laboratory, accessed January 2, 2015, Slide 5, http://energy.gov/sites/prod/files/2014/10/f18/emt49_gluesenkamp_042414.pdf.

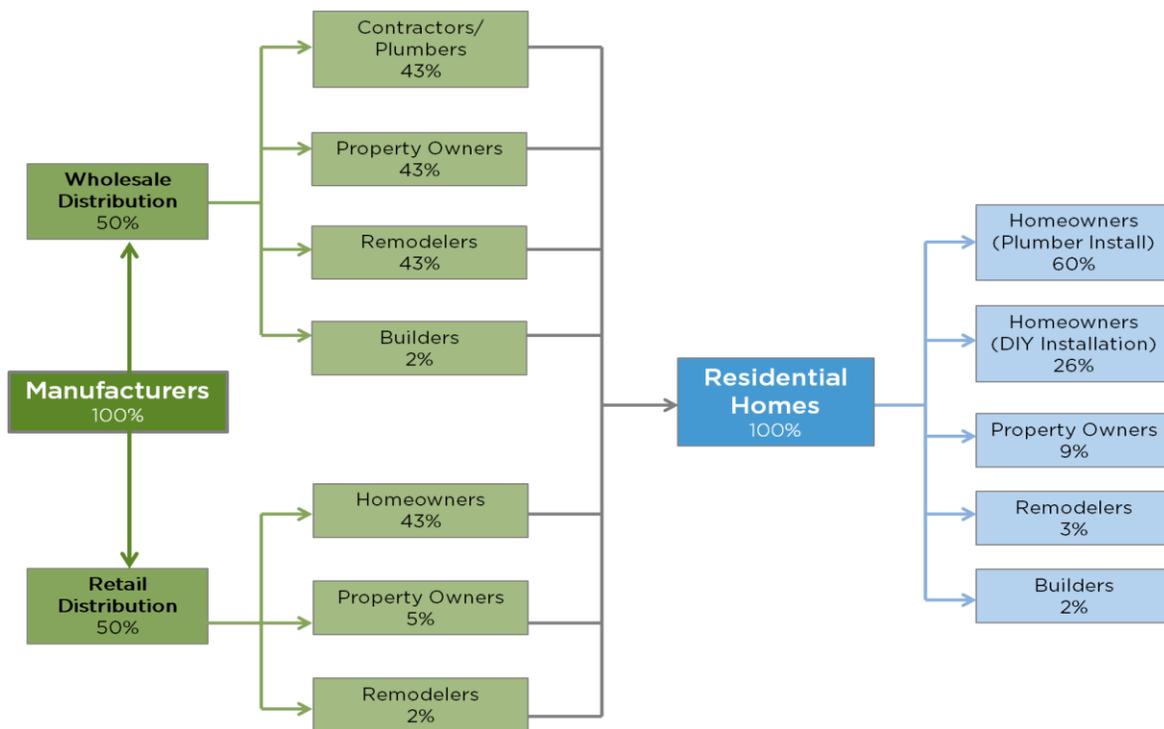
³⁸ AHRI Directory: <https://www.ahridirectory.org/Search/SearchHome>. Accessed December 22, 2017.

of an efficient HPWH ranges between \$1,300 and \$2,200, with an average of \$1,500.³⁹ The average net installed cost of an electric resistance water heater replacement, for comparison, is roughly \$1,100.⁴⁰

3.3 Industry Structure

Manufacturer sales of water heaters are split relatively equally between wholesaler distribution and retail distribution, with most manufacturers selling to both market channels. Wholesale distributors sell water heaters to plumbing contractors, builders and developers, local hardware stores, or homeowners. Large retailers typically sell water heaters to homeowners, but plumbing contractors are also known to purchase from this market channel. The water heaters reach consumers either through contractors who purchase from wholesale distributors or retail outlets or through direct purchase from retail. The flowchart below is adapted from a residential water heater market study prepared for the Northwest Energy Efficiency Alliance based on 2001 distribution information. It depicts the percentage of water heaters flowing through each market channel.

Figure 11. ENERGY STAR Data on Residential Water Heater Distribution⁴¹



³⁹ Jeff Maguire, Jay Burch, Tim Merrigan, and Sean Ong, “Energy Savings and Breakeven Cost for Residential Heat Pump Water Heaters in the United States,” National Renewable Energy Laboratory, 2013, <https://s3.amazonaws.com/rdcms-phcc/files/production/public/Depts/Technical/HeatPumpReportWeb.pdf>.

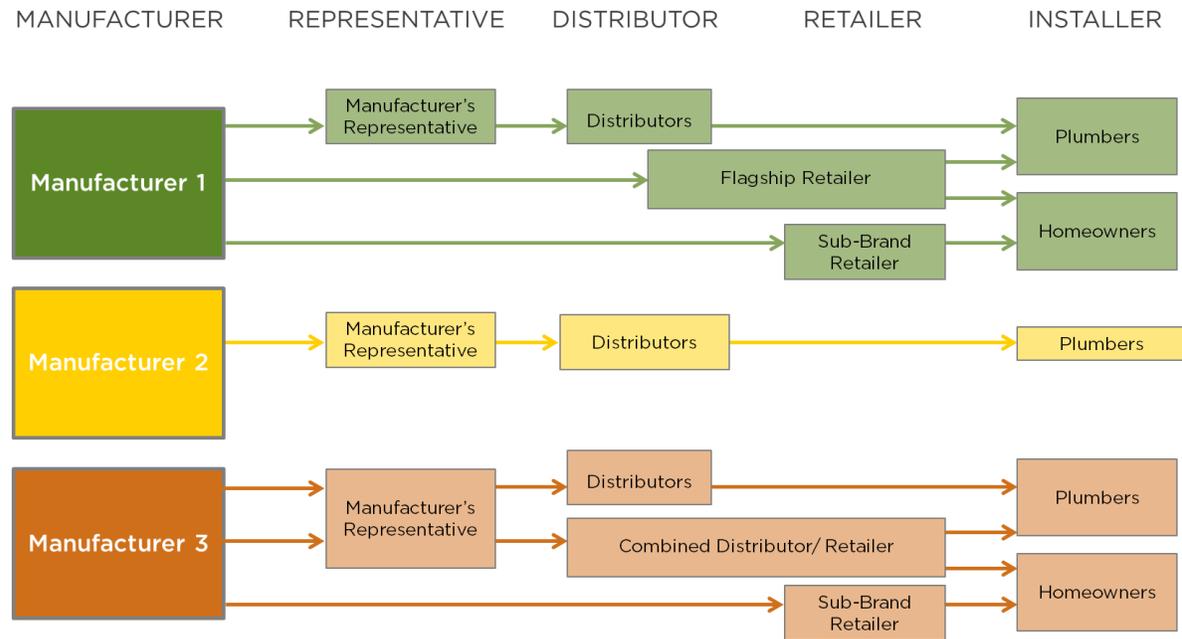
⁴⁰ “Heat Pump Water Heaters and American Homes; A Good Fit?” ACEEE, pg. 6, <https://aceee.org/files/proceedings/2010/data/papers/2205.pdf>

⁴¹ Adapted from Steve Ryan, “ENERGY STAR Water Heater® Update,” ACEEE Hot Water Forum, February 26, 2017, slide 3, http://aceee.org/sites/default/files/pdf/conferences/hwf/2017/Ryan_Session1D_HWF17_2.27.17.pdf.

In the Canadian market, approximately 80 percent of residential water heaters go in as replacement units to existing homes, while 20 percent are installed in new construction.⁴²

The figure below shows another depiction of how the distribution of water heaters occurs; this research demonstrates that there are multiple ways in which a manufactured product ultimately ends up in the hands of a consumer.

Figure 12. **Gas Water Heater Manufacturer to Installer Flowchart**⁴³



3.3.1 PLUMBING WHOLESALERS AND DISTRIBUTORS

Approximately 50 percent of all water heaters are distributed through plumbing wholesalers and distributors. In most cases wholesalers work mainly with installers, but occasionally they work directly with consumers or with local distributors. There are many wholesalers acting in the market, with no wholesaler making up more than five percent of water heater sales.

Manufacturer relationships with wholesalers vary widely; Bradford White distributes exclusively through wholesalers, while some manufacturers sell both to wholesalers and directly to consumers through retailers. Some manufacturers use independent wholesalers exclusively, some own all of their wholesale operation, and others use a combination of both.

⁴² Regulatory Impact Assessment Statement for Amendment 13, Natural Resources Canada, December 2016. <http://www.nrcan.gc.ca/energy/regulations-codes-standards/18419>

⁴³ Adapted from "Energy Trust of Oregon Existing Homes Gas Water Heater Market Research Report," CLEARResult, prepared for Energy Trust of Oregon, 2016, pg. 24, https://energytrust.org/wp-content/uploads/2016/12/Gas_Water_Heater_Market_Research_Report_Public_FINAL_wSR.pdf.

3.3.2 RETAILERS

Large retailers account for 50 percent of water heater sales, an increase from 40 percent in 2005.⁴⁴

Retailers sell products through three primary channels:

- Directly to consumers, using their own affiliated contractors for installation
- Through referrals, as many states require licenses for installation of water heating equipment, particularly gas products
- To plumbing contractors and builders and developers

Lowes, The Home Depot, and Sears are the major retailers in the market. Ace Hardware and True Value are smaller retailers that also supply water heaters. In many cases, manufacturers supply specific brands of water heaters for a given retailer.

3.3.3 PLUMBING CONTRACTORS

Plumbers are also known as installers or plumbing contractors. In general, there are three types of plumbers: independent plumbing contractors who install water heaters in addition to other services, franchise plumbers or water heater installation specialists, and plumbing contractors who are also distributors. Plumbers are a key link in the sales chain because they have direct contact with the end users and have the opportunity to influence equipment purchases. Since most water heaters are replaced on an emergency basis, with few consumers having the time to do research themselves, plumbers often make suggestions or decisions for a homeowner on either replacement units or new installations. Most plumbers receive their water heaters through distributors (although some work with retailers as well) and market their services through the phone book or on the Internet.⁴⁵

The Plumbing-Heating-Cooling Contractor Association (PHCC) is the largest national plumbers' trade association in the United States, with over 3,500 contractor members. It is comprised of open and union shops working across residential, commercial, and industrial segments.

3.3.4 BUILDERS AND DEVELOPERS

Homebuilders and developers are important players in the water heater distribution channel because they sell equipment to customers as part of home purchases. They often make suggestions or decisions for homeowners on new installations and home renovations. Builders often buy water heaters exclusively from wholesalers for new construction. Other emerging market actors in the new construction and retrofit industries include whole home energy efficiency performance contractors, raters, and HVAC specialists.

3.3.5 WATER HEATER MANUFACTURERS

The three largest manufacturers of residential water heaters in the United States and Canada—A. O. Smith, Rheem/Ruud, and Bradford White—account for roughly 95 percent of the market.

⁴⁴ "ENERGY STAR® Unit Shipment and Market Penetration Report: Calendar Year 2015 Summary," ENERGY STAR, https://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2015_USD_Summary_Report.pdf

⁴⁵ Ibid.

Manufacturers sell water heaters under a wide variety of brands. For example, Maytag, State, Reliance, and American are all A. O. Smith brands, while Rheem sells under the Rheem, Ruud and Richmond brands.

Table 1. Residential Water Heater Market Share⁴⁶

Manufacturer	Estimated Water Heater Market Share	Brands
A.O. Smith	41%	A.O. Smith, American, GSW, John Wood, Lochinvar, Reliance, State, Takagi, U.S. Craftsmaster
Rheem/Ruud	34%	Rheem, Ruud, Richmond
Bradford White	20%	Bradford White, Bradford White Canada, Laars
Other Manufacturers	5%	Bosch, Stiebel Eltron, Whirlpool, HTP, Giant Factories Inc, Rinnai

3.4 Market Barriers

Despite the significant savings opportunities that efficient water heaters present, there are a number of prevailing barriers that prevent the uptake and market acceptance of these products. The challenges fall into two main overarching categories: sales channel and distribution efficiencies and obstacles to the consumer process.

3.4.1 SALES CHANNEL AND DISTRIBUTION INEFFICIENCIES

Plumbers, contractors, builders, developers, and retailers often do not have the appropriate marketing tools or do not see the value in selling efficient equipment, since the water heating equipment sales industry is strongly driven by lowest-bid quotes. Plumbers, builders, developers, and retailers have an opportunity to sell efficient equipment (which can be a higher value and profit opportunity) by educating consumers about the life-cycle benefits of that investment, but they often lack the training and tools to effectively educate the consumer and promote the benefits and cost-effectiveness of efficient equipment.

Split Incentives Residential builders often choose water heating equipment on the basis of a low first cost. They do so to reduce the overall price of a house, increase profit margins, and allow money to be spent in areas more visible to consumers, such as kitchen or bath features. If builders and developers were to be incentivized, or if consumers knew to ask for efficient models, it might be possible to increase the number of installations of efficient water heaters in newly constructed homes as well as retrofit applications.

⁴⁶ “Forward Looking Statements,” A. O. Smith Deutsche Bank 7th Annual Global Industrials and Materials Summit, pg. 7, <https://www.sec.gov/Archives/edgar/data/91142/000119312516615907/d197646dex991.htm>.

Access to Reliable Information It can be difficult for consumers and trade allies to determine what water heater model is the right choice for a given application. Reliable sources of information on this subject will help create more clarity. Field testing to understand the true efficiency, reliability, and cost-effectiveness of water heaters will also help consumers and program administrators compare technologies based on performance. In addition, previous generations of heat pump water heaters experienced reliability issues, and many consumers have preexisting misconceptions about their performance.

Emergency Replacement Situations Given that emergency replacement situations require a quick turnaround, plumbers and contractors may not have an incentive to spend effort trying to sell efficient water heaters to consumers. The primary goal is typically to get the homeowner hot water as soon as possible, making efficiency an even lower priority than with a planned replacement.

3.4.2 OBSTACLES TO THE CONSUMER PROCESS

Homeowners consider many factors and drivers when choosing to buy or replace a water heater. Depending on the circumstances of the purchase and the conditions of the installation, they often face a wide range of issues that may impact their decisions. In order to address these challenges, consumers must be given increased access to information, financing, and timely product availability.

Up-Front Costs Efficient water heaters can initially be more expensive than traditional water heater types. Despite lower annual operating costs, the initial purchase price can deter potential buyers. In addition, installation costs may be higher for efficient water heaters than for minimum efficiency water heaters in retrofit situations. If efficient water heaters establish a stronger market presence with more units manufactured and sold per year, economies of scale may produce cost savings and lead to further sales through more competitive offerings.

Low Fuel Prices While efficient products experience lower annual operating costs, average fuel prices can significantly impact the annual cost of water heating, as demand within a home is typically consistent year to year unless changes to or within the household occur. In particular, low fuel prices can extend the payback period for efficient products, particularly those with higher incremental costs due to equipment costs, installation costs, or both.

Lack of Awareness and Information The majority of water heating sales take place in the replacement market, where equipment usually needs to be bought and installed quickly. Consumers often lack information to make informed decisions and rely on the plumbing contractor or retailer as an expert to guide them through the purchase. Water heaters are a low-involvement product area where consumers do not often take the time to research different options or learn about how efficiency can relate to lower overall cost. More efficient water heaters might be sold if homeowners had greater general awareness about water heaters and performance variation across products and increased access to information at the time of sale, both of which would help them make sufficiently informed decisions.

Emergency Replacement Situations The majority of water heater replacements occur on failure. Since consumers are generally unwilling to be without hot water for more than a few hours, they put a

premium on water heaters that can be delivered quickly. This shortened time period reduces consumer ability to research more efficient options. Also, since emergency replacements are unplanned expenses, consumers typically choose the least expensive replacement option offered by plumbing contractors.

These barriers across distribution channels and end customers compound each other. For instance, since many energy efficient add-on features result in an increase to the product’s overall upfront cost, a salesperson may choose to promote the products with the lowest first cost in order to secure a sale. Or, given the customer’s lack of awareness, a salesperson may offer a product that is most similar to the one in need of replacement in order to minimize confusion or complication.

3.5 Regulatory Landscape

3.5.1 UNITED STATES FEDERAL MINIMUM STANDARDS

The Energy Policy and Conservation Act (EPCA) was enacted in 1975 and creates uniform efficiency standards for many categories, including water heaters, under the Energy Conservation Program for Consumer Products.

The National Appliance Energy Conservation Act (NAECA) of 1987 was established to create energy conservation requirements and subsequent DOE rulemaking to evaluate amended standards. Revisions effective in January 2004 specified a minimum energy factor (EF), varying depending on the size of the heater, to which water heaters must adhere. DOE published amended standards for consumer water heaters on April 16, 2010 and a Uniform Energy Factor test procedure (UEF) for residential water heaters on July 11, 2014. US manufacturers are required by federal law to determine the UEF for all residential water heaters and to label them with this information.

The most recently revised and updated minimum federal standards went into effect on April 16, 2015; a summary of these requirements is outlined in the table below.

Table 2. 2015 EPCA Efficiency Requirement for Storage Water Heaters (UEF)

		20–55 Gallon Capacity				> 55 Gallon Capacity		
Rated Storage Volume (gal.)		20	30	40	50	65	80	120
Electric Storage Water Heaters	Very Low Usage (UEF)	0.86	0.86	0.83	0.84	1.85	1.84	1.79
	Low Usage (UEF)	0.92	0.92	0.91	0.91	1.97	1.96	1.91
	Medium Usage (UEF)	0.93	.092	0.92	0.92	1.97	7.96	1.91
	High Usage (UEF)	0.93	0.93	0.93	0.93	2.17	2.15	2.11
Rated Storage Volume (gal.)		20	30	40	50	65	80	120
Gas Storage Water Heaters	Very Low Usage (UEF)	.56	.54	.52	.50	.61	.6	.59
	Low Usage (UEF)	.56	.54	.52	.50	.74	.73	.72
	Medium Usage (UEF)	.61	.60	.58	.56	.76	.76	.75
	High Usage (UEF)	.67	.65	.64	.63	.79	.78	.78

Prior to 2015, there was no separate federal minimum standard for the efficiency of gas tankless water heaters. These products are defined as having storage capacities below two gallons with inputs between 50,000 Btu/h and 200,000 Btu/h. The 2015 standard introduced specific minimum standards for this equipment class for the first time.

Table 3. 2015 EPCA Efficiency Requirements for Gas Tankless Water Heaters

Usage Bin	Very Low	Low	Medium	High
Gallons per Minute	Up to 1.7	Up to 2.8	Up to 4	4 or more
Previous Standard	0.62	0.62	0.62	0.62
2015 Standard in EF	0.82	0.82	0.82	0.82
2015 Standard in UEF	0.80	0.81	0.81	0.81

The Energy Policy Act (EPACT) of 1992 creates uniform efficiency standards for many product categories, including residential duty commercial water heaters. These products are defined as gas-fired water heaters with inputs between 75,100btu/h and 105,000btu/h and storage capacity below 120 gallons. While these products are regulated as commercial water heaters, they have residential applications. Residential duty commercial water heaters typically have larger tank sizes, and their minimum standards are different from those that apply to residential storage products. Prior to the 2016 revised test procedure introducing the Uniform Efficiency descriptor, the efficiency of these products was rated using thermal efficiency and standby losses.

Table 4. EPACT Requirements for Residential Duty Commercial Water Heaters

	20–55 Gallon Capacity	> 55 Gallon Capacity
Current Standard TE	80%	80%
Current Standby Loss	$Q/800 + 110(V_r) 1/2$ (Btu/h)	$Q/800 + 110(V_r) 1/2$ (Btu/h)

Table 5. EPACT Requirement for Res Duty Commercial Water Heaters (UEF)

Rated Storage Volume (gal.)	20–55 Gallon Capacity				> 55 Gallon Capacity		
	20	30	40	50	65	80	120
Very Low Usage (UEF)	0.25	0.24	0.23	0.22	0.21	0.20	0.18
Low Usage (UEF)	0.51	0.50	0.49	0.48	0.46	0.44	0.42
Medium Usage (UEF)	0.58	0.57	0.56	0.55	0.53	0.51	0.49
High Usage (UEF)	0.63	0.61	0.60	0.58	0.56	0.54	0.51

3.5.2 UNITED STATES TEST PROCEDURES

As of 2017, the US Department of Energy rated residential and residential-duty commercial water heaters using the uniform energy factor (UEF) and tested them using a process described in 10 CFR Parts 429, 430, and 431.⁴⁷ The UEF methodology uses draw patterns varying in length, flow rate, and number of draws as a basis for how the water heaters are tested.

Products are sorted into usage bins defined by the product’s first hour rating (the amount of hot water it can deliver over an hour) as opposed to the size of the tank or the input rating. While first hour rating is correlated to both tank size and input, tanks of similar sizes or inputs may have different first hour ratings, and thus may qualify for different usage bins. The UEF test procedure incorporates different draw patterns for different intended uses, and the draw pattern for each usage bin is intended to reflect real-world use. Since the draw patterns used to test products differ by usage bin, comparing UEF across usage bins does not accurately reflect the relative efficiency of these products. For this reason, while all products are rated in UEF, the test is intended to provide direct comparison only between products sharing a usage bin.

Table 6. 2016 DOE Uniform Test Method Usage Bins

Usage Bin	First Hour Rating (for storage)	Gal./Minute (for tankless)	Number of Draws	Total Volume of Draws
Very Low	Greater than 0 gallons, less than 18 gallons	Greater than 0 gallons, less than 1.7 gallons	9	10 gallons
Low	Equal to or greater than 18 gallons, less than 51 gallons	Equal to or greater than 1.7 gallons, less than 2.8 gallons	11	38 gallons
Medium	Equal to or greater than 51 gallons, less than 75 gallons	Equal to or greater than 2.8 gallons, less than 4 gallons	12	55 gallons
High	Equal to or greater than 75 gallons	Equal to or greater than 4 gallons	14	84 gallons

3.5.3 REGIONAL AIR QUALITY STANDARDS

Under the federal Clean Air Act, US EPA establishes health-based air quality standards that all states must achieve and designates air quality management districts to help ensure compliance with these regulations. In addition, states may require cities and counties to meet additional regulations. Therefore, CEE members may have region-specific requirements for air quality standards, as certain jurisdictions have standards more stringent than general federal requirements. Of particular relevance for water heater programs, some local air quality management districts require stricter emissions limits for nitrogen oxides (NO_x), comprising nitric oxide and nitrogen dioxide. CEE members in regions subject to these requirements will specify products that meet these emissions requirements. CEE

⁴⁷ “Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Residential and Commercial Water Heaters,” 10 CFR Parts 429, 430 and 431 [Docket No. EERE-2011-BT-TP-0042] RIN: 1904-AC53, US Department of Energy, https://energy.gov/sites/prod/files/2014/06/f17/rwh_tp_final_rule.pdf.

members and manufacturers should consult local air quality standards to determine the appropriate levels for compliant products. Air quality requirements such as NO_x limits are typically in addition to efficiency requirements, such as those in the CEE specifications in this Initiative.

3.5.4 CANADIAN MINIMUM STANDARDS

Canada's Energy Efficiency Act was passed by Parliament in 1992 and provides for the making and enforcement of regulations concerning minimum energy performance levels for energy-using products, as well as the labeling of energy-using products and the collection of data on energy use. The *Energy Efficiency Regulations* (Regulations) came into effect in February 1995 and are administered by the Natural Resources Canada (NRCan) Office of Energy Efficiency.

The Regulations are amended periodically to strengthen existing performance standards or to introduce performance standards for new products. Standards for electric water heaters were last updated in 2004; those for gas-fired storage water heaters and oil-fired water heaters were last updated in 2016.⁴⁸ While there are currently no regulations for commercial or tankless gas water heaters, Natural Resources Canada has announced the intention to regulate these products by 2019.⁴⁹

The province of British Columbia has recently introduced higher minimum efficiency levels for water heaters than were previously adopted, and expects to advance those requirements further. Other provinces may also be planning to introduce higher efficiency regulations for water heaters.

The government of Canada is actively working to harmonize energy efficiency standards both within the country and internationally with the United States and other partners. The 2016 document *Encouraging Market Transformation through Collaboration on Energy Efficiency Standards: A Federal-Provincial-Territorial Framework* is a framework document that articulates ways to achieve these goals. The Regulatory Cooperation Council (RCC) was created in 2011 to increase regulatory coordination between Canada and the United States and is actively working to better align efficiency standards. The *Pan-Canadian Framework on Clean Growth and Climate Change* was published in August 2017 and outlines commitments of the federal, provincial, and territorial governments to reduce greenhouse gas emissions and promote clean, low-carbon economic growth for Canadians. For water heating, the report identifies the following aspirational goals:

⁴⁸ "Guide to Canada's Energy Efficiency Regulations," Natural Resources Canada, last modified September 18, 2017, <http://www.nrcan.gc.ca/energy/regulations-codes-standards/6861>.

⁴⁹ "Forward Regulatory Plan 2017-19: Regulatory Initiative: Canada's Energy Efficiency Regulations," Natural Resources Canada, last modified July 25, 2017, <http://www.nrcan.gc.ca/energy/regulations-codes-standards/18318>.

Table 7. Aspirational Goals to 2035 for Water Heating in Canada⁵⁰

Timeframe	Aspirational Goal
Short Term: by 2025	By 2025, all fuel-burning water heating technologies for sale in Canada meet an energy performance of at least 90% (condensing technology)
Medium Term: by 2030	All electric water heaters for sale in Canada meet an energy performance of more than 100% (EF greater than 1) A residential gas heat pump with an EF greater than 1.4 can be manufactured and installed cost-effectively
Long Term: by 2035	All water heating technologies for sale in Canada meet an energy performance greater than 100% (EF greater than 1)

3.5.5 CANADIAN TEST PROCEDURES

The Regulations refer to various Canadian Standards Association (CSA) and ANSI test methods. The table below indicates respective test methods for various residential water heater products as of 2010.

Table 8. Canadian Minimum Performance Levels by Product⁵¹

Water Heater Type	Water Heater Size	Test Method	Test Method
Gas-Fired Tankless	< 250,000 btu/h	N/A	CSA P.7
	> 250,000 btu/h	N/A	CSA 4.3 / ANSI Z21.10.3
Gas-Fired Storage	≤ 75,000 btu/h input	EF ≥ 0.675 – 0.00039 Vr	CSA P.3-04
	> 75,000 btu/h input	N/A	CSA 4.3 / ANSI Z21.10.3
Oil-Fired Storage	< 105,000 btu/h	EF ≥ 0.68 – 0.0005 Vr	B211-00
	> 105,000 btu/h	N/A	CSA 4.3 / ANSI Z21.10.3
Electric Storage	≤ 12kw and ≤ 454 litres	Standby loss requirements ⁵²	CSA C191-04
	> 12kw and ≥ 75 litres	N/A	CSA 4.3 / ANSI Z21.10.3

⁵⁰ “Market transformation strategies for energy-using equipment in the building sector: Supporting the transition to a low-carbon economy,” Pan-Canadian Framework on Clean Growth and Climate Change, Energy and Mines Ministers’ Conference, August 2017, pg. 22, http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/emmc/pdf/Market-Transformation-Strategies_en.pdf.

⁵¹ Natural Resources Canada. Bulletin on Proposed Regulations. June 2010, <http://oee.nrcan-nrcan.gc.ca/regulations/bulletin/water-heaters-june-2010.cfm?attr=4>

⁵² “Electric Water Heaters: Energy Efficiency Regulations: Technical Requirements for Energy-Using Products,” Natural Resources Canada, last modified December 10, 2017, <http://www.nrcan.gc.ca/energy/regulations-codes-standards/products/6951>.

3.6 Voluntary Specifications

3.6.1 ENERGY STAR®

In January 2009 ENERGY STAR launched criteria for residential water heaters, including storage, tankless, and solar product classes. Heat pump water heaters, as defined under the storage product class, were required to be either integrated or drop-in configurations to qualify. The most recent revision for this ENERGY STAR product category was finalized in August 2017.

Table 9. ENERGY STAR Version 3.2 Specification: Electric Water Heaters

Criteria	ENERGY STAR® Requirements	
	Using EF	Using UEF
≤ 55 gallons	EF ≥ 2.00	UEF ≥ 2.00
> 55 gallons	EF ≥ 2.20	UEF ≥ 2.20
First Hour Rating	FHR ≥ 50 gallons per hour	FHR ≥ 45 gallons per hour
Warranty	Warranty ≥ 6 years on sealed system	
Safety	UL 174 and UL 1995	
Lower Compressor Cutoff Temperature (Reporting Requirement Only)	Report ambient temperature below which the compressor cuts off and electric resistance only operation begins	

Table 10. ENERGY STAR Version 3.2 Specification: Gas Storage Water Heaters

Criteria	ENERGY STAR® Requirements	
	Using EF	Using UEF
≤ 55 gallons	EF ≥ 0.67	Medium Draw Pattern UEF ≥ 0.64 High Draw Pattern UEF ≥ 0.68
> 55 gallons	EF ≥ 0.77	Medium Draw Pattern UEF ≥ 0.78 High Draw Pattern UEF ≥ 0.80
First Hour Rating	FHR ≥ 67 gallons per hour	
Warranty	Warranty ≥ 6 years on system (including parts)	
Safety	ANSI Z21.10.1/CSA 4.1	

Table 11. ENERGY STAR Version 3.2 Specification: Gas Instantaneous Water Heaters

Criteria	ENERGY STAR® Requirements	
	Using EF	Using UEF
Energy Factor	EF ≥ 0.90	UEF ≥ 0.87
Gallons per Minute	GPM ≥ 2.5 over a 77° rise	GPM ≥ 2.9 over a 67° rise
Warranty	Warranty ≥ 6 years on heat exchanger and ≥ 5 years on parts	
Safety	ANSI Z21.10.3/CSA 4.3	

Table 12. ENERGY STAR Version 3.2 Specification: Residential Duty Water Heaters

Criteria	ENERGY STAR® Requirements	
	Using TE	Using UEF
Energy Factor	TE ≥ 90%	UEF ≥ 0.80
Warranty	Warranty ≥ 6 years on system	
Safety	ANSI Z21.10.3/CSA 4.3	

3.6.2 ADVANCED WATER HEATER SPECIFICATION VERSION 6.0

The Northwest Energy Efficiency Alliance (NEEA) has developed an [Advanced Water Heater Specification](#) that identifies units that are efficient in colder climates by using a test procedure accounting for lower ambient air temperature and inlet water temperature to reflect conditions in colder climates. A prerequisite to qualify for the specification is that the units must be ENERGY STAR certified. These HPWH units generally have larger compressors that cut off at lower temperatures in order to work more efficiently in the colds.

Table 13. NEEA Advanced Water Heater Specification Version 6.0⁵³

Tier	Minimum Northern Climate UEF	Minimum Features	Minimum Supported Installation Locations	Sound Levels**	Demand Response Enabled
Tier 1	2.0	<ul style="list-style-type: none"> ENERGY STAR compliance Freeze protection 	<ul style="list-style-type: none"> Semi-conditioned Unconditioned 	dBA < 65	Optional
Tier 2	2.3	Tier 1 plus: <ul style="list-style-type: none"> Minimal use of resistance heating elements (see section 5.1⁵⁴) Compressor shut-down/notification 10-year warranty Condensate management 	<ul style="list-style-type: none"> Conditioned Semi-conditioned Unconditioned 	dBA < 60	Optional
Tier 3	2.6	Tier 2 plus: <ul style="list-style-type: none"> Simultaneous intake and exhaust ducting capable Air filter management Unit to be tested in factory-default mode Override and default mode behavior as per Section 6.1⁵⁵ 	<ul style="list-style-type: none"> Conditioned Semi-conditioned Unconditioned 	dBA < 55	Optional, but preferred
Tier 4	3.0	Tier 3 plus: <ul style="list-style-type: none"> Physical design or default controls which limits resistance element heating to less than upper 50% of tank 	<ul style="list-style-type: none"> Tier 3 	dBA < 50	Yes
Tier 5	3.5	Tier 4 plus: <ul style="list-style-type: none"> No resistance element usage in default mode unless outside ambient air temperature below -5°F 	<ul style="list-style-type: none"> Tier 4 	dBA < 50	Yes

* See Appendix A of specification for details on definition and calculation method.

** See Appendix D of specification for details on measurement method.

⁵³ "A Specification for Residential Water Heaters: Advanced Water Heater Specification: Formally known as the Northern Climate Specification: Version 6.0," Northwest Energy Efficiency Alliance, May 10, 2016, Pg. 4, <http://neea.org/docs/default-source/advanced-water-heater-specification/advanced-water-heater-specification.pdf?sfvrsn=22>.

⁵⁴ Ibid., pg. 6

⁵⁵ Ibid., pg. 8

4 Energy Efficiency Program Considerations

4.1 Energy Savings Potential

The energy savings potential for water heaters is addressed by fuel type, as the appropriate application for any individual customer will include consideration of a number of factors, including fuel prices, availability of gas service, local generation mix, and installation considerations. Energy savings are estimated at the product level, without consideration of transmission, distribution, and generation efficiency or losses.

4.1.1 GAS-FIRED STORAGE WATER HEATERS SAVINGS POTENTIAL

Storage water heaters with higher levels of efficiency often have increased insulation, advanced valves, or direct vent technologies which control drafts and minimize airflow through the use of a draft inducer fan. Efficient units can also come equipped with power venting technologies that use a small fan to exhaust flue gases. Anti-convection valves, flue baffling, heat traps, and sealed combustion designs are other technology improvements that can increase the efficiency of the water heater by improving combustion efficiency or limiting standby heat losses.^{56,57} On average, efficient storage water heaters can save between seven percent and 14 percent in energy used per year in comparison to minimum efficiency storage water heaters.⁵⁸ If half of the storage water heaters sold in the United States were models that achieve 0.68 UEF rather than 0.63 UEF, approximately 37 million therms would be saved per year. If just five percent of the market were converted to 0.78 UEF storage water heaters, almost ten million therms would be saved per year.⁵⁹

The efficiency of gas storage water heaters can be further enhanced through the application of condensing technology. Standard gas water heater technology uses natural draft venting to move combustion byproducts outside through a vertical vent such as a chimney. This open vent allows usable heat to be lost through the chimney, lowering system efficiency. Higher efficiency gas water heaters use condensing equipment to remove extra heat from the flue gases, thereby recovering heat energy from the byproducts of combustion.

As heat is removed, water vapor in the flue gases condenses, producing a corrosive condensate that must be handled in a corrosion-resistant drainage system. In addition to the drain, condensing equipment typically incorporates a fan to help vent exhaust gases. The drainage and venting requirements are the primary sources of higher equipment and installation costs with these units.

⁵⁶ *Domestic Water Heating and Water Heater Energy Consumption in Canada*, Canadian Building Energy End-Use Data and Analysis Centre, 2005. https://sites.ualberta.ca/~cbeedac/publications/documents/domwater_000.pdf

⁵⁷ "ENERGY STAR Residential Water Heaters: Second Draft Criteria Analysis and Proposal," US Department of Energy, 2007. https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/WaterHeaterSecondDraftCriteriaAnalysis.pdf?8fd5-1967

⁵⁸ This savings information is based on the [DOE test procedure](#) measuring energy consumption per year. The standard equation is $(41,045 \text{ Btu/EF} \times 365) / 100,000$.

⁵⁹ *Ibid.*

Condensing water heaters typically have UEFs of 0.80 or higher, and can save over 22 percent in energy used per year over standard equipment.

4.1.2 GAS-FIRED TANKLESS WATER HEATERS SAVINGS POTENTIAL

The efficiency rating of tankless water heaters is typically higher than the rating for storage water heaters. This greater efficiency is in part because there are no standby losses of heat to the surrounding environment, as would typically be found with a storage water heater. Storage units are designed to maintain water stored in the tank at a constant temperature, and, in what is called standby loss, heat is lost through the tank when hot water is not being demanded. Tankless water heaters only heat water as it is needed, avoiding these standby losses and improving efficiency. However, while they do not experience standby losses, tankless water heaters can incur cyclic losses when the product is used after sitting idle for a period of time. The use of condensing technology in tankless water heaters can further improve efficiency; however, this technology does incur greater installation costs in order to accommodate the condensate disposal system.

In terms of overall costs, the installation of a tankless model is typically more expensive than that of a storage counterpart. While the lifespan of tankless products may be longer than that of storage units (one study indicates 20 years, compared to the typical 10- to 15-year lifespan), the individual lifespan for any given instantaneous water heater is largely determined by factors that are out of the manufacturer's control once the product is sold.⁶⁰ These include regular maintenance of the product, thermostat setting, and water quality.

4.1.3 HEAT PUMP WATER HEATERS SAVINGS POTENTIAL

Heat pump water heaters typically have a uniform energy factor (UEF) at least twice as high as that of conventional electric water heaters.⁶¹ According to analysis conducted by the Pacific Northwest National Laboratory (PNNL), the theoretical energy savings from replacing conventional electric resistance water heaters with HPWH are up to 63 percent per water heater. These assumptions are based on the DOE test procedure⁶² and comparison of an electric resistance water heater (UEF = 0.90) with an HPWH (UEF = 2.4).⁶³

The typical ENERGY STAR Version 3.2 qualified heat pump water heater saves households energy and money as compared to a standard electric water heater.

⁶⁰ "Tankless vs. Traditional Water Heaters | Which is More Efficient?" Constellation, October 6 2016, <https://blog.constellation.com/2016/10/06/which-is-more-efficient-tankless-vs-traditional-water-heaters/>.

⁶¹ Maguire, Burch, Merrigan, and Ong 2013, pg. vi

⁶² 10 CFR 430.32(d)

⁶³ S. H. Widder, G. B. Parker, J. M. Petersen, and M. C. Baechler, "Impact of Ducting on Heat Pump Water Heater Space Conditioning Energy Use and Comfort," Pacific Northwest National Laboratory, 2014, pg. 17, http://www.pnnl.gov/main/publications/external/technical_reports/pnnl-23526.pdf.

Table 14. ENERGY STAR Version 3.0 HPWH Savings Based on Household Size⁶⁴

Household Size	2	3	4	5	6
Annual Savings	\$160	\$240	\$330	\$410	\$490
Payback (Years)	4.9	3.3	2.5	2.0	1.6
Lifetime Savings	\$1,320	\$2,380	\$3,440	\$4,490	\$5,550

Assumes electricity rate of 12 cents/kWh, incremental cost = \$800, and 13-year lifespan

In terms of energy savings derived, a 50-gallon electric resistance water heater with a UEF of 0.90 will on average use nearly 4,800 kWh per year. In comparison, a 50-gallon HPWH with a UEF of 2.35 will use nearly 1,800 kWh per year. This represents an annual savings of 3,000 kWh per year. Assuming a lifespan of 13 years, this equates to a lifetime savings of almost 40,000 kWh.⁶⁵ It should be noted that this product area is still relatively nascent in the mainstream market, and there is therefore limited data about the total lifespan of current models; given this, there may be a variance in payback periods.

In a different study, Sacramento Municipal Utility District suggests the following use and savings for various sizes of homes:

Table 15. Expected Annual Energy Savings by House Size⁶⁶

Number of Bedrooms	Average Daily Hot Water Use (Gallons)	Expected Annual Energy Savings (kWh)
1	35 gallons	1,750 kWh
2	45 gallons	2,000 kWh
3+	55 gallons	2,200 kWh

The US Department of Energy estimates that if all electric resistance water heaters in the United States today were replaced with heat pump water heaters (assuming 0.90-0.95 UEF for electric resistance water heaters and 2.0 UEF for HPWH), consumers would save \$7.8 billion annually—an average of \$182 per household in water heater operating costs.⁶⁷ HPWH are not appropriate in all applications or scenarios, however, so this figure represents the upper limit of potential savings associated with replacement of electric resistance water heaters with HPWH.

4.1.4 PRODUCT LIFETIME

Storage water heaters, both gas and heat pumps, typically carry six-, eight-, or ten-year warranties. Tankless water heaters often have separate warranties for the heat exchanger and for all other parts,

⁶⁴ “Save Money and More with ENERGY STAR Certified Heat Pump Water Heaters,” ENERGY STAR, accessed January 28, 2018, http://www.energystar.gov/index.cfm?c=heat_pump.pr_savings_benefits.

⁶⁵ “Saving Calculator,” Sacramento Municipal Utility District, accessed January 3, 2017, <http://www.smud-heatpumph2o.org/calc.php>.

⁶⁶ Ibid.

⁶⁷ Carl Shapiro and Srikanth Puttagunta, Field Performance of Heat Pump Water Heaters in the Northeast, US Department of Energy, February 2016, pg. 2, https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/64904.pdf

and these warranties can vary between five and twelve years. Higher performing storage products, such as efficient gas and heat pump models, often carry warranties of ten years. Longer product warranties can help consumers feel comfortable trying new technologies and can help installers and contractors move consumers towards considering high efficient products. In particular, previous generations of heat pump products did not meet customer expectations in terms of quality or lifetime, and therefore reliable warranties can help overcome consumer and installer hesitation in considering this technology again.

In order to credibly claim savings from energy efficiency measures, program administrators must establish reasonable equipment lifetimes so as to calculate lifetime energy savings. While the national average for the life of a water heater is 13 years, local conditions such as water quality and sedimentation can impact equipment lifetimes. Moreover, since widespread adoption of HPWH has only occurred within roughly the last decade, there is not sufficient historical performance data to provide a reliable estimate of in-field lifespan. Therefore, program administrators often rely on manufacturer product warranties as a basis for establishing product lifetimes. Longer manufacturer warranties can result in more lifetime savings for programs and can impact program and incentive design. Programs may require minimum warranty lengths in order to ensure consumer satisfaction and credibly claim lifetime savings.

4.2 Further Product Distinction by Type

Programs may wish to further differentiate efficient products models on the parameters used in the DOE test procedure for consumer water heaters, including storage volume and first hour rating. Storage volume impacts the federal minimum standards products must adhere to, while first hour rating impacts the manner in which these products are tested. Further product distinctions are defined by the DOE test procedure and minimum standards as follows.

By Rated Storage Volume: Rated Storage Volume means the water storage capacity of a water heater, in gallons or liters, as certified by the manufacturer pursuant to 10 CFR part 429.

Rated Storage Volume Categories
≥20 gallons and ≤55 gallons
>55 gallons and ≤120 gallons

By First Hour Rating: First Hour Rating (FHR) is an estimate of the maximum volume of hot water that a storage water heater can supply within an hour that begins with the water heater fully heated (i.e, with all thermostats satisfied). It is a function of both the storage volume and the recovery rate.

Category	First Hour Rating
Very Small	FHR < 18 gallons
Low	$18 \leq \text{FHR} < 51$ gallons
Medium	$51 \leq \text{FHR} < 75$ gallons
High	FHR ≥ 75 gallons

Members, installers, and industry partners should recommend products that address customer considerations, such as a first hour rating that reflects the use patterns and needs of the consumer. Furthermore, as similar tank sizes may offer different first hour ratings, consumers should not be led to assume that similarly sized products will perform the same way. This may be of particular relevance when considering replacing a conventional residential product with a similarly sized residential-duty commercial water heater. Consumers benefit when the appropriate product is recommended for the needs of an individual application.

4.3 Installation Factors

4.3.1 NATURAL GAS FACTORS

While tankless water heaters offer a large potential gain in efficiency, they are not the right choice for all consumers. The burners on tankless water heaters activate only when a minimum water draw occurs, and many tankless units have a minimum flow requirement of 0.6 to 0.8 gallons per minute. Low-volume water applications, such as washing hands, might not draw enough water to activate the burners. This means that the consumer must either use a greater volume of water overall for the same end use or get no hot water at all for the desired use.

Tankless units may also affect homeowners' use of hot water. They can provide an endless supply of hot water because, unlike tank-type water heaters, there is no storage tank to reheat. If the hot water supply no longer runs out, homeowners may be encouraged to increase their overall consumption of hot water. If this occurs, expected gas bill savings may not be realized.

Finally, gas utilities have been concerned about consumers experiencing problems with levels of gas service. Because tankless water heaters operate with higher BTUs, they may require a minimum $\frac{3}{4}$ " diameter gas line, which could require homeowners to upgrade their gas line accordingly in order to ensure that the system functions appropriately.

Efficiency programs considering rebates and incentives for tankless water heaters should consider consumer education programs to help address these service issues and to identify where tankless water heaters would be most appropriately installed. Installer education programs may also be beneficial to efficiency and consumer experience, since tankless water heaters must be sized and set up correctly to avoid a diminished level of service and unintended increases in gas and water consumption. When

supported by appropriate educational efforts, tankless water heaters can be a valuable part of an effective portfolio of efficient water heating technologies.

For storage water heaters, more efficient products may have some additional installation challenges. They may be larger, due to increased insulation, and may not fit into existing spaces. Furthermore, power vented models may require an electrical connection, although atmospherically vented products do not. Legacy water heaters may not be adjacent to an electrical connection, and either moving the more efficient product to a location with access to an electrical connection or extending the electric connections to the existing location may require additional cost. Many plumbers may not be able to perform this electrical work, adding the cost and time burden of bringing in a second contractor.

Condensing models, for both storage and tankless water heaters, may require access to a sanitary sewer. The products of the condensing process are slightly acidic and must be disposed of properly. Local building codes should be followed in regards to proper disposal. Many legacy locations may not have immediate access to a sanitary sewer, and moving the location of the water heater, or creating this access, may increase installation costs.

4.3.2 HEAT PUMP WATER HEATER FACTORS

The performance of HPWH is affected by the conditions in which they are operated. During the heating process, heat transfer from the ambient air to the water produces cool, dry exhaust air. While this may be beneficial in the cooling months, during operation in the heating months it can produce unwanted cooler air when installed in conditioned or semi-conditioned spaces, potentially causing the heating system to work harder to compensate and thus erode overall energy savings. Additionally, localized cooling in these spaces may decrease occupant comfort, regardless of impact on the heating system. Furthermore, heat pump water heaters require sufficient volume of air to draw heat from the ambient air and may not be appropriate, unless ducted, in small spaces such as a utility closet. Plumbers and installers should be properly educated about appropriate installation locations and conditions, and should help inform customers about these potential impacts. Programs, manufacturers, and industry partners throughout the distribution chain have a role in ensuring proper installer training and education.

Heat pump water heaters also produce non-toxic condensate, which must be disposed of properly. Local building codes should be followed in regards to proper disposal, which often requires connection to a sanitary sewer. Legacy installation locations may not have easy access to a sanitary sewer, and moving locations or creating sewer access may increase installation costs. Condensate disposal may also require the addition of a condensate pump to move the condensation to a proper location.

Heat pump water heaters tend to be taller than traditional electric resistance models, due to the heat pump itself, and wider, due to increased insulation. These increased dimensions may impact their ability to be located in legacy locations (due mostly to the compressor and evaporators), potentially increasing installation costs.

In addition, HPWH do not heat water as quickly as conventional electric resistance water heaters when they are operating in heat pump mode, especially after recovering from a significant draw. They may switch to less efficient modes in order to maintain performance, and as a result, operate in a less efficient electric-resistant mode more often during these recovery times.

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), there is an added concern of freezing in cold climates and during power outages. The NEEA [Advanced Water Heater Specification](#) outlines guidance for a Freeze Protection Test that addresses these adverse environmental circumstances.⁶⁸

Lastly, sound is a consideration for these products, given that they make considerably more noise than a traditional electric resistance water heater due to the fan and compressor outputs. Most current models have noise ratings between 55 and 70 decibels (dBA), a fairly wide range. Some common household noises with similar levels include washing machines (50-75dBA), refrigerators (50dBA), air conditioners (50-70dBA), dishwashers (55-70dBA), and vacuum cleaners (60-85dBA).⁶⁹ Depending on the installed location of the HPWH, noise may be an important factor to take into account.

4.4 Consumer Engagement

Utility companies and efficiency programs have access to and credibility with consumers and can help move the market towards efficient choices. Consumer awareness of water heater efficiency can be raised through activities such as publicity campaigns, online information, in-bill mailings, and targeted early-replacement efforts. There are many factors, such as gas pressure, water quality, usage pattern, and location of water heater relative to major points of use, that affect which technologies are most appropriate for each individual home; consumers should be aware that there are many considerations that should affect their purchasing decision, including the number of occupants in the home and their personal hot water usage patterns. Efficiency programs can help serve as the conduit for raising awareness of these issues and providing customers with the resources they need in order to make informed purchases.

CEE members also feel it is important to assess the potential consumer, grid, and environmental benefits associated with products capable of two-way communication and to structure voluntary DSM programs to realize these new possibilities.⁷⁰ CEE members are currently considering ways to increase residential energy savings gained from consumer engagement strategies. Recent trends (as indicated by data collected in the annual [CEE Residential Water Heater Program Summary](#)) seem to indicate an increased interest by program administrators in addressing water heating energy storage and load

⁶⁸ "A Specification for Residential Water Heaters: Advanced Water Heater Specification: Formally known as the Northern Climate Specification: Version 6.0," pg. 16

⁶⁹ "Common Environmental Noise Levels," Center for Hearing and Communication, accessed February 2018, <http://chchearing.org/noise/common-environmental-noise-levels/>.

⁷⁰ The CEE working definition of connected products specifies those engineered to send and receive information to enable new value for utilities and customers, including necessary data for customer engagement platforms.

management, which may result in more consumer engagement opportunities; CEE will continue to monitor and assess these as appropriate.⁷¹

4.5 Energy Storage and Load Management

Water heating represents about 17 percent of household energy use; because this is such a significant share of total energy consumption for homeowners, even modest improvements in its efficiency can deliver significant benefits.⁷² One such benefit is the possibility of using advanced water heating systems, equipped with features such as heat pump technology and real-time communication capabilities with the grid, for dynamic energy storage and load management.

Only a few percent of residential water heaters are being used today for energy storage, but as "[The Hidden Battery: Opportunities in Electric Water Heating](#)" (2016) shows, using water heaters for energy storage could lead to significant energy savings.⁷³ The "Hidden Battery" study found that when utilities turn off a customer's water heater during periods of peak power demand, the power to a water heater with a 50-gallon tank could be interrupted for up to four hours with little risk of running out of hot water. The study also noted that the net benefits of water heater-based storage, demand reduction, or other technologies could approach \$200 annually per participant. As water heaters are particularly well suited for thermal energy storage, community storage initiatives have been gaining traction in recent years. Additionally, some manufacturers are creating customer-centric platforms for managing water heater energy use, either as a standalone application or in conjunction with a home's other products and systems, such as appliances and HVAC.

There are considerable energy efficiency and demand response (DR) opportunities associated with HPWH products, as water heater usage typically coincides with peak electric demand, the products have a rapid operational response, and they are inherently capable of energy storage. These considerations make them an ideal candidate for DR programs such as dynamic pricing and incentive based direct load control offerings.

According to the Pacific Northwest National Laboratory, the incorporation of HPWH products into demand response programs can promote increased system reliability, defray the cost of new infrastructure investment, improve system efficiency, and decrease carbon emissions through increased penetration of intermittent renewable resources.⁷⁴ A study conducted for the Northwest Energy

⁷¹ "2016 CEE Residential Water Heating Program Summary," Consortium for Energy Efficiency, 2016, <https://library.cee1.org/content/2016-cee-residential-water-heating-program-summary/>

⁷² "#AskEnergySaver: Home Water Heating," US Department of Energy, March 24, 2014, <https://energy.gov/articles/askenergysaver-home-water-heating>.

⁷³ Ryan Hledik, Judy Chang, and Roger Lueken, "The Hidden Battery: Opportunities in Electric Water Heating," The Brattle Group for the National Rural Electric Cooperative Association (NRECA), the Natural Resources Defense Council (NRDC), and the Peak Load Management Alliance (PLMA), 2016, https://www.eenews.net/assets/2016/02/10/document_gw_03.pdf.

⁷⁴ S. H. Widder, G. B. Parker, J. M. Petersen, and M. C. Baechler, "Demand Response Performance of GE Hybrid Heat Pump Water Heater," Pacific Northwest National Laboratory, 2013, pg. 17, http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22642.pdf.

Efficiency Alliance in August 2014 demonstrated that HPWH are viable products to include in demand management programs designed to reduce peak demand or provide energy storage services to the grid.⁷⁵ However, while there are many potential opportunities for grid-enabled HPWH products, the demand response characteristics are still being established. There are several current efforts to further research this topic, establish more comprehensive specifications and standards, and quantify more definitive savings associated with energy storage and load management.

4.6 Program Design Structures

There are a number of strategies for promoting the purchase and installation of efficient water heaters. The following is a list of approaches intended to incentivize various actions along the entire distribution chain.

Upstream Incentive: This type of incentive goes to the manufacturer to help lower the costs of efficient equipment. The reduced costs are then passed through to distributors and retailers and ultimately to the consumer. Because the incentive goes to the manufacturer, information regarding the end use customer is not typically passed along to the program administrator. Upstream incentives can be combined with downstream programs with the goal of creating both a push aimed at the distribution chain and a pull from consumers.

Midstream Incentive: This type of incentive goes to the retailer or the distributor. For a retailer, it may involve providing a point of purchase rebate for each efficient model sold in the store or a stocking incentive for simply having efficient models available for purchase. It may be challenging for retailers to provide a name and address for the customer purchasing the product, in order for programs to ensure the benefit is going to their customers; therefore, some programs offer a split incentive, with part of the rebate going to the retailer for each water heater sold and the rest available as a downstream mail-in rebate.

For distributors, a midstream incentive goes to the distributor itself, and the distributor accordingly lowers the cost of the equipment. Installers purchase the product from the distributor at this reduced cost and provide the name and address of the customer where it is to be installed. The distributor then provides the name and address to the efficiency program, which provides the rebate to the distributor.

Downstream Incentive: The rebate goes to the customer; the most common method for implementing this is a mail-in rebate, although the rebate can also be given at the time of purchase, through an online form, or through other delivery mechanisms.

⁷⁵ Diane Broad, Kenji Spielman, and Ken Dragoon, "Heat Pump Water Heaters for Demand Response and Energy Storage," Ecofys for Northwest Energy Efficiency Alliance, 2014, <http://neea.org/docs/default-source/reports/final-hpwh-dr-report-and-summary.pdf?sfvrsn=6>.

Bundled Promotion: This approach is particularly relevant where water heating measures are not viable to promote through stand-alone programs and do not pass cost-effectiveness tests. Bundled package offerings for residential customers are designed in a number of ways:

- Combining the water heater equipment with additional applications or installation requirements associated with the performance of the entire water heater system (examples include pipe wrap and faucet aerators)
- Combining the water heater offering with the purchase of a new furnace in order to prevent “orphaned water heaters,” as these can create health and safety risks when a high efficient furnace is added to a well sealed and insulated home while the water heater continues to be atmospherically vented
- Bundling the purchase of an efficient water heater with other efficient measures in the home, with the incentives provided only if the homeowner participates in multiple residential portfolio offerings

Whole House Approach: Water heating can be a helpful gateway into the home to facilitate a more comprehensive retrofit. Leveraging the installer or plumber, who is already in the house and can communicate with the homeowner, members may wish to integrate water heating programs into their broader residential portfolios. These can also be effective with respect to financing offers.

Financing: Efficiency programs most commonly provide financial incentives in the form of rebates. These can be offered to any stakeholder along the distribution and delivery chain—homeowner, contractor, retailer, or distributor—but the vast majority of today’s programs direct rebates to the homeowner. Other types of financing can also lower the barriers to efficient product uptake. The two forms of non-rebate financing most regularly employed to incentivize efficiency product uptake are efficiency loans (designed to offer terms often better than might be available elsewhere) and on-bill financing (in order to allow homeowners to pay incrementally over a period of time). These financing offerings are sometimes offered only to customers who are participating in a broader whole house program and sometimes as stand-alone options directly through the residential water heating program. They can be run either entirely through the efficiency program or in conjunction with various lending partners. Manufacturers, distributors, and contractors may also offer a wide variety of financing packages that customers can take advantage of.

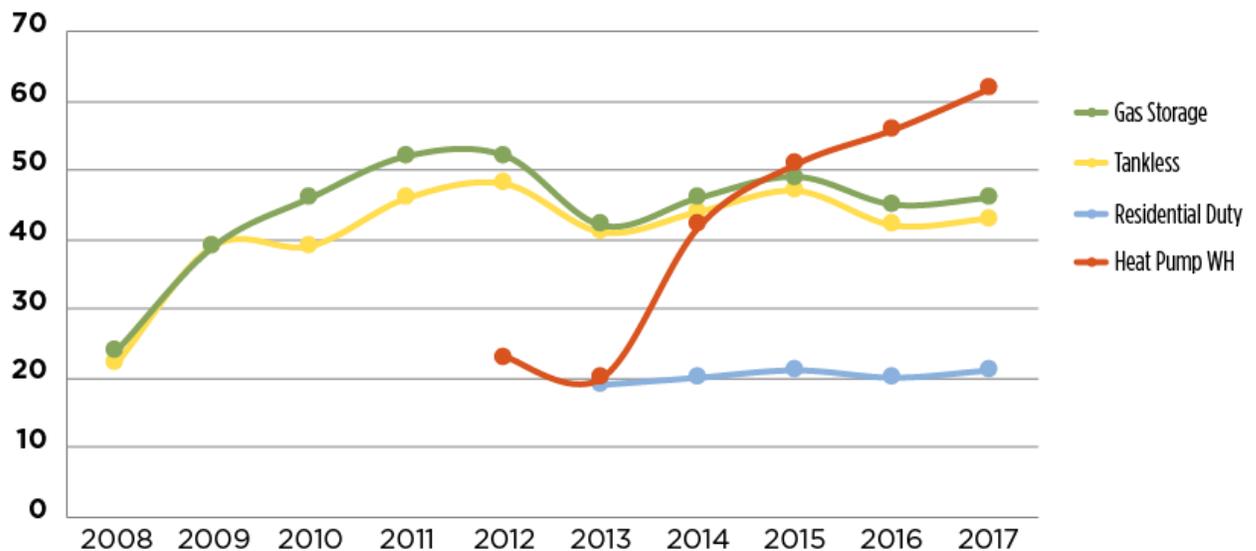
4.7 Energy Efficiency Program Trends

4.7.1 CROSS-CUTTING PROGRAM TRENDS

In 2016, CEE identified 134 member organizations that were actively promoting or designing promotions for the purchase and installation of efficient residential water heating products. These programs spanned 43 US states, the District of Columbia, and four Canadian provinces. The majority of organizations identified (71 percent) were investor-owned utilities, while the others were run by nonprofits, municipalities, provinces, states, or federal entities. Almost all of the programs provided downstream financial incentives directly to consumers, most commonly through mail-in rebates or

online submissions. A few programs offered midstream or upstream promotions, with incentives going to retailers, contractors, or distributors. Many programs were also seeking to address installation considerations, through either formal minimum requirements or reference to installation guidance resources aimed at customers, plumbers, or contractors. A minority of members also provided financing, often through loans or other options affiliated with their broader whole house programs.

Figure 13. Number of CEE Member Residential Water Heater Programs⁷⁶



4.7.2 NATURAL GAS PROGRAM TRENDS

The market penetration of efficient gas water heaters has not increased significantly since ENERGY STAR launched recognition criteria for this product class in 2008. Significant incremental costs and the low cost of natural gas result in challenging payback periods for consumers and make it difficult for programs to achieve cost-effectiveness in their residential water heating measures. By comparison, sale of high efficiency residential furnaces has increased significantly since the launch of ENERGY STAR recognition criteria for this product, rising from 23 percent of all US shipments in 1998 to 61 percent in 2010. CEE identified 41 member organizations running storage water heater programs in 2016, offering incentive amounts between \$40 and \$500. The 38 CEE members running tankless water heater programs offered incentive amounts ranging between \$100 and \$800. For the 20 CEE members running residential-duty commercial product programs, incentive amounts ranged from \$100 to \$1,000.

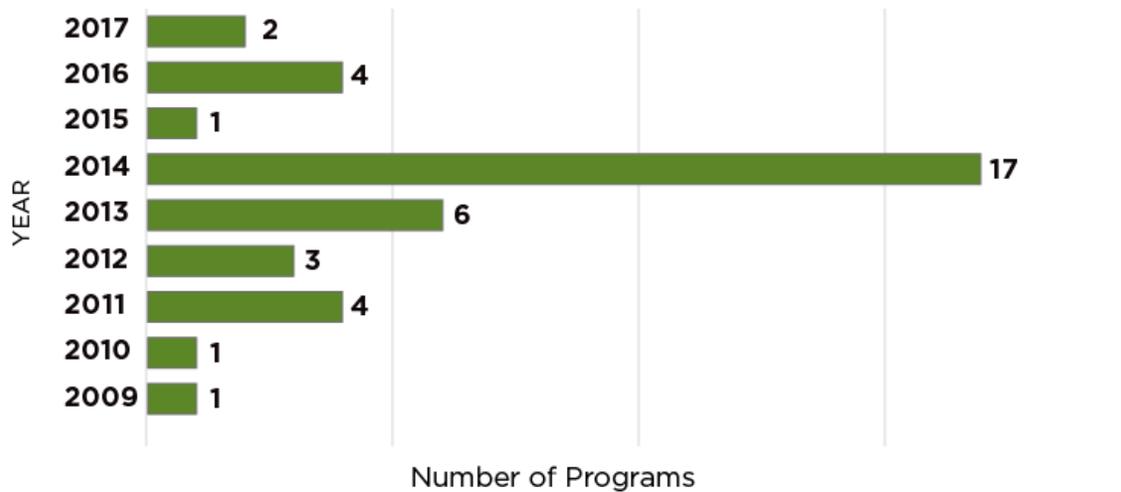
4.7.3 HEAT PUMP WATER HEATER PROGRAM TRENDS

Heat pump water heaters are becoming increasingly common in residential sector program portfolios. Ten CEE members launched HPWH programs in 2014, another two began in 2015, and four more

⁷⁶ CEE Program Summaries 2008–2016, Consortium for Energy Efficiency, <https://library.cee1.org>.

began in 2016. Members with data from 2014 to 2017 show an increase in program participation over time, with an average of 18 percent more units rebated in 2015 than in 2014.

Figure 14. **Year HPWH Programs Were Established (41 Total)**⁷⁷



The number of products incentivized relative to the total number of electric residential customers in a given member's service territory, however, varies greatly across programs and regions. From 2014 to 2017, most administrators saw penetration rates (annual number of units rebated per number of residential electric customers) between 0.0 and 0.15 percent. However, a few programs are outliers, with penetration rates reaching 0.20 percent or even 0.50 percent.

Key barriers to program adoption to date include limited stocking of products among retailers; lack of consumer demand; unavailability of models based on distributor access in given service territories; difficulty addressing the emergency replacement market; and unaware or misinformed contractors, installers, or plumbers.

While most program models remain downstream, several organizations are currently looking into midstream models that reallocate incentives to retailers or distributors. A few members are actively promoting connected heat pump water heaters, with several more researching the potential to use connected HPWH to address load management in the future.

4.8 Trade Ally Training and Outreach

Trade ally education and engagement play a critical role in the market penetration of efficient water heating equipment. This includes multiple players in the supply chain and distribution channel.

⁷⁷ "CEE 2016 Heat Pump Water Heater Program Overview," Consortium for Energy Efficiency, 2016, <https://library.cee1.org/content/cee-2016-heat-pump-water-heater-program-overview>.

4.8.1 INSTALLERS, BUILDERS, PLUMBERS, CONTRACTORS, DEVELOPERS, AND RATERS

The replacement market is the largest market for residential water heating equipment. As these products are often replaced on an emergency basis, contractors represent the primary market channel for their sale, and the plumbing contractor can significantly influence the consumer's decision about which equipment to purchase. While heating and cooling equipment provide opportunities for customers to plan and consider "off-season" purchases, water heaters are used continually throughout the year. Plumbing contractors therefore do not typically engage in the promotion of equipment in off-peak seasons, unlike other HVAC contractors.

Enlisting the support of frontline influencers such as contractors and plumbers in promoting energy efficient water heaters can be a highly effective program component. Training programs on the value of energy efficiency and ways to market it help plumbers and contractors not only assist their customers in making more efficient decisions, but also make a higher-value sale. Similarly, since many factors affect which technologies are most appropriate for each individual home, installers can greatly benefit from trainings focused on how to help guide consumers through the selection of appropriate efficient technologies. Furthermore, installers and plumbers should be properly educated regarding installation considerations that can impact product performance and occupant comfort, including impacts from localized cooling and noise considerations.

4.8.2 DISTRIBUTORS, WHOLESALERS, AND RETAILERS

Even when consumers are already motivated to make more efficient choices, efficient water heaters can be difficult to obtain. Moreover, water heater purchases by consumers are often made on an emergency, unplanned basis. Consequently, the purchase is greatly influenced by what models are available on short notice. In addition to educational efforts targeting plumbers and contractors, influencing distributors, wholesalers, and retailers to stock and support efficient products can help efficient water heaters penetrate the market.

5 Residential Water Heating Specification

Widespread promotion of common performance specifications provides a consistent definition of efficiency to all market actors. This initiative is designed to complement the ENERGY STAR Residential Water Heaters Specification by encouraging the support and adoption of the EPA platform. The CEE tiers seek to identify meaningful levels of additional energy savings.

5.1 Natural Gas Qualification Criteria

5.1.1 GAS-FIRED RESIDENTIAL AND RESIDENTIAL DUTY STORAGE WATER HEATERS

- **ENERGY STAR Version 3.2 Compliance**
 - **First-Hour Rating (FHR) ≥ 67 gallons per hour**
 - **Warranty ≥ 6 years on system (including parts)**
 - **Safety: ANSI Z21.10.1/CSA 4.1 or ANSI Z21.10.3/CSA 4.3. as applicable**
- **Efficiency Tiers**

Level	UEF	
	Medium Draw Pattern	High Draw Pattern
CEE Tier 1	≥ 0.64 UEF	≥ 0.68 UEF
CEE Tier 2	≥ 0.78 UEF	

5.1.2 GAS-FIRED RESIDENTIAL TANKLESS WATER HEATERS

- **ENERGY STAR Version 3.2 Compliance**
 - **Maximum Gallons Per Minute (GPM) ≥ 2.9 over a 67°F rise**
 - **Warranty ≥ 6 years on heat exchanger and ≥ 6 years on parts**
 - **Safety: ANSI Z21.10.3/CSA 4.3**
- **Efficiency Tiers**

Level	UEF
CEE Tier 1	≥ 0.87 UEF
CEE Tier 2	≥ 0.92 UEF

5.2 Electric Qualification Criteria

5.2.1 HEAT PUMP WATER HEATERS—MANDATORY REQUIREMENTS

- **ENERGY STAR Version 3.2 Compliance**
- **Efficiency Tiers**

Level	Tank Volume	UEF
CEE Tier 1*	≤ 55 gallons	≥ 2.00
	> 55 gallons	≥ 2.20
CEE Tier 2	Any	≥ 3.10
Advanced	Any	≥ 3.75

*Aligns with ENERGY STAR Version 3.2 specification

For Tier 2 and the Advanced Tier, the following additional mandatory requirements apply:

- **Compressor Shutdown Notification**

The unit shall provide notification to the consumer that the heat pump operation of the product has been disabled in any of the following situations:

Condition	Description	Notification
Normal, Temporary Event	The compressor is temporarily disabled due to specific operational controls (for example, low intake temperature or defrosting).	The unit shall display that the heat pump is not currently operating. The controls shall automatically restore compressor operation as soon as conditions return to allowable control parameters (for example, return to minimum intake temperature or completion of the defrost cycle).
User-Selected Override or Power Failure	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 100% electric resistance.
Product Failure Alarm	The unit's heat pump has a failure and requires service.	The unit shall provide to the consumer an audible and visible alarm on the interior unit. The unit shall provide a consumer acknowledgement feature which turns off the audible alarm. The visual alarm shall be visible without removal of panels or covers with clear nomenclature and enunciation to notify the homeowner to take the needed action to solve the problem.

- **Default Settings**

- **Minimal Use of Electric Resistance 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 standard DOE First Hour Rating Test, the electric resistance heating element shall not be turned on until at least 66 percent of the tank's measured water volume has been withdrawn. Measured water volume is defined as the amount of water the unit actually stores under test, and not the nominal rated tank volume.

- **Shipment Mode**

The unit shall be shipped in the default operational mode and settings 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 period of no more than 72 hours. 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, or installer shall have the ability to override the default setting. In the event of total power loss to the unit, it shall revert to the last setting selected, as long as this setting is not electric only.

5.2.2 HEAT PUMP WATER HEATERS—OPTIONAL CONNECTED CRITERIA

Units shall meet the following requirements and parameters in order to fulfill the optional CEE connected criteria.

A. Criteria Scope Products must meet the scope and efficiency requirements set forth under Heat Pump Water Heaters in the Initiative’s Electric Qualification Criteria (Section 5.2.1).

B. Connected Electric HPWH Definition and Key Aspects To claim compliance with the CEE Connected Criteria, a connected heat pump water heater must include the device plus at least one communication interface at the device level that conforms with an open communication standard, to enable the product owner or an authorized third party to monitor and predictably execute load management functions as defined in Section D. Manufacturers may also choose to include an additional interface that may or may not use open communication standards to provide load management and other services. The product must continue to comply with the applicable product safety standards; the inclusion of the functionality described below shall not supersede existing safety protections and functions.

C. Connectivity

- **On-Premise, Open Standards Connectivity**

CEE requires that a product must enable economical and direct, on-premise, open standards-based⁷⁸ translation using the physical and data-link layers of an industry-accepted, modular communication interface such as [ANSI/CTA-2045-A](#). The open standards interface must be combined with an open standards communication module. Manufacturers may also choose to include a secondary communication interface to facilitate load management or other services that may be proprietary to the manufacturer or a designated third party.

- **Open Access**

Manufacturers must provide any documentation that is required for the product owner or any third party to develop technologies to connect to the device’s communication interface.

D. Load Management Capabilities

⁷⁸ Open Standards: communication with entities outside the Connected Heat Pump Water Heater that enables connected functionality must use, for all communication layers, standards that meet the "open standards definition" outlined in Appendix B of the CEE Residential Water Heating Initiative.

Load Management Messages	General Description and Use Cases
Application ACK (acknowledgement)	Confirmation of signal receipt.
Application NAK (negative acknowledgement)	An indication that a signal was not received or was corrupted during transmission.
Outside communication connection status	The water heater must monitor for this “heartbeat” signal. If the water heater is processing a curtailment request and the heartbeat is not received within 15 minutes, the water heater will return to normal operation.
End shed/run normal	Used to inform the water heater that no events are in effect and to run normally. If received during a curtailment event, the water heater shall immediately return to normal operation.
Shed	The water heater shall avoid operation. If the stored energy drops below the minimum consumer comfort level, only the heat pump unit should engage to heat water if the shed event is in effect. Heat pump should attempt to avoid using resistive elements while this command is in effect.
Critical peak event	The water heater shall avoid operation, allowing the stored thermal energy in the tank to drop. Since these events are typically infrequent, the water heater should more aggressively curtail demand. Heat pump should attempt to avoid using resistive elements while this command is in effect.
Grid emergency	During an emergency event, the water heater shall immediately shut down, not heating water until the event has ended. Note: Customer overrides shall be allowed, even for grid emergencies.
Present relative price	The Relative Price command is used in association with a range of price-based programs and lends itself strongly to consumer configurability of response (that is, no particular response is mandatory from a utility perspective). Manufacturers are encouraged to design a response method that considers the customer’s price thresholds.
Autonomous cycling and terminate cycling	This message passes the water heater a request for operation at a particular duty cycle. The water heater acts to carry out this duty cycle of operation to the extent possible, given total cycle-count limits and the need to remain within the bounds of upper and lower temperature limits and maximum and minimum stored energy. For the heat pump water heater, it is acceptable for the unit to self-impose a minimum delay between cycled starts to protect itself. Heat pump should attempt to avoid using resistive elements while this command is in effect.
Load up	Sent from the communication module to the water heater to request that the unit increase the stored energy to the maximum allowable level, as determined by manufacturer. Heat pump should attempt to avoid using resistive elements while this command is in effect.
Get/set user preference level	The User Preference Level message provides values from low to high (0-10) that the manufacturer shall use to manage the level of customer comfort and grid services. The water heater can obtain the user preference level through the Get User Preference Level command.
Customer override	If an override occurs, the water heater must return to normal operation and ignore any new curtailment messages for the next 12 hours. The water heater must also provide a simple mechanism to proactively override any curtailment event requests for a duration of up to 24 hours.
Query and response: operational state	The communication module, at any time, can query the water heater for its operational state.
Query and response: device information request	At a minimum, water heater shall support all mandatory device information plus the model number and serial number optional fields associated with the information request.
Get/set commodity read request and get/set commodity read reply	Water heater shall support the following requests from a communication interface: electric power and cumulative lifetime energy consumed, total energy storage capacity, and present energy storage capacity. For HPWH, the capacity must be based on the use of the heat pump and not the electric resistance heating elements or a combination thereof. The accuracy of this estimation must be at most 25% of the full capacity.
Get present water temperature	The preferred value to report is the best estimate of the average temperature of the water in the tank.

E. Consumer Override Consumers shall be able to temporarily override their product's response to any current and future load management signals. The override status must be made available through the open communication interface. Upon expiration of the override, the product shall automatically return to the user-selected operational mode.

5.2.3 OPTIONAL HPWH ELEMENTS AND CONSIDERATIONS

CEE notes that there are several potential homeowner benefits and energy savings opportunities from models that possess additional characteristics beyond those outlined in the specification requirements. These include features such as sensing or notification mechanisms, water shutoff values, air ducting design aspects, condensate management, and connected capabilities. While the mandatory qualification criteria are limited to those listed in the above specification, CEE provides a list of optional criteria, which members can consider incorporating into their program offerings as appropriate, in Appendix C.

5.3 Engagement and Outreach Strategies

Given persistent market barriers to adoption of efficient water heaters, the CEE Initiative includes a variety of strategies that engage purchase decision influencers. Below are high-level approaches for leveraging partnerships with key stakeholders along the supply and distribution chain.

5.3.1 EDUCATION AND GUIDANCE

Programs must include each of the following three mechanisms, which are designed to address knowledge barriers associated with residential water heating. It is up to the program to determine the specific strategies and applications for each.

Consumer Awareness and Education

Provide consumers with information on the benefits of choosing efficient residential water heating equipment. An effective campaign targets both the emergency and planned replacement markets, and may include the use of brochures, fact sheets, advertisements, or online messaging. Materials can be supplied to consumers through direct contact from the program or through the equipment distribution channel, including both direct retail and contractors and installers.

Contractor Awareness and Education

Supply plumbers with information on the consumer benefits of choosing efficient residential water heating equipment. An effective campaign targets both the replacement and new construction markets and may include the use of brochures, in-person education and training sessions, fact sheets, advertisements, or online messaging. Materials can be supplied to contractors and installers through the equipment distribution channel, including through manufacturers, market representatives, wholesalers, and retailers.

Contractor Training, Support, and Installation Guidance

Provide plumbers with opportunities that focus on promoting efficient equipment and the

principles of installing and selling these systems. Education offerings should refer plumbing contractors to manufacturers for additional guidance on advanced venting and condensate drains required for condensing and heat pump equipment. Programs may either develop their own materials or use resources that already exist, such as training programs provided by manufacturers, distributors, or plumbing organizations. Various stakeholders throughout the supply chain may be available to offer additional support for these efforts.

5.3.2 PROGRAM STRATEGIES AIMED AT MIDSTREAM OPPORTUNITIES

Programs must include at least one of the following midstream strategies.

Efforts to Drive Local Stocking and Promotion of Efficient Equipment

Create mechanisms to help encourage retailers, distributors, or wholesalers to promote, stock and sell efficient equipment. By designing programs that directly address stocking and promotion practices, members will help ensure that efficient models are readily available in the market and accessible for both planned and emergency replacement purchases.

Midstream Program Design Models

Provide program offerings or incentives directly to parties in the distribution chain, where many purchasing decisions are influenced. This could include any variety of strategies that encourage trade allies to buy and sell efficient rather than inefficient models. CEE has not engaged in or reviewed any particular implementation or fulfillment strategy, and thus takes no position regarding any specific midstream platform or approach.

6 Initiative Participation

Initiative participation is an opportunity for individual efficiency organizations to amplify the impact of their local efficiency program. By participating in this Initiative, individual organizations are counted as part of a collective, harmonized effort to advance efficiency. As with all CEE initiatives, participation in the CEE Residential Water Heating Initiative is voluntary. The following are the minimum requirements to be considered an Initiative participant.

1. Promote at least one of the water heater tiers outlined in Sections 5.1 and 5.2 through an incentive or education program
2. Participate in the Engagement and Outreach Strategies outlined in Section 5.3 by
 - a. Promoting all three Education and Guidance mechanisms described in Section 5.3.1
 - b. Promoting at least one of the Program Approaches Aimed at Midstream Opportunities described in Section 5.3.2
3. Communicate to CEE that you elect to participate in the Initiative. CEE typically publishes publicly available program information furnished by Initiative participants in an annual program summary and in other communications that serve to advance the goals of the Initiative by informing key market players of Initiative impacts.

This Initiative is offered for use to any CEE member who agrees to the terms of use.

Appendix A Organizations and Abbreviations

ACEEE [American Council for an Energy-Efficient Economy](#)

AHRI [Air Conditioning, Heating, & Refrigeration Institute](#)

ANSI [American National Standards Institute](#)

AWHS [Advanced Water Heater Specification](#)

Btu British Thermal Unit

dBA A-Weighted Decibels, also abbreviated dBa or dB(a)

CEE [Consortium for Energy Efficiency](#)

CTA [Consumer Technology Association](#)

DOE [US Department of Energy](#)

DSM Demand Side Management

DR Demand Response

EF **Energy Factor**

EIA [US Energy Information Administration](#)

EPA [US Environmental Protection Agency](#)

EPACT Energy Policy Act (1992)

EPCA Energy Policy and Conservation Act (1975)

FHR First Hour Rating

NAECA National Appliance Energy Conservation Act (1987)

NEEA [Northwest Energy Efficiency Alliance](#)

NRCan [Natural Resources Canada](#)

NRDC [Natural Resources Defense Council](#)

NO_x Nitrogen Oxide

PHCC [Plumbing-Heating-Cooling Contractor Association](#)

PNNL [Pacific Northwest National Laboratory](#)

PPM **Parts per Million**

UEF **Uniform Energy Factor**

UL [formerly Underwriters Laboratories](#)

Appendix B Definitions⁷⁹

CEE adheres to the definitions provided by EPA as outlined in the ENERGY STAR Specification for Residential Water Heaters; for additional information about these requirements and terminology, visit the [ENERGY STAR site](#).

Basic Model: All units of a given type of covered product (or class thereof) manufactured by one manufacturer and which have the same primary energy source and essentially identical electrical, physical, or functional (or hydraulic) characteristics that affect energy consumption, energy efficiency, water consumption, or water efficiency.⁸⁰ Further, all individual models within a basic model have the same certified rating based on the applicable sampling criteria per US Department of Energy (DOE) regulations in Part 429,⁸¹ and this rating must be used for all manufacturer literature, the qualified product list, and certification of compliance to DOE standards.

Energy Factor:⁸² Energy factor (EF), a measure of water heater overall efficiency, is the ratio of useful energy output from the water heater to the total amount of energy delivered to the water heater.

First-Hour Rating:⁸³ The First-Hour Rating (FHR) is an estimate of the maximum volume of “hot” water that a storage-type water heater can supply within an hour that begins with the water heater fully heated (i.e., with all thermostats satisfied). It is a function of both the storage volume and the recovery rate.

Gallons per Minute:⁸⁴ Gallons per Minute (“GPM”) is the amount of gallons per minute of hot water that can be supplied by an instantaneous water heater while maintaining a nominal temperature rise of 77°F during steady state operation.

Lower Compressor Cut-Off Temperature: The temperature below which a heat pump water heater’s compressor will no longer operate, such that the unit will only work as a conventional electric resistance water heater.

Manufacturer Limited Warranty: Manufacturer limited warranty is an assurance by the manufacturer to the consumer that the water heater, including purchased system equipment and components, is guaranteed to work for a defined period of time.

⁷⁹ “ENERGY STAR® Product Specification for Residential Water Heaters.” 4-5, “Eligibility Criteria Version 3.2.” https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements_0.pdf

⁸⁰ 10 CFR 430, Subpart B, Appendix E, https://www.energy.gov/sites/prod/files/2014/06/f17/rwh_tp_final_rule.pdf

⁸¹ 10 CFR 431, Subpart B

⁸² Based on definition in 10 CFR 430, Subpart B, Appendix E

⁸³ 10 CFR 430, Subpart B, Appendix E

⁸⁴ Ibid.

Maximum GPM Rating:⁸⁵ Maximum GPM is the maximum gallons per minute of hot water that can be supplied by an instantaneous water heater while maintaining a nominal temperature rise of 67°F (37.3°C) during steady state operation.

Open Standards:⁸⁶ Must use, for all communication layers, standards that are:

- Included in the Smart Grid Interoperability Panel (SGIP) Catalog of Standards, and/or
- Included in the NIST Smart Grid framework Tables 4.1 and 4.2, and/or
- Adopted by the American National Standards Institute (ANSI) or another well-established international standards organization such as the International Organization for Standardization (ISO), International Electrotechnical Commission (IEC), International Telecommunication Union (ITU), Institute of Electrical and Electronics Engineers (IEEE), or Internet Engineering Task Force (IETF).

Rated Storage Volume:⁸⁷ Rated Storage Volume means the water storage capacity of a water heater, in gallons or liters, as certified by the manufacturer.

Solar Energy Factor: Solar Energy Factor (SEF) refers to the energy delivered by the total system divided by the electrical or gas energy put into the system.

Standby Loss:⁸⁸ Standby Loss (SL) means the average hourly energy required to maintain the stored water temperature.

Thermal Efficiency:⁸⁹ Thermal efficiency (TE) is the ratio of the heat transferred to the water flowing through the water heater to the amount of energy consumed by the water heater.

Uniform Energy Factor:⁹⁰ Uniform Energy Factor (UEF) is the measure of water heater overall efficiency. The method for computing UEF is outlined in Section 6.3.6.

⁸⁵ 10 CFR 430, Subpart B, Appendix E

⁸⁶ ENERGY STAR, as defined in other product specifications: [Residential Dishwashers Version 6.0](#), Pg. 5; [Clothes Washers Version 7.0](#), Pg. 7; [Room Air Conditioners Version 4.0](#), Pg. 5; [Connected Thermostats Version 1.0](#), Pg. 7.

⁸⁷ 10 CFR, Part 429, US Department of Energy, 2015, Pg. 107,
https://www.energy.gov/sites/prod/files/2014/06/f17/rwh_tp_final_rule.pdf.

⁸⁸ 10 CFR 431, Subpart G

⁸⁹ Ibid.

⁹⁰ 10 CFR 430, Subpart B, Appendix E, Pg. 146,
https://www.energy.gov/sites/prod/files/2014/06/f17/rwh_tp_final_rule.pdf

Appendix C Optional HPWH Elements and Considerations

The following list includes features of HPWH products, as well as aspects of their installation, that may impact overall energy performance and customer satisfaction. Members may consider incorporating any of these considerations as program offerings where appropriate or relevant.

- **Air Filter Maintenance and Notification**

Any air filters must be either 1) permanent, washable media or 2) replaceable, standard filters in shape and form that are obtainable at a typical hardware store. The unit shall provide visible notification (defined by the manufacturer) to the homeowner of a need to change or service the filter in order to prevent compromise of performance of the heat pump from reduced air flow.
- **Installation Guidance**

Installation guidance should be provided so that a unit is installed with adequate clearance for all airflow to and from the evaporator. Installation manuals should provide several possible configuration and/or installation scenarios to assist the installer.

 - **Condensate Management**

Condensate shall be drained away according to local plumbing codes and industry best practices. This includes the following subcomponents:

 - **Acceptable Condensate Piping**

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 importance of correct condensate line installation practices and adherence to local plumbing code.
 - **Condensate Overflow Shutoff and Alarm**

Unit 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 audible and visible alarm shall be activated to signal the need for service in the event of a compressor shutoff due to condensate drain failure.
 - **Condensate Collection Pan and Drain Service**

Unit 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.

- **Intake and Exhaust Ducting**

The unit may have a manufacturer-supplied optional ducting kit, available either from the same distribution or retail channels as the unit, to provide for simultaneous intake and exhaust air ducting. This ducting option should address the following considerations:

- **Ducting Hardware**

Unit shall include all necessary flanges, collars, or other connections that are capable of directly connecting to common ducting products, or, alternatively, manufacturer-supplied add-on ducting modifications that provide the same capabilities.

- **Minimum Flow Rate or Pressure Drop**

Unit shall maintain 80 percent of the necessary airflow to achieve the rated efficiency performance (UEF) when the fan is subject to an external static pressure of up to 0.2 inches water column.

- **Application Options**

Unit must be capable of operating with or without ducting installed. Manufacturers shall clearly identify which models are configured for which ducting option along with a clear description (for example, a parts list and drawing) of the appropriate layout or configuration and accessory parts necessary to meet the requirements for specific applications.