US HPWH Market Transformation: Where We've Been and Where to Go Next

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Abstract

Water heating is the second largest energy end use in the US residential sector, accounting for approximately 17% of US residential energy consumption. Heat pump water heaters (HPWH) consume 60% less energy than conventional electric-resistance water heaters. However, HPWHs presently make up just 1% of all electric water heaters sold in the residential sector. If market penetration doesn't increase, there is a possibility that major water heater manufacturers will decrease investment in their HPWH product lines and eventually discontinue their HPWH models. Both market barriers and technology limitations have prevented market adoption in the past. However, technological barriers have been diminished through cooperation between manufacturers and the energy efficiency community. This paper will serve as an important historical reference on HPWH commercialization and market transformation efforts in the US, as well as provide a detailed analysis of market opportunities and offer next steps to increase market adoption.

Introduction

Water heating is the second largest energy end use in the US residential sector, behind only space heating. It accounts for approximately 17 percent, or 1.87 exajoules (1.77 quadrillion BTUs), of national residential energy consumption.[1] The EIA currently projects US household energy use to increase from 11.2 exajoules (10.62 quadrillion BTUs) in 2016 to 11.39 exajoules (10.8 quadrillion BTUs) in 2050, including an increase in water heating energy use from 1.87 exajoules (1.77 quadrillion BTUs) to 1.95 exajoules (1.85 quadrillion BTUs). [1]

Approximately 47 million US households have electric water heaters, and an average of 4.2 million electric water heaters are sold annually into the residential sector. [2] Nearly all electric water heaters in the US installed base and sold in the market use electric-resistance technology, which converts electrical energy into heat by running electrical current through resistors (i.e., electric water heater elements). This technology has nearly maximized its efficiency potential in electric water heaters.

HPWHs are an energy-efficient alternative to electric resistance water heaters. HPWHs use a vapor-compression refrigerant cycle (similar to air conditioners and refrigerators) to transfer heat from the surrounding air to the water in the tank. HPWHs use up to 60-70% less energy than electric-resistance water heaters. The typical 189-liter (50-gallon) electric-resistance residential water heater in the US consumes 4,650 kilowatt-hours (kWh) per year, costing more than US$580 annually to operate. In comparison, the typical 189-liter (50-gallon) HPWH consumes 1,910 kWh per year, costing US$240 to operate. On average, a US household will save more than US$340 and 1,740 kWh annually if using a HPWH instead of an electric-resistance water heater.[2]

Currently, major water heater manufacturers[3] offer more than 180 HPWH models in the US market, but HPWHs only make up about 1% of the annual US electric water heater sales, and considerably less than 1% of the installed base. [3] A moderate displacement of electric-resistance water heater

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[1] For 2016, water heating is 16.7% of delivered energy consumption by end use. Energy Information Administration, 2017 Annual Energy Outlook.

[2] Average US electric rate of ($0.1255 per kWh) from November 2015 through October 2016. Average kWh savings of 2,740 annually based on a 2.3 Energy Factor HPWH, 0.945 Energy Factor electric resistance water heater, 242 liters (64 gallons) per day of hot water use, inlet water temperature of 14.5 °C (58 °F), set point temperature of 57 °C (135 °F) and ambient air temperature of 19.5 °C (67.5 °F).

[3] Manufacturers include A.O. Smith, Bradford White, GE Appliances, Rheem, Stiebel Eltron, and Vaughn, among others.

installations with HPWHs would lead to significant national energy savings. There are 37 million households with electric water heaters having a tank size of 117 liters (31 gallons) or greater. [4] If just 15% of these households replaced their electric-resistance water heaters with HPWHs, it would amount to more than 15.7 terawatt-hours saved annually. The greenhouse gas emissions avoided would be the equivalent of removing 2.3 million cars from the road each year.

Technological Considerations

HPWHs can achieve efficiencies greater than 100% because more than one unit of heat energy can be extracted from the surrounding air and transferred to the water for each unit of electrical energy used by the HPWH. However, since HPWHs must extract heat from the surrounding air, the temperature of the ambient air impacts the ability of the HPWH to heat water, and thus its efficiency. This is an important consideration when installing HPWHs in cold, unconditioned spaces (e.g., a garage in a northern climate). Identifying the HPWH's compressor cut off temperature is an important consideration in these circumstances. In addition to ambient air temperature, air volume is an important consideration for HPWHs. There must be 21 to 28 cubic meters (750 to 1,000 cubic feet) of air available to the unit so it has a sufficient supply of warm air for the evaporator. For this reason, a small closet, particularly one with a solid door, is an unsuitable location for a HPWH. [5] As the surrounding air is drawn across the HPWH's evaporator and cooled, moisture in the air will condense on the coil. This condensed water must be drained appropriately to protect the HPWH from damage.

In some circumstances HPWHs may not have adequate capacity to meet household hot water demand using only the heat pump. When the ambient air temperature is low, inlet water temperature is low, and/or hot water draw is high, HPWHs may automatically switch to electric-resistance mode to maintain the set point temperature of the stored water. Most HPWHs include resistance electric heating elements and are often referred to as hybrid water heaters in the water heating industry.

HPWHs typically have three to four manual settings to ensure operation meets user expectations:

- Heat Pump Only Mode, which maximizes energy efficiency during active use
- Default/Hybrid Mode, which automatically switches between heat pump and electric-resistance heating, as needed, to manage the tank's set point temperature.
- Electric-resistance Mode, which uses the electric elements to heat water and is least efficient
- Vacation Mode, which adjusts operational settings for extended periods of inactivity. [6]

When electricity generation and demand are in a period of imbalance on the distribution grid, the hybrid control of HPWHs offers flexibility for demand response. Electric water heaters are good candidates to balance the grid during these periods of imbalance since they can store electricity in the form of hot water, and can curtail electricity consumption to decrease demand on the grid with little or no impact on the user. While the HPWH is switched off, households need enough hot water in the tank to satisfy their hot water demand.

When using a HPWH for curtailing peak electricity load, a high set-point temperature (e.g., 65.5 °C or greater, or 150 °F or greater) combined with a thermostatic mixing valve can potentially ensure a larger supply of hot water during peak curtailment periods as well as provide a safe hot water delivery temperature (e.g., 49 °C, or 120 °F) for users. In addition, large tank HPWHs (e.g., 303-liter, or 80-gallon capacity) can ensure adequate hot water supply during peak curtailment periods for households with high hot water demand. [7] [8]

HPWHs installed within a home's thermal envelope can impact the home's space conditioning loads. The HPWH will provide a minor reduction in the home's cooling load during the summer, whereas it will cause a minor increase in the heating load in the winter. For a given home, the specific impact on space conditioning energy use depends on the climate, home's size/configuration, location of the HPWH in relation to the HVAC system's thermostat, and space conditioning systems used. One way to minimize the impact on heating and cooling loads is to install intake and exhaust ducting that allow the HPWH to draw exterior air from the outside, and expel cold exhaust air outdoors. Many HPWH models available in the market have connections available for aftermarket duct kits. Ducting can also ensure there's an adequate supply of air for HPWHs installed in confined spaces. [5]

The HPWH's fan and compressor emit between 45 and 65 decibels of sound while operating (depending on the model). This is roughly the amount of noise from a room air conditioner, dishwasher

or refrigerator. For this reason HPWHs should not be located near bed rooms. Areas of the home that are not frequently occupied, such as garages or basements, are good locations for HPWHs to limit the potential for noise disruption.

Technology Timeline

The HPWH has gone through a number of technological phases since it was first introduced to the US market. Much of the development resulted from collaboration among the US Department of Energy (DOE), state agencies, efficiency programs, non-profit associations and manufacturers.

First Generation

The Hotpoint Company, which later became the Hotpoint Division of General Electric Company, designed and developed the first HPWH model for mass production in the 1950s. While this HPWH worked well, low electric rates limited its appeal and development was halted. [9]

In the mid-1970s, a spike in energy prices renewed interest in HPWHs. The National Rural Electric Cooperative Association (NRECA) and DOE funded the development of a HPWH prototype, selecting Energy Utilization Systems as the manufacturer. This led to the development of both integrated and add-on models. The integrated design combines the heat pump and tank into one unit whereas the add-on design is a split system, separating the hot water tank from the heat pump, for the purpose of retrofitting existing electric-resistance water heaters. In an expanded study in which 85 integrated and 15 add-on units were tested by 20 utilities, the integrated model performed well, revealing annual HPWH energy and operating cost savings of about 50% and useful life of 10 years. [9]

During the early 1980s, at least sixteen HPWH models were available in the US market, resulting in 10,000 shipments per year. In addition, a number of electric utilities were offering incentives and zero-interest loans to stimulate the purchase of HPWHs. However, the US HPWH market soon collapsed. While HPWHs were twice as energy efficient as electric-resistance water heaters, they were three to five times more expensive. Electricity prices declined, impacting cost effectiveness. In addition, reliability and quality control were below consumer expectations. For regions with moderately hard water, scale build-up on the heat exchanger combined with poor componentry led to early equipment failure. This issue was exacerbated by the lack of HPWH repair expertise among mechanical contractors and plumbers. As a result, a number of manufacturers (an estimated ten of twelve) removed their HPWH models from the market by 1995, and market penetration remained low at approximately 2,000 shipments of add-on HPWHs per year. [10] [11]

Market-Optimized Integrated HPWH

In the late 1990s, DOE, California Energy Commission (CEC), and the New York State Energy Research & Development Authority (NYSERDA) sponsored an R&D project to develop a “market optimized” HPWH. The primary objective of this project was to develop a “drop-in” or integrated HPWH that could serve as an immediate replacement for an electric-resistance water heater that had reached the end of its life, thereby facilitating quick and easy installation.[4] The “market-optimized”, integrated HPWH model was intended to relieve certain installation challenges (e.g. circulation pump, additional piping and wiring) and engineering weaknesses that caused reliability issues for the add-on HPWH. The consulting company Arthur D. Little Co. patented the concept with technical assistance from the Oak Ridge National Laboratory. The EnviroMaster International (EMI) Division of ECR International was selected as the manufacturing partner. In 2002, ECR International (via EMI) released the Watter$aver drop-in HPWH model. This model achieved an Energy Factor of 2.47 in accordance with the DOE test procedure, indicating energy savings of more than 60% compared to the typical electric-resistance water heater. [12]

While ECR International’s (ECR) drop-in HPWH model was a significant improvement over previous integrated and add-on models, it still experienced reliability and quality control issues stemming from control board and temperature sensor failure. To compound these reliability issues, ECR didn’t have the marketing budget or supply chain relationships to overcome market barriers. In particular, ECR

[4] The majority of water heater installations are in response to failure of the existing water heater, calling for an emergency replacement to maintain hot water service.

lacked a network of technicians to install, service and repair units in the field. As a result, ECR discontinued the Watter$aver within five years of product launch and HPWH market penetration continued to be dormant.

Current Generation

In late 2005, ENERGY STAR, a voluntary labeling program for energy efficient products, focused its water heater strategy on working with major manufacturers to introduce integrated HPWH models to the US market, similar to the successful strategy used to introduce the front-load clothes washer in 1998. In 2009, after collaborating with manufacturers, trade associations, efficiency programs, utilities and retailers for four years, ENERGY STAR launched the residential water heater program, which featured the integrated HPWH. In six months, three manufacturers (GE Appliances, A.O. Smith and Rheem) released eight drop-in HPWH models (189- and 303-liter models, or 50- and 80-gallon models), all of which qualified for the label.

Concurrently with the launch of the ENERGY STAR water heater program, DOE initiated a rulemaking to update to US national, mandatory minimum energy efficiency standards for residential water heaters. In April 2010, less than a year from the introduction of HPWHs to the market, DOE ruled that all 208-liter (55-gallon) or greater electric water heaters would have to meet an efficiency level that only HPWHs could attain.[5] This rule went into effect in April 2015. [13]

After the launch of the ENERGY STAR water heater program and while DOE was finalizing its rule for water heater standards, the Northwest Energy Efficiency Alliance (NEEA) released its Northern Climate Specification for HPWHs in October of 2009. This voluntary specification calls for manufacturers to meet certain performance requirements (e.g., freeze protection, compressor cut-off temperature, condensate management, sound levels) that enable better HPWH performance, especially in colder climates. Many electric utilities and energy efficiency programs located in colder climates have adopted the NEEA specification as a requirement for their HPWH incentive programs. In response, manufacturers introduced new, improved HPWHs to the market.

The latest HPWH models can achieve an Energy Factor of 3.5 while operating in heat pump only mode with ambient air as cold as 1.5 °C (35 °F) or as hot as 63 °C (145 °F). They are duct ready with eight-inch diameter connections at the HPWH, capable of adapting down to five-inch diameter intake and exhaust ducting that can extend as far as 38 meters (125 feet). An important consideration for consumers is they operate at noise levels of 45 decibels. NEEA updated the title of this initiative to the Advanced Water Heater Specification in May 2016, introducing two new tiers of specifications, including demand response, intended to guide manufacturer HPWH development further. [14]

Emerging Technology

An emerging technology in the US market is the carbon dioxide (CO_2) HPWH, which uses CO_2 as the refrigerant. This technology has been in the Japanese market since 2001, when more than five manufacturers started selling the EcoCute design, initially developed through a partnership between Tokyo Electric Power Company, Denso Corporation and the Central Research Institute of Electric Power Industry (CRIEPI). The CO_2 HPWH has the unique ability to achieve a Coefficient of Performance (COP) greater than 3.0, while also maintaining 90 °C (194 °F) set point temperature at an ambient air temperature of -15 °C (5 °F). [15]

The Japanese manufacturer Sanden has introduced both integrated and split-system CO_2 HPWH models to the US market. The integrated model has a 163-liter (43-gallon) tank, achieves an Energy Factor (EF) of 2.65, First-hour Rating (FHR) of 261 liters (69 gallons), and can be fully ducted. The split system model has its compressor and evaporator located in an outdoor unit whereas the 314-liter (83-gallon) tank is located indoors. It achieves an EF of 3.35, FHR of 97 and operating noise level of 38 decibels for the outdoor unit. Both Sanden HPWH models are validated as capable of implementing

[5] The minimum mandatory Energy Factor as of April 15, 2015 for residential electric water heaters with a rated volume of 208 liters (55 gallons) or greater was determined by the volume of the water heater using the formula: minimum Energy Factor = 2.057 – (0.00113 x Rated Storage Volume in gallons).

demand response if equipped with the necessary software and hardware to initiate utility-generated DR signals. [16]

Market Dynamics

Understanding the state of the HPWH market involves understanding current HPWH market share, market actors, consumer decision-making factors and market barriers.

Market Share

Currently in the US, both the installed base of HPWHs and the number of HPWHs sold annually are small in comparison to the overall residential water heater market. The majority of residential water heaters sold annually in the US, as well as the majority of the installed base, are natural gas-fired units.[6] ENERGY STAR started tracking the number of qualified HPWH shipments in the US in 2010. Since then, approximately 260,000 HPWHs have been shipped domestically out of a total of 23.5 million domestic electric storage water heater shipments. In addition, there are approximately 46.8 million electric water heaters in the US installed base. This means that the estimated HPWH average annual share of the US electric water heater market is only 1.1%, and the HPWH share of the installed base of electric water heaters is 0.5%. [3] [2]

Table: Shipment Data for Electric Water Heaters and ENERGY STAR qualified HPWHs

Year	ENERGY STAR HPWH Shipments	Electric Water Heater Shipments	HPWH Market Share
2010[7]	59,000	3,736,597	1.6%
2011	23,000	3,738,882	0.6%
2012	34,000	3,733,988	0.9%
2013	43,000	4,008,478	1.1%
2014	46,000	4,277,329	1.1%
2015	55,000	4,027,067	1.4%
Total	260,000	23,522,341	1.1%

The updated US mandatory minimum energy efficiency standards for residential water heaters took effect in April 2015. These standards require all 208-liter (55-gallon) or greater electric water heaters meet an efficiency level that only HPWHs can attain.[8] It is now clear that these standards have not had the expected effect of significantly increasing the market adoption of HPWHs. There is evidence that installers have found multiple ways to work around the standards, such as installing two smaller electric-resistance water heaters or installing an electric-resistance water heater in combination with an electric tankless “booster” water heater. [17]

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[6] According to the 2009 Residential Energy Consumption Survey (RECS), 58.3 million US homes have natural gas-fired water heaters compared to 46.8 million homes with electric water heaters. According to the Air-Conditioning, Heating and Refrigeration Institute (AHRI), there were 4.4 million natural gas-fired water heaters shipped in the US in 2015 compared to 4 million electric water heaters.

[7] 2010 ENERGY STAR HPWH shipment data include shipment data from 2009 since qualified HPWHs entered the market part way into the year. 2009 ENERGY STAR HPWH shipments were not reported, but added to 2010 shipments.

[8] The minimum mandatory Energy Factor as of April 15, 2015 for residential electric water heaters with a rated volume of 208 liters (55 gallons) or greater was determined by the volume of the water heater using the formula: minimum Energy Factor = 2.057 – (0.00113 x Rated Storage Volume in gallons).

Market Actors

Water heaters move through a few different market channels from manufacturers to consumers. Three manufacturers, A.O. Smith, Rheem and Bradford White, produce an estimated 95% of residential water heaters sold on the US market. The remaining 5% are manufactured by dozens of smaller companies. Manufacturers distribute water heaters to wholesalers (also referred to as distributors) and retailers (e.g., Lowe's, The Home Depot, etc.). Wholesalers and retailers each account for approximately half of domestic water heater shipments. Retailers tend to sell more electric water heaters whereas wholesalers tend to sell more gas water heaters, both at approximately a 60/40 split. Plumbers and mechanical contractors sell and install 60% of all water heaters whereas consumers install 26% as Do-It-Yourself projects. Remodelers, builders and property owners account for the remaining 14% of shipments. [18] [19]

Electric water heaters are more likely to move through the retailer market channel and undergo a consumer DIY installation. HPWHs reflect this trend with 50% of HPWHs purchased at a retailer and installed by the consumer as a DIY installation. [17]

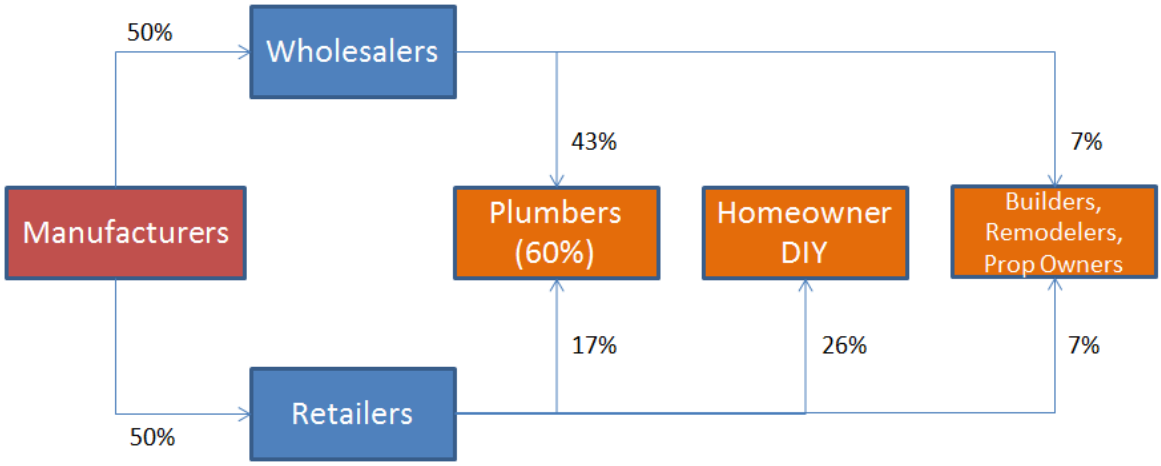

Figure: Water Heater Distribution Channels and Shares

Organizations that promote energy efficiency, such as for-profit electric utilities, municipalities, electric cooperatives, state energy offices and regional energy efficiency alliances, are not typically a part of the residential water heater distribution chain. Energy efficiency programs run by these entities tend to have subprograms emphasizing the market adoption of specific energy efficient technologies, such as HPWHs. The long-term objectives of these programs can include offsetting the need for electricity generation, decreasing peak load, decreasing greenhouse gas emissions, decoupling of revenue and profit generation, and meeting a clean energy portfolio standard. Energy efficiency programs intervene in the market to overcome barriers to technology adoption in order to achieve efficiency resources. Program strategies may target each market actor in the distribution chain to facilitate increased market adoption by consumers. The longest-running HPWH efficiency programs have been in existence since 2009.

Consumer Decision-Making Factors

Research by the NEEA suggests that the primary reason consumers purchase new water heaters is due to failure of the existing unit. Emergency water heater replacements account for an estimated 85-90% of water heater purchases. In these instances, it's typical for consumers to purchase the water heater model suggested by the installer, who either recommends installation of the same water heater model as the failed unit, or a model that is similar in its specifications. While the majority of consumers consider energy efficiency important, they do not perceive it as important enough to justify early replacement of a functional water heater. The other reasons consumers purchase new water heaters are the lack of hot water production, energy efficiency, leaks (i.e., near failure) and high operating cost. [17]

NEEA's research also suggests that current HPWH owners purchased a HPWH over alternatives to save energy, receive utility rebates, and decrease water heating operating costs. The majority of current HPWH owners planned their water heater replacement rather than waiting for the previous unit to fail. While these consumers previously had operational water heaters, they went forward with the planned HPWH replacements primarily due to the old age of the previous water heater and secondarily to upgrade to a more efficient water heater. These consumers considered at least one alternative to a HPWH, which is an advantage that planned replacements have over emergency replacements due to the lack of a time constraint. In addition, they came to the conclusion to purchase a HPWH on their own, not due to the suggestion of a contractor or installer. All of this suggests that current HPWH owners are not representative of typical water heater owners, who account for the majority of the market. [17]

Consumers who are aware of HPWHs but currently own electric-resistance water heaters claim to have three main drivers that could entice them to purchase a HPWH: decline in first cost, failure of the current water heater, and increased utility rebates. [17]

Market Barriers

A combination of barriers is inhibiting HPWHs from realizing their market potential. These barriers have evolved with economic, market and technological circumstances over time. Market barriers remain a significant challenge whereas technological barriers, through incremental innovation, have been diminishing. Key barriers are those considered most influential to inhibiting HPWH market transformation.

Table: Key Barriers to HPWH Market Adoption

Barrier	Description
First Cost	High upfront cost compared to the standard electric-resistance water heater. Consumers encounter "sticker shock" when discovering that the purchase and installation of a HPWH is 2-3 times more expensive.
Consumer Awareness and Education	Lack of awareness of HPWHs as a purchase option, its value proposition and what to do to facilitate a HPWH installation.
Availability	Lack of consumer access to HPWHs, particularly when in need of an urgent replacement due to the failure of the existing water heater.
Installer Expertise	Lack of trained and engaged installers. Lack of clarity on HPWH sizing to meet household hot water needs. Lack of interest or understanding in promoting HPWHs to consumers and resolving installation barriers.
Performance	Confusion over climate suitability and parasitic losses to heating systems. Dissatisfaction with hot water delivery in heat pump mode. Displeasure with the compressor noise level and cool air exhaust.
Installation Constraints	Lack of space at the current water heater footprint to accommodate a HPWH, inability to accommodate ventilation requirements, ducting and/or condensate drainage.

First cost is still the primary barrier to HPWH market adoption. The installed cost of a HPWH can run US$1,500 to US$3,500, depending on the model and installation circumstances. In comparison, an electric-resistance water heater tends to have an installed cost of US$600 to US$1,000. As a result, HPWHs typically have an incremental installed cost of US$1,000 to US$2,500. [20] Manufacturers, retailers, distributors and installers recognize this as a critical issue, particularly in the replacement market. Consumers who need an urgent water heater replacement often don't consider the lifecycle cost effectiveness of their purchase. They often don't have the time to research water heater options such as a HPWH and find incentives decreasing the first cost of a HPWH. In addition, they may not have the money readily available to make a purchase. [17]

Most US consumers are still unfamiliar with HPWHs, particularly the value proposition and whether their household is a good candidate for HPWH installation. Consumers will choose an incumbent water heater technology by default in absence of understanding the existence and benefits of owning a HPWH. The value proposition of purchasing a HPWH lies in its annual energy and cost savings. However, this is often not of interest to consumers unless their current water heater fails and they've been made aware of the cost savings benefit by their installer or retail sales associate at the point of sale. Water heaters are typically installed in obscure locations in a household and receive little to no attention until they break or don't provide enough hot water during a peak consumption period. The majority of consumers do not know how much energy their water heater consumes and/or how much it costs them to operate. [20]

Depending on the region, consumers may not have access to HPWHs, particularly when in need of an emergency replacement. Wholesalers and retailers may have few, if any, HPWHs in inventory. They may ask the consumer to put in a special order to receive the appropriate HPWH model for the household's hot water use and installation circumstances. It can take days, or even a week, for the HPWH unit to arrive for installation. Installers may not have HPWHs on the truck when an emergency replacement is needed. In certain regions, installers depend entirely on wholesalers or retailers for inventory and do not keep a stock of water heaters at their place of business.

Depending on the region, installers may have inadequate expertise in installing and promoting HPWHs to consumers. They may need different licenses to conduct the plumbing, maintain the heat pump and maintain the electronics (e.g., control board). They also may have a limited understanding of how to accommodate HPWH installations across various household scenarios. In these situations, consumers may not have the patience for the installer to conduct the due diligence needed to resolve complications such as HPWH size, ventilation, ducting and condensate drainage. Installers may also have issues with sizing the HPWH for the household hot water load. Last but not least, installers may have little interest in promoting HPWHs to consumers, particularly due to their fear of potential "call backs" if the HPWH has a maintenance issue.

Improvements in HPWH technology have lowered certain barriers. Over the past five years, manufacturers have decreased the noise level of HPWH compressors by roughly 15 decibels. They have also improved heat pump efficiency in cooler ambient temperatures by lowering the cut-off temperature for compressor operation. Most HPWHs in the market come with connections to fully duct (intake and exhaust) the unit using an aftermarket kit. This provides a solution to consumer displeasure with cool air exhaust and addresses concerns about parasitic losses to heating systems. Manufacturers have also increased the reliability of HPWHs by improving design and construction, which is reflected in longer warranties.

In certain instances, HPWH installation can be cost prohibitive if major renovations are necessary to accommodate the unit. This is more common for installing HPWHs in multifamily buildings, which may not have the space for a HPWH or may not have a way to drain condensate. In these instances, consumers may not have the option of relocating the HPWH or renovating the existing footprint to accommodate the HPWH.

Best Practices

Best practices can help improve HPWH market adoption at the national, regional or local level in target markets. Overcoming market barriers effectively calls for the involvement of multiple market actors to coordinate activities. When market actors partner, their initiative is stronger than if each had conducted its own effort. Co-marketing partnerships leverage the brand, relationships, and financial resources of each participating market actor involved. These partnerships can arise between all market actor types, but are more common through a retailer, manufacturer and efficiency program effort. [21]

Energy efficiency programs and market actors use a number of tactics to address critical HPWH barriers in an effort to increase market adoption.

Table: Best Practices for Overcoming Market Barriers

Barrier	Best Practices
First Cost	• Mail-in rebates • Instant rebates or buy downs • Low-interest loans • On-bill financing • State tax credits • Federal tax credit • Leasing • Consumer awareness
Consumer Awareness and Education	• Compelling consumer messaging • Bill inserts • Point-of-purchase displays and informational brochures • Web presence and mass emails • Advertisements • Press releases • Journal and newsletter articles • Live events • Social media campaigns • Sales training for installers and retail sales associates
Availability	• Wholesaler incentives • Installer incentives • Manufacturer influence • Promotion guidance • Business case research and analysis
Installer Expertise	• Trainings • Competitions • Certification, credential and marketing • Installation guidance • Sales guidance • Incentives
Performance	• Testing • Consumer feedback • Specification requirements • Tiered incentives • Golden Carrot competitions

The first cost market barrier offers a variety of options for reducing its impact on consumer purchase decisions. The most common tactic for reducing first cost is offering consumer incentives, such as mail-in or instant rebates (purchase subsidies). Low- or no-interest loans and on-bill financing are other ways to provide funding relief for consumers who pay a premium when purchasing HPWHs upfront. A potential way of addressing first cost is for efficiency programs to lease HPWHs to consumers at a discounted monthly cost for the HPWH, maintenance and repair over the unit's lifetime. In this case, consumers have zero upfront cost and receive immediate cost savings through decreased energy use. [22] Federal and state tax credits are another method of reducing first cost. It's important for market actors to promote all options available to consumers to relieve first cost. In combination, these options can have a substantial impact at reducing the incremental cost of a HPWH purchase.

Improving consumer awareness and education involves developing compelling consumer messaging and spreading this message through multiple avenues and market actors to impress upon target consumers. Messaging should clearly communicate the value proposition for HPWHs, call on consumers to plan their HPWH replacement, and catch attention (e.g., through vivid imagery or expression). Involving each market actor in the consumer awareness strategy improves its effectiveness. Installers and retail sales associates have direct engagement with consumers and can provide education and guidance in a one-on-one setting. Training and guidance can improve their ability to communicate the value proposition of HPWHs. Retailer promotions and discounts, often in partnership with manufacturers and/or efficiency programs, are a sizable driver of consumer purchases.

Point-of-purchase materials and displays can introduce a call to action for consumers to purchase a HPWH and start saving energy and money right away. [17]

Increasing availability begins with motivating wholesalers and retailers to keep a sufficient inventory of HPWHs and then motivating installers and retail sales associates to drive HPWH installations and sales. Manufacturers and efficiency programs can offer incentives, such as rebates or commissions, to these market actors for selling HPWHs. Providing training or promotional guidance can help these market actors with consumer messaging and targeting. Furthermore, communicating how HPWH sales benefit their business case is important, particularly for independent wholesalers, retailers and installers, since they may not fully appreciate the higher margins of HPWH sales and how HPWHs diversify their product portfolio. [20]

Establishing an experienced and engaged base of HPWH installers calls for a combination of activities. Trainings are a good way to improve installer expertise. They provide live instruction and offer tips for navigating complicated installation scenarios. They can also offer an opportunity to equip installers with the information and messaging to influence HPWH purchases. Written guidance can be provided via instruction manuals or smartphone applications, which can offer a resource for both routine and unique installation scenarios. Once trained, efficiency programs can certify and brand installers so they receive exclusive access to incentives and can have their expertise marketed to consumers. A unique method of increasing installer engagement is to offer instant rebates on each HPWH installed. Efficiency Vermont has increased market share considerably in its region using this approach. [23] Another unique method is to offer incentives to installers for reaching certain milestones for HPWH installations. NEEA has been successful using this approach to increase HPWH installations in its territory. [24]

While these best practices are relatively straight forward, there are opportunities for implementing innovative or unprecedented strategies. Other industries employ a myriad of strategies to address similar market barriers to those faced in HPWH market adoption. Solar developers conduct power purchase agreements to relieve market barriers, such as first cost, for installing solar panels. There is an opportunity to conduct efficiency purchase agreements for HPWHs with the emergence of wireless low-cost submeters and connected HPWHs. In this case, an efficiency program can purchase, install and maintain the HPWH at the cost of purchasing and installing an electric-resistance water heater to the customer. An efficiency program can use an algorithm to calculate the expected energy use of an electric-resistance water heater, given the home's metered hot water loads using the HPWH. The expected cost savings on energy bills could be allocated between the efficiency program and customer at a predetermined distribution. This would effectively be a pay-for-performance approach. Using a connected HPWH under this approach could also be an opportunity for demand response programs interested in peak load management. Efficiency programs, manufacturers, retailers, wholesalers and installers may discover that applying innovative methods can be more effective than the time-tested methods currently considered best practices.

Market Assessment

Approximately 46.8 million, or 41%, of occupied US homes have an electric-resistance water heater. However, not all of these homes are a good fit for a HPWH. Among the HPWH models in the market, the smallest tank size is 189 liters (50 gallons) and lowest FHR is 193 liters (51 gallons) of hot water delivery. [25] Electric-resistance water heater models with 114 liters (30 gallons) of storage have a maximum FHR of 185 liters (49 gallons) of hot water delivery. [26] Thus, homes currently using an electric-resistance water heater with 114 liters (30 gallons) or less of storage are not a good candidate for a HPWH replacement. Of homes with an electric-resistance water heater with storage of 117 liters (31 gallons) or more of storage, 68% are single-family homes, 23% are in multifamily homes and 9% are in mobile homes (small, prefabricated single-family homes – also called manufactured homes). [4]

Table: US Homes with Electric Water Heaters with 31-49 and 50+ Gallons of Storage

Residence Type	117-188 liters (31-49 gallons)	189+ liters (50+ gallons)	Total	Percent
Mobile Home	2,716,219	694,391	3,410,610	9%
Single-family: detached	14,184,598	9,358,231	23,542,829	63%

Single-family: attached	1,303,569	504,343	1,807,912	5%
Multifamily: 2-4 units	1,566,804	903,468	2,470,272	7%
Multifamily: 5+ units	3,753,591	2,290,839	6,044,430	16%
Total	23,524,781	13,751,272	37,276,053	100%

Based on data from Energy Information Administration's 2009 Residential Energy Consumption Survey

Mobile homes and multifamily homes tend to have HPWH installation complications due to space constraints, condensate drainage, and ducting. Multifamily homes are also more likely to be rented than owned, which causes a split incentive issue between the owner and renter for the investment in energy efficient upgrades. This makes these types of homes inferior candidates compared to single-family homes for replacing existing electric-resistance water heaters with HPWHs. However, the high hot water loads in multi-family buildings offer an opportunity for the installation of CO_2 HPWH technology combined with commercial-size tanks, where the equipment cost can be split among multiple housing units.

Target Household Profile

Based on market share, HPWH technology is in the early stages of the adoption curve. Consumers who fall in this range of the adoption curve are innovators and early adopters who tend to have above average financial resources and education levels. [27] The target household profile for a HPWH purchase is a single-family home with hot water usage suitable for an electric-resistance water heater with 117 liters (31 gallons) or more of storage, a household gross income of US$50,000 or greater, and householder education level of an Associate Degree or higher. [17] Using data from the US Energy Information Administration's 2009 Residential Energy Consumption Survey (RECS), there are approximately 6.9 million households in the US that fit this profile, making up approximately 14.8% of US households with electric water heaters. [4]

In addition to existing homes, new homes are continually constructed that also fit the target household profile. Based on US Census building permit data, the US has an annual average growth rate of 7.7% in new construction of single-family homes since 2012, meaning growth of new home construction has been accelerating over the past five years. Assuming this average growth continues, the US should add approximately 795,000 new single-family homes in 2017.[9] If new single-family home construction reflects existing stock, then 217,000 of these households fit the profile of needing a water heater with 117 liters (31 gallons) or more of storage (regardless of fuel type), a household gross income of US$50,000 or greater, and householder education level of an Associate Degree or higher. These households indicate the maximum HPWH installations in target households in the new construction market if fuel type were not a consideration. Assuming water heater fuel type for new single-family home construction reflects existing housing stock, then 76,800 of these households fit the profile of needing an electric water heater with 117 liters (31 gallons) or more of storage, a household gross income of US$50,000 or greater, and a householder education level of an Associate Degree or greater. These households indicate the expected target household HPWH purchases in the new construction market. [28]

Based on US Census building permit data, the US has an annual average growth rate of 7.85% in new construction of all household types since 2012. Assuming average annual growth continues, the US should add 1,264,000 new households in 2017. If new household construction reflects the existing stock, then 41.2%, or 520,400 households, are expected to install electric storage water heaters. Assuming one electric water heater is installed per household, this represents the annual US new construction market for electric water heaters. Total US electric water heater shipments have fluctuated between 3.7 million and 4.8 million annually over the past 20 years with an average of 4.2 million electric

[9] According to the US Census, actual single-family household new construction "starts" are 2.5% greater than building permits issued due to reclassification of multifamily households to single-family attached households as well as housing starts that do not require a building permit. However, actual single-family household new construction "completions" are 3.5% less due to household construction abandoned. Thus, building permits reflect a net decrease of 1% of actual single-family household new construction. Analysis reflects these data corrections.

water heater shipments per year. Removing the electric water heater shipments destined for the new construction market results in a replacement market of 3.67 million electric water heaters annually. Given that the target household represents 14.8% of all US households with electric water heaters, approximately 542,000 of annual electric water heater shipments in the replacement market are purchased by target households.

Table: Target Household Profile in US Installed Base and Market

US	**Target Household Profile**	**Households with Electric Water Heaters**	**Total Households with Water Heaters***
Installed Base	6,904,188	46,759,338	110,729,440
Annual Replacement Market	542,097	3,671,406	7,450,689
Expected Annual New Construction Market	76,836	520,377	1,264,416
Expected Total Annual Market	618,932	4,191,783	8,715,105
Potential Annual New Construction Market	216,726	-	-
Potential Total Annual Market	758,823	-	-

* Based on RECS 2009 data, there are 113.6 million total US households of which approximately 2.9 million do not have a water heater.

Target Region Profile

The ideal target region for HPWH market penetration should have a high saturation of target households. It should also have incentives and financing available for consumers to leverage in their purchase. For the purpose of a HPWH value proposition that resonates even better with consumers, it should also have comparatively high electric rates, improving the cost effectiveness of a HPWH purchase.

Assessing regional HPWH market adoption opportunities begins with identifying states or regions with a high saturation of target households. The methodology applied to RECS 2009 data to determine characteristics of the US housing stock, water heater installed base, and water heater market can also be applied to the RECS reportable domains, which are the states or groups of states by which EIA designs and conducts the survey sample for RECS. These states and regions provide the most detailed or disaggregated analysis using the RECS data. Total expected shipments per year for the target household profile offer a basis for determining which states or regions are better candidates for HPWH market adoption than others, assuming the fuel type selected in new construction reflects the state or region's disposition for electric water heating in the installed base. Total potential shipments per year for the target household profile provide a basis for determining which states or regions are better candidates if the new construction market were not disposed to a specific water heater fuel type and all target households selected electric HPWHs. This represents the potential shipments to target households if market actors influenced the new construction market to install electric HPWHs rather than the typical fuel installed in the region or state (e.g., natural gas).

States in the Southeast and Mid-Atlantic have the greatest number of projected annual 31+ gallon water heater shipments to target households, both expected and potential. These states also have strong new construction markets and hot/humid ambient temperatures that are favorable for HPWH operation.

Table: Target Household Projected Annual Shipments of Electric Water Heaters by RECS 2009 Reportable Domain

RECS Reportable Domains	Expected Shipments/year			Potential Shipments/year		
	Replace	NC	Total	Replace	NC	Total
FL	76,067	16,779	92,847	76,067	21,513	97,581
TX	42,098	9,313	51,411	42,098	32,498	74,596
SC, NC	38,818	9,594	48,412	38,818	15,669	54,487
DC, DE, MD, WV	38,236	3,582	41,818	38,236	6,171	44,407
OH, IN	33,855	2,327	36,182	33,855	7,955	41,810
PA	32,525	1,615	34,140	32,525	4,098	36,623
AZ	27,463	5,610	33,073	27,463	8,892	36,355
VA	28,745	3,655	32,400	28,745	9,029	37,774
AL, KY, MS	27,649	2,330	29,979	27,649	4,718	32,367
WA, OR, HI, AK	24,097	3,584	27,681	24,097	10,876	34,973
IA, MN, ND, SD	21,821	2,466	24,286	21,821	8,642	30,462
GA	20,026	3,611	23,637	20,026	10,598	30,624
TN	13,949	2,909	16,858	13,949	6,255	20,204
CA	14,114	1,168	15,282	14,114	17,721	31,835
WI	12,391	1,055	13,446	12,391	3,882	16,273
CT, ME, NH, RI, VT	11,367	745	12,112	11,367	3,202	14,569
MI	10,392	729	11,121	10,392	4,211	14,603
IL	9,426	378	9,804	9,426	2,892	12,318
AR, LA, OK	8,581	974	9,554	8,581	3,854	12,434
NY	9,135	360	9,495	9,135	3,501	12,636
MO	8,694	660	9,353	8,694	2,791	11,485
MA	8,627	625	9,252	8,627	2,736	11,362
NJ	7,898	417	8,316	7,898	3,573	11,471
NM, NV	6,194	886	7,080	6,194	4,367	10,561
KS, NE	5,281	493	5,774	5,281	2,448	7,729
ID, MT, UT, WY	2,494	540	3,035	2,494	7,032	9,526
CO	2,155	429	2,584	2,155	7,603	9,758
US Total	542,097	76,836	618,932	542,097	216,726	758,823

Table notes: Individual values may not sum to the total values due to rounding. “Replace” refers to the shipments in the replacement market and “NC” refers to shipments in the new construction market.

Based on data in the Database of State Incentives for Renewables & Efficiency (DSIRE) and ENERGY STAR Rebate Finder, there are more than 130 major efficiency programs offering HPWH incentives to households covered by efficiency programs and most of these incentives are mail-in rebates. These programs are accessible to more than 57 million electric utility households nationally. Rebate values range from US$50 to US$1,500 per HPWH, depending on the circumstances of the HPWH

installation.[10] States with a high number of households with access to HPWH rebates as well as high average rebate values are better candidates for market adoption than those with a low or no households with access to rebates. Active rebates provide an immediate opportunity for increased HPWH market adoption if combined with other best practices. [29] [30] [31]

Table: Rebate Programs by State (Minimum of 1,000,000 Customers Covered)

State	Total Electric Utility Households Covered	Weighted Average Rebate
California	11,200,000	$310
New York	4,500,000	$525
Massachusetts	3,000,000	$260
Wisconsin	3,000,000	$300
New Jersey	3,000,000	$500
Tennessee	2,900,000	$200
North Carolina	2,800,000	$350
Pennsylvania	2,800,000	$330
Georgia	2,300,000	$540
Washington	2,100,000	$520
Missouri	1,700,000	$500
Maryland	1,600,000	$500
Illinois	1,600,000	$475
Oregon	1,400,000	$250
Ohio	1,200,000	$440
Arizona	1,100,000	$220
Iowa	1,000,000	$310

The cost effectiveness of owning a HPWH is better for target households with high electric rates. The average US residential electric rate is $0.13 per kilowatt-hour (kWh).[11] The state with the highest electric rate is Hawaii with $0.27 per kWh whereas the state with the lowest electric rate is Louisiana with $0.09 per kWh. The Northeast, Mid-Atlantic and Pacific Non-contiguous regions, as well as the state of California, have electric rates greater than the average US rate, making the cost effectiveness of HPWH ownership even better in those areas. [32]

[10] Rebate requirements often include thresholds for tank size, efficiency rating and length of warranty. Installation by an approved or certified installer is typically required to ensure proper operation. In certain regions of the US, locating the HPWH in an unconditioned space, such as a garage or unconditioned basement, is a requirement. It is also not uncommon for programs to require the new HPWH to replace an electric water heater exclusively, or a gas water heater exclusively.

[11] Annual electric rates calculated based on average from November 2015 through October 2016. US average electric rate is a weighted average based on state occupied households.

Table: Electric Rates by Region

Region	States	Weighted Average Electric Rate ($/kWh)
Southeast	AL, FL, GA, KY, MS, NC, SC, TN	$0.112
Mid-Atlantic	DC, DE, MD, NJ, PA, VA, WV	$0.144
Northeast	CT, MA, ME, NH, NY, RI, VT	$0.182
Midwest	IA, IL, IN, MI, MN, MO, OH, WI	$0.128
South Central	AR, LA, OK, TX	$0.106
Mountain Plains	AZ, CO, KS, ND, NE, NM, NV, SD, UT, WY	$0.118
Pacific Northwest	ID, MT, OR, WA	$0.100
California	CA	$0.171
Pacific Non-Contiguous	AK, HI	$0.248

The cost effectiveness of owning a HPWH is also better for target households in regions with demand response programs. By enrolling in a demand response program, households can take advantage of time-of-use electric rates or other financial incentives to enable utilities, municipalities, and electric cooperatives to decrease peak load. Regions with peak load or grid congestion issues often have a larger need for demand response programs. The Mid-Atlantic and Southeast (particularly Florida) are two regions featuring demand response programs intended to relieve grid congestion.

Where to Go Next: National Strategy

An example of a national strategy for HPWH market adoption could consist of helping launch or improve HPWH efficiency programs in target regions through the implementation of best practices in combination with a national promotional campaign to spread HPWH awareness, education, and enthusiasm to program developers, manufacturers, wholesalers, retailers, installers, and consumers.

A national promotional campaign could utilize social media to generate interest in the awareness and education messages through the sharing of photos, videos, and consumer and installer experiences. It would leverage manufacturer incentives, HPWH program incentives and/or Federal tax credits, if/when available. Market actors would be invited to co-brand and collaborate on all initiatives. Awareness activities could include advertising (online and print), press releases, and point-of-purchase displays and puzzles (online and in-store) to emphasize the monetary savings, energy savings and technological advancement of HPWHs. Education activities could include site selection checklists, online installation trainings (targeting do-it-yourself consumers and installers), and installation competitions (video contests and live events).

Region-specific activities could focus on facilitating both the launch of new and improvement of existing HPWH energy efficiency and demand response programs in regions that have a strong target market opportunity. Launching new programs would involve providing research studies, case studies, testimonials, and other information to regional energy offices, utilities, municipalities, electric cooperatives, and non-profit organizations interested in pursuing objectives achievable through HPWH energy efficiency and demand response programs. In particular, existing studies could be analyzed to forecast the impacts of a successful HPWH energy efficiency program on a region's electric load (especially peak load) along with potential impacts on infrastructure, electric rates, carbon emissions, and clean energy portfolios for the target region. Once an organization decides to launch a new program, resources (e.g., marketing messages, drop-in web content, online tools and applications, online forms, bill inserts, images, etc.) would be available to ease the process. These materials could be made available on the national promotional campaign website.

Improving existing HPWH energy efficiency and demand response programs involves updating the program tactics and resources to the latest best practices and developing stronger partnerships with market actors in the regions. Programs could offer on-bill financing to households that qualify. Programs could partner with manufacturers to secure HPWH inventory equipped with a CTA-2045 port for the region's wholesalers and retailers, offering the potential to conduct demand response. [33] Manufacturers could collaborate with programs to co-host trainings for installers, their call center representatives and big box retail sales associates.

To help existing programs boost HPWH market adoption for emergency replacements, installers would receive instruction on how to expedite routine installations and overcome unique installation challenges. Installer call center representatives and big box retail sales associates would receive training on how to determine site selection for a HPWH installation as well as how to make HPWHs the first offer to consumers using region-specific savings figures in the sales process. Trained installers would receive program certification, branding, marketing support, and exclusive incentive offers for installing HPWHs in the program's region. Programs would partner with wholesalers to present HPWH point-of-purchase displays at the sales counter and implement instant rebates for HPWHs purchased by certified installers.

To help existing programs boost HPWH market adoption for both planned and emergency do-it-yourself replacements, programs would partner with retailers to present point-of-purchase displays along with both mail-in and online rebate forms (via sales associate with a tablet/smartphone and security passcode provided by the program). Retailers would receive program certification and trained sales associates would receive exclusive incentive offers, such as commissions, for HPWH sales headed to homes in the region.

To increase HPWH market adoption in the new construction market, programs could partner with new home production builders in the region. Programs could work with manufacturer partners to offer bulk procurement of HPWHs that meet program requirements. Builder partners could receive program certification, branding, marketing support, and exclusive incentive offers for installing HPWHs in their projects. Case studies could demonstrate how installing HPWHs in new homes has a positive impact on the business model for general contractors and builders. These case studies would be used in the recruitment of new partners operating in the new construction market.

Target Regions for Market Adoption Activities

A number of states have a combination of characteristics indicative of a strong opportunity for market adoption. Certain states have a high number of target households with access to rebates, combined with high expected shipments to target households in the replacement market and relatively high expected and potential shipments to target households in the new construction market. In the Southeast, North Carolina, South Carolina, Georgia and Tennessee fit this profile. In the Northwest, Washington and Oregon fit this profile.[12] In the Southwest, Arizona is a fit. HPWH programs in these states should focus their efforts on adopting best practices that overcome market adoption barriers in both replacement and new construction markets.

In the Mid-Atlantic, Pennsylvania, Maryland and DC have high expected shipments to target households in the replacement market combined with a high number of target households with access to rebates and relatively high electric rates. In the Midwest, Ohio has the same profile of having high expected shipments to target households in the replacement market combined with a high number of target households with access to rebates. HPWH programs in these states should focus on overcoming market adoption barriers in the replacement market through best practices.

California is unique since it has high potential shipments to target households in the new construction market, high number of households with access to rebates and high electric rates. Efficiency programs in California should focus on influencing and collaborating with market actors in the new construction market. Given the state's goals for decarbonization, efficiency programs should also pursue electrification of hot water loads using HPWHs to reduce carbon in the fuel cycle for water heating. The

[12] The Northwest has the strongest regional HPWH program (i.e., NEEA) in the US and has achieved the highest rate of market adoption of any US region.

primary barrier for electrifying hot water loads is the potential for electric upgrades. While adding a circuit in an existing panel can be relatively inexpensive, upgrading an electric panel can be costly.

Florida and Texas have the highest number of expected and potential shipments to target households in the replacement and new construction markets. These states are the ultimate opportunity in HPWH market adoption. However, they have a relatively low number of target households with access to rebates and their electric rates are low. Establishing more efficiency programs in these states is needed, along with engaging market actors in activities that overcome barriers to market adoption in both replacement and new construction markets.

Conclusion

The large-scale market adoption of HPWHs would achieve significant energy savings and peak load reductions nationally. While HPWH technology has advanced considerably over the past two decades, market share still remains very low. A number of market barriers have inhibited widespread market adoption, particularly first cost, installer expertise, availability, and consumer awareness and education. If market adoption doesn't increase, there is a possibility that major water heater manufacturers decrease investment in their HPWH product lines and eventually discontinue their HPWH models.

A national HPWH strategy would improve existing HPWH energy efficiency and demand response programs in target regions through the coordination of market actors and integration of best practices. It would recruit organizations in target regions to meet their objectives by launching new HPWH programs or improving existing their existing HPWH programs. It would complement these initiatives with a national awareness and education campaign, co-branded through partnerships with market actors. Through these focused efforts, the US has the potential to achieve a HPWH market share of 15%, which would save more than 15.7 terawatt-hours and 11 million metric tons of carbon dioxide annually.

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