Critical Heat Pump Water Heater Training and Tool Updates

Jamie Kono, Eduardo Rodriguez-Feo Bermudez, Cheryn Metzger,
Alek Parsons, Pacific Northwest National Laboratory

ABSTRACT

Federal incentives and general market fervor about decarbonization is driving an increased need for professionals capable of quality heat pump water heater (HPWH) installation. Heat pump water heaters are now widely available across the US for retrofit installation in homes, but professionals need training and tools to conduct these improvements. Pacific Northwest National Laboratory (PNNL) and the U.S. Department of Energy (DOE) have created open source HPWH training materials to help plumbing instructors quickly and efficiently update their training programs. These materials were curated to empower contractors to be confident and competent when including HPWHs in their service offerings. The developed training materials build upon industry best practices, are available online through DOE's Building Science Education Solution Center (BSESC), and are being incorporated into national plumbing textbooks.

Not only do these resources address the knowledge, skills, and ability gaps in existing programs, but also provide pathways for training programs to increase awareness of available jobs for prospective workers and leverage federal incentives for workforce development and system rebates.

Introduction

A heat pump water heater (HPWH), often referred to as hybrid electric water heater when designed to use 240 volts, uses heat pump technology to produce hot water. This is done by using electricity to move heat from one place to another. A HPWH creates hot water by capturing heat and humidity from the surrounding air, transferring it to a working fluid (e.g., refrigerant), and using a heat exchanger to transfer the heat from the refrigerant to water. Because HPWHs use electricity to move heat rather than creating it directly, they are generally regarded as one of the most energy efficient methods for water heating (BSESCa 2023). Combining this high efficiency with the ability to utilize renewable electricity, HPWHs are, in many cases, the best options for decarbonizing domestic water heating.

Differences from Heating, Venting, and Air Conditioning (HVAC) Heat Pumps

A plumber getting into HPWH installation for residential applications may be concerned that they will need to obtain HVAC training, but that is often not the case. A HPWH for a single-family home can be a straightforward installation when compared to heating, ventilation, and air conditioning (HVAC) systems.

Heat pump technology has been used for space heating and cooling for nearly 100 years (Lester 2015). Requirements on refrigerant management have driven HVAC professionals to have specific training and certifications, with particular care to minimize release and leakage of refrigerant. In contrast to many types of HVAC heat pumps, most single-family residential HPWHs are packaged units with factory-sealed refrigeration systems. These units, like window air conditioning units and refrigerators, require no direct refrigerant handling during installation, service, or removal.[1]

Because of this simplicity, HPWHs have a relatively shallow learning curve for single-family residential plumbers looking to add HPWH to their service offerings. With that said, there are still a few critical concepts a plumber will need to master to conduct successful HPWH installs, which are shared later in this paper.

Market Share of Heat Pump Water Heaters

HPWHs were released into the residential equipment market around 2003 (EPA, 2024). Over the first few years of the product being on the market, three major manufacturers of gas and electric water heaters also started selling HPWHs. Since then, many more manufacturers have released HPWHs, and numerous regional and national efforts have worked together to increase the market share of these products to help decarbonize homes.

One of the earliest efforts to deploy HPWHs in the market was by the Northwest Energy Efficiency Alliance (NEEA). HPWHs showed up as an energy conservation measure for the first time in the fifth edition of the Northwest Power Plan[2] in 2005 (NWPCC, 2005). This new measure greatly incentivized NEEA to help deploy HPWHs to meet the goals of the region. Since then, NEEA has conducted hundreds of stakeholder meetings and activities for manufacturers, policy makers, contractors and consumers. A primary gap that was identified early in their market transformation journey was the discomfort that plumbers and consumers had with HPWHs generally as a technology with which they were not familiar (NEEA 2017). To address this issue, NEEA developed the Hot Water Solutions website (https://hotwatersolutionsnw.org/), which provides a buyer's guide, describes utility rebates, and provides installation tips. Thanks in large part to NEEA's efforts, along with manufacturer outreach to their existing plumber networks, northwestern states (Washington, Oregon, Idaho, and Montana) have seen an increase in HPWH market share, from 8.5% in 2017 to 11.6% in 2020 (NEEA 2013, Nevius 2022). There is a particularly strong trend in new construction where HPWHs account for 59% of electric water heater installations in 2020 (NEEA, 2022).

Another major regional effort to deploy HPWHs was done by Northeast Energy Efficiency Partnerships (NEEP) in the Northeast/Mid-Atlantic region. In this region, NEEP focused on the implementation of city and state laws that grant rebate promotions for electrification of buildings, including heat pump technology for water heaters (NEEP 2022).

In California, the evolution of standards such as Title 24 have driven an increase in HPWH installation in new homes (CEC 2024). For example, the 2019 version of Title 24 allows HPWHs, but doesn't require it (CEC 2019). The 2022 version of Title 24 allows only HPWH and tankless gas water heaters as a prescriptive option for new construction (EnergyCodeAce 2024).

---

[1] Note that proper disposal of refrigerants is critical at the end of life of equipment, and technicians must be aware of requirements surrounding system disposal, similarly to disposal of other household appliances with refrigerants.

[2] The Northwest Power Plan considers the relatively finite amount of power that can be generated by the power plants in the northwest and how to ensure that a growing population and a large spike in consumer electronic use can receive the power they need from the grid. Conservation or energy efficiency is one tool that helps balance this "energy budget" for the region.

In part thanks to these regional deployment efforts and more recently, the coordination between them by the U.S. Department of Energy (DOE)[3] and the Environmental Protection Agency (EPA), ENERGY STAR® HPWHs[4] have had an upward market acceptance trend in the nation over the course of their tenure in our country. The ENERGY STAR program released its first specification for residential water heaters in 2008, which included qualifying criteria for heat pump water heaters (NEEA 2019). Figure 1 shows the market acceptance trend of HPWHs between 2009 and 2022 increasing from about 22,000 HPWH shipments in 2009 to about 141,000 HPWH shipments in 2022 (representing about 0.6% and 3.1% of U.S. water heater shipments in general) (Butzbaugh 2023).

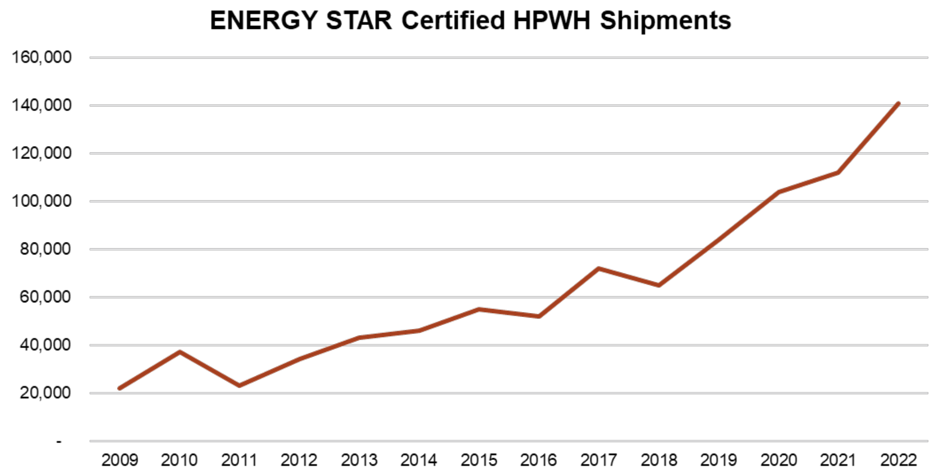

Figure 1: ENERGY STAR Certified[5] HPWH shipments per year (Butzbaugh 2023)

Using Open-Source Training and Credential Recognition to Upskill the Workforce

Based on the authors' interactions with many instructors and education organizations, for many instructors, revising their training curriculum is a daunting task. Among many demands for an instructor's time, researching new content, fitting it into the course schedule, and finding proper homework or exam problems requires a large time commitment for which many instructors do not have budget, time, or motivation. To address this issue, DOE has been working on measures to curate and promote existing training materials that instructors can use to bolster their training curriculum.

[3] Through projects funded by the Building Technologies Office during the American Recovery and Reinvestment Act era, starting in 2009
[4] These are ENERGY STAR certified HPWHs, which represent the overwhelming majority of HPWHs sold in the U.S.
[5] All HPWHs that were shipped after 2009 were also labeled as Energy Star

Open-Source Training Materials

Starting in 2017, the Building Science Education Solution Center (BSESC) began to curate open-source instructor resources covering key decarbonization topics within HVAC and plumbing programs, building on the Guidelines for Building Science Education published in the same year (Metzger 2017). Topics include heat pump installation, heat pump water heater decision-making and installation, and business development opportunities with HPWHs. These training resources were developed from existing DOE resources, NEEA's Hot Water Solutions website, National Laboratory staff expertise, and donated curricula from various partner organizations.

Energy Skilled Recognition

Noting a gap in the marketplace on assuring certifications and training programs meet specific skill standards aligned with decarbonization priorities, DOE launched the Energy Skilled recognition program. Energy Skilled-recognized credentials, which can be certifications, training programs, or other credentials, have been reviewed to meet DOE goals for decarbonization. This recognition allows training programs to leverage federal incentives more readily and distinguishes them as ahead of the curve when it comes to decarbonization and new technology.

For example, in 2023, DOE launched the Contractor Training Grants program (DOE 2023), which assigns $150,000,000 to upskilling contractors in key fields, including HVAC, plumbing, electrical, and home performance contractors. This program requires states to partner with training organizations that meet DOE requirements on training, or organizations recognized by Energy Skilled. (BSESCe 2024).

In 2023, Pacific Northwest National Laboratory developed a set of HPWH training requirements for the Energy Skilled HPWH Installation job scope. The training requirements focused on the key differences between HPWH and conventional electric resistance and fossil fuel water heaters. This set of criteria and training material focuses on unitary HPWH installation applications, often used in single family residential or small-scale commercial scenarios. The criteria mirrors the training material explored in more detail in this paper.

Heat Pump Water Heater Training

As of 2024, many residential water heaters are installed by professionals that have not received a formal education in plumbing. For plumbing contractors interested in expanding their business to offer HPWHs, it's important that they receive training on the new aspects of the HPWH, which can be found through several formal and informal training programs, including a college or vocational school, manufacturer, apprenticeship, utility program, or other continuing education program. Some examples of HPWH training in effect now are those administered by Clean Tech CA through ENERGY STAR's Manufacturer Action Council, training by several HPWH manufacturers, and the Advanced Water Heating Initiative (AWHI).

These recognized trainings cover the skills a plumber needs to successfully install a HPWH. Generally, a HPWH installation is very similar to any other water heater installation with a few exceptions, summarized in Table 1.

Table 1. New considerations when installing a HPWH compared to conventional water heaters.

HPWH Consideration	Details
Sizing	HPWHs require a different sizing approach compared to conventional equipment. Proper sizing ensures customer satisfaction and increases efficiency by reducing inefficient backup heating.
Location	HPWHs require additional airflow to operate in heat pump mode and produce a sound that may be disruptive if not located appropriately (e.g. away from bedrooms).
Condensate management	HPWHs create condensate, unlike most other water heaters, which needs to be directed to a drain.
Electrical capacity	Most HPWHs require 240v on a dedicated circuit, some newer models can be installed on a shared circuit.

Installer comfort with these concepts and others sets the industry up for success: higher customer satisfaction, lower call-backs, increased performance, and fully realized customer cost savings.

The following sections on HPWH basics, decision guidance, and innovative options describe the training content that can be incorporated into an existing plumbing course or provided as a supplement to an already-practicing plumber's education. These materials build on a person's prerequisite knowledge of plumbing, pipefitting, and water heater installation.

Heat Pump Water Heater Basics

While plumbers engaging with this HPWH material are expected to be familiar with generic water heater installation, HPWHs present a few new concepts that are useful to understand at a basic level. Knowing these basics sets a foundation for the plumber to avoid inefficient installs and ensure customer satisfaction. The HPWH basics include the following critical items to know when installing a HPWH:

- HPWH are packaged refrigeration systems, like a household appliance.
- Operating modes should be used appropriately to maximize efficiency and comfort.
- There are clear consumer benefits and impacts that should be communicated to the customer before installation and usage.

Using the vapor compression cycle – but like a refrigerator

Unlike electric resistance and fossil fuel powered water heaters that turn the fuel source directly into heat, HPWHs draw heat from an external source and transfer it to the water. Most residential HPWHs are packaged units, requiring no interface with refrigerant and eliminating the need for a plumber to obtain refrigerant licensing or learn refrigerant management skills. Because of these qualities, HPWHs are generally relatively easy-to-install systems that achieve 3-5 times the efficiency of their electric resistance and fossil fuel counterparts.

Operating modes

The most common HPWHs are 240V "hybrid" HPWHs which utilize two electric heating sources: the heat pump and an electric resistance element. Compare this functionality with a conventional electric resistance water heater, which just has electric resistance elements to heat the water, or a natural gas water heater, which uses burning fuel to heat the water. Hybrid HPWH systems typically balance the temperature of the tank and the operation of the heat pump and electric resistance element within four operating modes.

Heat Pump Operating Mode. This is the most efficient operating mode, which only uses the heat pump to heat the water. This mode has a longer recovery time once the tank is depleted. As of 2024, some newer, non-hybrid 120V HPWHs operate solely in heat pump mode and do not include an electric resistance element, but most HPWHs offer the other modes listed below.

Hybrid Operating Mode. This mode is the default mode selected when HPWHs are shipped. The hybrid mode has control logic to utilize the heat pump to heat the water when sufficient and switches to electric resistance when there is a risk of the hot water running out. This approach balances the high efficiency of the heat pump operation when usage is normal with the reliability of the backup electric resistance for unusual times when usage is high.

Electric Operating Mode. This mode only engages the electric resistance heating elements to heat the water and may be used if hybrid mode is insufficient. However, if the electric mode is required often, this may be a sign that the HPWH was poorly sized or installed incorrectly.

Vacation Operating Mode. This mode can be engaged when the system will not be used for an extended period of time. The water heater will keep the water at a moderate temperature range to reduce energy waste.

Consumer Benefits and Impacts

There are several reasons why a consumer may want the benefits of a HPWH, but they may need guidance to make an informed investment decision. Water heater replacement decisions are often based on the recommendation of a plumber or the person conducting the installation, so these professionals should understand and be able to communicate the benefits consumers will see from a HPWH installation.

Operating Cost Savings. The first potential consumer benefit of HPWHs is energy cost savings. For consumers with relatively high natural gas or other fossil fuel rates, switching to a HPWH may result in significant monthly savings on utility bills. For example, Figure 2 describes a 58% efficient gas tank water heater (typical for an older residential natural gas-fired tank water heater) could cost $470 per year to provide domestic water heating to a three-person household (requiring approximately 41 kBtu/day, which is 0.41 therms/day or 12.03 kWh/day) with U.S. national average utility rates. A HPWH for that same household may use $184 per year to operate, resulting in an annual cost savings of $286 per year.

Depending on the utility rates and efficiency of the units, cost savings of a HPWH may vary, or in specific cases, cost more to operate. Switching from an electric resistance water heater to a HPWH will always result in energy and cost savings. Switching from a natural gas or other fuel water heater will result in cost savings if the natural gas or other fuel rate is relatively high compared to electricity. For example, the same example shown in Figure 2, but with a 98% efficiency tankless gas water heater converted to a HPWH with a COP of 3.0 will result in a utility cost savings of $32 per year. Using a utility savings calculator is recommended in these situations, such as the Rocky Mountain Institute Green Upgrade calculator (RMI 2024).

$$\frac{\left[365\,\frac{days}{year}\times\ 0.41\,\frac{therm}{day}\right]}{0.58}\times\left(1.82\,\frac{\$}{therm}\right)$$

(The cost of natural gas on the Energy Label) = **$470 per year**

$$\frac{\left[365\,\frac{days}{year}\times\ 12.03\,\frac{kWh}{day}\right]}{4.0}\times\left[0.168\,\frac{\$}{kWh}\right]$$

(This is the latest cost of electricity used on the Energy Label) = **$184 per year**

Figure 2. Utility cost comparison for an example house converting a 58% efficiency gas water heater to a HPWH.

Cooling and Dehumidification. One consumer impact that may be a benefit, depending on the home and system configuration, is that the heat pump draws energy from the heat and humidity of the surrounding air. In a space where dehumidification or cooling is needed, this can be a benefit. For example, a HPWH located in a conditioned space in Florida may offset the air conditioning load in the space, lowering air conditioning costs. Another example is a HPWH installed in a basement (such as in the northeast U.S.) where a dehumidifier is needed to maintain acceptable moisture levels. The HPWH can offset the dehumidification required by the dedicated dehumidifier.

Other Impacts. Other benefits of HPWHs that may influence customer's opinion of HPWHs include the ability to lower greenhouse gas emissions, eliminate in-home combustion, or utilize utility rebates. Customers may be interested in eliminating in-home fossil fuel combustion and any associated safety concerns, such as eliminating carbon monoxide risks. Additionally, utilities may provide incentives for customers to enable HPWH grid-interactivity.

One additional critical item for installers to know is that, although they do not have to directly handle refrigerant in these factory-sealed systems, the disposal of these systems, like refrigerators and other small refrigeration equipment, must recover and not release the refrigerant in the system at the end of life.

Decision guidance

A few key considerations should be taken when installing HPWHs in a residence, including, but not limited to, HPWH size, location, condensate management, and electrical capacity. A HPWH unit comes in a variety of sizes and tank capacities. To optimize cost and energy saving potential, the unit's tank size should match the household's hot water needs. Avoiding under-sizing ensures adequate hot water supply and maximal use of the HP function, while avoiding oversizing minimizes first cost and alleviates space constraints. For space considerations, a HPWH should be placed in a location with adequate temperature and space around the equipment, and with appropriate orientation of the equipment for proper airflow. Other considerations include evaluating electrical connections and options for condensation drainage.

Sizing

Properly sized HPWHs should ensure hot water needs are met for the household while maximizing energy savings and efficiency. Efficient operation of the HPWH is defined by maximizing the use of the heat pump system and minimizing use of the electric resistance element in a water heater. To achieve the most energy efficient usage of a HPWH, the HPWH should be sized appropriately for the household demands and needs.

There are many ways to size a HPWH. Most states use a plumbing code that specifies a minimum first hour rating (FHR), or the number of gallons of hot water the HPWH can supply per hour with a full tank of heated water, for a given combination of bedrooms and bathrooms. The FHR of the HPWH will depend on the storage tank capacity and input rate of heat from the compressor. Table 1 shows the Uniform Plumbing Code (UPC) requirements for residential buildings, which are used in many states.

Table 1. UPC requirements for First Hour Rating of residential water heaters

Number of Bathrooms	1 to 1.5			2 to 2.5				3 to 3.5			
Number of Bedrooms	1	2	3	2	3	4	5	3	4	5	6
First Hour Rating, Gallons	38	49	49	49	62	62	74	62	74	74	74

Source: 2021 Uniform Plumbing Code, Table 501.1(2). IAPMO 2021.

The plumbing code requirements should be thought of as minimums and installers can use multiple factors to decide if "upsizing" the HPWH makes sense. A conversation with the occupants can provide insight into hot water demand in the home. Residents may be heavy hot water users if they take back-to-back showers, if there are large tubs in the home, or if they report running out of hot water frequently.

While all water heaters are affected by the temperature of inlet water, HPWHs are also impacted by the ambient air temperature. As the air temperature around the water heater decreases, the compressor can extract less heat. This means the recovery time will increase. Cold inlet water temperatures and cold ambient air temperatures are likely to coincide in the winter, potentially alongside increased demand. This is another reason to carefully size HPWHs so that certain conditions don't result in hot water runouts. Consider the climate zone of the home and the typical ambient temperatures in the installation location.

Location

It is recommended that a HPWH should be installed in a space with 700 cubic feet (19.8 cubic meters) of air space around the water heater (BSESCc 2023), for example in a room with 8-foot ceilings, a 9-foot by 10-foot area would have sufficient air space. Some recent HPWH releases have shown a reduced space requirement as low as 450 cubic feet for retrofits (Jutras 2024). Make sure the location meets the clearance requirements specified by the manufacturer, and that the system is easily accessible for controls and maintenance. Typical rooms in a home that meet the space requirement include a garage, basement, utility closet, or laundry room. The effectiveness of heat pumps in HPWHs are also dependent on the ambient air temperature. For optimal efficiency, the space should be able to maintain a temperature range of at least 40ºF (4.4ºC). Some newer, less conventional HPWHs can be operated at lower temperatures, but most standard hybrid HPWH operate best at mild temperatures.

Another consideration when deciding the location of the HPWH is the noise the unit creates. The majority of HPWHs generate sound less than 55 dBA ("Heat Pump Water Heater Installation Best Practices Guide" 2024). The sound is caused by the moving fan and compressor components of the heat pump on the appliance. The sound levels are comparable to those of a room air conditioner, dishwasher, or refrigerator, which also operate intermittently. HPWHs should be in a part of the house where the noise generated will not disturb the residents of the home (Butzbaugh 2017).

If the location of the existing water heater is too close to a bedroom, the water heater could also be moved to a different location or utilize a split system HPWH that has an indoor tank and an outdoor compressor.

Condensate

HPWHs produce condensate, which is not encountered for conventional tank water heaters. This condensate is a standard part of HPWHs and should be addressed accordingly when installing a HPWH. Condensate should be routed to a nearby floor or sink drain. In the absence of a nearby drain, a condensate pump can be used, which will require its own outlet connection (BSESCb 2023).

Electrical Capacity

Since power needs to be supplied to both the heat pump system and the backup electrical resistance rod, 240 volts and 30 amps are required for most units. This electrical service is comparable to existing electric resistance water heaters, but for homes with existing national gas equipment, new electrical wiring can be required. In older homes, the existing electrical panel or service may not be sufficient to handle this new electrical load, and an electrical panel or service upgrade may be required. (BSESCb 2023).

Innovative Options

Additional HPWH functionality and styles are in various stages of development or implementation that contribute to alleviating barriers to HPWH adoption, including 120V systems that can avoid electrical panel upgrades, and grid-interactive functionality that can help strengthen the electrical grid.

120V Option

A typical hybrid HPWH can require new electrical wiring or other service upgrades to provide 240V service to the HPWH. To alleviate this barrier, several 120V HPWH options are available on the market and have been field tested in California (Khanolkar 2023) and New Orleans (Pilet 2024). These more flexible options were found to be the appropriate solution for 22-30% of gas and propane domestic water heater replacements in California where a 120-volt outlet with sufficient available power was located near the existing water heater (Khanolkar 2023).

Newer 120V HPWHs require a 120-volt connection and a 15-amp circuit, as opposed to the typical 240-volt connection and 30-amp circuit requirement for the most common hybrid HPWHs. The 120V HPWHs can plug directly into an existing outlet using a 6 – 8 ft. (1.8 – 2.4 m) cord, though the amperage of the connected circuit should be verified. This change makes them more accommodating and compatible with older homes that may not have the required electrical capabilities to install a standard 240V/30A HPWH. The lower electrical requirements make them more accessible for gas retrofit installations, where an open circuit may not exist (BSESCd 2023).

Demand response capabilities

Grid flexibility is becoming more desirable in common household appliances, including HPWHs. Additional factors and installation requirements are also needed for grid integration, such as the installation of an American National Standards Institute (ANSI) certified device that allows for communication between appliances and utilities. An example of such a device is an ANSI/CTA-2045 device (CTA-2045-B, 2021). Currently, CTA-2045 devices are the standard add-on for HPWHs to gain the capability to actively interact with the grid and be adjusted in real time by utility providers. Benefits of having grid flexibility include having the capability to participate in peak rebate programs administered by local utility providers. These programs offer monetary incentive for gaining control of large electrical appliances during peak power grid usage, in which they reduce the operational demand of interactive units. As this technology becomes more common, and expected as a standard feature, the means to connect to it are becoming more standardized as well. Additionally, newer models are being released with the built-in ability to be remote controlled by connecting to a pre-existing wireless network such as Wi-Fi. This development into smarter home appliances and systems can facilitate opportunities to install HPWHs that can integrate with grid responses and take advantage of the associated benefits (BSESCd 2023).

Tools and resources available

PNNL has developed an educational tool for HPWH installers, installer call center agents, and homeowners. The Heat Pump Water Heater Installation Tool helps the user through the decision-making process for HPWH product selection and installation, focusing on key hurdles in the process such as sizing, electrical constraints, and location constraints. The tool uses a real or hypothetical installation scenario to walk through different aspects of system design and installation. The webpage for this tool is https://basc.pnnl.gov/hpwh_installation_tool.

NEEA has created a website with consumer and contractor resources on HPWH. On the consumer side, it provides guidance on finding utility rebates, retailers, and installation. On the contractor side, it provides sales resources, installation tutorials, and market research. The website is located here: https://hotwatersolutionsnw.org/.

Among other resources coming out, the Building Science Education Solution Center will soon host a set of open-source training modules on HPWH business development: discussing soft skills training, how to best interact with customers, and how to adapt an existing business to incorporate HPWH.

HPWH Training Deployment

With training materials and recognition program in place, PNNL worked with textbook publishers and training providers to incorporate this material into their curricula. One major textbook publisher is developing new plumbing training material that covers HPWH for future and online editions of their curriculum. In addition, several training organizations, one manufacturer, and the ENERGY STAR Manufacturers Action Council are now recognized by the Energy Skilled program, distinguishing their programs and connecting them with federal incentives.

Conclusions

With significant growth in the HPWH market in recent years, equipping plumbing and other professionals to install HPWHs properly is essential to quickly and effectively deploy HPWHs across the United States.

HPWH installers handling single-family HPWH applications need only a basic understanding of HPWH mechanics, no refrigeration certifications if they don't interface with refrigerants, and key decision-making guidance that handles the handful of new HPWH installation requirements. Training on HPWHs is essential to increase awareness of and comfort with HPWHs among water heating professionals, and to equip those professionals to smoothly add HPWHs to their business offerings.

More innovative HPWH technology is becoming available which will allow for even more extensive HPWH adoption, and more need for HPWH installation training. These systems, both current and upcoming HPWH technology will enable homes across the United States to heat their domestic water using efficient electric systems that will eventually be powered by renewable energy.

References

ANSI/CTA-2045-B. 2021. "Modular Communications Interface for Energy Management." Consumer Technology Association. Arlington, VA.

BSESCa (Building Science Education Solution Center). 2023. "Introduction to Heat Pump Water Heaters Level 1." U.S. Department of Energy, Building Technologies Office. https://bsesc.energy.gov/lecture-notes/introduction-heat-pump-water-heater-remember

BSESCb (Building Science Education Solution Center). 2023. “Decision Guidance for Heat Pump Water Heaters Level 3.” U.S. Department of Energy, Building Technologies Office. https://bsesc.energy.gov/lecture-notes/decision-guidance-heat-pump-water-heaters-apply

BSESCc (Building Science Education Solution Center). 2023. “Decision Guidance for Heat Pump Water Heaters Level 2.” U.S. Department of Energy, Building Technologies Office. https://bsesc.energy.gov/lecture-notes/decision-guidance-heat-pump-water-heaters-understand

BSESCd (Building Science Education Solution Center). 2023. “Decision Guidance for Heat Pump Water Heaters Level 1.” U.S. Department of Energy, Building Technologies Office. https://bsesc.energy.gov/lecture-notes/decision-guidance-heat-pump-water-heaters-remember

BSESCe (Building Science Education Solution Center). 2023. “What is Energy Skilled?” U.S. Department of Energy, Building Technologies Office. https://bsesc.energy.gov/recognition/energy-skilled

Butzbaugh J.B., L.J. Sandahl, and M.C. Baechler. 2018. "US HPWH Market Transformation: Where We've Been and Where to Go Next." In Proceedings of the 9th International Conference on Energy Efficiency in Domestic Appliances and Lighting (EEDAL 2017), , September 13-15, 2017, Irvine, California, 3, 922-941. Brussels:European Union. PNNL-SA-124638. doi:10.2760/113534

Butzbaugh, J. December 14, 2023. “Annual Summary of Market Data for Residential Heat Pump Water Heaters.” Advanced Water Heating Initiative (AWHI) Stakeholder Meeting.

CEC (California Energy Commission). 2019. “Building Energy Efficiency Standards.” https://www.energy.ca.gov/sites/default/files/2021-06/CEC-400-2018-020-CMF_0.pdf

CEC (California Energy Commission). 2024. “Building Energy Efficiency Standards.” https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards

DOE. 2023. State Based Home Energy Efficiency Contractor Training Grants. https://www.energy.gov/scep/state-based-home-energy-efficiency-contractor-training-grants

EnergyCodeAce. 2024. “2022 Energy Code Title 24, Part 6 Fact Sheet: Single-family, Multifamily, Hotel and Motel Domestic Water Heating.” https://energycodeace.com/resources/?itemId=156695

Energy Saver. 2024. “Sizing a New Water Heater.” https://www.energy.gov/energysaver/sizing-new-water-heater

EPA. 2024. “Unit Shipment and Sales Data Archives.” https://www.energystar.gov/partner_resources/products_partner_resources/brand-owner/unit-shipment-data/archives

"Heat Pump Water Heater Installation Best Practices Guide." 2024. Hot Water Solutions, Northwest Energy Efficiency Alliance. https://hotwatersolutionsnw.org/assets/img/documents/hws-installation-best-practices-guide.pdf

Jutras, Nathaniel. 2024. "What Goes into the Cost of Installing a Heat Pump Water Heater." ENERGY STAR. https://www.energystar.gov/products/ask-the-experts/what-goes-cost-installing-heat-pump-water-heater

Lester, P. 2015. "History of Air Conditioning." U.S. Department of Energy. https://www.energy.gov/articles/history-air-conditioning

Metzger, C., S. Rashkin, P. Huelman, A. Wagner. August 2017. "Guidelines for Building Science Education." https://bsesc.energy.gov/sites/default/files/2022-08/PNNL-24143Rev2.pdf

NEEA (Northwest Energy Efficiency Alliance). 2013. "Northwest Heat Pump Water Heater Market Test Assessment Final Report." https://neea.org/img/uploads/northwest-heat-pump-water-heater-market-test-assessment.pdf

NEEA (Northwest Energy Efficiency Alliance). 2017. "Northwest Heat Pump Water Heater Initiative Market Progress Evaluation Report #3." https://neea.org/img/uploads/northwest-heat-pump-water-heater-initiative-market-progress-evaluation-report-3.pdf

NEEA (Northwest Energy Efficiency Alliance). 2019. "A Specification for Residential Water Heaters Advanced Water Heater Specification (Formally Known as the Northern Climate Specification) Version 7.0." https://rpsc.energy.gov/sites/default/files/tech-resource/attachment/NEEA_Adv-WH-spec_5-10-2016.pdf

NEEA (Northwest Energy Efficiency Alliance). 2022. "Northwest Heat Pump Water Heater Market Progress Evaluation Report #6. https://neea.org/img/documents/Northwest-Heat-Pump-Water-Heater-Initiative-Market-Progress-Evaluation-Report-6.pdf

NEEP (Northeast Energy Efficiency Partnerships). 2022. "Northeast/Mid-Atlantic Heating Electrification Market Transformation Progress Report." https://neep.org/sites/default/files/media-files/2022_market_transformation_progress_report.pdf

Nevius, M., J. Powell, M. Meek. 2022. "Northwest Heat Pump Water Heater Market Progress Evaluation Report #6." Northwest Energy Efficiency Alliance. https://neea.org/resources/northwest-heat-pump-water-heater-market-progress-evaluation-report-6

NWPCC (Northwest Power and Conservation Council). 2005. "The Fifth Northwest Electric Power and Conservation Plan." https://www.nwcouncil.org/sites/default/files/Volume1_screen_1.pdf

Khanolkar, A., M. Egolf, N. Gabriel. 2023. “Plug-In Heat Pump Water Heater Field Study Findings & Market Commercialization Recommendations.” New Buildings Institute.

Pilet, T. 2024. “Lessons Learned from the Field: Challenges and Opportunities from 120V Heat Pump Water Heater Deployment in New Orleans.” ACEEE Hot Water Forum 2024.

RMI. 2024. “Green Upgrade Calculator.” https://greenup.rmi.org/