This Must Be the Place: Plug-In 120 V Heat Pump Water Heater Retrofits and Associated Costs

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ABSTRACT

Improving the energy efficiency of residential water heating can have positive impacts on ratepayer utility bills and human health. A technology recently introduced to the market, the plug-in 120 V heat pump water heater (HPWH) has a rated efficiency 3–4 times higher than that of conventional residential water heaters. This paper provides an analysis of installation retrofits and associated costs for 120 V HPWHs across a variety of water heater locations based on data from a field study of 21 homes in New Orleans, LA, and 6 homes in Boston, MA. Installation retrofits are profiled by four water heater location categories, accounting for physical space, air volume/temperature, condensate drainage, and electrical. Disaggregated equipment and installation costs are provided for each retrofit profile as a baseline for this new-to-market technology.

For this study, the average installed cost of a 120 V HPWH was $6,519, which included $3,485 in equipment and $3,033 in installation costs (i.e., labor and materials), comparable to the average installed costs reported in two other 120 V HPWH studies. Equipment costs ranged from $2,594 for a 50 gal model to $3,858 for an 80 gal model, and installation costs ranged from $1,713 for a utility room installation in New Orleans, LA, to $4,172 for a basement installation in Boston, MA. Further insights are provided for airflow and condensate retrofit, relocation, and outdoor enclosure costs.

Introduction

Water heating is the second-largest energy end use in U.S. residential buildings (behind space heating), accounting for approximately 12%, or 2.35 exajoules (2.24 quadrillion British thermal units [Btu]), of national residential energy consumption (EIA 2025). In the U.S. residential sector, approximately 77 million single-family homes and 15 million multifamily homes use individual consumer water heaters to meet their hot water needs (EIA 2023). Given the high volume of installed consumer water heaters, improving their efficiency can have substantial impacts on ratepayer utility bills and human health.

Heat pump water heaters (HPWHs) use a vapor-compression refrigeration cycle to transfer heat from the surrounding air to water in a storage tank. Refrigerators and air conditioners use the same fundamental technology to expel heat to provide cooling. Because they transfer rather than generate heat, HPWHs are the only scalable water heating technology capable of extracting more than three units of heat for each unit of energy consumed.

Despite their considerable efficiency, HPWHs only account for approximately 2% of U.S. consumer water heater sales (ENERGY STAR 2024). This is due to a variety of market barriers, notably high first cost, which has spurred energy efficiency programs to offer incentives for HPWH purchases. Even with certain challenges, manufacturers have remained committed to the long-term promise of this technology and continue to innovate their HPWH product lines.

A recent HPWH innovation is the development of the plug-in 120 V HPWH, designed for homes that lack the electrical service or panel capacity necessary to accommodate the more typical 240 V, 30 A HPWH equipped with 4.5 kW back-up electric-resistance heating elements. The 120 V HPWH allows homeowners to improve their water heating energy efficiency without the considerable investment required to retrofit the home's electrical infrastructure but in doing so, requires limited back-up electric-resistance heating. In 2018, manufacturers met with the energy efficiency industry to draw up the "Retrofit-ready Heat Pump Water Heater Specification," which led to the design of a 120 V HPWH that can plug into a typical 120 V outlet using a 15 A circuit (Larson 2019). Currently, five water heater manufacturers sell 120 V HPWH models that have been voluntarily certified by ENERGY STAR (ENERGY STAR 2026).

Given the recent market introduction of 120 V HPWHs, few studies and data sources have provided publicly available data on equipment and installation costs. The Advanced Water Heating Initiative (AWHI) studied 120 V HPWH equipment and installation costs for 32 households (Khanolkar, Egolf, and Gabriel 2023). The TECH Clean California program (TECH) provides a cost database of 120 V HPWH installations performed since the start of the program in July 2021. The cost data from these studies are discussed further in the results.

Pacific Northwest National Laboratory (PNNL) conducted a field study of 120 V HPWHs in 21 homes in New Orleans, LA, and 6 homes in Boston, MA, across a variety of water heater installation locations. As part of this study, disaggregated data were collected on equipment and installation costs for each water heater location and retrofit intervention. This paper provides a detailed analysis of installation retrofits and associated costs for the 27 homes studied by PNNL.

Study Regions and Recruitment

The planning of the PNNL field study involved identifying study regions, selecting 120 V HPWH models to research, recruiting participants, and partnering with installers. The metro areas of New Orleans, LA, and Boston, MA, were the two regions chosen for the PNNL field study. New Orleans was selected as the initial study location because of its hot/warm temperatures and housing characteristics. The first 120 V HPWH model brought to market was recommended for installation in regions with warm temperatures, notably International Energy Conservation Code (IECC) climate zones 1–3. New Orleans is in IECC climate zone 2, meeting the recommended criterion.

For understanding retrofits, New Orleans residential housing stock offers a wide variety of water heater locations within homes. Approximately one-quarter of New Orleans homes were constructed before the widespread adoption of indoor plumbing (Census 1990; Census 2022). In addition, New Orleans is largely below sea level and surrounded by levees, making it vulnerable to flooding (Pistrika and Jonkman 2010). Many homes in New Orleans are designed to reduce flood damage, so water heaters are often installed in locations above base flood elevation within the home and exterior structures. This has led to unconventional water heater locations in homes, including outdoor dedicated enclosures, detached sheds, outdoor closets, and attics. These housing stock characteristics offer meaningful lessons learned and considerations for 120 V HPWH installation and related retrofit costs which are discussed in the results.

The PNNL field study expanded to the greater Boston, MA, area with the objective of understanding 120 V HPWH performance in a cold region (IECC climate zone 5). In Boston, water heaters are located primarily in basements (unconditioned and conditioned), which are distinct from the installation locations in New Orleans homes, which rarely have basements.

The participant recruitment plans for New Orleans and Boston relied on outreach throughout their metropolitan areas. Recruitment materials were developed to aid study recruitment and protect participants, including a recruitment postcard, a one-page summary of the study for participants, a pre-installation questionnaire, and informed consent. Since the study necessitated the collection of personally identifiable information, all relevant materials were approved by the PNNL Institutional Review Board.

In New Orleans, postcard mailings were sent to approximately 20,000 single-family homes, identified using an online property search tool, filtered by zip code, building type, and occupancy status. Word-of-mouth was also used. Study candidates returned pre-installation questionnaires and site photos for the research team to assess eligibility. When questionnaire responses and photos were ambiguous, a site visit was conducted.

For the Boston area, PNNL partnered with a technical services contractor to help conduct participant recruitment. A regional energy efficiency program shared a list of approximately 100 households that had volunteered for equipment upgrades. Similar to New Orleans recruitment, study candidates returned a questionnaire and site photos for potential eligibility, and site visits helped clarify uncertain circumstances. Ultimately, 21 participants were selected for the New Orleans metro area, representing a diverse range of installation scenarios meeting the qualification criteria. In addition, six participants were chosen for Boston metro area installations, all of which were in basements.

Manufacturer and Installer Partners

PNNL's field study had two manufacturer partners, designated as Manufacturer A and Manufacturer B. These manufacturers captured the highest and second highest share of the U.S. water heater market and were the only two manufacturers who had announced 120 V HPWH product releases at the time of study planning.

In July 2022, Manufacturer A was first to release a product line of 120 V HPWHs to the market. It offers two designs, one for a dedicated 15 A circuit and one for a shared 15 A circuit, both of which were researched in the study. The dedicated-circuit design has approximately 1,180 W of input power (measured at 67.5 °F air temperature), whereas the shared-circuit design has 364-W of input power paired with a thermostatic mixing valve (Larson and Larson 2022). Neither design includes back-up electric-resistance heating, which is an important consideration since the operating air temperature range is 37–145 °F. Manufacturer A provided installation guidance indicating its 120 V HPWHs were designed for regions with a January average ambient air temperature greater than 37 °F (IECC climate zones 1, 2, and 3 in the United States) and for siting in rooms with 1,200 cubic feet or more of air volume (in absence of airflow intervention). Manufacturer A's 120 V HPWHs were only installed in New Orleans, LA.

Manufacturer B released its product line of 120 V HPWHs to the market in July 2023. Its 120 V HPWH design is promoted as suitable for a shared 15 A circuit for homes in all U.S. climate zones. The input power is approximately 400-450 W, and operates in an air temperature range of 40–120 °F. Unlike Manufacturer A's, Manufacturer B's 120 V HPWH is equipped with 900 W of back-up electric-resistance heating, which activates if the air temperature falls outside of the compressor operating range or if the heat pump itself fails. Manufacturer B's installation guidance calls for installation in rooms with 450 cubic feet or more of air volume for proper 120 V HPWH operation (in absence of airflow intervention). Manufacturer B's 120 V HPWHs were installed in both New Orleans, LA, and Boston, MA homes.

For both study regions, the pursuit of an installer partner ran parallel to participant recruitment. For the New Orleans area, PNNL outreach for an installer partner was guided by the ENERGY STAR installer list for Louisiana (ENERGY STAR 2022). Securing an installer partner was an underestimated challenge, requiring a considerable amount of outreach. Many had never heard of a HPWH, and of those who had, most had not seen one in person. Installers were reluctant to commit to installing unfamiliar technology. Only one had ever installed a HPWH, and they were primarily a heating, ventilating, and air-conditioning (HVAC) installer. This company initially committed to partner for installations and then withdrew during the planning process because of high HVAC business volume.

After the initial installer partner withdrew, all potential installer partners were exhausted from the ENERGY STAR list. To find new prospects, a list of licensed plumbers in the New Orleans area was acquired, which led to finding a partner. The study's installer partner had never installed a HPWH prior to working on the study but was eager to learn. For the Boston area, PNNL's research partner helped identify the installer, who primarily installs solar water heaters, but had experience installing 240 V HPWHs in single-family homes in the area.

Prior to scheduling participant installations, PNNL held meetings with the installer partner and each manufacturer individually to discuss 120 V HPWH sizing, site selection, and installation considerations. PNNL developed a sizing methodology that adapts the Uniform Plumbing Code's recommended first-hour rating by factoring in the 120 V HPWH's expected coefficient of performance (COP) and one-hour delivery capability during peak water heating load conditions, given the expected surrounding air temperature and inlet water temperature. The installer and manufacturer partners supported the proposed sizing and retrofits for every participant. For the New Orleans region, Manufacturer A sent one of its staff members with installation expertise to accompany the installer for the first two installations.

Installation Retrofit and Cost Results

Appropriate siting, sizing, and installation is important for ensuring a water heater can meet a household's hot water demand. HPWHs have specific requirements for the spatial dimensions, air volume or airflow, surrounding air temperature, condensate drainage, and electrical infrastructure of the installation space. When these requirements are not met, HPWH performance and reliability are often affected. Multiple retrofits were implemented to resolve specific installation challenges encountered in the PNNL study.

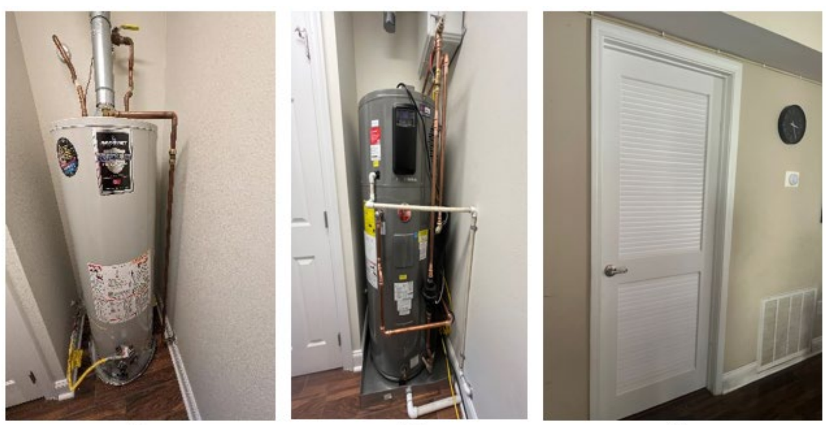
One of the objectives of the research was to conduct installations without adding or replacing circuits in the panel, running new conduit and wiring, or installing new outlets and receptacles. None of the installations required changes to the electrical infrastructure. However, pre-installation electrical assessments were necessary to ensure the 120 V HPWH would have enough available amperage on the circuit to fulfill power demand without tripping the breaker. This meant using a circuit finder tool to identify the other electrical receptacles and end uses sharing the same circuit, ensuring no large loads would share the same circuit as the 120 V HPWH. During these assessments, the research team identified and excluded sites with unsafe wiring, circuits at amperage capacity, and water heater locations that lacked electrical outlets, which would have required upgrading electrical, moving large loads onto other circuits, and/or relocating the water heater.

Most participants had 40 gal gas storage water heaters. One had a gas tankless water heater outside the home, and two had 50 gal electric storage water heaters. Homes converting from a gas water heater had additional installation steps. The installer had to valve the gas line at the water heater, remove any fittings, and seal and cap the line. The installer also had to remove the exhaust vent and seal the vent chimney. In combination with other installation tasks, every installation lasted four to eight hours for homes in this study.

The study's installation locations reflect the U.S. stock of single-family homes. Most U.S. single-family homes have water heaters installed in conditioned basements (28%), followed by the main living spaces (i.e., utility rooms and closets) (26%), garages (23%), unconditioned basements (13%), outside/detached locations (8%), and unconditioned attics (3%) (EIA 2023). The PNNL study included 120 V HPWH installations in each of these locations. The six installations in the Boston metro area were in basements, and the 21 installations in the New Orleans metro area included utility rooms, indoor closets, garages, detached outdoor structures, exterior utility rooms, and an attic. The following results are organized by each identified installation location.

Indoor Utility Room and Closet

Indoor utility rooms and closets within the main living space of the home are the second most common water heater location in U.S. single-family homes and the most common location for homes in Louisiana (43% of single-family homes). In the PNNL study, there were six installations in indoor utility rooms and three in indoor closets. Unlike closets, utility rooms contain a clothes washer, dryer, or other equipment. Placing 120 V HPWHs indoors offered easy access to electrical receptacles and plumbing lines. For utility room installations, 120 V HPWHs often shared circuits with the clothes washer. In this study, clothes washers were all 120 V, used a dedicated 15 or 20 A circuit, and had a peak operating current of less than 10 A, allowing the 120 V HPWH to share the same circuit as the clothes washer without tripping the circuit breaker. Figure 1 is an example from the PNNL study of a utility room installation with a louvered door.



A B C

Figure 1. Replacement of a conventional water heater (A) with a 120 V HPWH (B) installed in a utility room with a louvered door (C). *Source*: Pilet (2024).

Replacing a conventional water heater with a 120 V HPWH calls for approximating the physical dimensions of the water heater location and route to reach this location. The typical 120 V HPWH is an additional 12 inches taller and 6 inches wider than conventional water heaters, and an additional 8 inches of clearance is needed to ensure proper air exhaust, prevent exhaust condensation on surfaces, and provide access to the air filter. For the utility room installation for participant site NOLA-1,[1] both the clothes washer and dryer were moved to create space for the 120 V HPWH, which ultimately had about two inches of separation from the dryer. At NOLA-6, both the clothes washer and dryer were relocated to an adjacent utility room to provide enough space. For NOLA-9, shelving was removed from the utility room for the 120 V HPWH to fit in the water heater location.

The NOLA-5 installation (shown in Figure 2) was unique because it was the only water heater relocation in the study. The existing tankless water heater was on an exterior wall of the home with just 2–3 feet of separation from the neighboring home. Given the space constraints, and after assessing viable locations and consulting with the participant, the 120 V HPWH was relocated to an indoor closet. A key consideration for relocating the water heater is the added cost due to labor time and materials. NOLA-5 had the third highest installation costs in the New Orleans region, driven mostly by the piping retrofit ($1,249), condensate retrofit ($649), and ducting ($249) costs.

A B C

Figure 2. Replacement of an outdoor tankless water heater (A) with a 120 V HPWH (B) installed in a closet with a flex duct and grille retrofit (C). *Source*: Pilet (2022).

Co-location of a 120 V HPWH and clothes washer provides easy access to clothes washer drain lines for removing condensate. Three utility room installations and two indoor closet installations had their condensate drain lines tied into clothes washer drains. These two indoor closet installations (participants NOLA-05 and NOLA-06) both required wall penetrations for the condensate lines to reach the clothes washer drains in the adjacent utility rooms. NOLA-5 had the highest condensate retrofit cost in the study, at approximately $649, whereas the average cost was $256 for utility rooms and closets with condensate retrofits. For the other three utility rooms in the study, two had condensate lines tied into outdoor downspouts and one was tied into a nearby sewer pipe. Routing condensate lines to downspouts is only recommended in warm regions where freezing temperatures are uncommon.

Installing 120 V HPWHs indoors offers the benefit of conditioned air, which provides a consistent ambient air temperature within Manufacturer A's and Manufacturer B's operating ranges. However, indoor utility rooms and closets commonly lack air volume, necessitating airflow retrofits (e.g., ducting, door grilles, louvered door) since the cool air exhaust of a HPWH

[1] To allow comparisons, each installation site was assigned an ID consisting of either "NOLA" (for New Orleans) or "BOST" (for Boston) followed by a number (e.g., NOLA-1 or BOST-2).

can quickly cool a confined space, reducing the HPWH's efficiency and capacity, eventually causing shutdown. Of the six indoor utility room installations, two had a higher-than-recommended air volume within the room, which meant no airflow retrofit was necessary. Three utility room installations (NOLA-02, NOLA-20, and NOLA-21) had solid doors replaced by louvered doors, and one had a preexisting louvered door. The average installed cost of a new louvered door was $842. Retrofitting existing doors with upper and lower grilles would have cost less, but participants requested louvered doors instead for aesthetic reasons.

All three of the indoor closet installations had airflow retrofits. For the NOLA-05 (shown in Figure 2) and NOLA-09 installations, the 120 V HPWH exhaust was ducted outside of the closets with an exhaust duct kit, flex duct, and duct grille. For the NOLA-09 installation, the bottom three inches of the closet door was cut and removed to accommodate intake air, whereas the slider door for NOLA-05 had a preexisting air gap. NOLA-09 had the highest ducting cost among the indoor closet installations, at $573 (average: $418). The third closet installation had a preexisting cloth curtain instead of a door. This installation did not necessitate an airflow retrofit, but because the utility room was beside the kitchen, the participant requested for the intake air to pull from the top of the kitchen to cool the space more effectively. This meant installing an intake duct kit, flex duct, and duct grille. Figure 3 shows the total installed cost and sub-costs for every indoor utility room and closet installation in the study. The average installed cost at this location was $6,428, of which $3,450 was from equipment and $2,978 was from installation.

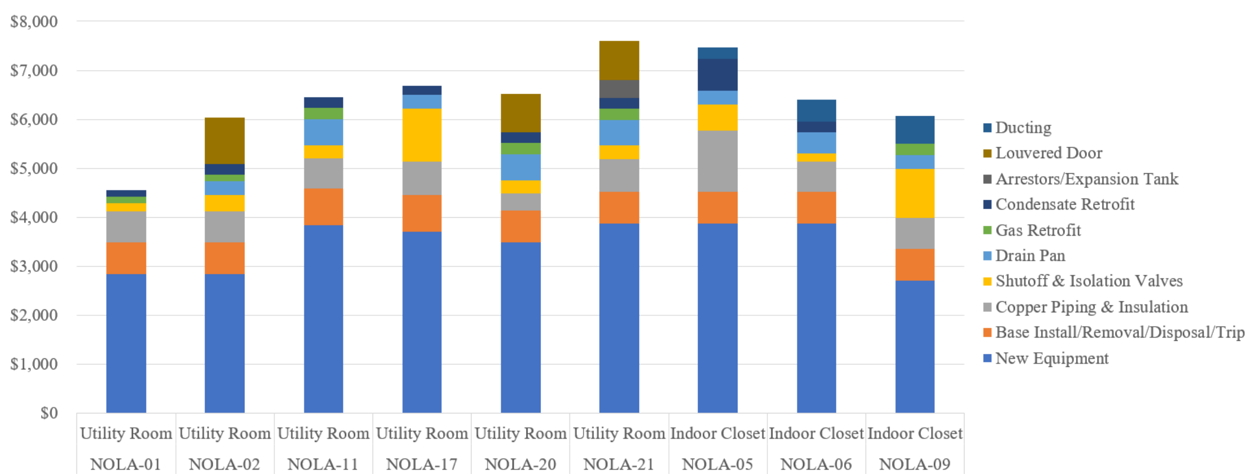


Figure 3. Installed costs for 120 V HPWH retrofits in indoor utility rooms and closets by site ID.

Indoor utility room and closet installations are often near living spaces, introducing the risk of sound and/or vibration disturbing occupants. Unlike conventional water heaters, HPWH compressors and fans generate sound when in operation, similar in magnitude to a refrigerator or dehumidifier (approximately 45–55 decibels). Two of the three indoor closet installations were beside the kitchen, and the third was beside an office. To reduce the potential for disruptive sound and vibration, rubber isolators were installed beneath each HPWH unit, and flex duct was used instead of rigid duct to reduce transfer of vibration. Responses to the mid-study and end-of-study questionnaires indicated that no participants had sound or vibration issues.

Basement

Basements are the most common water heater location in U.S. single-family homes and the dominant location in Massachusetts (91% total, comprising 51% unconditioned and 40% conditioned). In the PNNL study, there were six installations in basements. Generally, basement installations provide the benefit of access to electrical receptacles, plumbing, drainage, and space. In addition, basement temperatures are typically above 37 °F, within Manufacturer A's and Manufacturer B's operating ranges. Figure 4 provides an example from the PNNL study of a 120 V HPWH installed in a basement.

A B

Figure 4. Replacement of a conventional water heater (A) with a 120 V HPWH (B) installed in a basement. *Source*: Guerrieri (2025).

In the PNNL study, basement locations had ample space. However, when reviewing potential study candidates, some had narrow/spiral staircases and low-hanging beams that posed spatial difficulties for moving a HPWH (via dolly) to the water heater location and thus were excluded. Another study candidate was excluded due to reported air temperatures remaining below 45 °F during winter in their unconditioned basement. The lack of electrical capacity on the basement's 15 A circuit also led to the exclusion of one study candidate.

All basement installations in the PNNL study had access to condensate drains. Three basements had floor drains, one had a nearby utility sink, one had an HVAC drain line, and one had a clothes washer drain line. Five of the six sites required condensate pumps to reach drains; only the clothes washer drain was gravity fed. However, just two of the sites needed new condensate pumps, which led to $300 in costs for the pump and installation labor. Otherwise, basement installations had typical costs. Installation materials included copper piping, condensate piping, valves, fittings, a drain pan, and an expansion tank. Figure 5 displays the total installed cost and sub-costs for every basement installation in the study. The average installed cost was $7,105, of which $3,557 was for equipment and $3,548 was for installation. This was the highest average installed cost among water heater location categories in the study. Basement installations did not have airflow retrofit costs, and condensate retrofit costs were modest. RSMeans data indicate that plumbing labor costs are roughly double in Boston than in New

Orleans (Gordian 2026), and Boston installations occurred 2-3 years after those in New Orleans. These two factors likely explain the high average installed cost for basements.

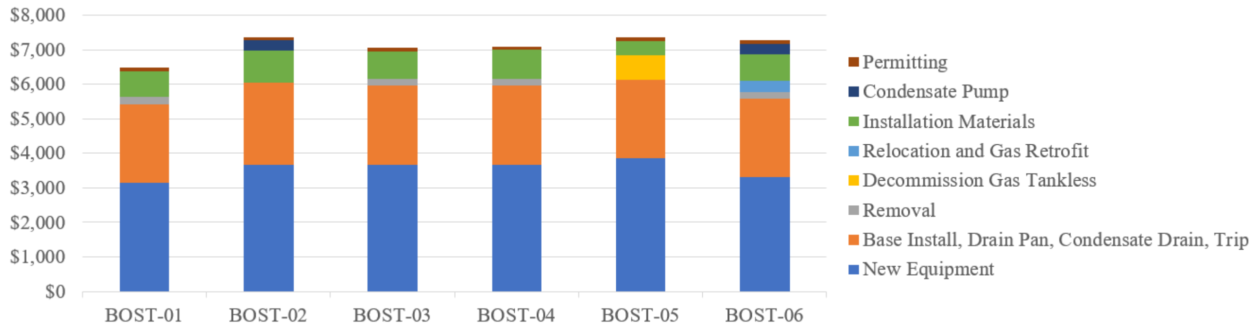


Figure 5. Installed costs for 120 V HPWH retrofits in basements by site ID.

Garage and Attic

Garages are a common water heater installation location across the United States (23% of single-family homes) but are less representative in Louisiana, accounting for only 9% of water heater locations. By contrast, attics are not a common water heater installation location in the United States (3% of single-family homes) but are relatively common in Louisiana, accounting for 28% of water heater locations. For the PNNL study, six sites were selected where the existing water heater was installed in a garage or attic.

Garages typically provide favorable conditions for 120 V HPWH installations due to ample space, sufficient air volume, existing electrical outlets, convenient access to plumbing and drain lines, and thermal communication to conditioned spaces (i.e., door and shared wall). Despite these benefits, garages are less favorable for 120 V HPWHs when the home is in a cold region or if the garage collects debris/particulates (e.g., woodworking) or lacks sufficient space. The PNNL study had five 120 V HPWHs installations in garages. In three of the garage sites, the existing water heater was adjacent to the clothes washer, facilitating access to existing water lines and drainage. The other garages had the condensate drainage routed through the wall to the interior laundry room. Because 120 V HPWHs have a larger diameter than a typical water heater, one site required removal of the existing utility sink (Figure 6) to fit the 120 V HPWH. Five of the six garage sites were unconditioned, and none encountered air temperatures outside of the HPWH's operational range during the study.

A B

Figure 6. Replacement of a conventional water heater (A) with a 120 V HPWH (B) installed in an attached garage. *Source*: Pilet (2024).

Installing 120 V HPWHs in attics calls for case-by-case assessment, given the variations in spatial dimensions, availability of electrical outlets, and access to water and drain lines. In hot-humid regions, attic installations benefit from an uninsulated boundary with conditioned space, which adds heat during winter, reducing the risk of temperatures falling below the operating range. Attics may pose access limitations (e.g., pull-down staircases) that make installation challenging for a 120 V HPWH. Elevated temperatures during summer and space constraints pose potential worker safety issues. Only one attic site was selected for this study.

The attic selected for this study had a sturdy built-in staircase, which aided transport of the 120 V HPWH (weighing 300 pounds), though two people were needed to move it (Figure 7).

A B C

Figure 7. Replacement of a conventional water heater (A) with a 120 V HPWH (B) moved upstairs (C) for installation in an attic. *Source*: Pilet (2024).

Once in the attic, the installers had to move the HPWH sideways across a makeshift plywood bridge over ductwork and beams. After the HPWH reached its destination, it was lifted upright and installed atop vibration isolators and a drain pan, which was routed outside of the house via soffit vent. Existing plumbing connections and routing were reused with minimal additional routing, and condensate was gravity fed into an HVAC drain line.

For garage and attic installations, plumbing complexity was a key driver of installation costs (Figure 8). None of the sites required water hammer arrestors, expansion tanks, or ducting, which reduced overall costs. Shutoff and isolation valve costs were approximately two times higher for the attic installation (NOLA-18) than the garage installations; this was due to the high risk of damage during a leak, which necessitated extra valves to fully isolate the 120 V HPWH. Drain-related costs were higher for NOLA-22 because this site required roughly twice the length of polyvinyl chloride (PVC) pipe for the condensate drain than the other garage sites. Garages and attics had an average installed cost of $6,381, with $3,700 for equipment and $2,681 for installation.

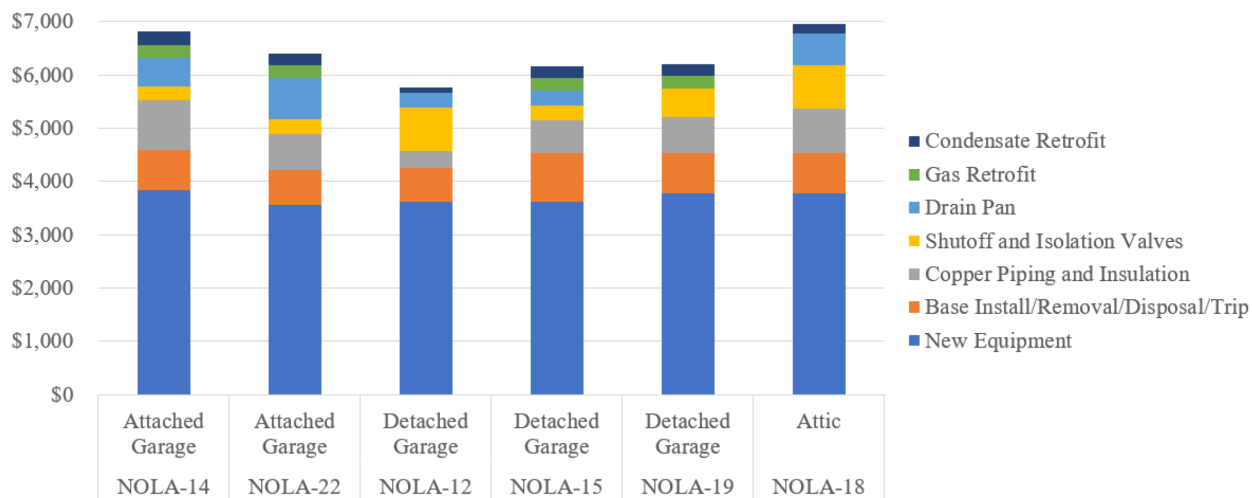


Figure 8. Installed costs for 120 V HPWH retrofits in garages and attics by site ID.

Outdoor Enclosures and Sheds

Outdoor enclosures and sheds represent an uncommon water heater location in U.S. single-family homes (approximately 8% nationally) but a relatively common one in homes in Louisiana (18%) and across the U.S. Sun Belt, where air temperatures are typically warm or hot. For homes constructed prior to the widespread adoption of plumbing, water heaters were installed in exterior structures or utility rooms because of the lack of a suitable location indoors. For these homes, prefabricated metal water heater enclosures were convenient for housing water heaters outdoors while providing protection from rain and storm debris. In the PNNL study, there were six 120 V HPWH installations in outdoor enclosures and sheds. Figure 9 provides an example of before and after a retrofit in an outdoor water heater enclosure.

A B C

Figure 9. Replacement of a conventional water heater located in an outdoor enclosure (A) with a 120 V HPWH (B) in a new enclosure (C). *Source*: Pilet (2023).

The PNNL study had two participant sites with outdoor metal water heater enclosures (NOLA-03 and NOLA-10). For both, the existing water heater enclosures were too small to accommodate the 120 V HPWH, and local plumbing suppliers and hardware stores did not stock large enclosures. This meant PNNL had to special order two new enclosures that could fit the 65 gal HPWHs, contributing an average of $843 for the enclosure and installation labor. These enclosures were three-sided, which provided an air gap between the enclosure walls and home's exterior wall. They also contained vent grilles on the door. These features provided enough airflow for intake but not for exhaust. To duct the exhaust outside the metal enclosure, the installer had to cut into the enclosure wall, fasten a duct kit and flex duct to the water heater, and attach a vent hood to the enclosure. Both sites with outdoor enclosures had electrical receptacles nearby, but access to functional electrical receptacles can be problematic for this type of location.

Four 120 V HPWHs were installed in sheds. For two installation sites, the 120 V HPWH was co-located with the clothes washer, which allowed the condensate drain line to tie into the clothes washer drain. The remaining sites had condensate drained outdoors (only recommended in warm regions). The condensate drain retrofit for NOLA-07 cost the most ($432), driven by both the relocation of the floor drain and the participant's request for an acrylonitrile butadiene styrene (ABS) drain for reliability. The average condensate retrofit cost was $229.

Ducting retrofits were needed for all installations in sheds. NOLA-04 and NOLA-07 had one-directional ducting installed because of limited air volume, which incurred an average cost of $365. NOLA-07 was exhaust ducted outside, whereas NOLA-04 was intake ducted because the detached shed was used for woodworking and pottery, generating dust and debris. NOLA-08 and NOLA-16 were both dual ducted. NOLA-08 had adequate air volume in the exterior utility room, but low air temperature caused HPWH shutdown just a few months after installation, which prompted a duct retrofit because the 120 V HPWH model lacked back-up electric resistance. This exterior utility room shared a wall with the kitchen, so both intake and exhaust were ducted from the top of the kitchen, separated approximately six feet from one another.

NOLA-16 had insufficient air volume in the detached shed, located in a carport which shared an attic with the home. Both intake and exhaust ducting were routed into and out of the attic, with duct boots used at the terminations instead of grilles, and were separated approximately six feet apart with duct boots facing opposite directions. Dual ducting had an average cost of $524 for these two sites. In addition, even though the local plumbing code did not require drain pans for exterior water heater locations, all four participants requested them, which incurred an average of $342 in costs for materials and labor. Figure 10 shows an example of a HPWH retrofit in a shed.

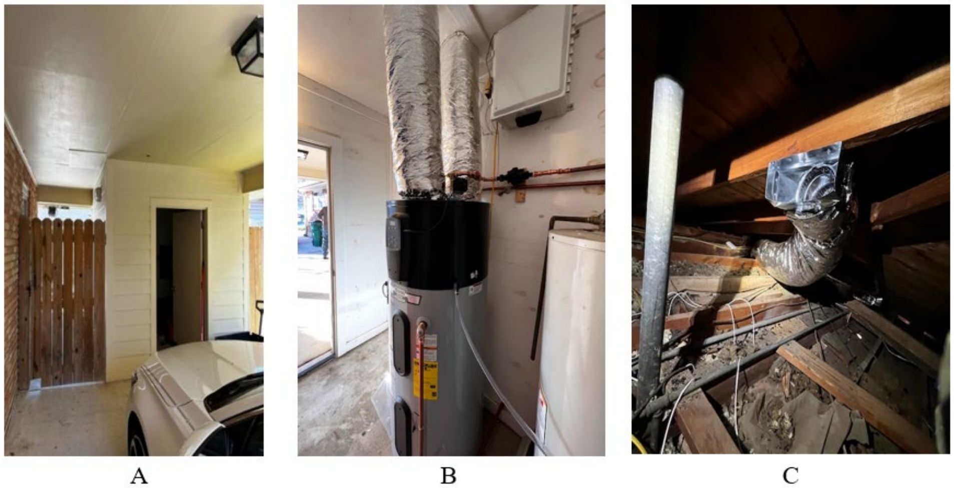


Figure 10. Replacement of a conventional water heater in a carport shed (A) with a 120 V HPWH (B) dual-ducted to the attic (C). *Source*: Pilet (2024).

For outdoor enclosures and sheds, installed costs ranged from $5,290 to $7,911, with an average cost of $6,207 (Figure 11). Across this cohort of installations, the highest installed cost was for NOLA-10, which had a special-ordered metal enclosure ($1,090 for the enclosure and associated labor). If the existing enclosure could have been reused, the installed cost would've been similar to NOLA-16.

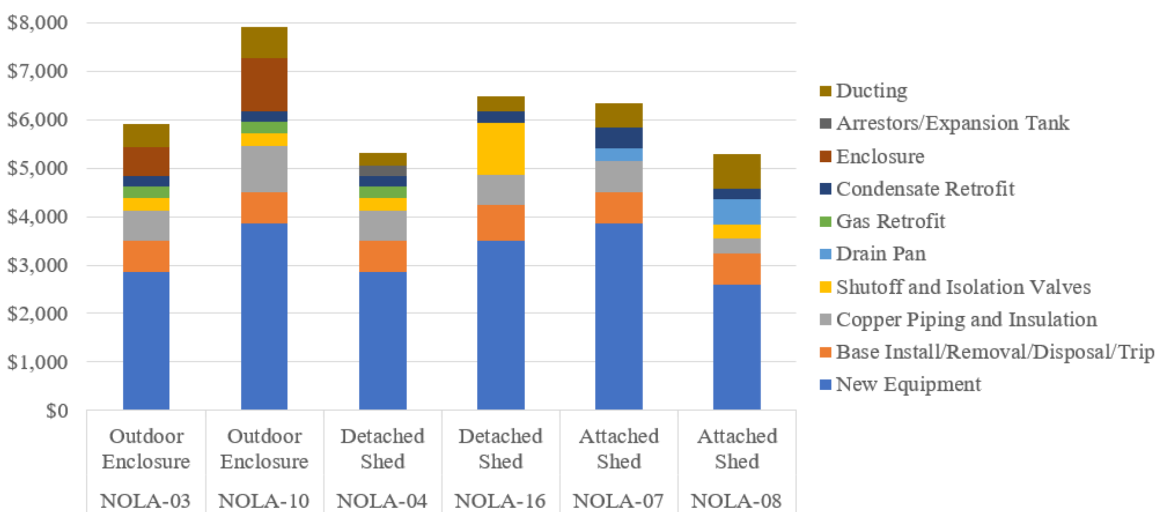


Figure 11. Installed costs for 120 V HPWH retrofits in outdoor enclosures and sheds by site ID.

Cost Overview

In addition to the 120 V HPWH installations, the PNNL study involved one gas storage installation and three warranty replacements of 120 V HPWHs. A study participant with a 120 V HPWH installed in an outdoor enclosure experienced a hot water shortage due to the outdoor air temperature falling below the compressor cutoff temperature for three days. This participant requested to have the 120 V HPWH replaced by a gas storage water heater with the same input capacity and storage as their previous one. The installed cost of the gas storage water heater was $3,654 and included a new outdoor enclosure. For comparison, the installed cost of the 120 V HPWH at this site was $5,906. Warranty replacements did not incur equipment costs, and retrofits were unnecessary since retrofit measures were already in place. The cost of warranty replacements averaged $854 and primarily consisted of labor to deliver and install the new unit, along with removing the failed unit and returning it to the distributor.

For the PNNL study, the average installed cost of a 120 V HPWH was $6,519, which included $3,486 in equipment costs and $3,033 in installation costs. Figure 12 provides average installed costs by water heater location, disaggregated by equipment, base installation, airflow retrofit, and condensate retrofit costs. The average airflow and condensate retrofit costs in Figure 12 include installation sites where no retrofit was conducted. For just the 12 installations with airflow retrofits (louvered door or ducting), the average cost was $561.

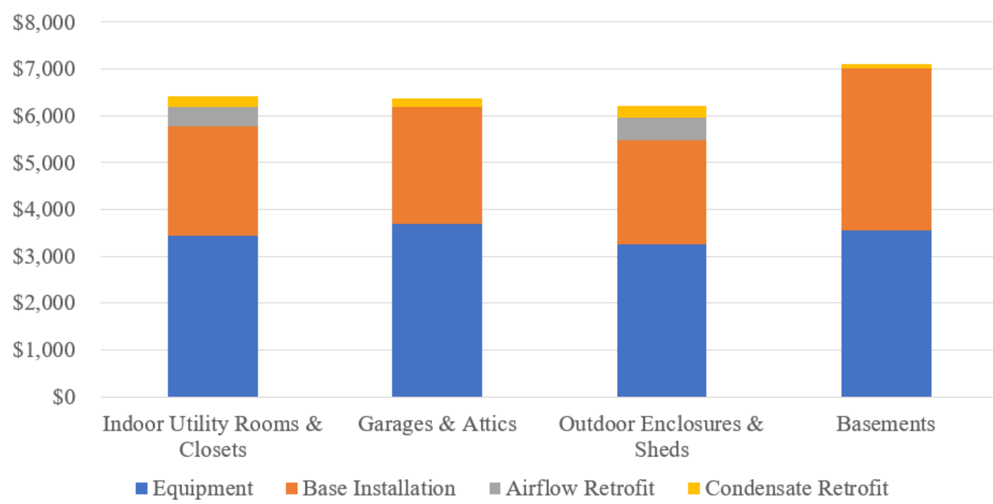


Figure 12. Average installed costs for 120 V HPWH installations by location category.

The costs in the PNNL study were compared with 120 V HPWH installed costs from two other data sources, based on installations in California. The AWHI study reported a median total installed cost of $5,758 and average equipment cost of $2,679, indicating a typical installation cost of approximately $3,079. Most participants (72%) had their 120 V HPWHs installed in the garage, and half of the participant sites in this study underwent electrical upgrades (e.g., circuit, wire, conduit, and receptacle), which ranged in cost from $100 to $500.

For single-family homes that did not require electrical upgrades, the TECH database contained installed cost data for 2,026 installations of 120 V HPWHs. The average installed cost was $5,849. The database can filter these installations further by water heater location. The most common location for 120 V HPWHs was garages (61% of the total), which had an average installed cost of $6,557. The average installed cost was $5,746 for closets (5% of the total), $8,134 for basements (2% of the total), and $4,348 for other (32% of total).

Conclusions

The PNNL study completed 27 installations of 120 V HPWHs in water heater locations reflecting the U.S. stock of single-family homes. The average 120 V HPWH installed cost was $6,519, with $3,485 for equipment and $3,033 for installation (i.e., labor and materials), comparable to the average installed costs reported by TECH and AWHI. Equipment costs ranged from $2,594 (50 gal model) to $3,858 (80 gal model), and installation costs ranged from $1,713 (utility room in New Orleans) to $4,172 (basement in Boston).

Using the retrofit and disaggregated cost results, energy efficiency programs can supplement installer training based on housing characteristics in their region. While none of the installations involved upgrading the home's electrical infrastructure, assessments were needed to ensure the wiring, receptacles, and available circuit amperage were adequate. Programs may consider supplementing existing installer training to include electrical assessment tasks that installers historically haven't conducted.

Airflow interventions were implemented in 12 of the PNNL installations where the air volume or surrounding air temperature was considered insufficient, namely indoor utility rooms and closets, and outdoor enclosures and sheds. For these airflow retrofits, the average cost was $561. Notably, louvered door installations had an average cost of $842. Retrofitting existing solid doors with grilles instead of replacement with louvered doors could lead to much lower costs. For retrofits in metal water heater enclosures, custom-ordered enclosures modified for exhaust ducting had an average cost of $843. The bulk procurement of metal enclosures that are sized and designed specifically for HPWHs could reduce this cost considerably.

Depending on the installation circumstances, retrofit costs for plumbing, airflow, and condensate can be costly (e.g., water heater relocation). While these retrofit costs may be an initial hurdle, they have long-lasting benefits. The average installation cost ($854) for warranty replacements indicates that retrofit measures are steadfast and lead to lower costs for subsequent HPWH installations over the home's lifetime. As these water heaters sell in higher volumes, equipment costs can decrease with economies of scale. In addition, PNNL will use the findings from this research to identify ways to reduce installation costs, leading to greater lifetime cost savings for homeowners.

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