How to Apply 120V HPWHs for Residential and Light Commercial Applications

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ABSTRACT

New 120V heat pump water heaters (HPWH) are being introduced to the market, but what are the appropriate applications of this technology? Should 120V HPWHs be used in place of every natural gas water heater? Having a low-powered, efficient HPWH may be attractive to some home and business owners, but others may be more concerned with performance and comfort. When switching from a natural gas water heater, what are the real and/or perceived sacrifices that a user experiences with a HPWH? Many proponents of natural gas water heating technology expect that the user will run out of hot water more often. Through laboratory evaluation and field demonstration, we have gathered data on the real-world operation and installation challenges that may be encountered when trying to install 120V HPWHs. This paper will explain new 120V features, share data on recovery times, and provide guidance on application best practices of this new product type. Analysis will be presented both from the perspective of transitioning from a natural gas water heater to a HPWH and from the perspective of when to choose a 120V HPWH versus a 240V HPWH.

Introduction

HPWHs have been available in the U.S. market for residential and light commercial applications for over a decade but have experienced only modest adoption. According to the most recent ENERGY STAR annual report on unit shipment, EPA estimates heat pump water heaters have approximately 3% market penetration in the residential market (EPA, 2023). While HPWHs are a highly efficient way to heat water, they have several barriers that inhibit increased adoption, such as high first cost, larger physical size, slower recovery rates, and increased noise in some scenarios. While significant improvements to product performance have been made over recent years, one challenge that has been especially problematic for homes looking to retrofit from natural gas water heaters was the requirement for a new dedicated electrical circuit to accommodate a 240V HPWH. The additional costs and time delays incurred by this electrical work often made the 240V HPWH too complicated or too time-consuming in this use-case. To resolve this issue, manufacturers have invented 120V HPWHs with hopes to reduce or even eliminate this barrier to electrification of water heaters.

New 120V HPWHs have several unique features that differentiate them from their 240V counterparts. One primary feature is the addition of a 120V cord and plug on the unit. These cords are typically around ten feet long and allow the unit to be plugged into a nearby 120V outlet. Outlets are often nearby in garages or basements, but some locations like closets or outdoor sheds may not have one readily available. If the previous water heater was a powered-vent natural gas unit, then a 120V outlet should be nearby and available. Another new feature is the integration of mixing valves on the unit, either thermostatic or electronic. The inclusion of mixing valves from the factory can allow the water heater to store water at temperatures higher than the delivery temperature in order to provide additional storage capacity. Yet another new innovation released in one of the new 120V products is the use of a larger compressor for the heat pump. Typical HPWH compressors have consumed 300-500W, whereas this larger compressor consumes 900-1400W, depending on air and water conditions, allowing for faster recharge of the tank. Each new 120V offering has different features and characteristics that should be weighed before purchase.

There have already been a few laboratory and field studies that have been conducted on new 120V HPWHs. A NEEA report was released in 2022 that tested two 120V HPWH products from a single manufacturer before commercial release. The work found that the tested units had lower first hour ratings (FHR) and longer recovery times than 240V HPWHs, but the use of a mixing valve to increase tank capacity was effective and only had a minimal impact on energy efficiency (Larson 2022). A 2023 report from NBI revealed the results of the first field demonstration of 120V HPWHs. This study found that out of 32 California homes in the demonstration, the residents saved between $800-15,000 compared with a 240V HPWH installation, primarily due to reduced or eliminated electrical infrastructure upgrades or modifications (Khanolkar, 2023). Other findings from the report indicate that most users were satisfied with the new 120V HPWHs. Furthermore, approximately 60% of the customers saw bill savings. This is an important point because fuel-switching can sometimes result in higher bills for customers depending on local fuel prices and electric rates.

EPRI has also recently completed laboratory evaluations on several commercially available 120V HPWHs and have installed a few units in field sites. The goal of EPRI's research was to explore the new features of 120V products, identify new sizing and installation considerations, and determine how 120V HPWHs can be beneficial to advancing the decarbonization of water heating in residential and light commercial applications. The following sections outline present the findings and conclusions from this work.

EPRI Lab Testing

EPRI installed three 120V HPWHs from two different manufacturers in the Knoxville lab to evaluate the performance of these new-to-market technologies. To reference the water heaters, they are denoted as Unit 1-Manufacturer A, Unit 2-Manufacturer A, and Unit 3-Manufacturer B. Units 1 and 2 are both 40-gallon units (actual tank volume of 36 gallons), while Unit 3 was a 66-gallon unit (actual tank volume of 68 gallons), the smallest sizes in their respective manufacturer's offerings. Although Units 1 and 2 share similarities in some features, they possess distinct characteristics that render them unique. In a common trait, both units contain no resistive backup elements, relying solely on their heat pumps for operation. They also both operate on a 15A breaker, and both utilize R134a as the refrigerant. Additionally, each unit is furnished with a CTA-2045 port, facilitating easy integration with demand response programs for enrolled users. However, they diverge in their electrical characteristics. Unit 1 is designed to operate on a multiple-outlet branch circuits with its power consumption being lower than 50% of the 15A breaker rating. Unit 2 requires an individual branch circuit since the power consumption is above 50% of a 15A breaker rating. These disparities are due to their compressors as Unit 1 features a 4,000 BTU compressor and Unit 2 features a 12,000 BTU compressor, the industry's current largest in a residential integrated unit. Despite Unit 1's smaller compressor, it compensates with a factory-installed thermostatic mixing valve, enabling adjustment of the tank setpoint temperature above supply temperatures, resulting in increased hot water supply.

Unit 3 has many features that make it unique in the market as well. It is the first U.S. residential unit to use R513a refrigerant. The benefit of R513a is that it has a much lower GWP (573) than R134a (1430). Unit 3, unlike Unit 1 and 2, comes equipped with resistance heat in the form of two 900W elements (upper and lower). With this, Unit 3 does have an electric mode that allows the tank to be heated in case the heat pump malfunctions or if ambient temperatures extend outside of its specified operating conditions (37-120°F). As Unit 1 and 2 are not equipped with backup elements, the only modes offered are heat pump and vacation.

EPRI conducted several tests on each of the units, including First-Hour Rating (FHR), Uniform Energy Factor (UEF), Cold-Climate Efficiency (CCE), and compressor cut-out tests. The FHR test is used to determine the amount of hot water that can be produced by a unit within an hour, while the UEF test is used to simulate an example day of performance. In order to complete the UEF testing during extended workdays, EPRI conducted the standby portion of the test on a separate day. The CCE is calculated based on the results and comparison of the standard UEF test and another UEF test that is performed at cold climate conditions. FHR, UEF, and CCE tests were conducted first at default conditions and then also at 140°F storage temperature for the units with integrated mixing valves. Based on the FHR results, the UEF test draw patterns were determined. Finally, the compressor cut-off test is used to establish what temperature the heat pump is able to work down to. *Table 1* below shows the published ratings for each of the units.

Table 1 - Manufacturer Ratings

Unit #	FHR (gal)	UEF (-)	CCE (-)	Compressor Cut-off (°F)
Unit 1A	45	2.8	2.3	37
Unit 1B	51	3.0	2.7	37
Unit 2	76	3.2	2.7	37

Unit 1 Test Results

While there is one standard FHR test procedure, four different FHR tests were conducted on Unit 1. As this unit is equipped with an internal mixing valve, an FHR test with a tank set point of 140°F was also conducted to analyze the performance and possible benefits of the valve itself. Additionally, cold climate versions of these two tests were also performed to see how the ambient air temperature impacted the results.

The standard FHR test for Unit 1 is shown in *Figure 1* below. The test was initiated shortly before 3:25 P.M. and was concluded exactly an hour later. At the start of the draw, the average tank temperature was roughly 121°F, just below the 125°F setpoint. The draw lasted 12 minutes before the tank temperature dropped 15°F to 107°F from the maximum outlet temperature. During these 12 minutes, the unit was able to provide 33.6 gallons of hot water. Due to having a smaller compressor and no backup heating elements, the HPWH was not able to heat the water enough to perform a second draw at the end of the hour as it had an average tank temperature of 83.5 °F. Consequently, the final FHR was concluded to be 33.6 gallons, more than ten gallons less of the published value.

Proceeding this test was the cold climate version of the standard FHR test. Conditions for these tests were an ambient air temperature of 50°F, a water inlet temperature of 50°F, and a tank setpoint still holding at 125°F. At the start of the test, the average tank temperature was approximately 119°F, with the maximum outlet temperature being 124°F. The unit was able to provide 33.2 gallons of hot water during the first draw before the tank temperature decreased to the minimum temperature. The unit was not able to recharge enough to perform a final draw after the hour. This test provided a peak power consumption of 0.360 kW and a total energy consumption of 0.282 kWh.

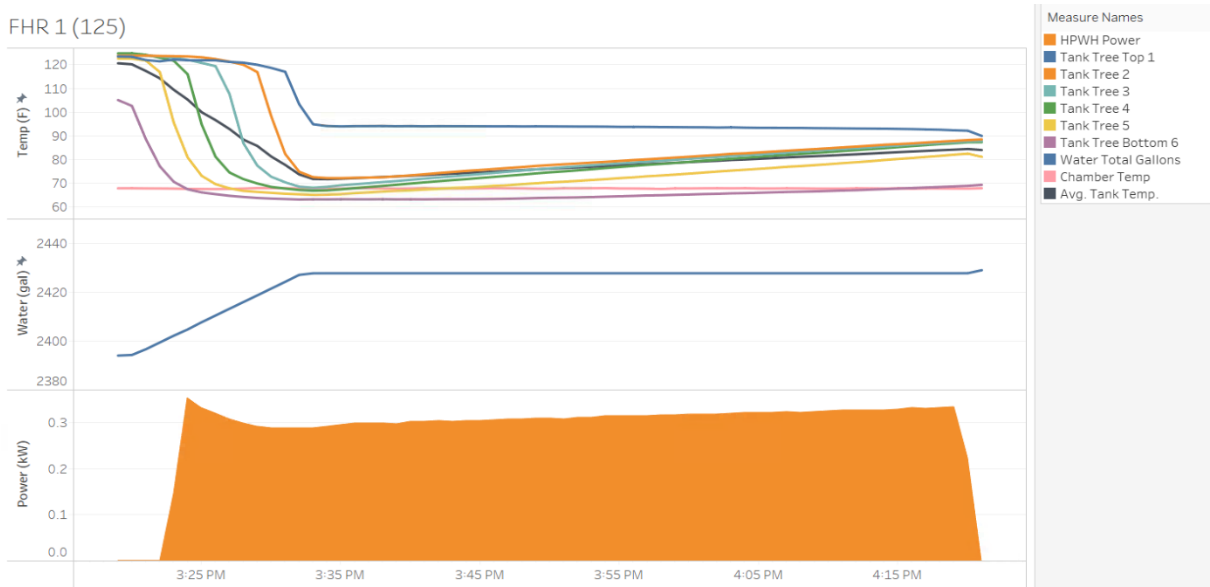

Figure 1 - Unit 1 FHR Test

Next, the same two tests were performed, however, the set point of the tank was increased to 140°F in order to evaluate the performance of the mixing valve. The standard FHR with a higher tank set point initiated with an average tank temperature of approximately 134°F. While the standard requires the maximum outlet temperature to be between 125±5°F, there is no requirement on average tank temperature. The water at the top of the tank was above the 140°F setpoint, however the bottom of the tank was not as hot pulling down the average tank temperature. The unit was able to produce an extra 6.1 gallons to the first and only draw resulting in a total of 39.7 gallons. During this test, the peak power consumption was 0.430 kW with a total energy consumption of 0.295 kWh.

The cold climate test with the same higher set point performed almost identically to the previous test yet started with an average tank temperature almost 4°F higher. The first draw was able to produce 41.1 gallons within the first draw. The peak power consumption was 0.395 kW with a total energy consumption of 0.279 kWh.

The next four tests conducted were the UEF tests, conducted at the same conditions of each of four FHR tests mentioned above. As mentioned, the profile draw patterns are based on the units FHR result which classified this unit as a low-draw profile. The standard UEF test performed is a modified version with an 8-hour standby test conducted on a separate day. **Error! Reference source not found.** shows the roughly 11-hour testing period to give a visual aid to the results. During this test, 45.6 gallons were drawn from the tank causing the unit to recharge six times, minus a single defrost event. The peak power consumption landed at 0.432 kW with a total energy consumption of 1.738 kWh over the test period. EPRI calculated the UEF to be 3.5.

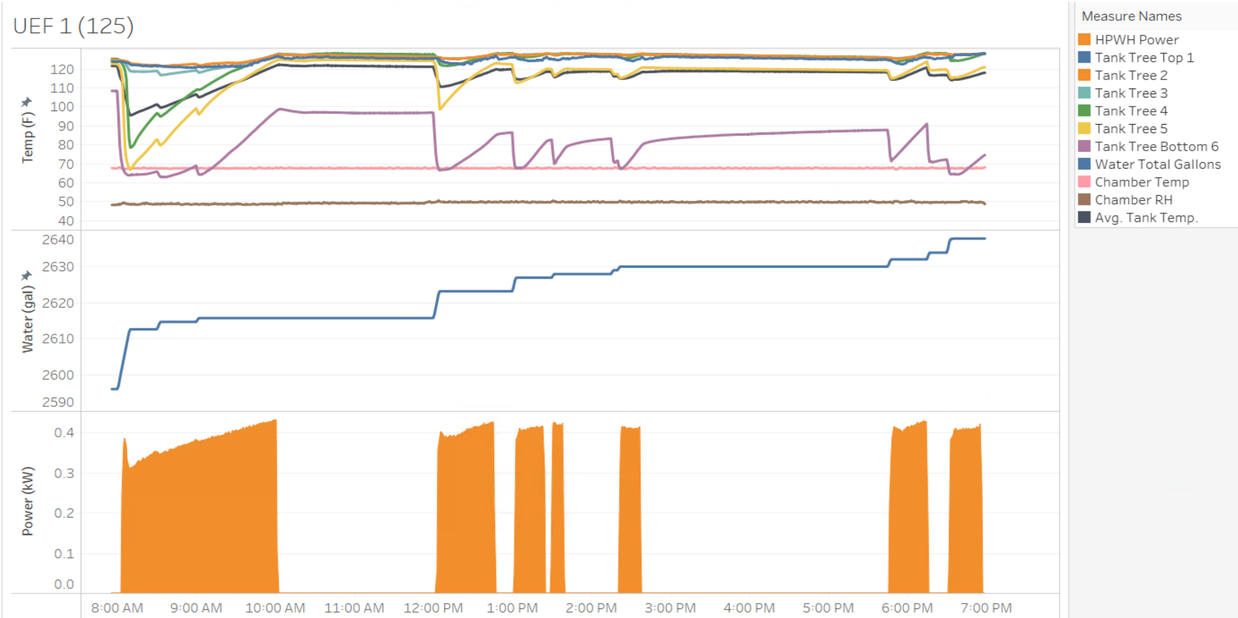

Figure 2 - Unit 1 Standard UEF – 125F Setpoint

The same test was conducted but with the cold climate conditions. The cold-climate tests are in line with NEEA's cold climate efficiency (CCE) requirements. CCE calculated are based on a weighted temperature bin system with full calculation requirements found in the Advanced Water Heating Specification Version 8.0 (NEEA 2022). During testing, it was apparent that the unit was charging for longer periods as the ambient temperature was much lower than previous, yet the unit only had to charge one extra time than before. The results of this test provided a UEF of 3.1, which while lower than our previous test still exceeds the published rating. This unit was rated to be Tier 2, a CCE of 2.3-2.5, however results concluded a CCE of 3.2.

The next test conducted was the standard UEF test with a 140°F setpoint. This test performed similarly to the last as the higher setpoint caused the unit to charge for longer periods of time, which in turn resulted in a UEF of 3.3. The peak power consumption was 0.481 kW, while the total energy consumption amounted to 2.081 kWh. The following test was the same but with cold climate conditions, and the results were unique from the previous. The unit initiated four long recharge periods, yet the second half of the recharge occurred much later in the test. This is most likely a result of the harsher conditions associated with cold climate testing as well as the heightened set point. The resulting UEF was 2.8.

Concluding the testing is the compressor cut-off test. The published temperature for this unit was said to be 37°F and upon incrementally decreasing the temperature of the psychrometric chamber, the compressor was able to work down until the published value. The test provided a peak power consumption of 0.378 kW.

Unit 2 Test Results

For Unit 2, only five tests were conducted on this unit as it is not equipped with a mixing valve as previously stated. This unit underwent the standard FHR and UEF test, the cold climate versions, and lastly the compressor cut-off test. Starting with the standard FHR test, the initial tank temperature sat at approximately 117°F before the first draw. During the first draw, the unit was able to produce 25.4 gallons of hot water before needing to recharge. Unlike Unit 1, Unit 2 has triple the compressor size and was able to recharge enough by the end of the hour to allow a second draw as shown in Figure 3. The second draw allowed the unit to gain an extra 24.2 gallons to the total resulting in an FHR of 49.6 gallons, slightly below the manufacturer rating of 51 gallons. The peak power consumption for this test was 1.216 kW and total energy consumption reached 1.004 kWh.

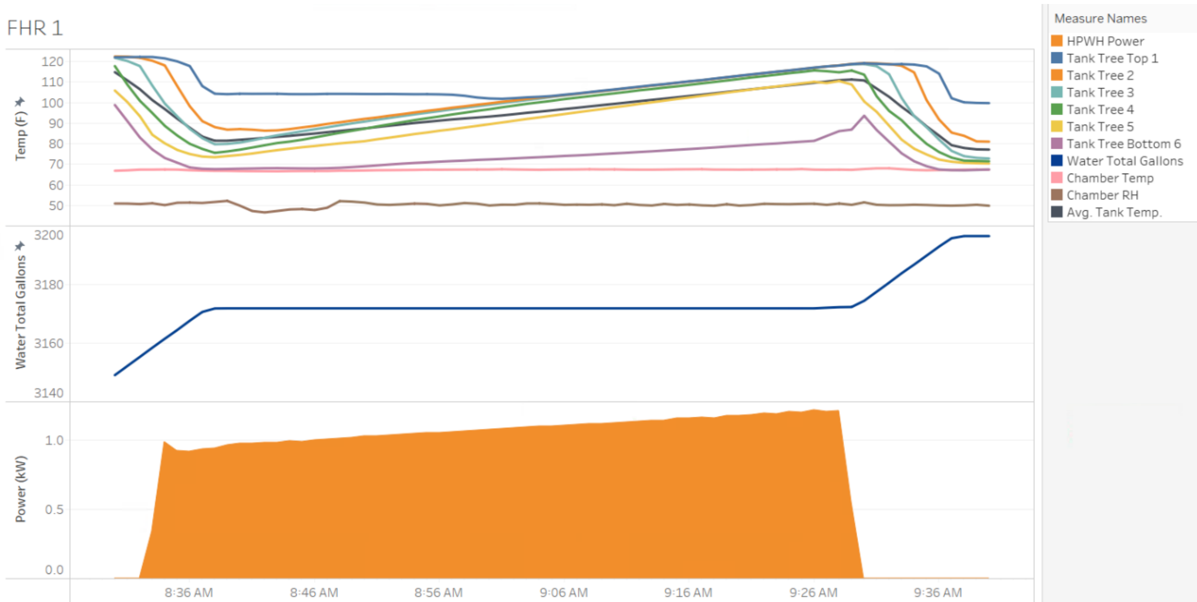

Figure 3 - Unit 2 Standard FHR

The cold climate version of this test only produced a total of 24.7 gallons, all provided by the first and only draw. Despite having a larger compressor, the climate conditions made it difficult for the HPWH to recharge within the hour. This test reached a peak of 0.990 kW in power consumption and 0.802 kWh in total energy consumption.

During the standard UEF test with the low-draw pattern, 39.9 gallons were drawn over the testing period causing the water heater to reheat five times briefly. Upon calculating the UEF, EPRI's results showed a UEF of 2.9, just 0.1 shy of the manufacturer rating. The peak power for this test was 1.179 kW with the total energy consumption being 1.832 kWh.

The cold climate UEF showed the consequence of the harsher environment conditions as the UEF was calculated to be 2.6. The unit performed very similar as the main difference was the unit had a cycling event in the beginning and the unit needed to charge slightly longer than before. The peak power consumption was recorded to be 1.084 kW and the total energy consumption to be 2.706 kWh. Unit 1B is rated to be Tier 3 for NEEA's CCE ranking, this equates to a CCE of 2.6. Based on EPRI's test results, the CCE was calculated to be 2.7.

Lastly, the unit's published compressor cut-out temperature is 37°F, however, EPRI was able to get temperatures down to as low as 31.7°F before the unit shut off. The compressor cut-off test provided a peak power of 1.059 kW. Overall, the unit performed as expected during the FHR and UEF tests and exceeded compressor cut-off expectations.

Unit 3 Test Results

Unit 3 underwent seven different tests, as not only is it the only unit equipped with strip heat and a larger tank size but also has an internal mixing valve like Unit 1. All tests presented on this unit were conducted in heat pump mode, despite offering an electric mode using the two 900W elements. The first test conducted was the standard FHR, which when set to the standard 125°F setpoint, began with an average internal tank temperature of 139°F. This shows how the use of the electronic mixing valve allows the product to store at higher tank temperature. The first draw was able to provide 75.65 gallons of hot water in the first draw, meeting the 76-gallon published value for this test. The unit was not able to recharge enough to allow a second draw, yet the first draw was able to meet the expected results. The peak power consumption for this test was 0.284kW, while the total energy consumption was 0.233 kWh.

The cold climate FHR performed similarly as it started with almost the same average tank temperature and produced an FHR of 73.65 gallon, all gained from a single draw. The peak power and total energy consumption were slightly lower due to the difficulty of the harsher conditions resulting at 0.264 kW and 0.214 kWh.

The following two tests performed were both FHR tests performed with a user setpoint of 140°F instead of 125°F. The FHR with the heightened setpoint produced 65.45 gallons, a little over 10 gallons short of the previous, in the first and only draw. Despite the test starting with an average tank temperature of 145.5°F, 5.5°F higher than the setpoint, the temperature of the outlet water dropped quicker than the previous even with the mixing valve. The peak power for this test was 0.304 kW and the total energy consumption amounted to 0.253 kWh. The cold climate FHR with a 140°F setpoint provided a lower result at 63.9 gallons, which is to be expected based on the previous test as well as the frigid conditions of the water and chamber temperatures. The power peak occurred at 0.264 kW and the total energy consumption was 0.215 kWh for this test.

The larger storage tank resulted in the use of the high-profile draw pattern for the two UEF tests. The first UEF test, shown in **Error! Reference source not found.**, started off with a large water draw of 28.25 gallons causing the tank to start charging almost immediately. The unit recharged three times over the testing period, the longest duration occurring in the beginning due to the first large draw. The UEF was determined to be 3.4 based on EPRI's testing, slightly exceeding the published result of 3.2. The peak power consumption was 0.488 kW and a total energy consumption of 3.623 kWh during the test. The cold-climate UEF produced lower results with a UEF of 2.5. Due to the colder climate, the HPWH remained charging almost the entire duration of the test and resulted in lower efficiency. This test reached a peak of 0.448 kW in power consumption and used a total energy consumption of 4.849 kWh. The CCE rating for this unit is rated to meet NEEA Tier 3 requirements which equates to 2.7. When calculating the results, EPRI determined a CCE of 2.8.

The final test was a compressor cut-off test, where the rated cut-out value was 37°F. Upon the first twenty minutes of this test the compressor slowly began to ramp down until plateauing out at 0.5 kW. The inlet air temperature reached 24.5°F before the compressor cut-out and the resistive heat enabled.

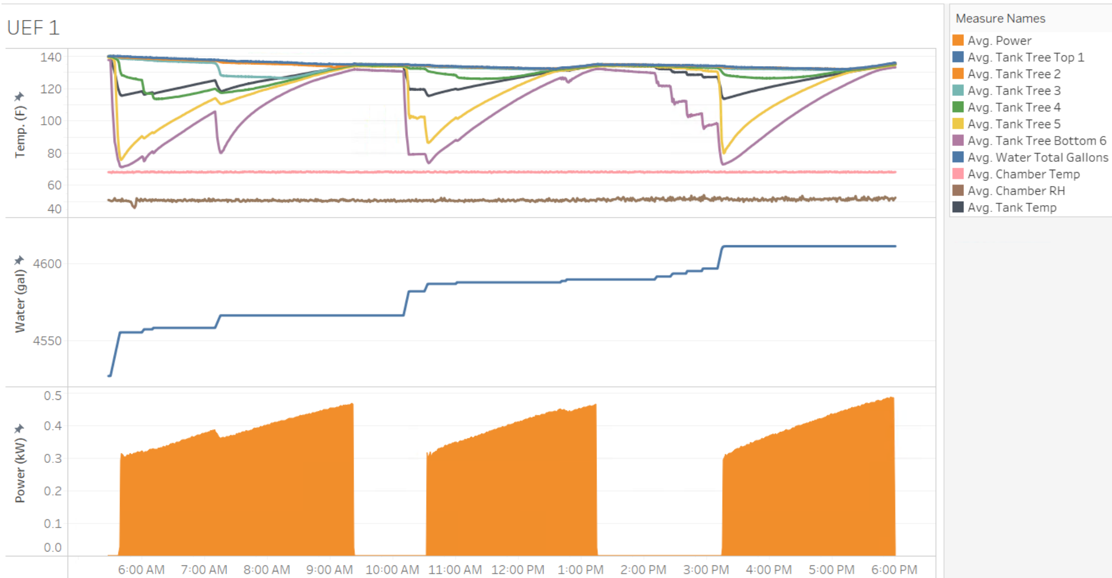

Figure 4 - Unit 3 Standard UEF

Overall Laboratory Test Results Summary

Tables 2-4 below show a summarized view of the rated test results discussed above. The tables show the values determined during the laboratory testing for each unit.

Table 2 - Comparison of Lab Testing to Manufacturer Rating

	Unit 1 – 40 gal		Unit 2 – 40 gal		Unit 3 – 66 gal	
Test Conducted	FHR (gal)	UEF (-)	FHR (gal)	UEF (-)	FHR (gal)	UEF (-)
Rated	45.0	2.8	51.0	3.0	76.0	3.2
Standard FHR	33.6	3.5	49.6	2.9	75.7	3.4
FHR with 140°F setpoint	39.7	3.3	24.7	2.6	73.7	2.5

Table 3 - Standard CCE Result Comparison

Standard CCE (-)	Unit 1	Unit 2	Unit 3
Rated	2.3	2.7	2.7
Result	3.2	2.7	2.8

Table 4 - Compressor Cut-Off Results Comparison

Compressor Cut-Off	Unit 1	Unit 2	Unit 3
Rated	37°F	37°F	37°F
Result	37°F	32°F	25°F

Example Field Installations

In addition to the laboratory evaluation, a follow-on project demonstrated the performance of 120V HPWHs in two light commercial applications in Southern California. Water heating is 5% of commercial water heating, but approximately 43% of this comes from buildings under 50,000 sq ft (EIA 2022). This demonstration study was conducted with the intent of evaluating energy savings of 120V HPWHs in light commercial applications, so having existing electric resistance water heaters was a criterion for host site selection. The following table provides the specs of the units and the demonstration sites. The existing electric water heaters were used to meet hot water loads from a bathroom and two break room sinks at site 1, and a bathroom at site 2. The water heater for site 1 was located in a service closet, while the water heater for site 2 was located outdoors in a garage. A summary of the host sites is shown in Table 5.

Table 5. Host sites for 120V HPWH demonstration in light commercial applications

	Site 1	Site 2
Business Type	Hardware Store	Auto Tech Shop
Hot Water Service (baseline electric resistance)	Two bathroom sinks and two break room sinks	One bathroom sink
Hot Water Service (120V HPWH)	Two bathroom sinks and two break room sinks	One bathroom sink and one break room sink
Existing water heater	Resistance Hot Water Heater (40-gal tank)	Floor mounted on-demand electric water heater
120V HPWH	Multi-outlet circuit (50-Gal)	Individual circuit (50-Gal)

The project team installed monitoring instrumentation at both sites for 3 months prior to installing the HPWH. This was done to establish the baseline hot water consumption and ensure the 120V products would be suitable for the hot water demands. Table 6 summarizes the measurements that were taken at 1-minute intervals. A sample week of the baseline data is shown in Figure 6, which includes the inlet and outlet water temperatures, power consumptions, and water flow rates. As both sites are commercial businesses, the hot water consumption is largely during the weekdays (May 8 – May 13) with very little hot water demand on the weekends (May 14 – May 15).

The power consumption for both sites is constant when the water heaters are operating the heating element, with 3.5 kW (208V) for site 1 and 1.3 kW (120V, on-demand) for site 2. For both sites, the hot water outlet temperature reached 120°F when there was hot water load.

Table 6. Instrumentation list for baseline monitoring

Measurement	Units
Power	kW
Water Flow Rate	gpm

Measurement	Units
Water Inlet Temperature	°F
Water Outlet temperature	°F
Ambient Temperature	°F
Ambient Relative Humidity	°F

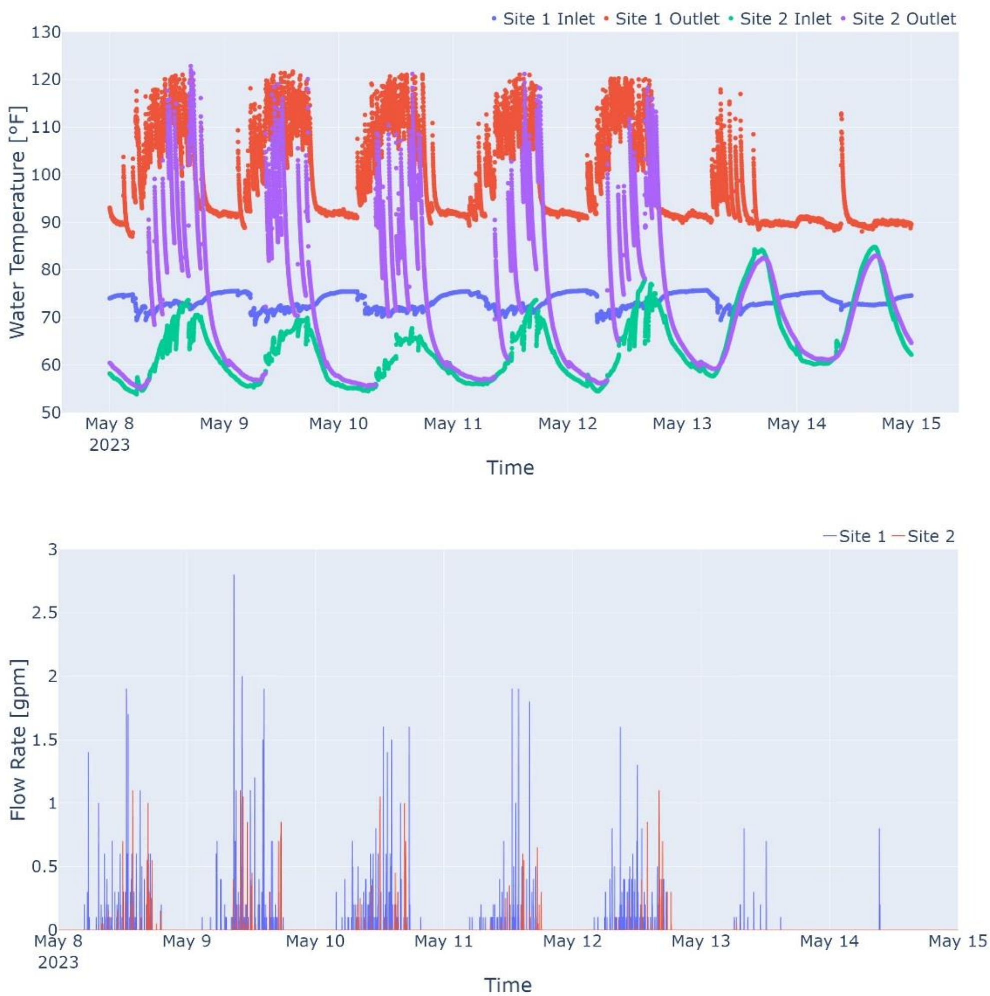

Figure 5. Baseline resistance water heater operation over a typical week. Water inlet and outlet temperatures (top) and hot water flow rate (bottom). Source: EPRI.

After 3 months of baseline monitoring, the 120V HPWH products were installed, replacing the baseline electric resistance water heaters at each site, as shown in Figure 7. Site 1 received a 50-gallon shared circuit model, and site 2 received a 50-gallon dedicated circuit model. While the 40-gallon was more appropriate for the low hot water load, it was unavailable at the time of purchase and since there were no space constraints, the 50-gallon was installed. The instrumentation used for baseline monitoring was transferred to the 120V HPWH during installation to ensure consistent measurement quality. At site 1, the 120V HPWH was used to meet the same load as the baseline. At site 2, the 120V HPWH was used to meet the baseline hot water load (1 bathroom sink) and an additional break room sink due to the new increased hot water storage. The project team did not provide any instructions concerning how to use the water heater or what setpoint to operate at so that researchers could observe how users would interact with the product naturally. There was one challenge during the installation with site 1's HPWH. The HPWH has a water leakage detector around the bottom of the unit which controls a water shut-off valve. The HPWH was installed in a utility closet which contains a sink for cleaning and is also used to store cleaning supplies. It was easy for water to splash onto the leak detector when the host site employees clean using the mop and sink. This caused the HPWH to shut off the water valve and required a technician to reset the unit. This issue has been resolved after the sensitivity of the leakage detector was communicated to host site employees.

Figure 6. 120V HPWH installation at demonstration site 1 (left) and 2 (right). Source: EPRI

The measured data revealed little changes post-installation for hot water demand. For site 2, there was no significant change in hot water usage even though the 120V HPWH is used to meet the load from the additional break room sink. The hot water outlet temperature was at 120°F when there was hot water demand, which was consistent with the baseline data. The inlet water temperature was also consistent, with site 1 at ~75°F and site 2 varying from 55°F – 70°F. The peak power draw of the 120V HPWH was around 0.4 kW for site 1, and 1.2 kW for site 2. The difference in peak power is due to site 1 having a shared circuit model and site 2 having a dedicated circuit model with larger compressor.

As of the authorship date of this paper, the 120V HPWHs have been operational for seven months in the field. There have been no complaints or issues from the host site participants with regard to hot water temperature availability.

Figure 8 shows a summary of the field performance data using daily COP at both sites. The daily COP can be a useful metric to evaluate HPWH efficiency since it aggregates the daily amount of useful heat provided in hot water and the daily energy consumption. The left plot shows the daily COP as a function of the daily hot water consumption. The result from both sites shows a correlation between these two variables, with daily COP increasing with daily hot water usage. This can largely be attributed to the low amount of hot water usage, and HPWHs are likely just cycling on days with very low consumption which results in lower efficiency. When compared to the efficiency of the baseline equipment with a maximum achievable COP of 1, the HPWHs show superior efficiency when the hot water consumption is above 10 gallons per day. The average COP thus far for site 1 has been 1.31 and the average COP for site 2 has been 1.54.

While this is unlikely to yield substantial savings for the host site participants due to the low amounts of hot water usage, the results still reflect the efficiency gains compared to the baseline resistance water heaters.

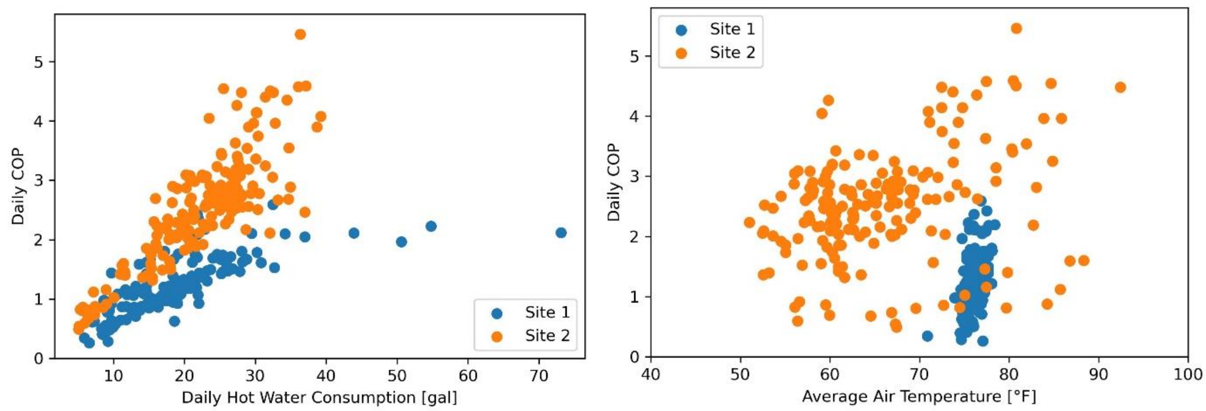

Figure 7. Daily COP at both demonstration sites correlated with daily hot water consumption (left) and average air temperature (right). Source: EPRI

HPWH efficiency is also affected by the ambient temperature. The right plot shows the daily COP as a function of the average air temperature surrounding the HPWH. For site 1, the air temperature is in a narrow band between 75°F and 78°F since the unit is located in a utility closet. For site 2, the air temperature shows a much larger range between 50°F and 90°F since it is located in an outdoor garage. The results show no significant correlation between the air temperature and the daily HPWH COP. This can be due to the low amount of run time per day, or a mismatch between the daily average air temperature and the air temperature during runtimes. The major concern with respect to air temperature is the loss of heating capacity at low air temperatures. This is unlikely for both demonstration sites due to the mild and warm weather in Southern California.

Figure 9 shows the daily hot water consumption, with site 1 typically consuming less than 20 gallons per day and site 2 typically consuming less than 30 gallons per day. The amount of hot water consumed is much less than the tank capacity of both HPWHs, and therefore, the compressor only runs sporadically to maintain the tank temperature. Short runtime and cycling can reduce the efficiency of the units compared to sustained steady state operation. While the COP values shown previously provides efficiency benefits over electric resistance water heaters, the HPWHs may not be the most optimal choice economically when factoring in the high first costs and low water usage on site. Future studies can certainly consider other light commercial settings with higher hot water demands to determine suitable sizing. EPRI has explored wall-mounted HPWHs from international vendors that may be more suitable for low-water draw applications. These systems are offered in storage volumes as low as 20 gallons (EPRI 2020).

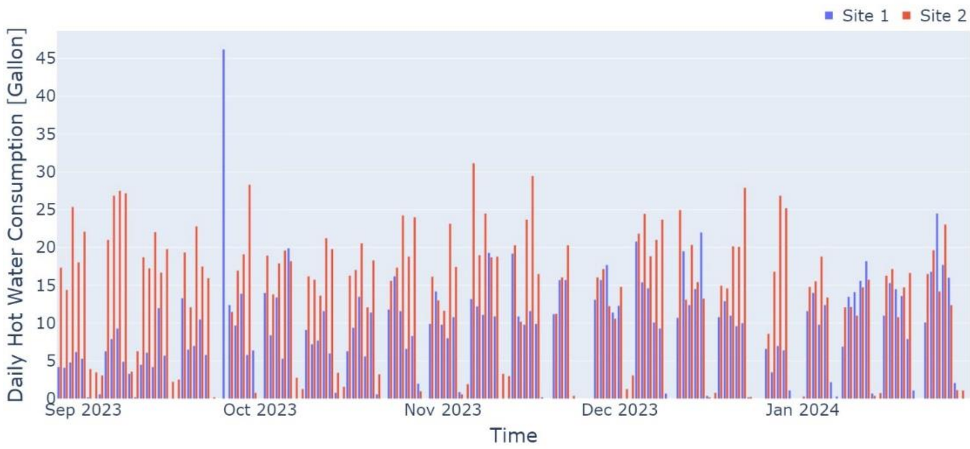

Figure 8. Daily hot water consumption for both demonstration sites. Source: EPRI

This field demonstration is ongoing, and the team will continue to monitor the 120V HPWH for a total of 12 months. The results thus far show the 120V HPWHs satisfying all hot water demand on site, with no significant deviation in outlet temperature from the baseline resistance water heaters. One learning to note specific to commercial buildings is the sensitivity of the water leakage detector, which may cause unexpected water shutoff. This is particularly important if the unit is installed in close proximity to sinks or other water sources, which is common in commercial applications. This demonstration has oversized the 120V HPWHs due to limited product availability, while this helps to prevent hot water shortages, it may have undesirable effects on the units' efficiency.

When to choose 240V vs 120V HPWH?

Unlike the field demonstration described above, most people will not be given a free HPWH for a demonstration. There are now a variety of 120V and 240V HPWHs that can meet customer needs. The homeowners or facility managers will have to weigh various factors before deciding what water heater to install, such as product availability, first costs, rebates and tax credits, and local codes. The decision of whether to install a 120V HPWH or a 240V HPWH is now an additional option that most users will not be aware of and need guidance on how to make the best decision. Contractors will also need to be trained in how to help customers make this decision.

As described in this paper, different manufacturers and models have various features to consider, but the voltage decision needs to happen at the beginning. This decision will need to be guided by a trained contractor, especially when replacing a natural gas water heater as there are several factors to consider. The decision tree in Figure 10 shows a high-level thought process to guide this decision. There may be unusual circumstances that also guide the decision (such as space limitations or available incentives), but regarding electrical configuration, this decision tree can be used as a tool.

First, the water heater that is being replaced will play a key role in guiding the decision. If replacing an electric resistance water heater, the site will already have a dedicated 240V circuit at the water heater making the 240V solution the easiest replacement and one that has full size backup resistance elements in case of large water draws or heat pump malfunction. If replacing a natural gas-powered tankless water heater or natural gas tank with a power-vent, then a 120V circuit already exists near the water heater.

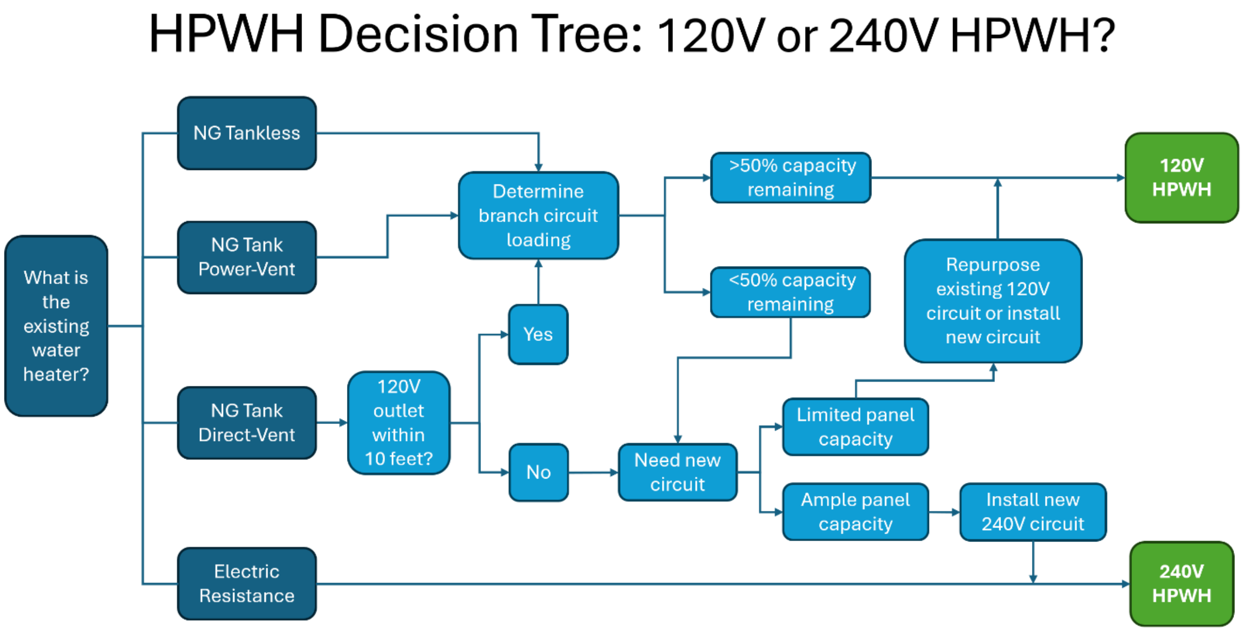

Figure 9. HPWH Decision Tree

The more difficult situation is when replacing a natural gas tank with direct-vent (unpowered) which has been the lowest cost natural gas water heater type and therefore the most prevalent. In this situation, there may or may not be a nearby 120V outlet depending on where the water heater is located in the house. If there is an outlet within 10 feet (the length of cords on 120V HPWHs), then that outlet can likely be used depending on the branch circuit loading. If there is not an existing outlet nearby, then a new circuit will be needed. This can take the form of a new 240V circuit from the panel or a repurposed/extended existing 120V circuit. Each option will have different costs and levels of difficulty depending on the distance to the electrical panel.

For each natural gas water heater replacement, there needs to be an accounting of what loads are on an existing circuit. Per NEC Article 210.23 entitled *Permissible Loads, Multiple-Outlet Branch Circuits*, "in no case shall the load exceed the branch-circuit rating." Furthermore, 210.23(A)(2), "the total rating of utilization equipment fastened in place, other than luminaires, shall not exceed 50% of the branch-circuit ampere rating." A water heater is considered a "fastened in place" piece of equipment and therefore must not represent more than 50% of the circuit rating. Once the circuit loading is determined, the decision of whether a 120V or 240V HPWH makes sense can progress.

Another key factor is the state of the electric panel. Is the panel at or near capacity? Or is there sufficient room for a new 240V circuit? Are any other electric technologies expected to be installed in the near future such as an electric vehicle charger or heat pump? The answers to these questions will impact which option makes the most sense. Furthermore, how much time the homeowner has to make changes will drive the decision. In an emergency replacement scenario, any significant electrical upgrades will likely be turned down due to the urgency of getting hot water restored.

Additional factors that are not considered in this diagram are changes that would need to be performed for either 120 or 240V HPWHs, such as the addition of a louvered door or ducting inlet and/or outlet air to another space to improve performance.

Conclusion

New 120V HPWH offerings have much promise to expand the electrification of water heating. While there are limitations in terms of performance, upsizing when possible could minimize any customer comfort impacts. However, upsizing comes with an increased cost. 240V HPWHs should still be the primary choice for electric water heating whenever possible if performance and comfort are of concern. The efficiency and first-hour rating of 240V HPWHs currently exceeds that of 120V HPWHs and with the inclusion of full-size backup resistance elements, customers can have a higher guarantee of hot water. That being said, there are many good use-cases for 120V HPWHs, especially pertaining to the replacement of direct-vent natural gas water heaters. The easier electrical install will further enable efficient water heating to expand into more applications. In light commercial applications with low hot water demands, the 120V HPWH can be a simple decarbonization solution to transition away from natural gas. However, if the commercial buildings do not have high water demands, the efficiency of HPWHs will not be up to the ratings. EPRI will continue to scout, test, and demonstrate new water heating technologies to evaluate their effectiveness for various applications.

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