Evaluation of 120V Heat Pump Water Heaters in Light Commercial Environments

Aaron Tam, Ammi Amarnath, EPRI
Rafik Sarhardian, Southern California Edison
Chris Mellen, Ron Kliewer, Kliewer and Associates

ABSTRACT

New 120V heat pump water heaters (HPWH) are being introduced to the market, offering a simple and energy-efficient alternative to traditional water heating technologies. While these units are often considered for residential use, their potential in light commercial buildings—such as offices, retail spaces, and small multifamily properties—warrants closer examination. For facility managers and business owners, the appeal of reduced energy consumption and simplified electrical requirements must be balanced against concerns about hot water availability, recovery times, and installation constraints. This paper will provide real-world performance, installation challenges, and customer experiences of 120V HPWHs in three different light commercial environments. The assessment will focus on how these systems perform under typical usage patterns, compare both natural gas and electric resistance baselines, and identify best practices for deployment. The findings will support informed decision-making for energy and environmentally conscious retrofits in light commercial buildings.

Introduction

Heat pump water heaters (HPWH) represent a transformative advance in the realm of energy-efficient technologies. Designed to extract heat from the air and use it to heat water, these systems offer a significant reduction in energy consumption compared to traditional electric resistance water heaters (ERWH). In 2022, market penetration in the U.S. for HPWHs was roughly 3%. (EIA, 2022) This statistic indicates that the market is ripe for substantial growth. In 2018, water heating accounted for 5% of end use energy consumption in commercial buildings (EPA, 2018). While this represents a minor fraction of energy use, it accounts for about 339 trillion BTUs, a substantial amount of energy.

With advancements in materials, compressor efficiency, and refrigerant technology, the size, cost, and performance of heat pumps improved dramatically. The introduction of 120-volt (120V) systems marked a significant milestone in this evolution, offering a compact and affordable solution for smaller households and retrofit markets. The emergence of 120-volt applications has expanded HPWHs' accessibility and adaptability, enabling broader use in homes and facilities where standard 120V power is prevalent. The innovation of 120V HPWHs has broadened HPWH usage across various settings:

- **Residential Use:** For homeowners, 120V HPWHs provide an energy-efficient solution without the need for electrical upgrades. These systems are particularly suited for smaller homes, apartments, and condominiums where space and power constraints exist.

- **Commercial and Institutional Settings:** In offices, schools, and small businesses, 120V HPWHs serve as practical alternatives for point-of-use water heating. They can be integrated into existing infrastructure with minimal disruption.
- **Off-Grid and Temporary Installations:** In remote or off-grid locations, 120V models can operate on portable generators or solar power systems, ensuring sustainable water heating in challenging environments.

Project Objectives

HPWHs present a significant potential to efficiently decarbonize water heating, and many utility programs already offer incentives to encourage their adoption. The same is true for the 120V products, however, they can have drastically different capabilities and limitations from traditional products due to the different designs and controls. While manufacturer provided data may be publicly available, manufacturers do not often provide a complete picture of how such technologies will operate in the field. For example, the controls of heat pumps are often "black boxes" for utilities. Anecdotes from field trials suggest these technologies can experience excess cycling or turn on resistance elements even when they're not required. As HPWHs become more widely available and accessible, comprehensive assessments are critical to maximizing their impact across climate zones and building types.

This study presents a field evaluation of 120V products with a focus on system efficiency and customer experience in commercial applications. The use of 120V products in this setting is of particular interest, as the predominant technology in many small load applications (e.g. bathrooms, break rooms…) is small form factor "low-boy" resistance water heaters. Many traditional heat pump water heaters with larger storage capacities may not be a good fit for direct replacements, but the smaller capacities of 120V products may be suitable. Their lower recovery rates may still be a good match for these low load applications. Many studies are already investigating the residential use of 120V HPWHs, this study aims to complement these ongoing efforts and consider additional applications of these technologies. The overall objectives are as follows:

- Evaluate the efficiency of emerging 120V HPHWs compared to electric resistance water heaters at similar operating conditions
- Evaluate emerging 120V HPWHs and their ability to provide hot water in small commercial applications with lower emissions than electric resistance water heaters
- Identify small applicable commercial applications (e.g., breakrooms and bathrooms) of the 120V HPWH and potential barriers in adoption.

Product Specifications

At the time of this study, 120V HPWH products are only offered by a limited number of manufacturers in the U.S. Table 1 provides details on the three different products that were demonstrated in the study. It should be noted that during the initial site scouting phase of the project, only Product A and Product B were available on the market. Product C was included in the project after the evaluation with Product A and B was already underway.

Table 1. 120V HPWH Product Specifications.

	Product A	Product B	Product C
Nominal Capacity	50 gallons	50 gallons	66 gallons
Refrigerant	R-134a	R-134a	R-513a
UEF	3.0	3.75	3.2
UEF First Hour Rating	55 gallons	52 gallons	76 gallons
Compressor Capacity	4200 Btu/h	12000 Btu/h	Not specified
Backup heating	None	None	900W element

Demonstration Site Selection

This project evaluated the three HPWH products in three different light commercial applications, summarized in Table 2 and shown in Figure 1. The initial site scouting involved reaching out to several commercial business owners to gauge their interest in participating in this study. EPRI and its mechanical contractor made visits to the potential sites and discussed the details with the owners.

Table 2. Host Sites For 120V HPWH Demonstration in Light Commercial Applications.

	Site 1	Site 2	Site 3
Business Type	Hardware Store	Auto Tech Shop	Restaurant
Hot Water Service (baseline)	Two bathroom sinks and two break room sinks	One bathroom sink	Two bar sinks and two bathroom sinks
Hot Water Services	Two bathroom sinks and two break room sinks	One bathroom sink and one break room sink	Two bar sinks and two bathroom sinks
Existing water heater	Resistance Hot Water Heater (40-gal tank)	Floor mounted on-demand electric water heater	Gas Water Heater (50-gal tank)
120V HPWH	Product A - Multi-outlet circuit (50-Gal)	Product B - Individual circuit (50-Gal)	Product C - Individual circuit with resistance heaters (66 Gal)

Figure 1. Installed 120V heat pump water heaters at site 2 (left) and site 3 (right). *Source*: EPRI.

Baseline M&V Installations; Instrumentation & Configuration

The project team installed monitoring instrumentation at the sites for 1-3 months for baseline monitoring. This was done to establish the baseline hot water consumption and ensure the 120V products would be suitable for the hot water demands. Table 3 summarizes the measurements that were taken at 1-minute intervals, and Figure 2 shows a simplified schematic of the instrumentation locations on the HPWH. As the sites are commercial businesses, the typical hot water consumption occurs during the weekdays with very little hot water demand on the weekends except for Site 3 which has a 7-day operation schedule.

Table 3. Instrumentation Table for Baseline Monitoring Points.

Measurement	Units
Power	kW
Water Flow Rate	gpm
Water Inlet Temperature	°F
Water Outlet temperature	°F
Ambient Temperature	°F
Ambient Relative Humidity	%

The EPRI Data Boxes and the instruments were installed and recorded data for both pre and post installation. Baseline and post installation data was transmitted by cellular modem in the Data Box to the EPRI cloud server and stored. An exception was made for Site 3 where an existing gas water heater was installed so power readings were not recorded for baseline data, but temperature and flow readings were captured and recorded.

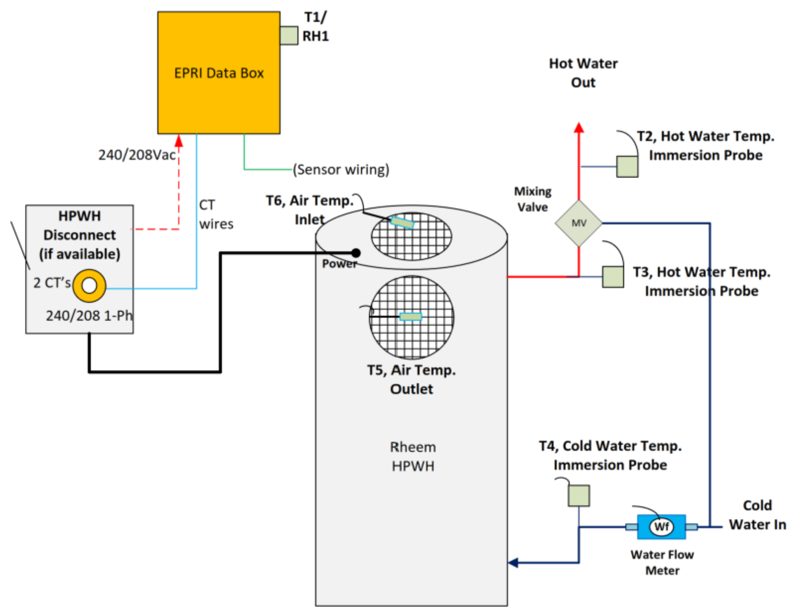

Figure 2. Baseline Inlet/Supply Water Temperatures. *Source*: EPRI.

Baseline Data

A sample of the baseline data is shown in Figure 3 for all three sites, which includes the inlet and outlet water temperatures, and water flow rates. Sites 1 (dark blue) and 2 (green) showed baseline outlet temperatures peaking at 120°F. Site 3 showed the baseline outlet temperature (orange) was consistently high, approaching 180°F which presented a scalding hazard to users. Also note that for Site 3, inlet supply water temperatures (light blue) became periodically high, sometimes over 120°F for short periods of time. This phenomenon can be traced back to the usage of bridge valves at the bar sinks and restroom sink fixtures. The bypass through these bridge valves from the hot water supply (very high temperature) finds its way back to the water supply to the water heater. The response time for bridge valves is relatively slow, allowing excessive bypass water unnecessarily preheated the cold water supply.

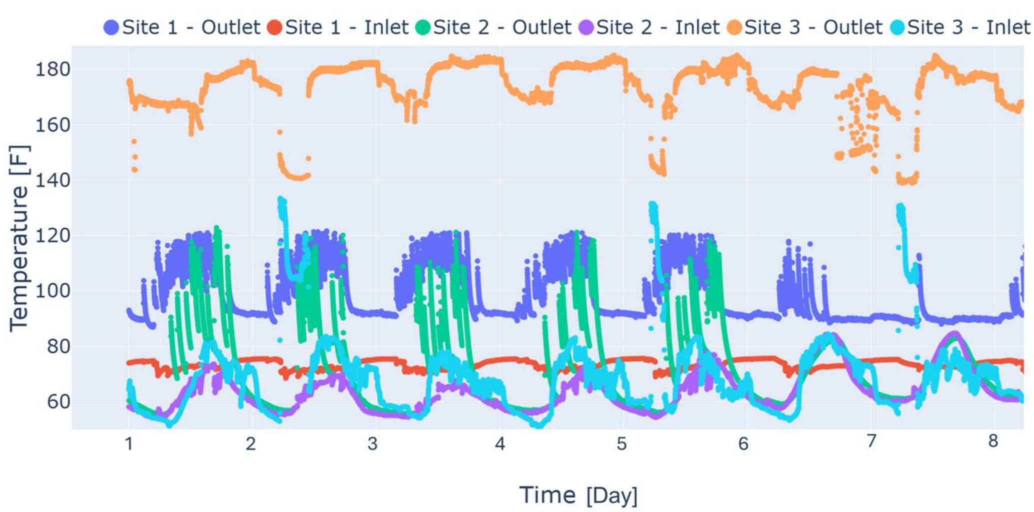

Figure 3. Baseline Inlet/Supply Water Temperatures. *Source*: EPRI.

As can be observed from Figure 4 below, the daily hot water consumption for all sites varies significantly. Note while Site 1 and 2's sample baseline data are collected from the same time period, a different season was used as the baseline data for Site 3 due delays related to site re-allocation. Sites 1 & 2 (blue and red) represent lower hot water demands, at less than 60 gallons of water consumption per day and reflect a typical 5-day work week where water consumption is reduced to near-zero on the weekends. On the other hand, Site 3 (green) represents a significantly greater consumption due to longer operation schedules (seven day) and higher demands due to a more commercial setting. The water consumption at Site 3 exceeds 100 gallons per day regularly, which also reflects the higher recovery rate of the baseline gas water heater.

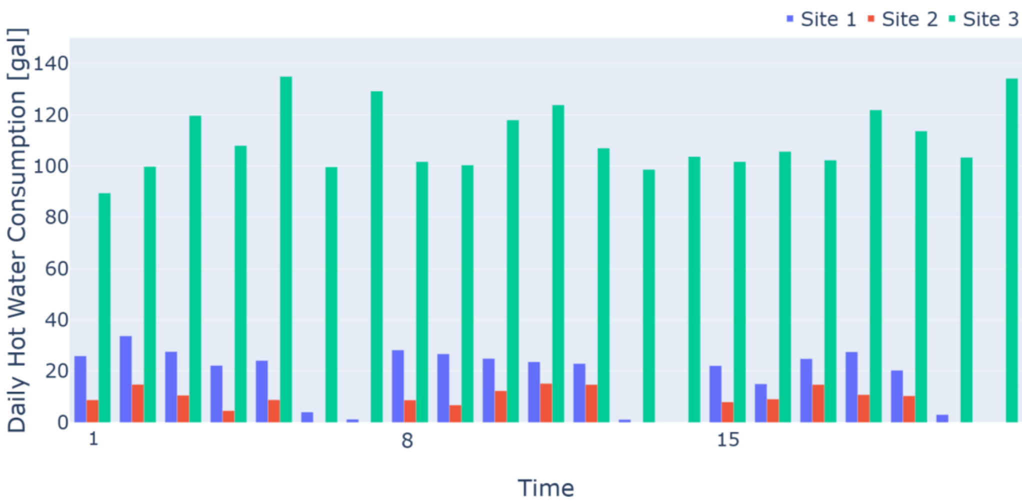

Figure 4. Baseline Daily Hot Water Consumption. *Source*: EPRI.

Field System Installation

For Site 1 and 2, the 120V HPWH products were installed after a 3-month baseline M&V period. For Site 3, this baseline period was shortened to 1.5 months. All the HPWH's used in this study were procured from local plumbing supply houses. There were some delays in receiving the equipment as these 120V units were newly released and had to be reserved on the assembly line. All the instrumentation used for baseline monitoring was re-used to monitor the 120V HPWH sites during installation to ensure consistent measurement quality. 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. Initially, the setpoint temperatures of the HPWH were all set at 120°F.

Site 1 Installation

Site 1 received Product A, a 50-gallon 120V shared circuit model. Shortly after installation at Site 1, a fully louvered door was retrofitted by the customer for the closet room where the HPWH is located to improve airflow and potentially boost efficiency. 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 basin leak detector when the host site employees used the sink. This caused the HPWH to shut off the water valve and required a technician to reset the unit. This issue was initially resolved after the sensitivity of the leakage detector was communicated to host site employees. This issue occurred a few times over the course of the monitoring period, and it can be resolved by power cycling the HPWH to minimize downtime (usually less than one day).

Site 2 Installation

Site 2 received Product B, a 50-gallon dedicated circuit model. While the 40-gallon model 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 model was installed. There were no issues with this product throughout the demonstration period.

Site 3 Installation

Site 3 received Product C, a 66-gallon unit with a 900W backup element. A 66-gallon unit was chosen for the larger hot water load determined at baseline. This unit also contains resistance elements for backup water heating if needed. However, these elements do not operate in conjunction with the heat pump, either heat pump mode or electric resistance mode must be chosen. Heat pump mode is the default mode and electric mode can only be initiated for up to 30 days where then it defaults back to heat pump mode.

After the installation of the HPWH, the team received a complaint from users since the water is not as hot as it once was at the bar sinks. This was confirmed with the M&V data, with the previous gas water heater providing water upwards of 160°F (without a mixing valve). The team explained to the users that the HPWH system is code compliant and provides hot water at 120°F with a code compliant mixing valve now installed, and that the previous system had to be tempered down at the bar sink (manually) to prevent scalding.

Intermittent challenges also arose during the demonstration period, where the HPWH struggled to restore tank temperature fully before the subsequent day's usage; as a result, bar sink supply temperatures occasionally dropped to approximately 100°F unless the HPWH was allocated a full 24-hour recovery period. Further investigation revealed that these issues predominantly occur during winter months following periods of low ambient temperatures. The root cause was traced to existing distribution piping routed through the attic, where most piping was poorly insulated located in a poorly insulated attic. Attic access was restricted during site selection due to asbestos exposure risks so the contractors could not inspect at the baseline characterization phase. Additionally, the presence of a distribution pump set for continuous operation with bridge valves at the plumbing fixtures exacerbated the problem during the cold nights despite no fixture loads. To address these challenges, the project team implemented several operational changes:

- Adjusted the recirculation pump schedule to initiate in the afternoon prior to peak lounge occupancy at 3:30 pm, thereby preventing nighttime transfer of recirculation load to the HPWH until warmer conditions in the afternoon and allowing the HPWH to fully recharge after lounge closure at 11:00 pm and completion of bar cleanup.
- Using the application software, the HPWH tank temperature was set to 150°F in electric mode to increase capacity during cold weather. Setting changes on the equipment itself are capped at 130°F unless first adjusted via the app; even then, the maximum limits was

150°F for electric and 145°F for heat pump mode. This higher setting was implemented for approximately 1 week and then returned to 130°F after the cold weather had passed.

- It is also noted that this hybrid model could not operate in a true hybrid mode like a 240V model, which can engage both immersion heaters and heat pump modes simultaneously.
- During periods with multiple consecutive events, the recirculation pump was turned off (manually) to enable complete tank recovery. This led to extended waiting times for hot water to reach the tap (approximately two minutes), however the tank was able to provide ~120°F water to the bar sinks using this strategy during the cold ambient conditions.
- Regular site visits were conducted to refine operational parameters and manage customer expectations regarding delivery of 120°F water at bar sinks. The occupants were accustomed to un-tempered 160°F+ supply from the previous gas heater (without a mixing valve) were informed about the revised and safer hot water temperatures.

Since the operation measures have been implemented, the hot water temperatures have met user expectations, and the unit was switched back into heat pump mode. The unit has since operated without further complaints in the spring and summer season. These operational measures, such as switching into resistance mode and reducing circulation pump runtime, may be employed in the future if similar issues arise. The owner of the building is planning a re-piping project in the future when funding becomes available, and better piping insulation is planned to be employed.

Field Evaluation Results

As of the authorship date of this paper, the 120V HPWHs have been operational for over 1 year in the field. The team made several visits to the sites throughout this demonstration period to interview the equipment operators and to check on the HPWHs. The air-filters were cleaned during each visit. The analysis presented in this report investigated several key metrics: the overall efficiency of the HPWHs, power consumption of these products, the delivered water temperatures, inlet water temperatures, and ambient air temperatures. This section provides the typical operating conditions of the products, along with the efficiency calculations and savings for the customers.

Hot Water Usage and Temperatures

The measured data revealed little changes in post-installation for hot water demand apart from the events at Site 3 discussed previously. Figure 5 below shows sample daily hot water consumption data for all 3 sites. Daily hot water consumption for Sites 1 and 2 showed no significant change in hot water usage from baseline, with typical consumption below 60 gallons on most days. On the other hand, Site 3 had significantly higher water consumption and was greater than the baseline data reflected. The baseline data showed consumption peaking at 140 gallons daily, while post retrofit data showed a peak daily demand approximately 100 gallons greater than baseline. In conversations with the site, there has been no significant changes in their operation or event schedule, so this change may reflect a difference in number of attendees at their events.

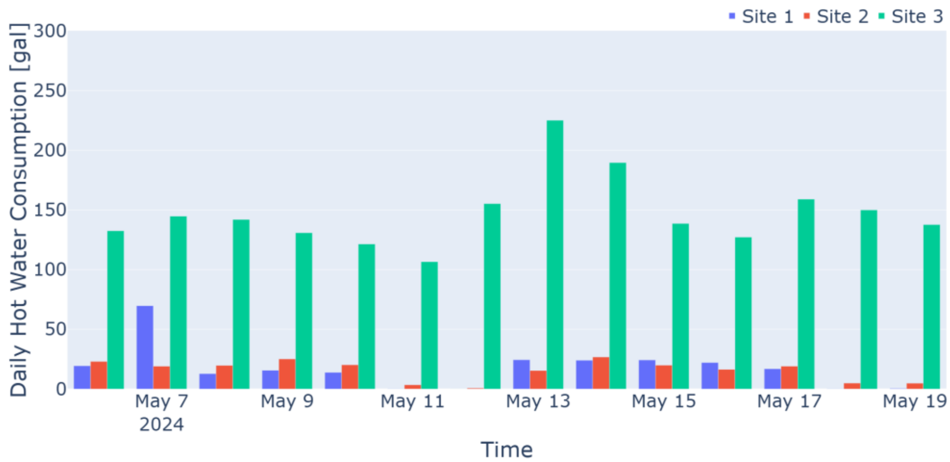

Figure 5. Daily Post Hot Water Consumption for All Sites-May 2024. *Source*: EPRI.

Figure 6 shows the inlet and outlet water temperatures for all 3 sites. The hot water setpoint temperature for all sites were initially set at 120°F, however, the setpoint for Site 3 was increased to 140°F after discussions with the site operators due to concerns of hot water shortages. The inlet water temperature was also consistent, with Site 1 at about 75°F, Site 2 varying from 55°F to 70°F, and Site 3 varying from 55°F – 70°F. This data aligns with expectations as Site 1 is located indoors in a centralized location surrounded by conditioned spaces. While Site 2 is located outdoors in a garage exposed to near ambient conditions and Site 3 is located inside an unconditioned mechanical room.

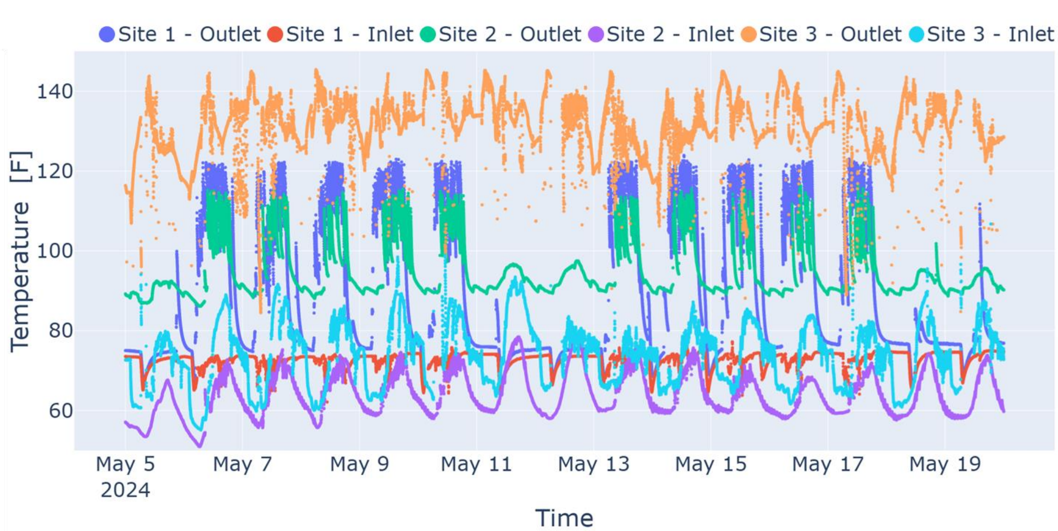

Figure 6. Sample Data of Daily Post Retrofit Hot Water Temperature Differences for All Sites. *Source*: EPRI.

Figure 7 shows the peak power draw of the 120V HPWHs for this sample period was approximately: 0.4 kW for Site 1(blue), 1.2 kW for Site 2 (red), and 0.5 kW for Site 3 (green). The differences in peak power draw is due to Site 1 (shared circuit model) and Site 3 (shared circuit model with resistance heaters) having smaller compressors while Site 2, a dedicated circuit model, was fitted with a larger compressor. The trends also show the while the HPWHs at Site 1 and Site 2 are likely oversized for their application, Site 3's HPWH is close to being undersized. The power consumption at Site 1 and Site 2 are very sporadic and suggests the HPWHs are mostly cycling in their operation, where the compressor is turned on for the minimum duration for safe operation then shutting down. This also means the tank temperatures are likely at setpoint most of the time. On the other hand, Site 3's HPWH is operating nearly continuously. There are minor gaps in power consumption, but the HPWH is operating for most of the day. This means the equipment is struggling to fully recover the tank temperatures between periods of hot water usage. The behavior shown in the data also agrees with the feedback from the site operators, who mentioned that the water temperatures typically starts to decrease at the end of each day.

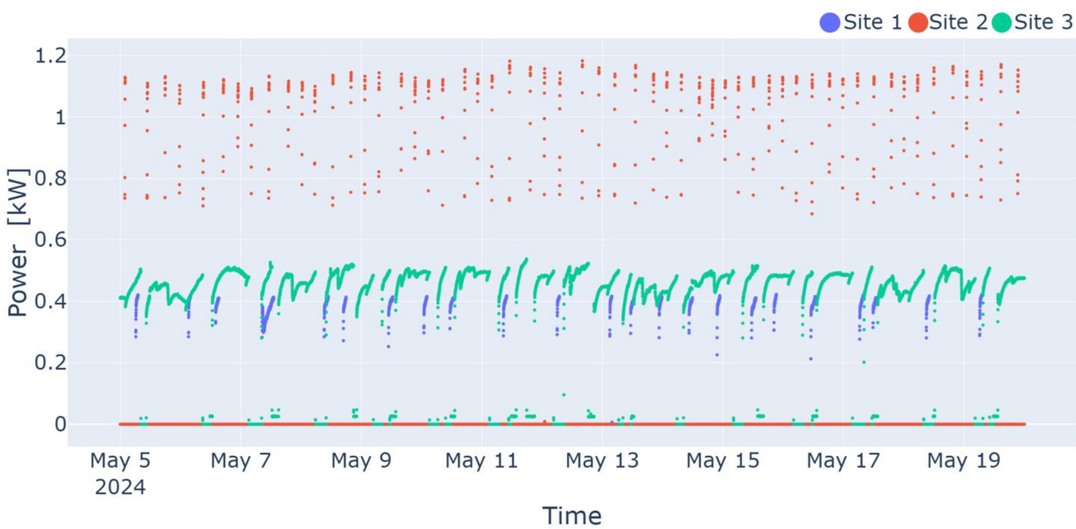

Figure 7. Sample Data of Daily Post Retrofit Power Consumption for All Sites. *Source*: EPRI.

Efficiency Analysis

The Coefficient of Performance (COP) is a dimensionless efficiency metric often used to evaluate the performance of heat pumps. For example, a COP of 2 corresponds to two units of useful heat energy delivered for one unit of input energy. COP is widely used as an efficiency metric because it captures the instantaneous performance of the system. However, since the HPWH contain a storage tank, the production and consumption of hot water may not happen simultaneously. Therefore, an aggregated approach is more suitable for the analysis of such technologies. In this report, both monthly and daily COPs are used to compare the performance of the HPWHs against the baseline technologies. It should also be noted that manufacturers typically denote the equipment efficiency using UEF, which is dependent on the water usage bin and first hour rating. The aggregated COP approach used here provides a simpler comparison of the field data.

COP Dependence on Water Consumption

Figure 8 shows a comparison of the daily COP as it varies with the daily hot water consumption. The top figure provides the efficiency data of the baseline resistance water heaters (Sites 1 and 2), while the bottom figure provides the post-installation HPWH's efficiency data for comparison. A dotted line is overlaid on the lower figure to denote the maximum achievable efficiency of resistance water heaters. Note Site 3 used a natural gas water heater for the baseline, so no daily COP is applicable for comparison on the top figure.

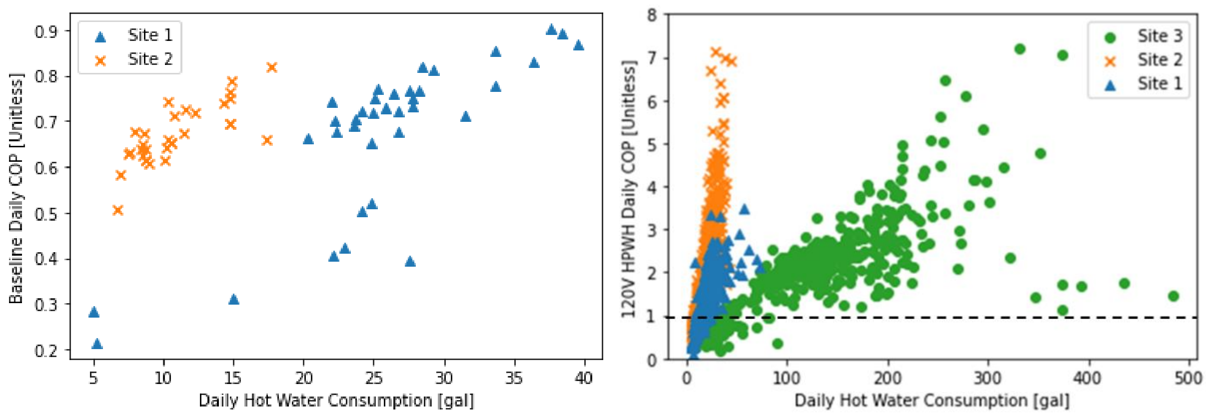

Figure 8. Daily COP Of Baseline Resistance Water Heaters (left) and HPWHs (right). A Dotted Line Shows the Maximum Efficiency of Resistance Water Heaters. *Source*: EPRI.

In the right figure, the 3 sites show a correlation between higher COP with higher amounts of water consumption (hot water load). Lower values less than 1.0 are likely due to cyclic losses when the daily consumption is low. This trend is clearly shown with Site 1 (blue triangle) and Site 2 (orange X) having COPs less than 1 when the daily consumption is very low (below 30 gallons). While both sites show a trend of increasing COP with water consumption increasing, the improvement is significantly more pronounced at Site 2. This improvement at Site 2 could be due to several factors, including the higher ambient air temperatures and a larger compressor fitted to this unit.

Site 3 (green circle) clearly shows a direct relationship with hot water consumption and COP with outliers of lower COP at high consumption rates possibly reflecting high supply water temperatures resulting from excess bypass from the bridge valves installed at the faucets, which lowers the temperature difference of the refrigeration system lift and negatively affects COP. Another cause of the low COP outliers for Site 3 can be attributed to the initiation of the heating elements during the unseasonably cold events as described previously. Clearly at least some of the relatively high COPs of all sites benefited from higher hot water loads but other factors also appear to have an influence.

COP Dependence on Ambient Air Temperature
HPWH efficiency is also affected by the ambient temperature. Figure 9 below shows the daily COP as a function of the daily average air temperature surrounding the HPWH.

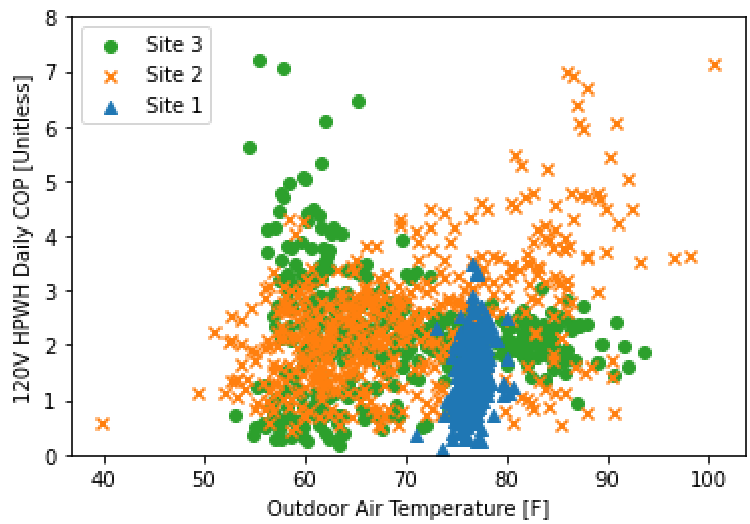

Figure 9. Daily COP of HPWHs at different average daily air temperatures. *Source*: EPRI.

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. A similar trend is seen in Site 3, where the HPWH is located in an unconditioned mechanical room. The major concern with respect to air temperature is the loss of heating capacity at lower ambient air temperatures, particularly under 40°F. This is typically unlikely for these demonstration sites due to the generally mild and warm weather in Southern California.

Due to the narrow band of temperatures at Site 1, it is difficult to draw conclusive correlations between that and the unit's efficiency. Upon further analysis, it was found that the air temperature at Site 1 drops significantly when the HPWH is operating, sometimes reaching below 65°F. This is likely the culprit to the relatively low daily COPs for Site 1. Even though a fully louvered door was retrofitted soon after the installation, the heat pump is extracting a lot of heat from a relatively small volume of air and lower the evaporator temperature, causing the efficiency to decrease. The lowest daily COP values are likely attributed to the time period of when the installation was completed and the installation of the fully louvered door occurred. The facility did not indicate how long the closet was not fully louvered, but a follow-up inspection after several weeks indicated the door had been installed.

Site 2 shows a better correlation between air temperature and the HPWH daily COPs. As the ambient temperature increases, the HPWH is more efficient at extracting heat from the environment. This profile demonstrates the effect of ambient air temperature on daily COP as can be seen, a low ambient temperature of 40°F resulted in a poor daily COP of under 1.0. Conversely, the same site saw a daily COP of 7.0 when the ambient temperature was 100°F. A wide variety of ambient temperatures were observed for this garage site which provided good data on the relationship of ambient temperatures on HPWH efficiency.

Site 3's results show no clear correlation between the air temperature and the daily COP. This can be due to a mismatch between the daily average air temperature and the air temperature during runtimes. When compared to the previous figures on hot water consumption, it shows that the high daily COPs at Site 3 coincides with lower ambient temperatures and high daily water consumption. As this location is a large volume mechanical room located on the north side of the building, fitted with a fully louvered wall for ventilation, higher ambient temperatures over 90°F were encountered but a direct relationship to daily COP improvement was not demonstrated as was for Sites 1 & 2. Instead, the daily COP peaked at over 7.0 around the 55°F -60°F ambient temperatures. When correlated with the water usage data, these days also had abnormally high water consumptions (>250 gallon/day). Several reasons could be the reason behind this trend, including the mismatch of when the HPWH operated and when the hot water was used, different refrigerants (R-513A refrigerant is used in product C while products A & B used R-134a), different manufacturers' controls (product C had a different manufacturer than products A & B). Additionally, it should be noted that the ambient temperature represented in the plot is the daily average temperature, so the ambient temperature coincidence with the HPWH operation could be much higher than shown.

Efficiency Improvements

The improvements in average COP efficiency of each site with respect to baseline is shown in Figure 10 below. This COP value is the daily aggregate averaged over the entire monitoring period, providing a simple snapshot of the overall results. This more accurately represents the efficiencies of the HPWHs over entire seasons compared to the previous daily COPs, as it accounts for daily standby losses or incidentally high water uses over the project duration.

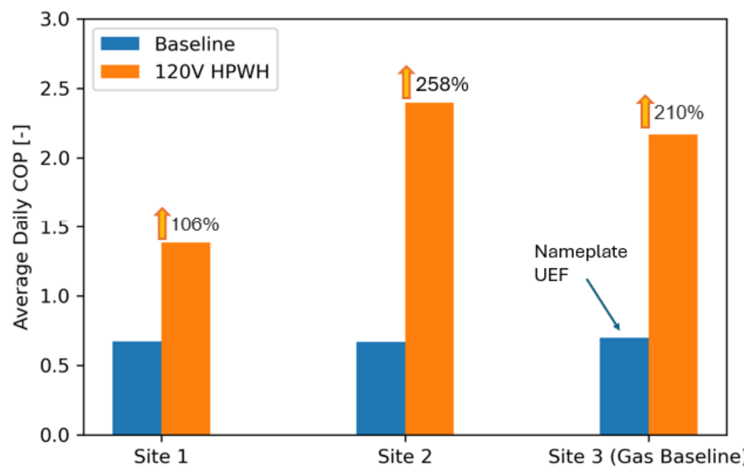

Figure 10. Average Daily COP Comparisons for All 3 Sites. *Source*: EPRI.

All 3 sites showed substantial improvement over the baseline technologies, with all 3 sites achieving a COP over 1, which is the maximum possible COP with an electric resistance water heater. It should be noted that while a COP of ~0.7 is reflected in the data, electric resistance water heaters can operate closer to a COPs of 0.9. This difference is likely due to the baseline systems being in the field for extended periods of time, leading to performance degradations from sources such as scaling. Summarizing the improvements:

- Site 1 Showed a 106% increase in efficiency over baseline. Average UEF of 0.7 based on baseline consumption data.
- Site 2 Showed a 258% increase in efficiency over baseline. Average UEF of 0.7 based on baseline consumption data.

- Site 3 Showed a 210% increase in efficiency over baseline. Assume a 0.7 UEF based on manufacturer nameplate information.

Customer Cost Savings

The efficiency analysis above provides the overall energy savings at each of the 3 sites and can be used to evaluate the customer cost savings in conjunction with the basic utility data described previously. The customer savings is calculated using the annual water consumption data collected at each site. However, Site 3 showed a negative savings of $359.11 since their baseline technology is a gas water heater. This is despite a 210% increase in efficiency and an energy use reduction of 6189.68 kWh. This is due to the large difference in electricity and natural gas costs, which is too great for the efficiency improvements to offset. Table 4 provides a summary of the savings across the 3 sites.

Site 1 and 2 both showed significant energy and cost savings when compared to the baseline electric resistance water heaters. Site 1 showed a savings of $63.53 with the 106% increase in efficiency, reducing the energy use by 277.14 kWh. Site 2 showed a savings of $113.99 with the 258% increase in efficiency, reducing the energy use by 492.13 kWh. The savings are much higher at Site 2 due to the higher efficiency of the HPWH, largely due to product being exposed to higher ambient temperatures. However, Site 3 showed a negative savings of $359.11 since their baseline technology is a gas water heater. This is despite a 210% increase in efficiency and an energy use reduction of 6189.68 kWh. This is due to the large difference in electricity and natural gas costs, which is too great for the efficiency improvements to offset.

Table 4. Summary of Energy Use and Cost of HPWH and Baseline for All Sites.

	Site 1	Site 2	Site 3
Heat delivered [kWh]	362.31	457.7	6396
Baseline Efficiency	0.67	0.67	0.7
HPWH Efficiency	1.39	2.4	2.17
Baseline Energy Use [kWh]	538.59	682.88	9137.14
HPWH Energy Use [kWh]	261.45	190.75	2947.47
Average Utility Rates	$0. 34/kWh $2.062/Therm		
Baseline Operating Cost [$]	152.42	178.85	643.03
HPWH Operating Cost [$]	88.89	64.85	1002.14
Savings [$]	63.53	113.99	-359.11

Conclusion

In this project, EPRI installed three different packaged tank type 120V HPWH systems to evaluate the performance of these new-to-market technologies in light commercial applications. These systems replaced existing electric or natural gas systems in various environments including indoors, sheltered outdoors, and a naturally vented mechanical room. The findings indicate variations in performance among the tested units, with insight into their operational efficiency, recovery times, and suitability for different installation environments. The field demonstration showed the 3 units operated well in Southern California climate, with the major issues stemming from a large uninsulated hot water distribution system. The following list shows a summary of key learnings of this demonstration:

- All 3 sites showed significant improvements in energy efficiency, with Site 1 showing 106% improvement, Site 2 showing 258% improvement, and Site 3 showing 210% improvement.
- The price difference between electricity and natural gas is critical when considering the cost savings for the end users. While the improvements in efficiency are significant, only Site 1 and 2 (both with electric resistance water heaters) generated savings for the customers. On the other hand, Site 3 showed an increase in energy cost since the baseline was a gas water heater.
- Careful application selection is key to successful implementation of 120V HPWH technology. Baseline demand loads should be carefully considered prior to equipment selection as 120V HPWH's do not have high recovery due to their power limitations. Intermittent demand loading works well.
- Installations of HPWH's require an open volume of space for efficient operation, 120V units are no exception. Interior closet locations should consider fully louvered doors or ventilation to maximize airflow available to the heat pump.
- Hot water distribution system impacts may be detrimental for recovery if significant piping losses result from exposure to low ambient temperatures. Distribution piping should be well insulated to minimize adverse impacts to recovery and efficiency.
- Interior closets may not have floor drains, so accessories such as leak detection shutoff valves should be considered in case of leakage.
- 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 to align with a common 120V receptacle. The cords are typically approximately ten feet long. Receptacles 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 receptacle should be nearby and available.
- Another new feature for these HPWH's 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.
- A new component released in one of the new 120V products is the use of a larger compressor for the heat pump (site 2). 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.
- Future work should also consider the demand flexibility capabilities of these new 120V HPWHs to complement the existing work focused on energy efficiency. The innate storage capacity provides some ability to shift the hot water production towards hours with minimum emissions associated with electricity consumption, which can be beneficial for reducing indirect emissions.

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