Advancing Grid Sustainability: Heat Pump Water Heaters for Load Shifting in Commercial and Multifamily Applications

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ABSTRACT

With legislative initiatives driving the decarbonization of our grid, utility companies nationwide face increasing pressure to meet electricity demands, particularly during peak periods. Commercial heat pump water heaters (CHPWH) are an invaluable resource for grid sustainability. CHPWHs consume significantly less energy than their electric resistance counterparts and they possess inherent load shift capabilities due to their substantial storage volumes, which can function as thermal batteries.

Demonstration projects show that central HPWH systems can successfully shift demand outside of grid peak periods without disrupting hot water supply to building occupants. The Bayview Tower project, featuring the country's first load shift capable CHPWH system, validated the effectiveness of demand shifting with the use of remote controls and provided data essential to developing best practices for this emerging technology. Subsequently, two additional load shift-capable CHPWHs have been installed and monitored in affordable housing multifamily buildings in California, further confirming their ability to shift demand. Beyond grid support, load shifting has the potential to further reduce carbon emissions by operating during periods of readily available renewable energy and reduce consumer costs for participants enrolled in Time of Use programs.

These field studies support the development of online tools that help designers size load shift-capable systems and predict emission reductions for incentive programs. The paper will highlight results from the demonstration projects, design and control strategies, and discuss how utilities can utilize such tools to support scaling this technology as a resource for grid support.

Introduction

This paper will highlight three notable multifamily load shift demonstration projects. Site 1 (Bayview Tower) retrofitted an aging electric resistance water heating system in an occupied, 100-unit, affordable housing high-rise located in Seattle, WA. The new commercial heat pump water heating system marked the first United States installation of Mitsubishi's HEAT2O (QAHV) system – the country's first large-capacity CO2 refrigerant-based domestic water heating system. It is also the first installation of a load shift capable CHPWH system nationwide. Following this milestone, four Mitsubishi HEAT2Os were also retrofitted at Sites 2 and 3, replacing their existing natural gas-fired central systems. Sites 2 and 3 are senior low-income housing buildings in San Francisco, CA, with 120 and 135 units, respectively.

Acknowledgements

The demonstration at Site 1 was possible thanks to several years of collaboration between BPA, Ecotope, SkyCentrics, Seattle City Light, and Steffes. ASK Energy, AESC, and Ecotope

built on this foundational work by conducting further research at Sites 2 and 3 through the CalNEXT program with support from Southern California Edison and the Emerging Technologies Program.

Background

Domestic hot water (DHW) has one of the largest energy footprints of all residential end-uses in the United States. According to the Energy Information Administration, DHW accounts for about 32 percent of site energy consumption in multifamily buildings with five or more units across the country (U.S. EIA 2018a). Across the individual California multifamily building responses in the 2020 Residential Energy Consumption Survey, this figure was about 45 percent of total site energy usage (U.S. EIA 2023a). Thus, it is natural for this high-impact end-use and building sector to be the focus of substantial effort by the energy efficiency industry towards energy savings, decarbonization, and greenhouse gas (GHG) emission reduction goals.

CHPWH systems have become a viable, commercially available solution for multifamily and non-residential buildings in the United States. Although CHPWHs have predominantly been applied in multifamily buildings thus far, there are many other building types that are excellent candidates for this technology. Building types such as food service, grocery, hospitality, lodging, schools, offices, and healthcare are all promising applications of CHPWH systems, assuming the designers and implementers have a solid understanding of the technology and design considerations.

Across these markets, the replacement of natural gas central water heating systems with CHPWHs will add load to the electrical grid. Thus, it is crucial to include electrical demand management at individual installations and in aggregate by using CHPWH load shifting controls and storage capacity. This is a necessary facet for ensuring beneficial electrification in the public interest (Farnsworth, Lazar and Shipley 2019). By leveraging the stored hot water as a thermal battery, the load can conceivably be shifted away from periods of peak grid demand, when energy costs and carbon emissions are high. Such controls will not only mitigate the grid impacts of this market transformation but will also minimize energy costs incurred by building owners and residents for their hot water.

Load Shift Demonstration

Site Information

All three buildings utilize a Swing Tank design – defined in the Northwest Energy Efficiency Alliance (NEEA) Advanced Water Heating Specification (AWHS). The Swing Tank design includes a primary system of two QAHVs for heating cold incoming municipal water and a temperature maintenance swing tank for trim heating the recirculation loop during periods of low water usage. Here, the recirculation water is piped back to the swing tank, a separate, smaller tank in series with the primary storage tank. The HPWH heats the primary storage and does not heat the swing tank directly. However, as the hot water from the primary storage (typically between 140 and 180°F) flows to the swing tank, it heats up the swing tank and offsets the heat loss that occurs as water recirculates around the building. The swing tank design supports HPWHs that operate most efficiently on cold incoming water from needing to heat recirculation water directly. Figure 1 shows an example of a swing tank schematic.

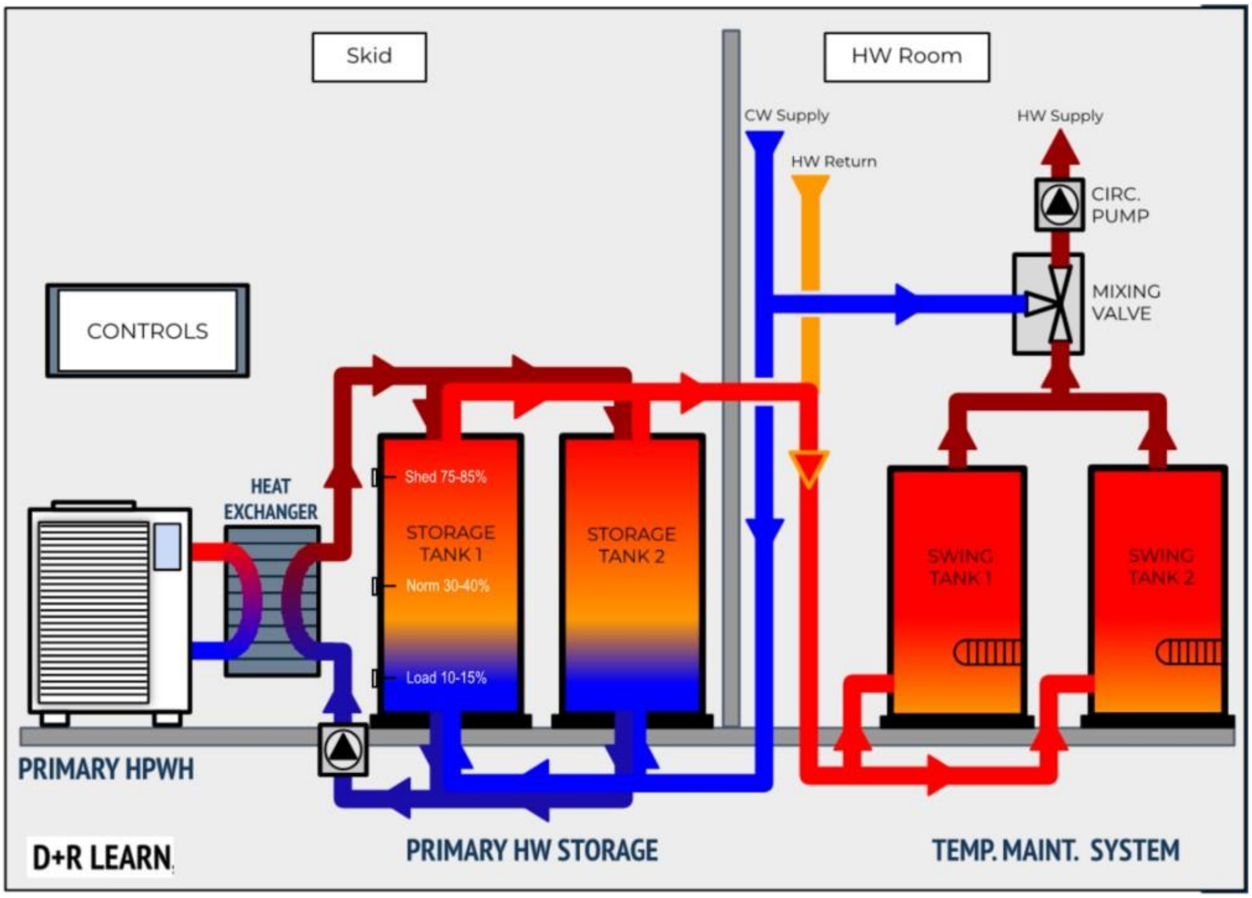

Figure 1. Swing tank schematic

Table 1 relates the size of the installed systems at all three sites. Site 1 utilized three primary storage tanks piped in parallel. The primary storage volume was restricted by the weight limit of the roof, so the system is slightly undersized. Sites 2 and 3, however, featured a grid-like arrangement of tanks piped in parallel and in-series that contain more storage than required, particularly Site 3, which has 190% the recommended volume. The combination of in-series and parallel plumbing may have led to difficulty with system balancing, reducing the effective storage volume. Further research is underway to understand the causes of what appears to be less effective thermal storage utilization at Sites 2 and 3.

Table 1: Sizing Specifications

Site	Primary Storage Volume (gal)	Recommended Primary Storage Volume (gal)	Number of Primary Storage Tanks	Number of HPWH units	Swing Tank Volume (gal)	Swing Tank Capacity (kW)
1	855	1,200	3	2	476	81
2	1,550	1,000	8	2	200	18
3	2,150	1,120	11	2	200	18

Controls

Compared to electric resistance or natural gas water heating systems, heat pumps typically have a lower heating capacity and thus take more time to generate hot water. Therefore, heat pumps are paired with large storage tanks, which can support the system during periods of the day with particularly high DHW use. These tanks, when paired with proper controls, allow the system to load shift while maintaining reliable hot water delivery. In general, the load shifting of a CHPWH system is performed through “load up” and “shed” programming. During load up mode, additional heat is stored in the tanks in preparation for shed mode where that stored heat is then used to coast through the high-emission, high-cost period.

Load up commands are sent to the heat pump to fully charge the thermal storage tanks ahead of expected grid peak periods, which allows the HPWH system to remain idle as long as possible during peak periods using a shed command. However, the HPWH will turn on during a shed to provide uninterrupted hot water delivery to the building occupants should it be necessary. The substantial storage volume of commercial HPWH systems facilitates load shifting. The large storage tanks can store immense volumes of water prior to peak events and allow storage to deplete during shed periods. This enables the system to not use electricity during shed and maintain hot water supply to residents. To enable load shift, Ecotope developed three control strategies:

Strategy #1: Altering which location in the storage tank is used to turn the HPWH on and off: HPWHs are controlled to turn on and off with temperature sensors located in the storage tank. Installing three temperature sensors at Site 1—at the top (82% tank height), middle (46% tank height), and bottom (11% tank height) of the tank allowed for effective management of the HPWH's operations during shed, normal, and load up operating modes respectively. Refer to Figure 1 for temperature sensor locations. During load-up, the HPWH controller was set to heat the water until the bottom temperature sensor (11%) met setpoint, maximizing the stored hot water volume. During shed periods, the HPWH controller was set to satisfy a setpoint at the top (82%) of the tank. This allows the HPWH to remain off for long periods of time between load up and shed as the middle of the tank – full of hot water – could be used to ride through long periods without the need for electricity. During normal operation, the middle sensor (46%) is used to provide long compressor cycles while maintaining a large amount of hot water storage. Altering which storage tank sensor was used for HPWH on/off control was the most significant contributor to Site 1's successful load shift demonstration. Site 1’s monitoring system allowed the research team to analyze the tank stratification through temperature data while designing the control sequence. For manufacturers, engineers, and contractors to design and implement load shift while ensuring consistent hot water supply, standardized guidance on placing tank temperature sensors to achieve load shift is needed. While the Site 1 research suggests a HPWH sensor location at 75- 85% for shed, and a 5-15% location for load up, more studies, both field and simulation, are needed to provide guidance on temperature sensor placement for load shifting. Similar temperature sensor staging was used at Sites 2 and 3, however, the piping of the primary storage tanks caused complications that will require more research as the project continues in 2024.

Strategy #2: Increasing the temperature of hot water produced by the HPWH during load up: Increasing outlet temperature increases primary storage temperature which generates denser energy storage. Denser energy storage allows the same storage tank volume to provide more hot water (increasing thermal storage capacity) when provided through a mixing valve. However, increasing HPWH outlet temperature has not been successfully tested at Site 1 due to complications with controls around the secondary heat exchanger.

Strategy #3: Adjusting the output capacity of the HPWH: During load up with the HEAT2O system, the heating capacity of the HPWH can be increased to speed up hot water recovery in the thermal storage tanks. This was done by requesting high-capacity output from the HEAT2O during load up periods via control signal from the control panel – which receives load shift commands – to the HEAT2O. However, this capacity increase only works when outdoor air temperatures are above ~45°F and the higher the air temperature, the more the capacity will increase. Capacity adjustment strategy is limited to certain HPWH models and seasons. Currently, the research team does not see significant value in decreasing capacity of a single HPWH during shed for commercial HPWH systems. The existing HPWH technology does not significantly increase coefficient of performance (COP) through capacity reduction, and the added complexity with marginal value makes this strategy unfeasible at this stage of commercial HPWH load shift technology maturity. However, when multiple HPWHs are used, using simple staging controls to turns on one at a time can be implemented.

The CHPWH industry has prepared for external signaling that can trigger such programmed load shifting modes or settings. The Advanced Water Heating Initiative grid connectivity working group has coordinated with stakeholders to establish the Consumer Technology Associate (CTA) 2045 technical specification (brand name EcoPort) for products certified by the OpenADR Alliance. This device-to-device communication port allows for such external triggering of load shifting. A service provider, utility, or program administrator can use this for load management of these distributed resources via standard communication protocols

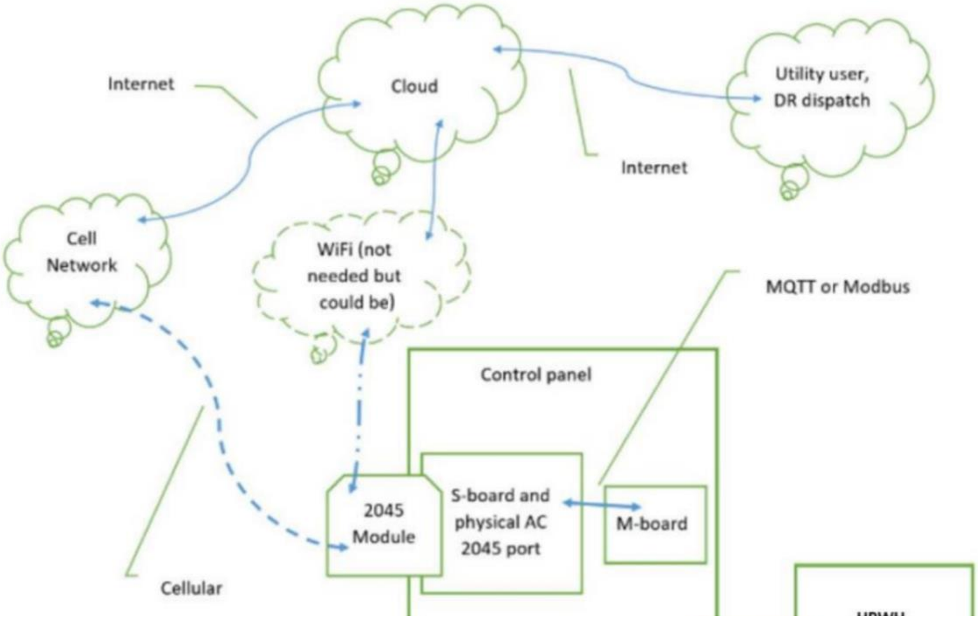

Figure 2. Sample CHPWH communication diagram using CTA 2045 module (Spielman 2022).

(e.g., via Wi-Fi, Zigbee, Bluetooth, FM, etc.). Figure 2 shows an example of CHPWH communication diagram using CTA 2045.

At Site 1, the load shift communication was tested through the SkyCentrics EcoPort and OpenADR Virtual End Node, which interacted with the SkyCentrics SkyKit integrated into the Mitsubishi HEAT2O control panel. This setup allows the system to receive signals for two levels of load up and three levels of shed, consistent with CTA-2045-B standards. The CTA-2045 protocol, an open standard which describes a physical port and a command set for demand response to enable load shift, simplifies grid-to-device communication, fostering a more efficient implementation of load flexibility programs for a sustainable and reliable electric grid.

Site 1 Results

The team experimented with various control sequences that ran for 1.5-2 months each and after reviewing data, updated schedules based on observed trends and weather conditions. The system performed exceptionally during the summer. The winter presented challenges that impacted the HEAT2O system's load shift capability. For example, the system defrosted significantly during December which required the team to pause load shift testing due to reduced heating capacity of the system. A summary of the results from each schedule can be found in Table 2, where "Percent Shed Met" is defined as the percentage of time that the primary system remained off during scheduled shed periods. Note that October through December, an ambitious schedule of two sheds per day was attempted. During the coldest winter months, December 2022 through February 2023, testing was paused due to cold conditions and reduced equipment capacity.[1]

Table 2. Summary of Results from Demand Response Testing Period

Start Date	End Date	Total Shed Hours	Percent Shed Met	Avg OAT (F)	Avg COP	Control Sequence	Schedule
5/2/2022	6/19/2022	168	91	55	2.3	Load Up: 5am-6am, 12pm-6pm Shed: 6am-9am, 6pm-9pm	M,W,F,Sa
6/20/2022	7/27/2022	132	100	66	2.6	Load Up: 5am-6am, 10am-6pm Shed: 6am-9am, 6pm-9pm	M,W,F,Sa
7/28/2022	8/17/2022	-	-	-	-	Lost majority of data due to control panel malfunction.	-
8/18/2022	10/20/2022	208	85	66	2.8	Load Up: 5am-6am, 10am-6pm Shed: 6am-10am, 6pm-10pm	M,W,F,Sa

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[1] For more information regarding winter performance and system improvements see https://www.bpa.gov/-/media/Aep/energy-efficiency/emerging-technologies/20230829-mitsu-co2chpwh-bayview-towers-report.pdf

10/3/2022	12/15/2022	336	62	47	2.2	Load Up: 5am-6am, 10am-6pm Shed: 6am-10am, 6pm-10pm[2]	M,W,F,Sa
12/16/2022	1/1/2023	0	-	39	2.1	Baseline operation.[3]	-
1/2/2023	2/5/2023	0	-	43	2.3	Baseline operation.[4]	-
2/6/2023	2/19/2023	0	-	43	2.2		-
2/20/2023	3/5/2023	56	53	38	2		-
3/6/2023	3/19/2023	56	54	44	2.1	Load Up: 12am-6am Shed: 9am-1pm (Building's peak water use)	Daily
3/20/2023	4/20/2023	54	88	46	2.3	Load Up: 12am-6am, Shed: 6am-9am	M,W,F,Sa

Figures 3 and 4 illustrate the comparative energy use during the 3-hour period for three different scenarios: the pre-retrofit electric resistance system (calculated from water usage), an uncontrolled HEAT2O CHPWH system (data collected on control days – T, Th, Sat), and a load shift capable HEAT2O CHPWH system (data collected on load shift days – M, W, F, Sun). Figure 3 shows summary data, gathered from May through July 2022. The figure demonstrates a substantial average demand reduction. First, replacing the electric resistance system with the HEAT2O system reduced peak demand and provided significant energy savings (from ~70 kWh to ~25 kWh). Then, the load shifting further reduced peak demand from ~25 kWh to ~2 kWh. Figure 4 shows the average energy use per hour by each system over a 24-hour period. The figures were created using uncontrolled energy usage data from Tuesdays, Thursdays, and Sundays (no load shift) and controlled energy usage data from Monday, Wednesdays, Fridays, and Saturdays (with load shift).

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[2] System was not re-programmed after daylight savings, schedule shifted back 1 hour after 11/6/2022.

[3] Heat pump struggled with two shed periods per day under winter conditions. System was set to normal operation to allow hot water generation to catch up.

[4] Miscommunication resulted in a lack of commands sent to the heat pump on scheduled start date and improper commands sent later in the month that did not allow the system to load shift properly.

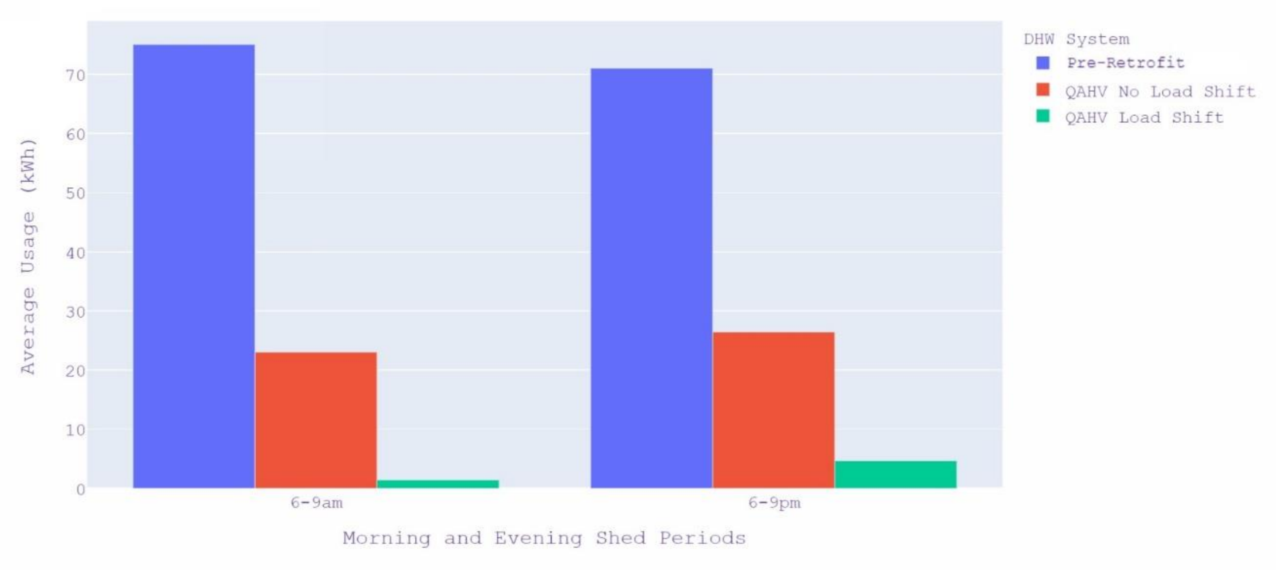


Figure 3. Average demand reduction during peak periods by hot water system.

Figure 4. Average daily energy use profiles for hot water systems.

Figures 3 and 4 clearly demonstrate the substantial peak demand reduction (~97%) potential of CHPWHs equipped with load shift controls. When combined across numerous buildings, this could translate to a significant demand reduction resource. Additionally, the demand reduction observed at Site 1 likely underestimates the potential in other multifamily buildings. Site 1 is a senior affordable housing building. Unlike most multifamily buildings, its load shape features a single, less pronounced mid-day peak. (Refer to Figures 5 and 6 for comparison.) In most multifamily buildings the peak hot water usage aligns with peak electricity use periods in the morning and evening, which creates a greater opportunity for load shifting.

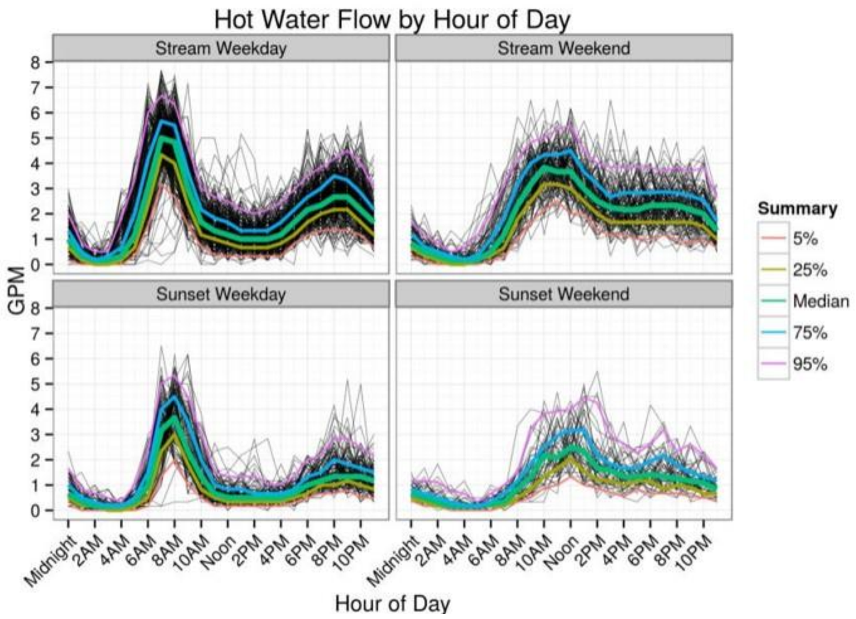


Figure 5. Common Seattle market rate load shapes.

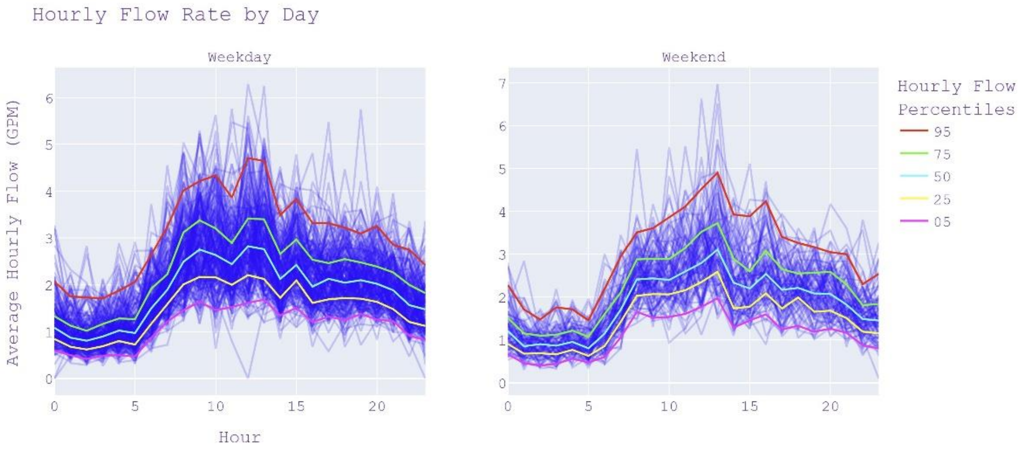
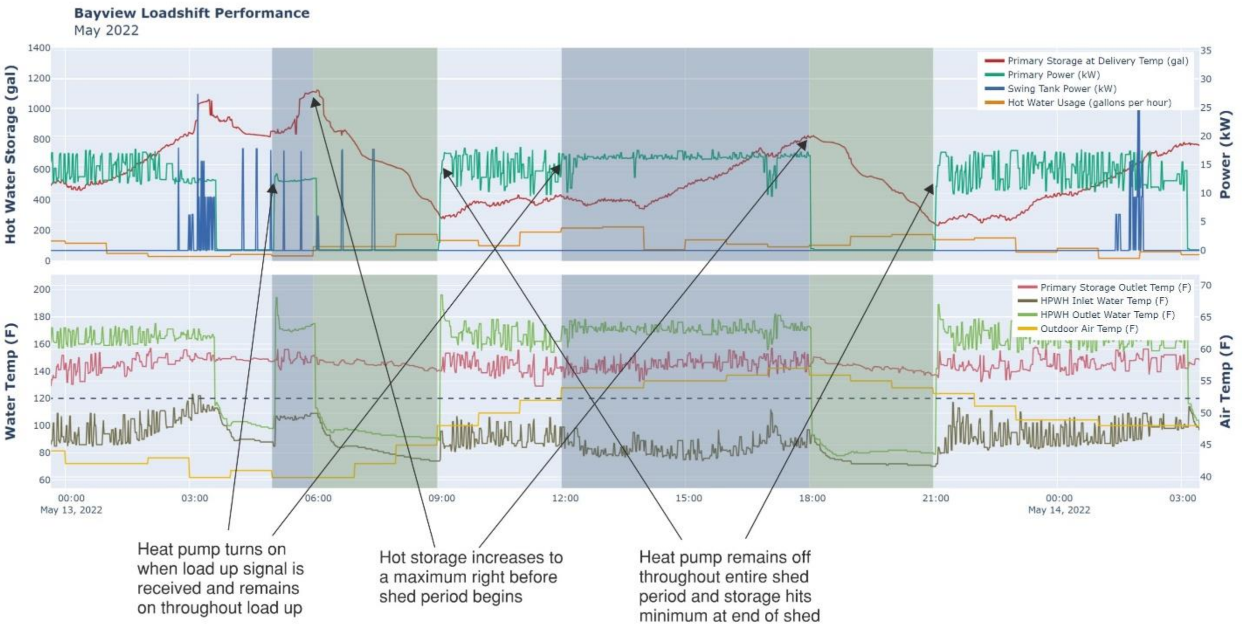


Figure 6. Site 1 load shapes.

Load shift testing initiated on March 21, 2022, encompassing two 3-hour shed events from 6AM-9AM and 6PM-9PM on Monday, Wednesday, Friday, and Saturday. Initially, a 1-hour load up was implemented before each shed event. Most morning shed events were successfully executed without turning on the HPWH, but evening shed events were less successful. High midday water usage at Site 1 prevented the HPWH from fully recovering in its standard capacity mode. Three control modifications made by May 2, 2022, enhanced the system's ability to meet both morning and evening shed events consistently: 1) The hot storage water temperature setpoint was raised from 138°F to 150°F. 2) HPWH capacity during load up was increased from 40kW to 60kW nominal heat output. 3) Load up duration was extended from a 1-hour period (5PM-6PM) to a 6- hour period (Noon-6PM). These changes resulted in the system successfully meeting hot water demand during sheds without the use of electricity 90% of the time. Further control modifications on June 20, 2022 expanded load up to an 8-hour period from 10AM to 6PM, enabling the HPWH to meet all shed events without needing to use electricity to heat water.

Figure 7 provides a snapshot of the system's optimal performance in May 2022, where the system successfully fulfilled two 3-hour shed periods. The chart's background colors highlight the scheduled events, with load up denoted in blue and shed in green.



Heat pump turns on when load up signal is received and remains on throughout load up

Hot storage increases to a maximum right before shed period begins

Heat pump remains off throughout entire shed period and storage hits minimum at end of shed

Figure 7. Ideal control day.

Hot Storage at Delivery Temperature (subsequently referred to as Vsupply), shown in red on Figure 7, is calculated from fifteen temperature sensors installed in the site's three storage tanks. The calculation generates a temperature profile for the tanks and estimates the volume of hot water stored at the delivery temperature. Essentially, Vsupply is the total volume of 120°F water available if the storage tanks were drained through a mixing valve with cold municipal water at any given moment. Although the primary storage tanks have a volume of 855 gallons, with elevated temperature they can effectively store over 1200 gallons of 120°F Vsupply. The Vsupply line on Figure 7 clearly shows the system's capability to store sufficient hot water during both load up periods. The power input to the HEAT2O remains zero during both shed periods, reflecting a successful shed. This behavior is representative of the system's performance in the summer months, and what the team aimed to replicate at Sites 2 and 3.

Site 2 and 3 Results[5]

While Site 1 tested a series of experimental schedules, the two San Francisco buildings were sent load shift schedules based on Pacific Gas & Electric (PGE) Time of Use (TOU) pricing. Load shift controls were programmed and triggered externally on Monday, Wednesday,

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[5] For full report see https://calnext.com/wp-content/uploads/2023/12/ET22SWE0017_Commercial-and-Multifamily-CO2-Heat-Pump-Water-Heater_Final-Report.pdf.

Friday, and Saturday with load up from 12pm – 4pm and load shed from 4pm – 9pm. Other days and hours operated under standard settings. Once implemented, there were no reports of low hot water availability from building staff or occupants; by all accounts, hot water demand is still being met during the load shift days without interruption. Two sequences of operation (SOO) were used at both sites. This paper will focus on the second SOO, which was refined based off results from the first SOO.

Figure 8 shows the consolidated daily profile of logged tank temperatures and system power on standard operation and load shift days for Site 1. The tank temperatures were taken at different heights in the total storage to observe the thermocline. The plots clearly show that the recirculation supply temperature stays unaffected by load shifting, and that tank temperatures throughout the thermocline are increased during the load up period, resulting in a higher level of total thermal storage at the beginning of the load shed period.

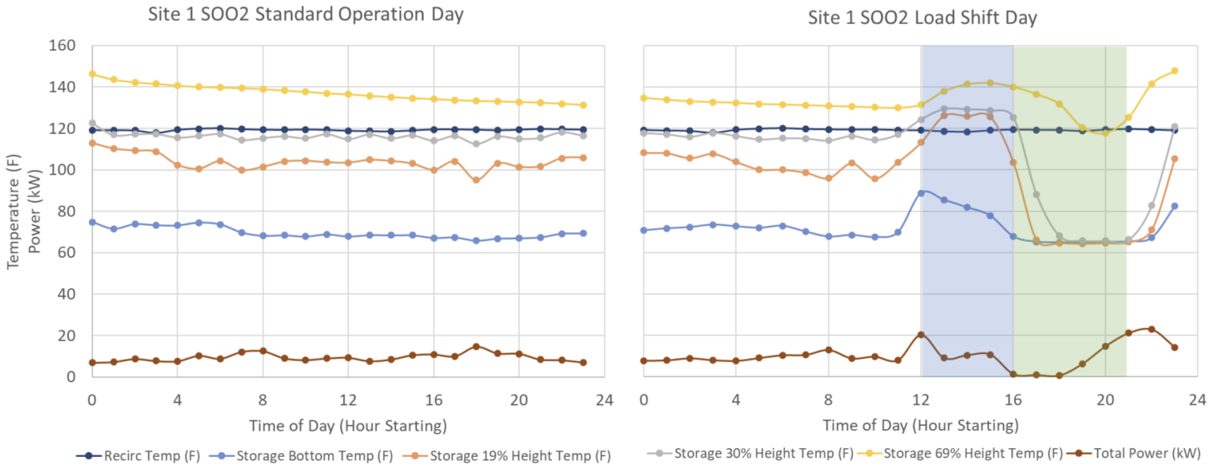

Figure 8. Standard operation and load shift day thermocline temperatures.

Figures 9 and 10 display the average system power and maximum system power across typical and load shift days for both sites. At both sites, the system was able to load shift quite well, compared to control days, Site 1 used less energy on average for the first four hours of the scheduled shed, and Site 2 used less energy all five hours on average. It is important to note that the tested schedule was selected only to demonstrate the capability of this equipment to shift load off the 16:00-21:00 peak TOU period. There is ample room to further optimize controls based on load patterns, CHPWH capabilities, TOU pricing, and GHG avoidance.

As the market transitions from natural gas to electric, consumer cost reduction is of the upmost importance. While energy use was significantly decreased during peak pricing, the maximum power consumption during the peak period was not. The buildings reside in PGE territory, where customers face monthly demand charges, in which they are billed for their maximum power consumption during the 16:00-21:00 peak period. These demand charges make up a significant portion of the total monthly bill and it is therefore important to not only minimize energy consumption during the peak period, but to also refrain from drawing large amounts of power, even if it is for a short period of time at the end of the shed. As mentioned in the controls section, the QAHVs have the potential to be turned on in stages. Staging the heat pumps during shed is one potential solution to minimizing the power draw at the end of a shed period should there not be sufficient battery to coast through the entire shed period.

This load shift demonstration project has received renewed funding, and as the project resumes, the team will test strategies for optimizing load shift and minimizing demand charges.

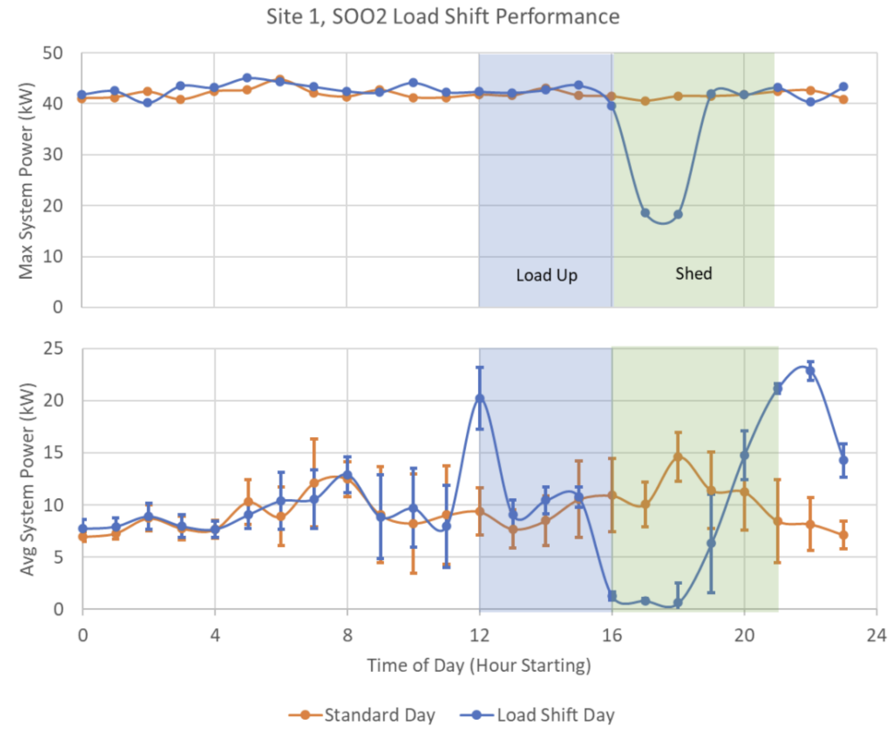

Figure 9. Site 1 load shift performance.

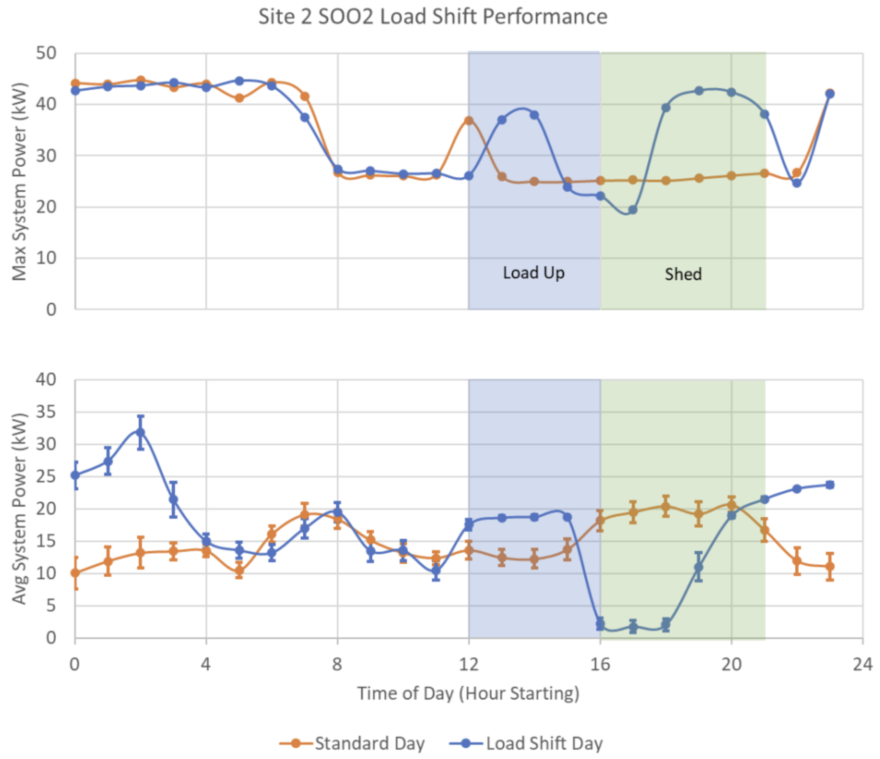

Figure 10. Site 2 load shift performance.

Load Shift Tools

The following section outlines tools that can be used by designers and utilities to drive the integration of load shift capable HPWH systems to market.

Ecosizer[6]

Sizing of the primary storage volume, heat pump capacity, and temperature maintenance system are crucial to a CHPWH's ability to shift load. As this new technology enters the market, designer support is needed to maximize this technology while minimizing increased cost to the consumer.

The Ecosizer is a free online tool, developed by Ecotope, for sizing CHPWH in multifamily and commercial buildings. Hot water usage profiles for multifamily building sizing are developed from field data collected by Ecotope. Hot water usage profiles for other commercial building types are based on the ASHRAE Applications Handbook. Current supported commercial building types include hotels, dorms, offices, schools, and restaurants, although load shift sizing is currently only available for multifamily buildings.

Ecosizer requires the user to input the building type, domestic hot water consumption, temperature maintenance design, and design day conditions and returns the minimum capacity and storage required on design day. Additionally, users may specify that they would like to size for load shifting, which allows them to select a load shifting schedule and the percentage of days they would like to be able to shift 100% of the scheduled load.

In the case of Site 3, Ecosizer suggests that the site's storage volume is 190% of what is required to conduct daily load shifting from 4-9pm. In the project's current state, the additional storage volume did not increase the ability of the system to loadshift. Rather, the complicated (and non-AWHS compliant) design led to unexpected system behavior and increased costs to the building owner that cannot be justified through peak demand savings. Upcoming research will investigate discrepancy between storage volume and ability to load shift at this site, but this site illustrates the importance of tools such as Ecosizer to support this emerging technology.

Ecosizer was developed by Ecotope and funded by Southern California Edison, Sacramento Municipal Utility District, and Oak Ridge National Laboratory. Ecosizer currently supports single pass systems with swing tank or parallel loop tank temperature maintenance systems. Important next steps towards market transformation include incorporating multipass systems and return to primary temperature maintenance configurations into Ecosizer, conducting further research on commercial load shapes, and adding load shifting functionality to commercial buildings.

Multifamily TECH HPWH Incentive Calculator[7]

TECH Clean California, whose mission is to accelerate the market adoption of clean space and water heating technology in California and install six million heat pumps by 2030, is incentivizing the installation of load shift capable heat pump water heaters in multifamily buildings (TECH Clean California 2024). Ecotope created a tool, the Multifamily TECH Incentive Calculator (found on Ecosizer.com), which allows applicants of the TECH program to

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[6] https://ecosizer.ecotope.com/sizer/

[7] https://ecosizer.ecotope.com/sizer/annualsim/

submit geographical location, building specs, hot water usage, and system design to estimate the reduction in carbon emissions from implementing load shifting.

The calculator works by running an annual simulation of the building's domestic hot water system with weather and CO2 emissions data from the designated climate zone without load shifting controls. Then, the simulation is run again with user guided load shift controls, and the emissions are compared to that of the original system. If the emissions reduction relative to the volume of storage meets the threshold for the program, users may submit the output of the calculator to the TECH program for approval.

While this tool was designed for a California based program, it offers a valuable foundation for estimating load shift capacity of heat pump water heating systems. As the program launches, data will be collected from approved sites which can be used to help refine the assumptions made in the tool and improve accuracy.

Advanced Water Heating Specification[8]

The NEEA's AWHS defines requirements which support consistent, reliable, and efficient central heat pump water heater system installations. AWHS establishes a Qualified Products List (QPL) through a tiered rating system, based on system COP in different climates, for energy savings estimations in incentive programs.

The newest version, AWHS 8.1, streamlines the process of adding systems to the QPL through an updated product assessment datasheet (PADS), and transparent system COP calculation methodology. The updated AWHS also includes Market Delivery Methods; products may be listed as fully packaged, fully specified built up, or custom engineered, which allows utility programs to vary performance validation requirements based on delivery method.

The next version of AWHS, version 8.2, will include methods for estimating load shift potential of Qualified Products. A NEEA Load Shift Test has been developed to quantify the thermal energy storage of the storage tanks and controls that are provided as part of a Qualified Systems listed on the QPL. The thermal energy is then divided by COP to understand the electrical load shift potential. Because electrical load shift potential varies by COP, it also varies by climate and season. Primary HPWH provided with the PADS, shown in Figure 11 below, is used to quantify different electrical load shift potentials. For example, the Summer load shift potential is based on the COP at 95°F, whereas the winter load shift potential (in a Mild Climate) is based on the COP at 34°F.

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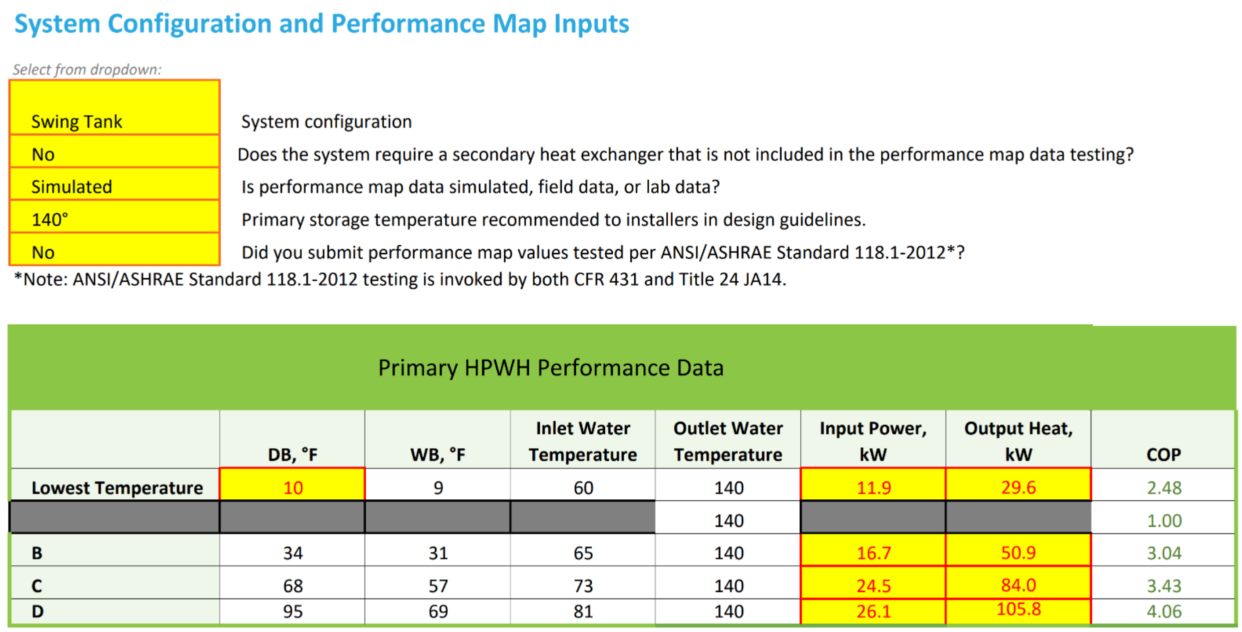
[8] https://neea.org/img/documents/AWHS-v8.1-Draft.pdf



System Configuration and Performance Map Inputs

Select from dropdown:

Swing Tank	System configuration
No	Does the system require a secondary heat exchanger that is not included in the performance map data testing?
Simulated	Is performance map data simulated, field data, or lab data?
140°	Primary storage temperature recommended to installers in design guidelines.
No	Did you submit performance map values tested per ANSI/ASHRAE Standard 118.1-2012*?

*Note: ANSI/ASHRAE Standard 118.1-2012 testing is invoked by both CFR 431 and Title 24 JA14.

Primary HPWH Performance Data

	DB, °F	WB, °F	Inlet Water Temperature	Outlet Water Temperature	Input Power, kW	Output Heat, kW	COP
Lowest Temperature	10	9	60	140	11.9	29.6	2.48
				140			1.00
B	34	31	65	140	16.7	50.9	3.04
C	68	57	73	140	24.5	84.0	3.43
D	95	69	81	140	26.1	105.8	4.06

Figure 11. Product Assessment Datasheet (PADS).

Conclusion

The demonstration at Site 1 marks a significant milestone by successfully implementing the country's first load shift capable CHPWH system. This achievement, along with the valuable practical lessons and insights gained from monitoring and studying these retrofits, showcases the potential of such systems to consistently reduce load during peak periods and support the adoption of renewable energy, electrification, and grid stability.

Economically, DHW systems offer numerous advantages over other energy storage sources, making them cost effective with a lifespan over 30 years. These systems provide high temperature lift, require minimal maintenance, and have nearly infinite cycle lives. To maximize the benefits of these systems and implement load shifting and TOU pricing, additional research and industry guidance on system control logic are needed.

DHW's significant energy storage potential can provide further benefit when aggregated across various installations and applications. Testing at Site 1 suggests that the key to leveraging TOU pricing lies in determining when the system should begin a load up to achieve a fully charged state at the beginning of the peak period or shed event. To maximize utility and customer benefits, control logic is needed to automate the decision of when to begin load up. Control logic must be researched and developed to optimize heat pump operations because commercial building draw profiles vary and CHPWH systems will be built with varying storage and heating capacity.

These load shift demonstration projects represent a successful first step. However, further efforts are necessary to facilitate rapid market transformation. This includes improving sizing and system modeling assumptions and tools, standardizing equipment control guidance, and establishing supportive energy codes. These next steps will optimize CHPWH system performance and may reduce first costs thereby accelerating the market rate of adoption.

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