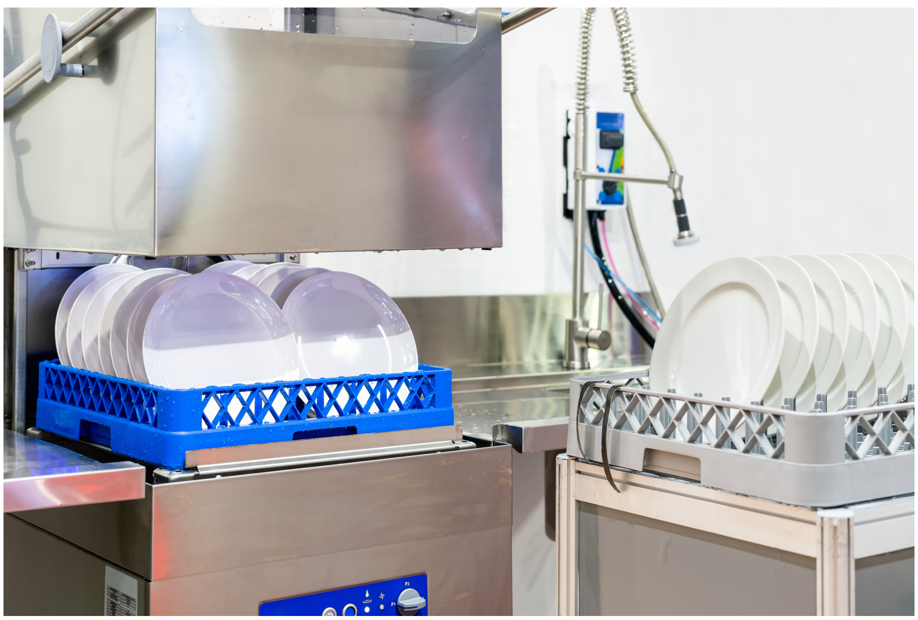
Overcoming Key Barriers to Electrification of Foodservice Hot Water in California

Final Report

ET23SWE0057



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Disclaimer

Executive Summary

Commercial foodservice facilities are among the most energy- and emissions-intensive buildings in California. As such, electrification of both cooking and water heating equipment in commercial foodservice facilities will be necessary to support California's decarbonization goals. Water heating decarbonization within foodservice has a number of barriers, including water heater sizing guidelines, which are enforced by California county health and safety departments. This report summarizes an existing literature and data set review, shares key findings from field monitoring from three full-service restaurants, and outlines specific approaches to revising the California Conference of Directors of Environmental Health Water Heater Sizing Guidelines.

Objectives

The overarching goal of this project is to gather data to dismantle a key barrier to commercial kitchen water heating decarbonization: water heater sizing guidelines in California that do not support efficient decarbonization technology. This study has the following objectives to support the project goal:

1. Characterize full-service restaurant (FSR) and equipment hot water demand consumption through field data collection.
2. Develop an alternative foodservice water heater sizing methodology that supports HPWH technology.
3. Present field data and alternative sizing guideline to key stakeholders.

Methodology

To achieve the objectives listed above, the research team completed a literature, data, and policy review, engaged with stakeholders, and gathered data from three FSR field sites. Field data collection included installing non-invasive ultrasonic flow meters, temperature sensors, and supporting equipment to gather cold, hot, and recirculation water flow rates and temperatures for roughly five to eight months per site. The team then analyzed the data to characterize the hot water draw profile, the recirculation loop hot water load, dishmachine hot water use, and operating temperatures. Additional methodology and analysis details may be found in the Field Data Collection section of the main report.

Results

The research team analyses yielded valuable observations about fine-dining cold, hot water, and recirculation flowrates, draw profiles, peak demand, and temperatures. The key results are listed in Table 7: Key data point results. which is followed by a detailed review of weekly and daily hot water draw profiles and dishmachine hot water load disaggregation for two sites. The research team also completed a comparison analysis of water heater sizing under the standard CCDEH approach and the alternative sizing approach recommended by the research team. These results are outlined in Table 11: Full-service restaurant water heater sizing example.

Key Findings

- **High potential for decarbonization of café, quick-service, and fine-dining FSRs:**

- The literature and data review confirmed that decarbonizing commercial foodservice sector water heating systems offers a significant emissions reduction opportunity, particularly in the full-service restaurant sub-sector. Additionally, there is high potential for HPWH adoption in cafés and small quick-service restaurants, since hot water loads are low, there is limited use of continuous recirculation systems, and one-for-one storage water heater replacement is viable.
- Through the field data collection, the research team found fine-dining restaurants—or restaurants or supermarkets with similar loads—are good candidates for demonstrating HPWH systems and growing acceptance for the technology in the foodservice sector. However, HPWHs have certain design and installation barriers, meaning there is no simple drop-in replacement for larger hot water loads. Additional technical product advancement and plumbing design resources and calculators will be essential for a smooth transition to all-electric HPWH installations in foodservice facilities.

- **Decarbonizing foodservice hot water systems will require a holistic approach that considers all end uses.** It is important to start with energy efficiency, leveraging high-efficiency appliances and low-flow fixtures to reduce hot water demand. At two field sites, the dishmachine use accounted for 40 to 50 percent of total daily hot water use on average, indicating the potential to pair HPWHs with heat recovery dishmachines that only use a cold water supply connection to reduce hot water load and thereby reduce the HPWH system size and the first cost.
- **CCDEH Guideline updates will be key to allow for cost-effective HPWH installation:** The research team's water heater sizing comparison results show that using a more accurate peak hot water demand and HPWH system COP—rather than the original CCDEH Guideline approach—provides equipment first cost savings and reduces the required electric panel capacity, limiting the scale of the panel or building electrical infrastructure upgrade.

Recommendations

The following section outlines key CCDEH Guideline and future research recommendations, find the full list in the Recommendations section of the main report.

CCDEH Guidelines

The research team recommends CCDEH adopt revisions to the Guidelines that increase sizing accuracy and support efficient decarbonization technology. In addition, the team recommends utilizing a calculator tool similar to the one outlined in Appendix D. Immediate Guideline recommendations include:

- Increase accuracy for temperature rise, including providing a lookup table for cold water design day and default hot water supply temperatures.
- Add HPWH sizing equations. The estimated COP calculation should be based on:
    - Refrigerant type
    - Water heater setpoint
    - Design day intake air and cold water temperature
    - Whether it has a continuous recirculation system

A version of the Guidelines with draft mark-up language is included in Appendix C. The proposed Guideline revisions and future recommendations seek to “right size” for hourly hot water demand and water heater input requirements.

Ongoing and Future Research

The research team recommends future research that builds upon the draft suggestions presented in this report, refining the Guidelines and building out a comprehensive water heater sizing calculator, and ultimately gaining approval and adoption by CCDEH. Future versions of the Guidelines and calculator should include increased accuracy of the peak demand calculation by updating the GPH default values for fixtures such as pre-rinse spray valves, three-compartment sinks, dishmachines, and hand sinks. In addition, the tool should support additional HPWH system configurations, such as using storage tanks in series and providing sizing considerations around load shifting. This work has already begun, funded by PG&E’s Code Readiness Subprogram and in collaboration with an existing Code Readiness project that is lab testing HPWHs under foodservice draw profiles.

Abbreviations and Acronyms

Acronym	Meaning
AHJ	Authority Having Jurisdiction
AQMD	Air Quality Management District
BAAQMD	Bay Area Air Quality Management District
CARB	California Air Resources Board
CCDEH	California Conference of Directors of Environmental Health
CEC	California Energy Commission
dBA	A-weighted decibel
ECM	Electronically commutated motor
ERWH	Electric resistance storage water heater
ET	Emerging technology
FDA	Food and Drug Administration
FSR	Full-service restaurant
GPH	Gallons per hour
HP	Heat pump
HPWH	Heat pump water heater
IOU	Investor-owned utility
NREL	National Renewable Energy Laboratory
QSR	Quick-service restaurant
SCAQMD	South Coast Air Quality Management District
TOU	Time of use

Acronym	Meaning
WH	Water heating

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Introduction

Commercial foodservice facilities are among the most energy- and emissions-intensive buildings in California. As such, electrification of both cooking and water heating equipment in commercial foodservice facilities will be necessary to support California's decarbonization goals. Water heating decarbonization within foodservice has a number of barriers, one of them being the water heater sizing guidelines enforced by California county health and safety departments.

In California, the California Conference of Directors of Environmental Health (CCDEH) outlines Water Heater Sizing Guidelines (Guidelines), which are enforced by local county health and safety departments as requirements for all commercial kitchen water heater installations and replacements. The Guidelines currently do not include guidance for heat pump water heaters (HPWH), a key technology to decarbonize water heating. This project aims to provide data and a proposed HPWH sizing pathway to support revisions to the Guidelines. To support this objective, the project will conduct a literature review of commercial kitchen hot water research and data, collect primary data of foodservice facility hot water peak and hourly demand, and engage with environmental health department stakeholders.

Objectives

The overarching goal of this project is to gather data to dismantle a key barrier to commercial kitchen water heating decarbonization: water heater sizing guidelines in California that do not account for HPWH technology. This study has the following objectives to support the project goal:

1. Characterize full-service restaurant (FSR) and equipment hot water demand through field data collection.
2. Develop an alternative foodservice water heater sizing methodology that supports HPWH technology.
3. Present field data and alternative sizing Guidelines to key stakeholders.

This report summarizes the existing literature and data set review, shares key findings from field monitoring from three FSRs, and outlines specific approaches to revising the CCDEH Water Heater Sizing Guidelines.

Background

Market Size

In the shift to decarbonization to meet California's climate goals, water heating is one key end use that needs attention to support a successful transition to high-efficiency all-electric technology, specifically, heat pump water heaters (HPWH). Some sectors that are large hot water consumers, such as multifamily buildings, have begun to install HPWH technology already, but one large sector that has lagged is foodservice.

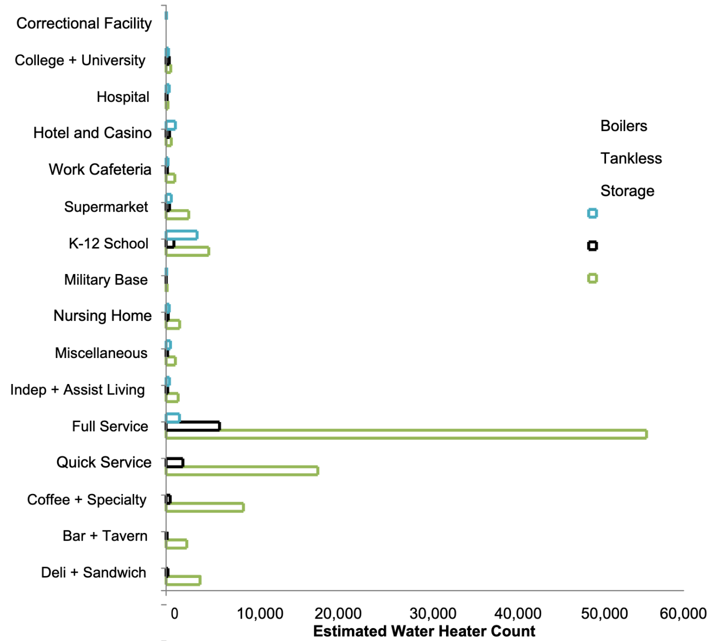


Figure 1: Estimated water heater Inventory in California foodservice sector.

Source: Delagah, Fisher 2010.

Data suggests there is a significant opportunity to prioritize commercial foodservice sector water heating decarbonization, particularly in the FSR sub-sector. According to a 2010 study by Pacific Gas & Electric and Fisher-Nickel, there are an estimated 76,750 commercial foodservice facilities and 20,100 institutional foodservice facilities in California. Based on the study's estimated inventory per segment, this translates to an estimated inventory of 99,090 storage, tankless, and boiler water heaters for the commercial sector foodservice facilities, which include FSRs, quick-service restaurants (QSRs), coffee and specialty shops, bars and taverns, and deli and sandwich shops.

QSRs consist of fast-food restaurants or restaurants with limited sit-down service, and the sector is dominated by takeaway restaurants with a smaller cooking and sanitation load. FSRs are sit-down restaurants with a high cooking and sanitation load, as shown above in Figure 1, which is equivalent to 96.4 percent of the total estimated foodservice water heater inventory of 102,730. The domination of commercial foodservice water heaters also aligns with the estimated annual gas consumption, as seen in Figure 2. FSR and QSR water heaters alone are estimated to use 259 million therms of gas annually—equivalent to 1.37 million metric tons of carbon dioxide (CO_2) (Delagah and Fisher 2010) (EPA 2024).

This 2010 study is the latest available data. Anecdotally the growth in restaurants over the last 15 year period, the decline of FSRs, and a shift to fast-casual dining likely has led to a slight decrease in the gas load presented in the 2010 study. However, the research team still notes the significant potential to decarbonize this industry sector.

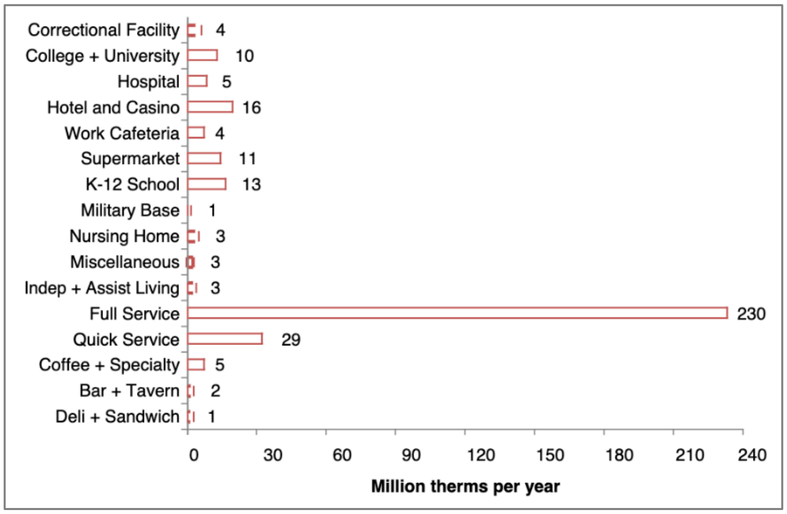


Figure 2: Estimated annual gas consumption of california foodservice sector water heaters.

Source: Delagah, Fisher 2010.

Foodservice Hot Water End Uses

In the commercial foodservice sector, there are five main hot water end use categories: preparation area, bar, dish room, mop sink, and restrooms. According to field data from Frontier Energy, Inc. (Huestis, et al. 2021), the dish machine and dish room sinks account for approximately 73 percent of the total hot water consumption per day, with the dish machine accounting for 42 percent of total hot water load per day in FSRs. The traditional door-type dish machines typically take in water between 140 to 150°F from a gas water heater and have an integrated electric booster heater to heat water to 180°F, which is necessary for sanitization. Once the dishwashing cycle is complete, the dishwasher vents the steam and drains the hot water.

An alternate emerging technology on the US market is the ventless, or heat recovery, dish machine. Heat recovery dish machines reduce overall energy use by using heat that would otherwise be exhausted or drained; they can also reduce water heating loads by an estimated 42 percent (Huestis, et al. 2021). These machines have integrated exhaust air and drain water heat recovery, where recovered heat is used to preheat cold supply water and is then further heated by a booster heater (Frontier Energy, TRC Companies 2023). Heat recovery and chemical dish machines are more prominent in Europe, where a 2013 field data study in the United Kingdom noted that the evaluated sample public house restaurants only used hot water for cleaning operations and in lavatories; it found that generally, dish machines used cold water (Mudie, et al. 2013). Decarbonizing foodservice hot water systems will require a holistic approach that considers all end uses and will include leveraging high efficiency appliances and low-flow fixtures to reduce hot water demand.

Hot Water Peak and Hourly Demand Profile

There is limited hot water consumption data available for foodservice facilities, particularly regarding the range of hot water consumption and the differences between different foodservice facility types (e.g., fast food versus a café). The research team aims to help mitigate this data gap with detailed field data collection—including disaggregation of dishwashers—at three foodservice sites. Ahead of the field collection effort, the research team gathered and analyzed data from prior Frontier Energy field research projects conducted over the past 10 years at 16 different foodservice facilities. Figure 3 shows all 16 facilities' hot water consumption, grouped by facility type: café, quick service fast casual (FC) and fast food (FF), and FSRs, aligning with the ComStock profile categories,[1] more details of which are available in Appendix A: ComStock Service Hot Water Flow Fraction Schedules. Average hot water daily consumption ranged from 80 to 170 gallons for cafés; 470 to 690 gallons for fast casual; 1,450 to 1,900 gallons for fast food; and 2,100 to 5,310 gallons for FSRs. The data also shows that the peak day—i.e., the day with the highest hot water consumption—is much higher than the averages, with peak days hitting 111 percent to 187 percent of average daily consumption across all sites.

In addition, the data shows the overlap in consumption across categories; one fast food restaurant that is categorized as a QSR consumes 1,900 gallons per day, while an FSR consumes 2,100 gallons per day on average, indicating that the standard foodservice categories are too simplistic and don't indicate hot water consumption. In support of that observation, research team members noted that facility practices and end use equipment vary significantly between restaurants within the same category. Facility practices and end use equipment are a better indicator than restaurant category of a site's hot water consumption and load profile.

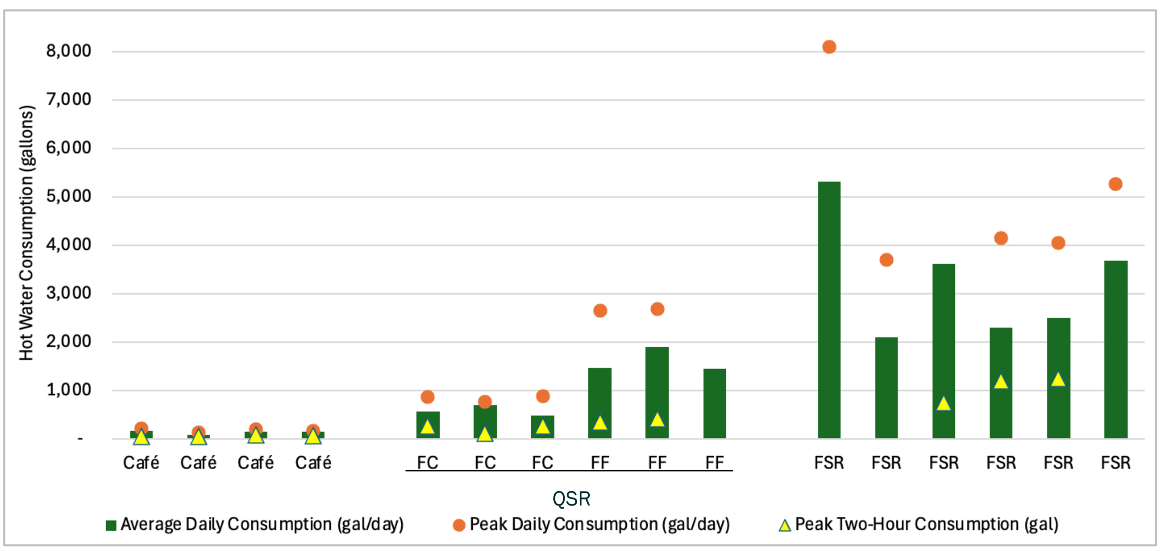


Figure 3: Average daily hot water consumption across foodservice facility categories.

[1] ComStock, developed by the National Renewable Energy Laboratory (NREL), is a modeling tool for US commercial building stock. Additional information can be found at: https://comstock.nrel.gov/

The following three figures show site average hourly hot water consumption, separated by facility type. The load profiles show some consistency within individual facility types but differ across the different facility types. Figure 4 and Figure 5 highlight the variation between the different individual facilities across cafés and QSRs. Aside from the fast food field sites, the average hourly load for each facility type generally aligns with the ComStock fraction schedules, as shown in Appendix A: ComStock Service Hot Water Flow Fraction Schedules.

The hourly consumption charts will help determine a decarbonization strategy for each facility type.

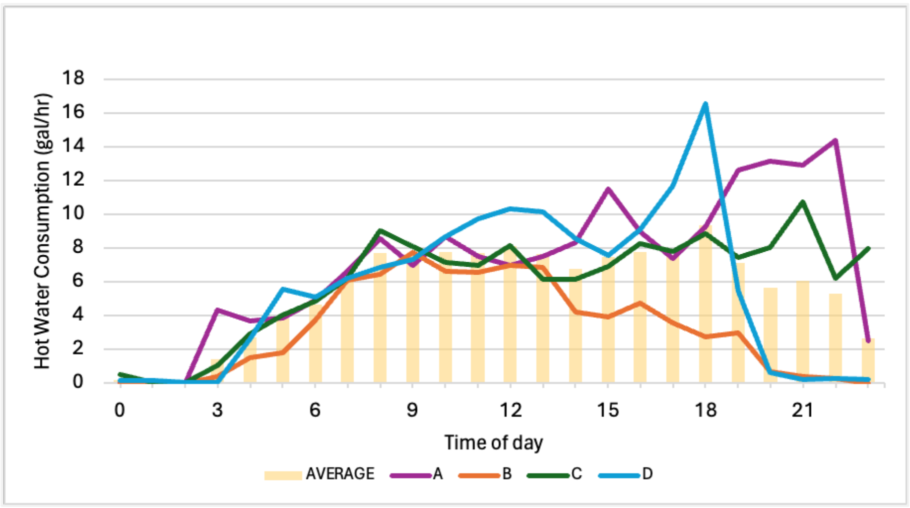


Figure 4: Average daily hot water draw profile, café.

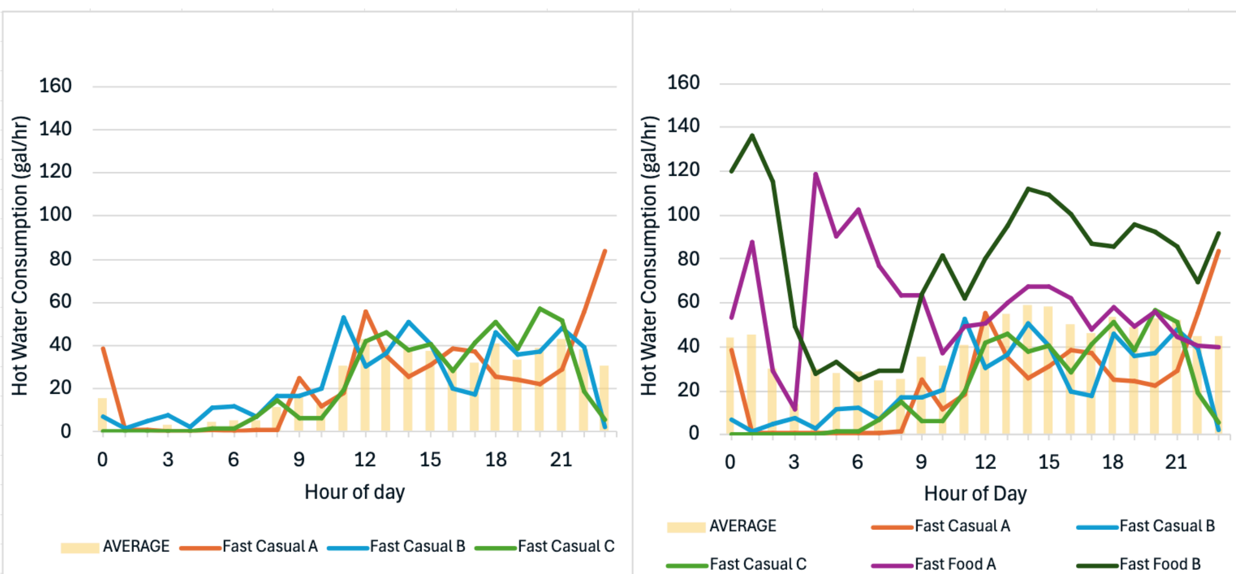


Figure 5: Average daily hot water draw profile, QSR types.

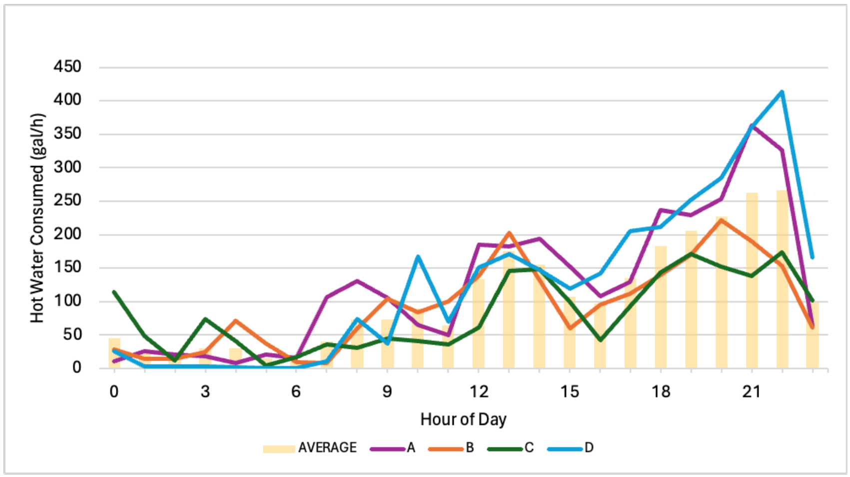


Figure 6: Average daily hot water draw profile, FSR.

Heat Pump Water Heater Technology

HPWHs are a valuable technology to decarbonize water heating systems. Instead of generating heat by burning fuel, an HPWH uses electricity to move heat from outside air or indoor air to water via a refrigerant cycle, which is composed of a compressor, evaporator, and a fan. HPWHs can be integrated, with the heat pump located in the same integral unit as the water storage tank, or they can be split system, with the heat pump typically located outside and the storage tank inside, with cold and hot water pipes going between the two locations. HPWHs on the market today are sized to serve small to large loads and are packaged with different sized heat pumps, which is further explained in the HPWH Market Assessment section of this report.

To date, there have been numerous successful demonstrations of centralized HPWH plants in multifamily applications, both within and outside California. For example, the Bonneville Power Administration published a case study of a HPWH system in the colder Seattle, Washington climate. The case study demonstrated that four Sanden HPWH units were able to produce hot water temperatures near 150°F and meet the building load of 1,198 gallons per day (Banks, Grist and Heller 2020), a daily load similar to a medium-sized FSR. In another example, a CalNEXT study led by ASK Energy observed two buildings in San Francisco, California, which had an average daily hot water consumption of 2,976 gallons per day and 3,699 gallons per day, serving 120 and 130 dwelling units, respectively. According to the study, the HPWH plant—which each operated two large CO_2-based HPWHs—delivered sufficient hot water, typically 125°F, at a coefficient of performance[2] (COP) of 2.6 and 2.7, reducing the hot water energy consumption at the sites by 68 percent and 69 percent (Valmiki, et al. 2023).

Because HPWHs have a lower output capacity, their performance characteristics are different from gas-fired water heaters. Commercial HPWHs typically output between 15,000 to 287,000 British

[2] The COP metric describes a ratio of the delivered heating effect divided by the input energy, similar to a thermal efficiency (TE) metric for gas-fired or electric water heaters. A water heater performing at 2.4 COP is operating at three times the efficiency of a fuel-fired water heater performing at 80 percent TE.

thermal units per hour (Btu/h), compared to gas storage water heaters, which are typically rated between 150,000 and 499,000 Btu/h. As a result, HPWHs have a lower first-hour recovery, meaning it takes a longer time to fill a storage tank with hot water, or “charge.” Therefore, it is essential to optimize HPWH system designs so that hot water storage tanks are slowly charged during periods of low hot water demand and discharged during peak hot water demand periods. Larger storage tanks also allow for load shifting capability, allowing the heat pump or any supplemental electric resistance heaters to turn off or operate on a limited basis during peak electric charge periods, or peak time of use (TOU). Designers of HPWH systems also seek to:

- Reduce hot water load by specifying lower flow fixtures and high efficiency hot water end uses, such as dishmachines for the foodservice sector.
- Optimize recirculation load and reduce the volume of hot water returned to the HPWH system by utilizing an ECM variable speed pump with temperature controls.
- Optimize the HP efficiency with thoughtfully designed piping and system configuration, such as utilizing swing tanks.

Technical Barriers to HPWH Technology in the Foodservice Sector

- **Space Constraints:** HPWH systems generally require more interior space due to storage tanks and swing tanks, and outdoor space for the heat pump condenser units.
- **Electrical Infrastructure:** Foodservice kitchens generally have limited excess panel capacity. Adding load for HPWHs and other all-electric cooking equipment would likely require significant infrastructure upgrades and cost (Monsur, Kuck and Honegger 2022).
- **Noise:** Commercial kitchens are already loud spaces, so additional noise from a HPWH fan could be problematic if it raises the level above 85 dBA for a prolonged period of time (Fountain et al 2023).
- **Installation Requirements:** There are a number of unique installation requirements for HPWH systems, including pipe penetrations to the exterior, condensate drain lines, and adequate ventilation.

Existing Case Studies

While electrifying foodservice cooking equipment has garnered attention in recent years, there are limited reports of electrification of foodservice hot water systems. During this literature review, the research team found few articles or case studies studying all-electric water heating or HPWHs in restaurants. Many articles tout the success of induction cooking technology but exclude details on the water heating design; for example, a case study of the Microsoft East Campus in Washington describes an all-electric cafeteria with a central water heater plant, but it doesn’t confirm whether the system is all-electric (Microsoft 2022).

The team found one case study featuring HPWHs in Bennington, Vermont, where—with the support of Efficiency Vermont—Publyk House restaurant completed a retrofit upgrading a propane system to high efficiency, low-GWP heat pumps (Efficiency Vermont n.d.). This system used two low-GWP heat pumps and two storage tanks located in the rear of the kitchen, and according to the head chef, the cool air by-product of the heat pumps was welcome and “[made] a huge difference in the quality of work in this kitchen” (Efficiency Vermont n.d.). The lack of widespread water heating electrification in this sector can be partially attributed to health code restrictions, which are described in this report's Policy Overview section.

One active CalNEXT-funded project—titled, "ET22SWE0046 - Restaurant Field Monitoring," led by TRC Companies, and with a project completion date of November 2025—demonstrates installing an HPWH at a restaurant in California as an add-on to the existing gas water heating system. The research team is also aware of monitoring efforts by New Buildings Institute, studying real-world performance of integrated HPWHs in a range of foodservice applications, the project is expected to conclude in 2027.

HPWH Market Assessment

In the 2024 HPWH market, assuming that HPWHs can be sized according to their hot water output (rather than input) capacity, there is no shortage of equipment that can meet the hot water needs of foodservice facilities when incorporated in a thoughtful water heating system design. In certain foodservice facilities, there are cases where a single HPWH could output the entire requirements set forth by the CCDEH Guidelines. However, current market penetration is still limited at the time of writing. The CalNEXT project, "Market Potential for Heat Pump Assisted Hot Water Systems in Foodservice Facilities," collated a range of HPWH products, with key criteria in Table 3 of the final report (Fountain, et al. 2023). Excerpts of key data are replicated in Table 1 below.

Table 1: Key criteria for a representative collection of HPWHs.

Product	Configuration	Rated HP Heat Capacity (kBtu/h)	Rated Heating COP	Max Output Temperature (°F)	Refrigerant & Ambient Operating Temperature Range (°F)	Sound Level (dBA)
A	Integrated Hybrid Storage	HP: 33.7 ER: 40.9	4.2	HP-150°F ER-180°F	R-134a 40-110°F	59
B	Split	HP: 15 ER: N/A	5.1	150°F	R-744 25-104°F	37
C	Split	HP: 68.4 ER: N/A	3.2	140°F	R-410A 10-90°F	72
D	Split	HP: 136.5 ER: N/A	4.1	176°F	R-744 13-109°F	60
E	Split	HP: 136.9 ER: N/A	4.3	160	R-513A 23-120°F	63-76

As seen in Table 1, there are several product lines, ranging from unitary hybrid storage to split systems, that use a range of refrigerants. Design considerations include installation location, refrigerant type, and corresponding heat output at temperatures expected in the installation location. Noise ratings are another key criterion to consider when selecting HPWHs, since some units will be installed indoors where back-of-house employees will be working in close proximity, or in utility closets adjacent to dining and serving areas.

ADDITIONAL HPWH MARKET TECHNICAL GAPS

- **Robust Intake Air Filter for Integrated HPWHs.** Because integrated HPWHs would be located inside the kitchen preparation area with potential exposure to grease and other kitchen contaminants, integrated HPWHs need to have a high-quality filter—one that can be cleaned and replaced easily—or a layer of filters. In addition, it would be ideal for manufacturers to provide two filters so maintenance staff can use the backup air filter during cleaning without turning off the water heater and disrupting hot water delivery.
- **Noise Dampening Options for Integrated HPWHs.** Kitchen preparation areas are already loud, and outdoor dining spaces are sensitive to additional noise. Designers will need to be thoughtful when placing integrated or split systems in restaurant spaces. Additional noise-dampening strategy options, such as a larger fan, would be helpful to eliminate this barrier and make HPWHs an easier choice.
- **High HPWH Efficiency with Recirculation.** Many commercial kitchens use recirculation loops to maintain adequate temperature throughout the system. However, not all HPWH products operate well under a multi-pass configuration, where the heat pump intakes warm return water; the performance depends on the specific refrigerant and configuration. There is a key opportunity to develop HPWH models that can perform optimally with a recirculation loop (without a swing tank).

Policy Overview

Other Applicable Codes and Standards

Recent regulatory activity, including a California Air Resources Board (CARB) regulatory proposal and air quality management district rulings, indicate a future shift to limit emissions of water heaters. It is critical that health and safety codes and standards are in alignment with CARB and air quality management district rulings and support high-efficiency low-emission water heating technology.

In September 2022, CARB approved the State Strategy for the State Implementation Plan, which included controlling greenhouse gas emissions from newly sold space and water heaters after 2030. CARB has not yet released the final ruling, which will likely be proposed in 2025 (CARB 2024). In alignment with CARB, the Bay Area Air Quality Management District (BAAQMD) and South Coast Air Quality Management District (SCAQMD) have recently adopted rulings that limit the allowable nitrogen oxides of residential and commercial water heaters sold in California.

On March 13, 2023, the BAAQMD adopted a revision of Regulation 9, Rule 6, which states: “No person shall sell, install, or offer for sale within the District any large natural gas-fired boiler, storage tank water heater, or instantaneous water heater with a rated heat input capacity from 75,001 to 2,000,000 Btu per hour, inclusive, manufactured after January 1, 2031, that emits more than 0.0 nanograms of nitrogen oxides (calculated as NO_2) per joule of heat output.” The rule also has a designation for water heaters up to 75,000 Btu per hour, with an earlier implementation date (BAAQMD 2023).

On June 7, 2024, the SCAQMD adopted Rule 1146.2, which states that commercial water heaters have a nitrogen oxide emission limit of 20 parts per million by volume, which will go into effect in phases between 2026 to 2033 (SCAQMD 2024).

Health and Safety Codes and Standards

The Food and Drug Administration Food Code is “a model that assists food control jurisdictions at all levels of government by providing a scientifically sound technical and legal basis for regulating the retail and foodservice segments of the industry (restaurants and grocery store and institutions such as nursing homes)” (US Food and Drug Administration 2023). Authorities Having Jurisdiction (AHJs) over these food establishments can adopt the Food Code directly or use it to develop their own food safety policies. Forty-nine states have adopted some version of the Food Code, first published in 1997 and most recently revised in 2022, with California being the only exception—though New York has two agencies, only one of which has adopted the 2001 version (US Food and Drug Administration 2024). The Food Code offers brief guidance on hot water supply in retail food establishments in section 5-103 *Quantity and Availability [of water]*: 5-103.11 (B), which states, “Hot water generation and distribution systems shall be sufficient to meet the peak hot water demands throughout the food establishment.”

Nationally, 64 state agencies are responsible for the regulatory oversight of retail food stores and restaurants. Nine agencies are responsible only for restaurants, 10 agencies are responsible only for retail food stores, and 45 agencies are responsible for both restaurants and retail food stores. The majority (42) of the agencies are specifically health agencies, while the remainder are agricultural agencies (17), or departments such as business and professional regulations (5). As mentioned previously, all these agencies except two in New York and California have adopted the Food Code (US Food and Drug Administration 2024).

The research team reviewed regulations for 20 AHJs and found the regulations are effectively the same, with the responsibility for ensuring adequate hot water left to the local AHJ. A few have created guidelines for foodservice hot water heating at the state level, such as Michigan, North Carolina, and Georgia. For example, Michigan’s Department of Agriculture and Rural Development and North Carolina’s Department of Health and Human Services have each published an Excel calculator that can be used to help size water heaters for foodservice establishments, while Georgia’s Department of Public Health provides a 36-page written document with data, equations, and example calculations.

Despite declining to officially adopt any version of the Food Code, the California Retail Food Code follows the same pattern in Section 114195 of “Article 1. Water” in “Chapter 7. Water, Plumbing and Waste,” which states in section 114195 (b): “Hot water generation and distribution systems shall be sufficient to meet the peak hot water demands throughout the food facility.” The California Retail Food Code assigns “primary responsibility” for its enforcement to the local enforcement agency and defines “enforcement agency” as the department or local health agency having jurisdiction over the food facility. As a result, there is effectively no California regulation dictating the sizing of water heaters in retail food establishments beyond local authorities verifying that the hot water supply is sufficient.

Each county or municipal AHJ—e.g., health department or local building and safety department—is expected to understand and evaluate the hot water requirements for each foodservice establishment and ensure that the equipment installed at each establishment can meet the hot water demands of the facility. For example, in Los Angeles, all food facilities being remodeled or constructed must have plans reviewed and approved by the health department and the local building and safety department; the Los Angeles local construction requirements align with the California Retail Food Code, specifying that hot water must be at least 120°F and that hot water generation must meet the peak hot water demands. It also includes a reference to the CCDEH Water Heater Sizing Guidelines (County of Los Angeles Public Health n.d.).

CCDEH

The California Conference of Directors of Environmental Health (CCDEH) is a 501(c)(3) non-profit organization whose "membership is comprised of Environmental Health Directors from 62 jurisdictions, including all 58 California counties and 4 California cities" (California Conference of Directors of Environmental Health 2020). The CCDEH developed Guidelines[3] for sizing water heaters in 1995 to help alleviate the lack of guidance at the state level. The Guidelines have only been updated once since their formation, in 2020, to include sizing requirements and needs for instantaneous or tankless water heaters. These Guidelines generally follow two models—one for storage and one for tankless—for water heater sizing. The storage water heater sizing model is based on the recovery rate of the water heater and an estimated maximum hourly hot water heater demand, which is calculated by summing all the potential draws for each fixture that uses hot water. The tankless model uses the thermal output of the water heater and an estimated maximum minute demand achieved by summing all the potential draws for each hot water end use.

The following section outlines a step-by-step sizing example for a storage water heater at an FSR.

EXAMPLE FSR SIZING USING CCDEH GUIDELINES

The first step in the Guidelines is determining the food facility type to select a recovery rate percentage of the hourly hot water demand in gallons per hour (GPH). Since this example FSR uses multiservice eating and drinking utensils, the heat recovery rate must be at least 100 percent of the hourly hot water demand in GPH.

Next, the hourly hot water demand for the food facility is determined by summing the estimated hot water demand for all hot water end uses. Appendix I of the CCDEH Guidelines lists the estimated hot water demand for various sinks and equipment. Table 2 below shows a summary of equipment that uses hot water in our example restaurant, where the fixture types and counts are based on project team field work experience, and the fixture flows come from the CCDEH Guidelines.

[3] CCDEH Guidelines for sizing water heaters can be found at ccdeh.com.

Table 2: Storage hot water heater sizing for medium FSR with bar and multiservice utensils.

Fixture type	Quantity	Tank Recovery rate per fixture (GPH)	Total Tank Recovery Rate (GPH)
Restroom Sinks	4^	5*	20
Hand Sinks	5^	5*	25
3-Compartment Sinks (18” x18”)	1^	42*	42
3-Compartment Bar Sink	1^	18*	18
Dish machine	1^ (Door Type)	51^	51^
Pre-Rinse Hand Spray Valve	1^	45*	45
Mop Sink	1^	15	15
Food Prep Sinks	2^	5*	10
Total Minimum Storage Water Heater Recovery Rate (GPH)			**226**

*Default value per Appendix I of CCDEH Guidelines.
^From project team previous fieldwork experience

After developing the minimum water heater recovery rate in GPH—which is 226 GPH in this example—the input rate of the water is calculated for either gas or electric water heaters using Equation 1 below. The required temperature rise and thermal efficiency of the water heater type are also needed to calculate the input rate. The required temperature rise is calculated by subtracting the incoming tap water temperature from the desired hot water temperature, as shown in Equation 2 below. For gas thermal efficiency, the Guidelines dictate that “unless otherwise listed by a nationally recognized testing laboratory, will be assumed to be 75 percent.” For the electric thermal efficiency, “unless otherwise listed by NSF or other nationally recognized testing laboratories, will be assumed to be 98 percent” (California Conference of Directors of Environmental Health 2020).

Equation 1: kW input calculation for electric storage water heater.

$$kW\ Input = \frac{Heat\ Recovery\ Rate\ (GPH) \times T_{Rise\ required}(°F) \times \frac{8.33lb}{gal.}\left(\begin{matrix}Density\\ of\ water\end{matrix}\right)}{Thermal\ Efficiency \times 3{,}412\left(\frac{BTU}{kW}\right)}$$

Equation 2: Required temperature rise equation.

$$T_{rise\ required} = T_{Hot\ water} - T_{incoming\ water}$$

Using values of 140°F and 70°F for $T_{Hot\ water}$ and $T_{Incoming\ water}$ respectively, yield a required temperature rise of 70°F. Taking each of these elements into consideration results in Equation 3 below.

Equation 3: Electric storage water heater input calculation for medium FSR with multiservice utensils.

$$39.4\ kW = \frac{226\ GPH \times 70°F \times \frac{8.33lb}{gal.}\begin{pmatrix}Density\\ of\ water\end{pmatrix}}{0.98 \times 3{,}412\ (\frac{BTU}{kW})}$$

Following the CCDEH Guidelines results in a required input of 39.4 kW from an electric resistance storage water heater (ERWH). A standard ERWH that would satisfy this minimum requirement would be rated at 40.5 kW.

This method of calculating water heater sizing presents two disadvantages for a restaurant developer or owner interested in installing HPWHs:

- The methodology includes a default electric efficiency of 0.98, which is much lower than efficiencies available from HPWH systems.
- There is no consideration for thermal energy storage in the form of available hot water stored in the tank.

Because the size of the tank is not incorporated into the sizing calculation, storage water heaters are effectively treated as instantaneous water heaters and are sized based on hourly hot water use (GPH) and energy input per hour rather than per minute. Additionally, sizing HPWHs using a 98 percent thermal efficiency—when they operate at COPs of 2.5 to 4.0—greatly oversizes them, and increases equipment installed costs, electrical capacity, and space requirements.

If the calculations were carried out using the more appropriate efficiency value of 250 percent, or 2.5, as demonstrated in Equation 4 below, the Guidelines would specify a far smaller system:

Equation 4: Unitary HPWH kW input calculation for large FSR with multiservice utensils.

$$15.4\ kW = \frac{226\ GPH \times 70°F \times \frac{8.33lb}{gal.}\begin{pmatrix}Density\\ of\ water\end{pmatrix}}{2.5 \times 3{,}412(\frac{BTU}{kW})}$$

SUMMARY OF IDENTIFIED CCDEH GUIDELINE SHORTCOMINGS

- Does not support all water heater technology, including electric heat pumps.
    - Designers report that in practice, heat pump efficiency (COP) is not accepted by their health and safety department, despite it being tested by a nationally recognized test lab.
        - COP should be accepted, and to improve accuracy, COP should be calculated depending on heat pump install location, climate zone, heating plant and distribution system configuration, and design set points.
    - Storage capacity of the water heater is not considered, including the ability to shift load to off-peak time-of-use (TOU) rate hours.

    - Does not support hybrid HPWH systems that include a heat pump with electric resistance backup elements.
    - Does not support dual fuel approaches, such as HPWHs with natural gas back-up, which is being adopted by some while HPWHs gain support from owners and operators.

- Simplistic approach to water heater sizing.
    - The current Guidelines do not factor in:
        - Design day ambient air conditions and cold water supply temperatures
        - Typical hot water outlet temperatures
        - Ventilation requirements
        - Hot water storage capacity
        - Impact of recirculation flow rate (with/without pump controls) on recovery rate
        - Pipe distribution heat losses
        - Minimum hot water delivery time requirements for new construction at hand sinks
- Uses fixture recovery rate defaults from the 1990s, which have not been aligned to fixture water efficiency improvements in present day codes and standards.

Pathways to Modify the Guidelines

There are a number of different approaches to adjust the Guidelines to allow for heat pump technologies and address the previously described gaps. The research team has outlined three different pathways in Table 3 below, with pros and cons for each option.

Table 3: Pathways to modify the CCDEH Water Heater Sizing Guidelines.

#	Pathway Description	Pros	Cons
1	**Update Existing Guidelines** Update the current document of prescriptive guidelines to incorporate HPHWs and other non-HP-specific improvements	Shortest revision timeline CCDEH likely most comfortable with this approach	Manual calculations and look up tables can introduce more errors The added complexity for sizing HPs may be challenging for some users Would take more time for CCDEH to review and approve. More difficult to improve guidelines as needed statewide and have it filter down to municipalities.
2	**Complete Sizing Tool** Establish an alternate pathway for heat pump technology, in which users complete a sizing tool (spreadsheet- or online-based) that comprehensively factors in all design set points. This tool would be funded, created, and managed by a third party. One example is the Ecosizer tool.	Thorough approach, would include sizing for ER/gas heaters. Can output sizing details digitally for easy processing or via pdf document Free online software, if funded by public entities One-stop design, can incorporate T24, footprint, operating cost and efficiency tools and guidance	Long timeline to develop tool that incorporates lab testing data. Continuous collaboration and long-term funding required to maintain and host tool.

#	Pathway Description	Pros	Cons
3	**Submit HP Projects to Building Department** Establish an alternate pathway for HPWHs, in which users can submit their plan set to building department, who has engineering expertise to verify proper sizing of the HPWH and appropriate system design to deliver necessary hot water.	Builds on existing relationships between departments Short to medium timeline depending on several factors More uniform approach on commercial systems	Still requires a new sizing guideline to be developed for foodservice Does not address other needed revisions to the Guidelines. Adds extra processes and related training and staffing considerations.

Methodology and Approach

The research team used the following research methods.

Literature and Data Set Review

The research team searched for all relevant published research papers, case studies, design guides, California Energy Commission (CEC) reports, and CalNEXT reports, and organized them into categories of application. Once identified, the team reviewed all literature, took notes, and summarized themes under each research topic sub-category.

The team evaluated the HPWH market landscape by reviewing existing market characterization tables from other CalNEXT project reports, searching for new products, and creating a summary of market information relevant to this research project.

In addition, the team gathered data from recent Frontier Energy field studies of hot water usage in commercial kitchens, summarized it in a single data table, and extracted the data points necessary for this research study. The data points included facility type, water heater type and system details, peak hour and two-hour hot water demand in gallons, average daily hot water consumption, and hourly hot water consumption over research duration.

Stakeholder Engagement

As a key component of the study, the team engaged with key environmental health department stakeholders to educate them about HPWH technology and work to find a path forward to revising the CCDEH Guidelines in support of HPWH technology. The research team met with:

- Industry subject matter experts
- An MEP designer who has designed HPWH systems in Washington State
- Health specialists and plan checkers from the following County health departments or agencies: Orange, San Bernadino, Riverside, and Ventura
- Health department leaders at Orange, San Francisco, and San Mateo Counties who are also involved with CCDEH
- Members from the FDA Retail Food Protection, Retail Food Policy Team
- South Coast Air Quality Management District representatives

- Fellow researchers under CalMTA and PG&E's Code Readiness Subprogram

In addition, the research team presented at a Bay Area Foodservice Technical Advisory Committee meeting to members from 14 Bay Area counties in August 2025 to share research progress, an overview of HPWH technology, and the proposed revisions for the CCDEH Guidelines and received positive feedback.

Field Data Collection

A key objective for this project was to characterize full-service restaurant hot water demand and equipment consumption through field data collection. The following sub-sections document the methodology, and include:

- Field site recruiting and screening
- Data collection approach, including monitoring plan and equipment installation
- Analysis and calculations
    - Characterize the hot, cold, and recirculation draw patterns
    - Identify dishwasher draw characteristics to disaggregate the load
    - Evaluate HPWH installation potential and cost

Field Site Recruiting and Screening

The research team determined the following facility criteria for recruiting field sites:

- Program requirement: must have electricity served by an investor-owned utility
- Full-service restaurants (ideally each with different throughput)
- Water heater must be tank-type and have a recirculation loop
- Site must have a door-type dishmachine
- Diverse climate zones
- Sufficient pipe access and length for ultrasonic flow meters

The research team conducted outreach to a wide array of restaurants across California. If the site met key criteria and the site owner was interested, the research team conducted a field audit to confirm it was conducive to the team's data collection approach, e.g., confirming there was sufficient pipe length for the ultrasonic flow meters.

Recruiting field sites was a challenge for the team; it was also difficult to achieve certain ideal criteria, such as diverse full-service restaurant types and locations. To meet the project timeline, the team collected data from responsive sites that met the high-priority criteria and monitored three fine-dining Bay Area restaurants. Table 4 below outlines key facility and water heating system details for each monitored site.

Table 4: Field site details.

	Site 1	Site 2	Site 3
California Climate Zone	3		
Restaurant Type	Full Service: Fine Dining		

	Site 1	Site 2	Site 3
Operating Days and Meal Services	Every day: dinner	Every day: dinner	Tues – Sat: lunch and dinner Sun: lunch
Approximate Facility Size (ft^2)	5,300	2,200	15,000
Water Heater Input (Btu/h)	199,900	120,000	270,000
Water Heater Storage Capacity (rated gallons)	100	60	100
Thermal Efficiency (%)	97	95	81.3
Water Heater Setpoint (°F)	175	140	122 [A]
Distribution Type	Recirculation		

[A] Estimated set point, as water heater has a mechanical thermostat.

Data Collection Approach

Once the research team selected a site for monitoring, we prepared a plan to gather each data point. Table 5 below outlines each collected data point. The team also collected supplemental spot measurement flow data for each fixture, including the dishmachine.

All ultrasonic flow meters were calibrated in the lab on a water flow station by referencing an upstream badger M25 record all positive displacement nutating disk type water meter that had been calibrated using the weight of water method at a resolution of about 0.005 gallons. Multiple calibration points were tested from about 10gpm down to 0.2 gpm.

Thermistors were calibrated against a Fluke NIST calibrated thermocouple model 54IIB. Thermistors were calibrated/checked at 32°F and 212°F in water baths.

The existing utility flow meters could not be lab calibrated, however the pulses per gallon were measured and calculated by observing water meter dial movements over about 10 gallons of flow and comparing the result to the number of pulses output by the meter.

Table 5: Monitored data points.

Measured Parameter	Data Acquisition Method	Unit of Measurement	Installed at Site 1	Installed at Site 2	Installed at Site 3
Primary Hot Water Flow (includes recirc)	Ultrasonic Flow Meter	Pulses (converted to gallons)	X		
Secondary Hot Water Flow (Bar Sink)			X		
Hot Water Supply Flow				X	
Cold Water into Water Heater Flow					X
Recirc Return to Pump Use			X	X	X
Metered Utility Water Meter Use	Utility Flow Meter		X	X	X
Cold Water In Temperature	Thermistor	°F	X	X	X

Measured Parameter	Data Acquisition Method	Unit of Measurement	Installed at Site 1	Installed at Site 2	Installed at Site 3
Hot Water Out Temperature			X	X	X
Recirc Return to Pump Temperature			X	X	X
Water Heater Room Air Temperature	Attune Air Quality Monitor	°F	X	X	X
Water Heater Room Air Relative Humidity		%	X	X	X
Water Heater Room Air CO_2		PPM	X	X	X

The research team was able to gather data from each site for roughly five to eight months. Figure 7 shows the schedule of the monitoring period by site and identifies changes in data logging intervals. At all three sites, there were small gaps of data due to sensor disconnect or battery run out, which is a common field monitoring challenge. Any instances of data extrapolation are noted clearly in the Findings section (only completed for the monthly summary).

Figure 7 also highlights a known site issue, which occurred at Site 3: The water heater began malfunctioning in June and continued to have issues through the conclusion of the metering period at the end of July, during which time it was unable to consistently meet the water heater setpoint. The site was aware of the issue and had the water heater serviced multiple times during that period without success. Data from June and July is excluded from the analysis for Site 3, apart from the hot water draw analysis, which the team found to fall within the typical range.

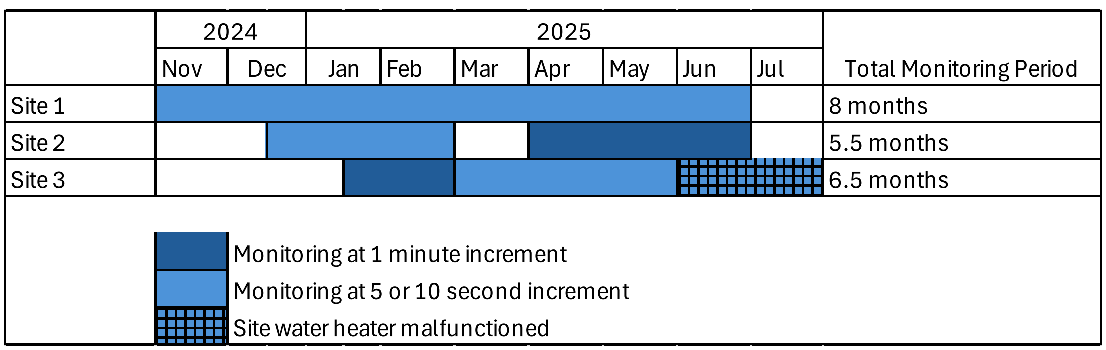


Figure 7: Field site data collection period.

The following images in Figure 8 and Figure 9 show examples of the monitoring instrumentation.

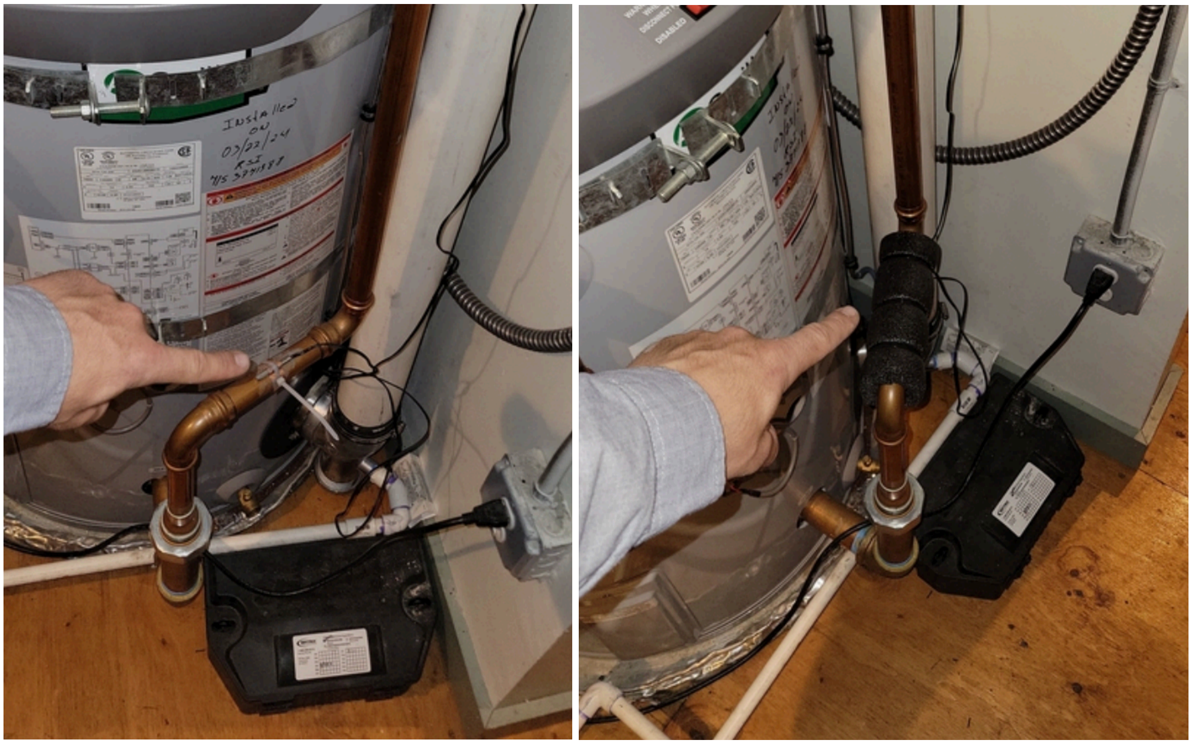


Figure 8: Temperature sensor installation before and after pipe insulation.

Figure 9: Installed ultrasonic flow meter (left) and monitoring equipment: data node and bridge (right).

Analysis and Calculations

The research team analyzed the data to characterize hot, cold, and recirculation water use; the draw profile; and other system characteristics, such as supply, return, and cold water temperature. This section defines the analysis methodology, while Table 6 includes additional variable nomenclature unique to the analysis.

Table 6: Analysis variable nomenclature.

Variable Symbol	Variable	Variable Units
q_{HW}	Thermal energy added to hot water	BTU
q_{RW}	Thermal recirculation losses	BTU
ρ	Density	$^{lbm}/_{ft^3}$
V_{HW}	Daily Average Hot Water Flow	GPM
V_{RW}	Daily Average Recirculation Water Flow	GPM
c_p	Specific heat for constant pressure process	$^{BTU}/_{lbm * °F}$
T_{CW}	Mass Weighted Temperature of Cold Water	°F
T_{HW}	Mass Weighted Temperature of Hot Water	°F
T_{RW}	Mass Weighted Temperature of Recirculation Water	°F

Several minor conversions and assumptions are required to convert the measured data for analysis. These key assumptions include:

- The specific heat of water for constant pressure processes is approximated as 1 BTU/lbm*°F
- The density of water is calculated as a temperature dependent value; a unique value for density is assigned for each one-degree Fahrenheit via linear interpolation between United States Geological Survey published values (United States Geological Survey 2024)
- The heating value of natural gas is assumed to be 1,038 $^{BTU}/_{Cubic\ Foot}$

For both Site 1 and Site 2, the team could not install a single ultrasonic flow meter on the cold water supply to the water heater to directly measure hot water use. This was the result of insufficient straight pipe lengths, which allow the water flow to become laminar inside the cold water pipe; the ultrasonic flow meters need this to achieve accurate flow readings. The team instead had to install the water meter on the hot water pipe, which had sufficient straight pipe sections for flows from both hot water use and recirculation. To determine hot water use at Site 1 and Site 2, the team subtracted recirculation water flows from the flow in the hot water pipe. Additionally, at Site 1, a pipe serving the bar sink branched before the location of the ultrasonic flow meter, so we installed an additional flow meter to capture total hot water use. Equation 5 and Equation 6 outline the calculations used for Sites 1 and 2.

Equation 5: Site 1 hot water flow.

$$Site\ 1\ Hot\ Water\ Flow = Primary\ HW\ Pipe\ Flow + Bar\ Sink\ HW\ Flow - Recirculation\ Water\ Flow$$

Equation 6: Site 2 hot water flow.

$$Site\ 2\ Hot\ Water\ Flow = Hot\ Water\ Pipe\ Flow - Recirculation\ Water\ Flow$$

When analyzing instantaneous data, the team cleaned it of metering noise by making any negative results 0. For longer periods, we also applied this method, but it was less necessary as the averaged results greatly reduced the negative values.

At Site 3, the team could place the water meter on the cold in-pipe upstream of the recirculation line to directly measure hot water used by the facility.

MASS WEIGHTED TEMPERATURES

To determine daily recirculation losses and water heater energy consumption—as there was no direct gas meter installed—the team first had to calculate the mass weighted temperatures. This method weights the temperatures only recorded during flow events by the amount of flow during that event. This effectively eliminates hot water pipe temperature readings that decline due to pipe losses from little to no water draw. Similarly, it eliminates cases where cold water temperature readings might rise from ambient air or thermal conductivity from the hot water storage tank, when there is little to no water draw. To accomplish this, the team implemented Equation 7 below:

Equation 7: Mass weighted temperature of hot water calculation.

$$T_{HW} = \frac{Average\ of\ Day(Temperature\ at\ Sampling\ Frequency\ x\ Flow\ at\ Sampling\ Frequency)}{Average\ of\ Day(Flow\ at\ Sampling\ Frequency)}$$

All water temperature data presented in tables in this report follow this method and are a mass weighted average (MW average), as opposed to an arithmetic average, unless noted otherwise.

ENERGY TRANSFER CALCULATIONS

With these daily mass weighted average temperatures, the team could then calculate the energy added to water by the water heaters and energy lost by the recirculation loop, as shown in Equation 8 and Equation 9 below.

Equation 8: Energy added to hot water.

$$q_{HW} = (T_{HW} - T_{CW})\ x\ V_{HW}\ x\ c_p(T_{HW})\ x\ \rho(T_{HW})$$

Equation 9: Recirculation loop losses.

$$q_{RW} = (T_{HW} - T_{RW})x\ DV_{RW}\ x\ c_p(T_{HW})x\ \rho(T_{HW})$$

DISHMACHINE USE DISAGGREGATION

The research team completed dishmachine disaggregation for Sites 1 and 3, which proved challenging. Although the team sampled water flows at 5 or 10 seconds, depending on the hardware installed, dishmachines tend to draw water for only 30 to 45 seconds, meaning the resulting shape was not well defined.

The team validated the cycle profile in the field by turning on the dishmachine when no other fixtures were being used. We then wrote a script to identify the dishmachine draw profile for all days. The team set a minimum flow threshold that would indicate a dishmachine cycle, based on manufacturer information and a flow profile from running a rack with no other uses. Additionally, we implemented logic to restrict the dishmachine use indications to only one per 30 seconds. Although Sites 1 and 3 have two dish machines, the team determined it was unlikely that the second dishmachine—a single-rack, glass dishmachine operated at the bar—would run very often, and that this was an acceptable method.

Findings

Table 7 provides a consolidated summary of the selected data points calculated for this study.

Table 7: Key data point results.

Data Point		Site 1	Site 2	Site 3
Restaurant Sub-Type		Fine-dining FSR		
Water Heater Setpoint Temperature (°F)		175	140	122 [A]
Mass Weighted Mean Hot Water Supply Temperature (°F)		170.1	140.2	123.3
Mass Weighted Mean Return Water Temperature (°F)		165.5	131.3	95
Cold Water to Building	Mean Use Per Day (Gallons)	1,648	1,723	1,860
	Mean Use Per Weekend Day Fri-Sun (Gallons)	1,845	1,788	1,707 [B]
Hot Water Supply	Mean Use Per Day (Gallons)	629	838	1,115
	Mean Use Per Weekend Day Fri-Sun (Gallons)	675	854	959 [B]
	Mean Use Per Weekday Mon-Thurs (Gallons)	594	826	1,213 [C]
	Peak Day Hot Water Use (Gallons and Date)	991 (04/26/2025)	1,119 (1/26/25)	2,252 (4/4/25)
	Peak 1-Hour Draw (GPH, Date and Time) [E]	186.3 (12/23/2024, 8:35-9:35pm)	218.5 (6/23/2025, 10:32-11:32pm)	251.8 (3/25/2025, 8:34-9:34pm)
	Peak 2-Hour Draw (GPH, Date and Time) [E]	274 (11/16/2024, 8:36-10:36pm)	310.7 (6/23/2025, 9:33-11:33pm)	427 (5/6/2025, 7:06-9:06pm)
Mean Recirculation Pump Flowrate (GPM)		5.70	1.01	0.17 [D]
Recirculation Loop Loss Energy (Percent of Total Btu)		57.1%	32.7%	17.9%
Thermal Energy Added to Water per Day (Btu)		538,150	334,041	414,081
Thermal Energy Added to Water per Day (Therms)		163.7	101.7	126

[A] Water heater has a mechanical thermostat; this is an estimate.
[B] Excludes Sunday, as site is open for a part-day.
[C] Excludes Monday, when site is closed.

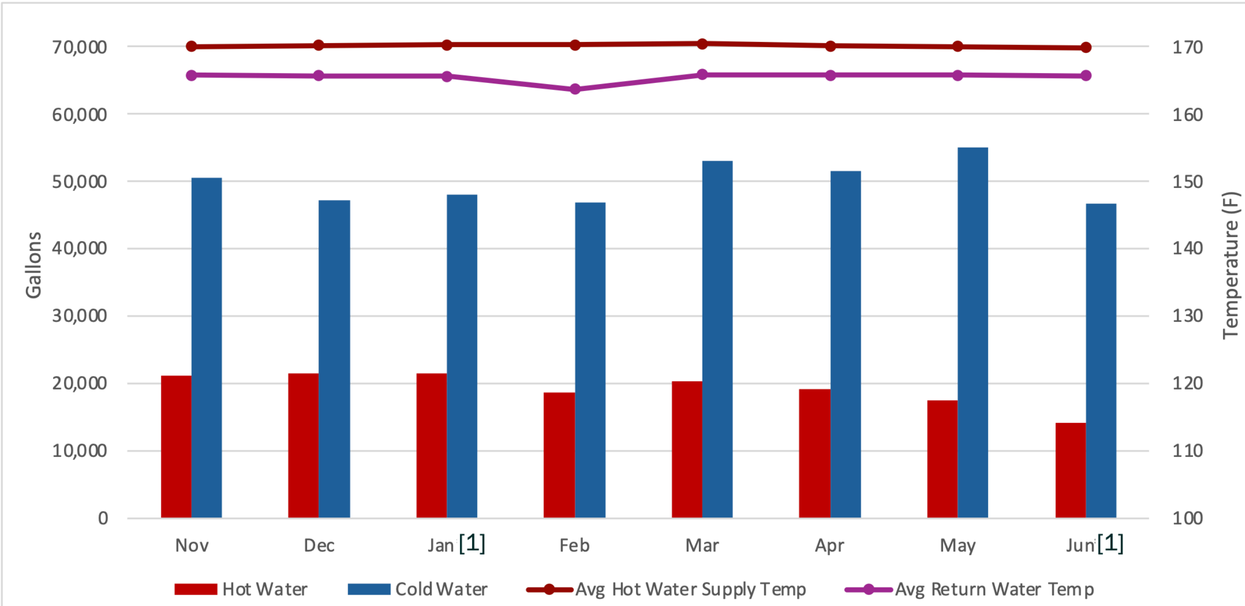
[D] Site recirculation pump is not functioning as intended; appears to be partially functional.
[E] Peak draws are calculated on a rolling-sum per minute basis.

Key observations from the table include:

- **All three sites consumed similar amounts of cold water:** Mean cold water use per day ranged from 1,648 to 1,860 gallons.
- **Hot water gallon use alone does not tell the whole story:** The restaurants used very different amounts of hot water, with Site 1 using the least at 629 gallons per day and Site 3 using the most at 1,115 gallons per day. However, it is important to note the difference in recirculation losses and setpoint temperatures, which ranged from 122 to 175°F. Viewing hot water consumption in terms of Btus tells a different story. Daily hot water Btus ranged from 335,000 to 540,000 Btus, with Site 2 having the lowest and Site 1 having the highest hot water energy consumption.
- **Varying recirculation pump flowrates:** Flowrates ranged from 0.17 to 5.70 GPM across the three sites. Site 3's pump had a known issue and malfunctioned during the field monitoring period. Site 1 has a 5.7 GPM constant speed pump, which is well above the necessary GPM for the facility. Recirculation flowrate and temperature impacted the recirculation loop energy loss, which ranged from 18 to 57 percent.
- **Pumps and piping:** The research team recommended Site 1 replace the pump with an ECM pump or a lower speed pump with a timer to improve water heating system efficiency and extend the distribution system piping's service life. High temperatures and flow rates can greatly accelerate copper piping degradation.

Monthly Summary

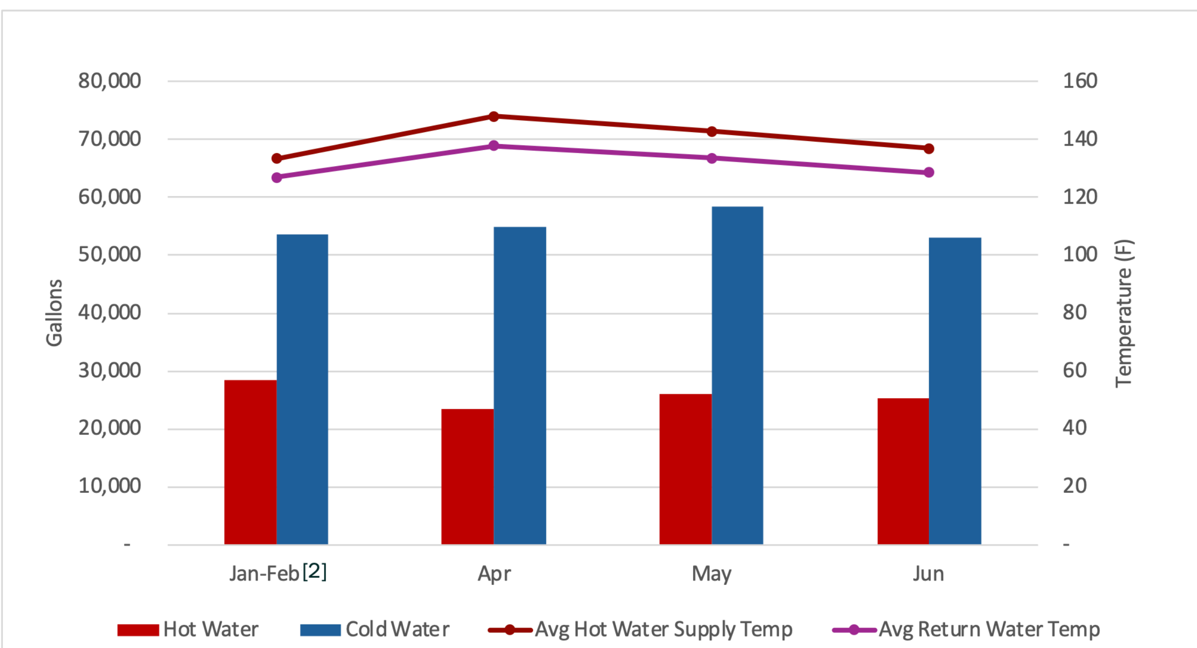
Figure 10, Figure 11, and Figure 12 outline the monthly cold and hot water consumption and the mean monthly mass weighted hot and return water temperatures for Sites 1, 2, and 3, respectively. The Site 1 water heater maintained a fairly consistent supply temperature of 170°F and a return of 165°F, with a delta T of only 5°F. Hot and cold water use at the site was also mostly flat across monitored months, with slight dips in February, May, and June.



[1] Cold water flow meter data collected for this month was incomplete. Monthly use is extrapolated from 21 days of collected data.

Figure 10: Site 1 monthly cold and hot water consumption.

At Site 2, the team collected four months of complete data, which showed consistent ratios of hot and cold water use. Supply and return water temperature had more variability at this site, where hot water was supplied around 140°F and returned around 130°F, resulting in a consistent 10°F delta T.

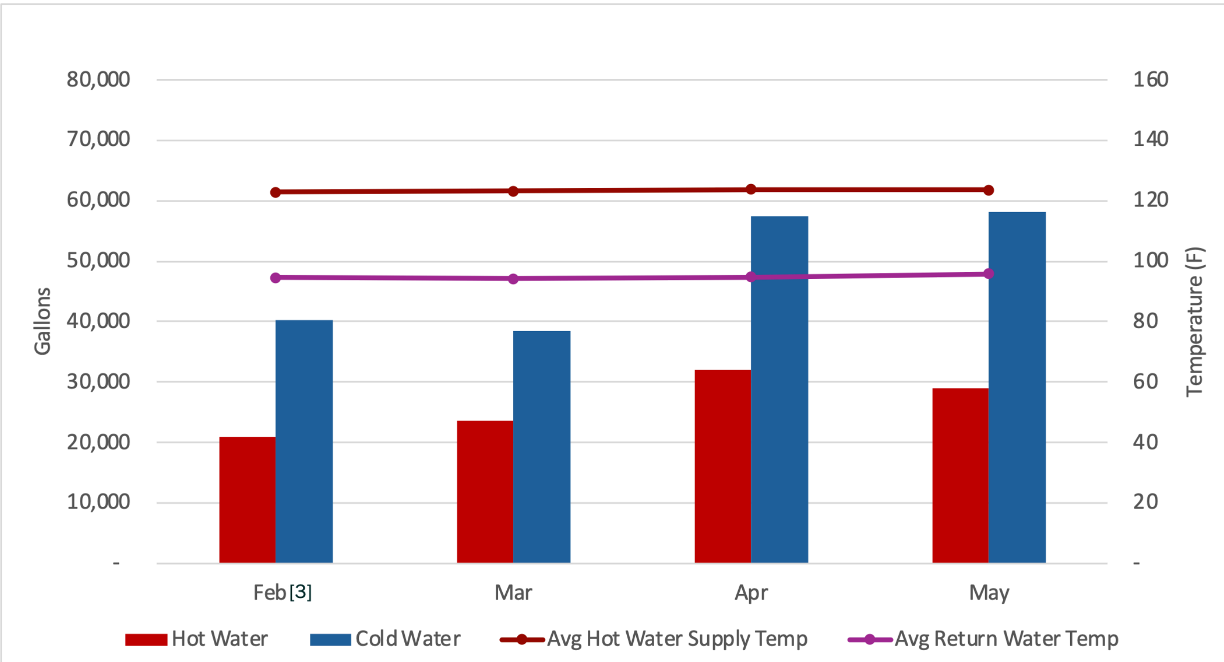


[2] Represents one month of data collected over January and February.

Figure 11: Site 2 monthly cold and hot water consumption.

Compared to the other sites, both hot and cold water use were more variable at Site 3, as shown in Figure 12. The hot to cold water ratio remained close to 50 percent each month, aside from March, which was closer to 60 percent. A contact at the site did not provide a reason for the March deviance.

The Site 3 water heater maintained a consistent supply temperature of 125°F and a return of 95°F, with the highest delta T of all three sites of 30°F. This is partially due to the low recirculation flow rate of around 1 GPM at this site, allowing the water to cool down significantly by the time it returned to the water heater.



[3] Hot and cold flow meter data collected for this month was incomplete. Monthly use for February is extrapolated from 20 days of collected data.

Figure 12: Site 3 monthly cold and hot water consumption.

Hot Water Weekly Draw Profile

Next, the team completed an analysis of the weekly draw pattern for each site, which highlighted the differences and similarities in hot water use per day. Figure 13 shows Site 1 mean and maximum hot water draw per hour in GPH from Sunday through Saturday. Site 1 has a similar draw profile shape each day, with varying average peak draws: the site has lower average use Wednesday and Thursday, with relatively similar average peak draws Thursday through Tuesday, occurring around 7:00 p.m. to 10:00 p.m. each day. For reference, this site is open from 5:00 p.m. to 9:00 p.m. or 10:00 p.m. each day.

Because the environmental health department is interested in whether a water heater can meet the maximum peak hot water demand, with this study, the research team wanted to dig into the difference between maximum peak GPH compared to the average peak GPH. The maximum hot water flow is shown in orange in Figure 13, illustrating that the maximum draw per hour at this site is generally close to the average, with peak evening usage still less than two times higher than the average daily draws. The largest variation in mean and maximum peak draw occurs on Friday and Saturday, with mean peak draws of around 100 GPH, and maximum peaks of around 190 GPH. Another notable difference between mean and maximum hourly draw is on Thursday, where there is a distinctly larger variability in hot water usage compared to other days.

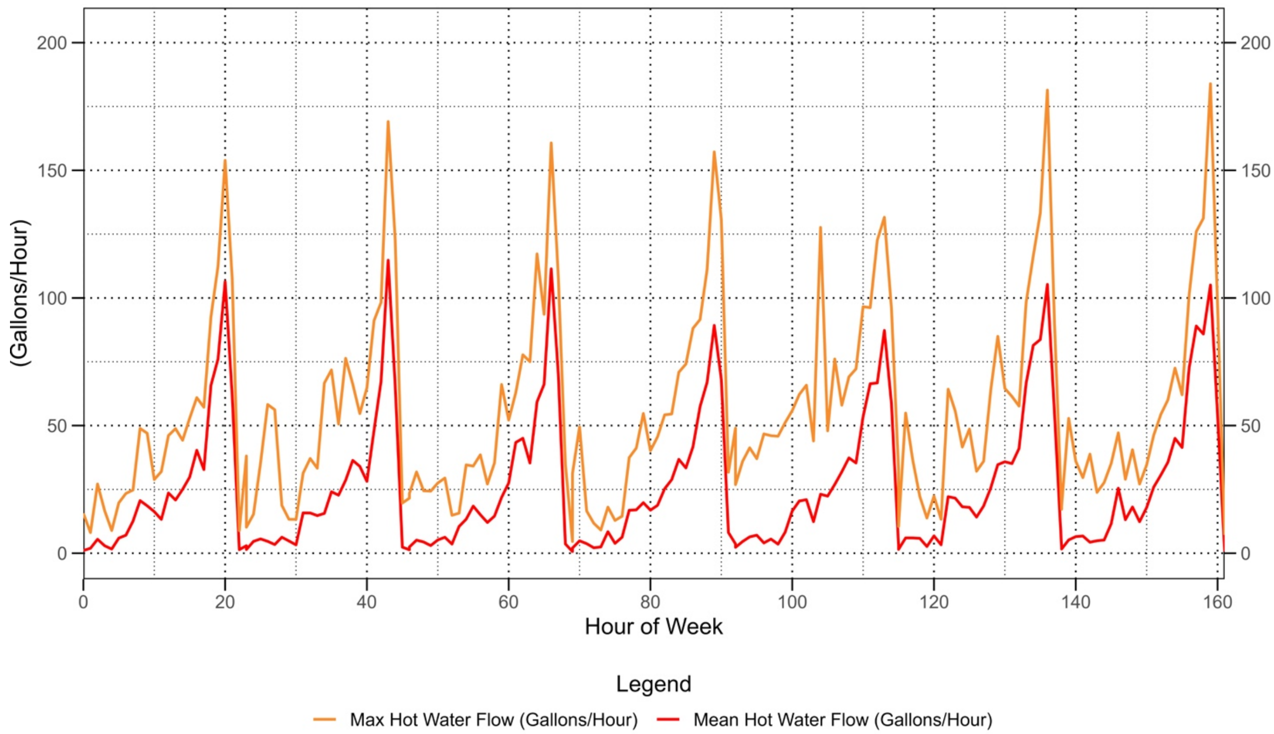


Figure 13: Site 1 maximum and mean weekly hot water draw.

Figure 14 shows the Site 2 mean and maximum hot water draw GPH from Sunday through Saturday. As with Site 1, Site 2 shows a very similar draw profile shape each day, characterized by a consistent morning draw around 8:00 a.m.—possibly equipment on a specific schedule—and steady draws of 60 to 100 GPH between 4:00 p.m. to 11:00 p.m. Only Friday had slightly lower than average draws per hour. This site is open from 5:30 p.m. to 10:00 or 10:30 p.m. each day, so the staff use more hot water before opening, likely for preparation. In comparison, Site 1's usage was over 50 GPH starting about two hours after opening.

Site 2 also had less variability between average and maximum hot water draw, indicating less overall hot water draw variability compared to Site 1. The maximum peak draw, around 180 GPH, occurred very late on Saturday; otherwise, the maximum daily draws remained closer to 150 GPH, not far from the average daily peak draw of 100 GPH.

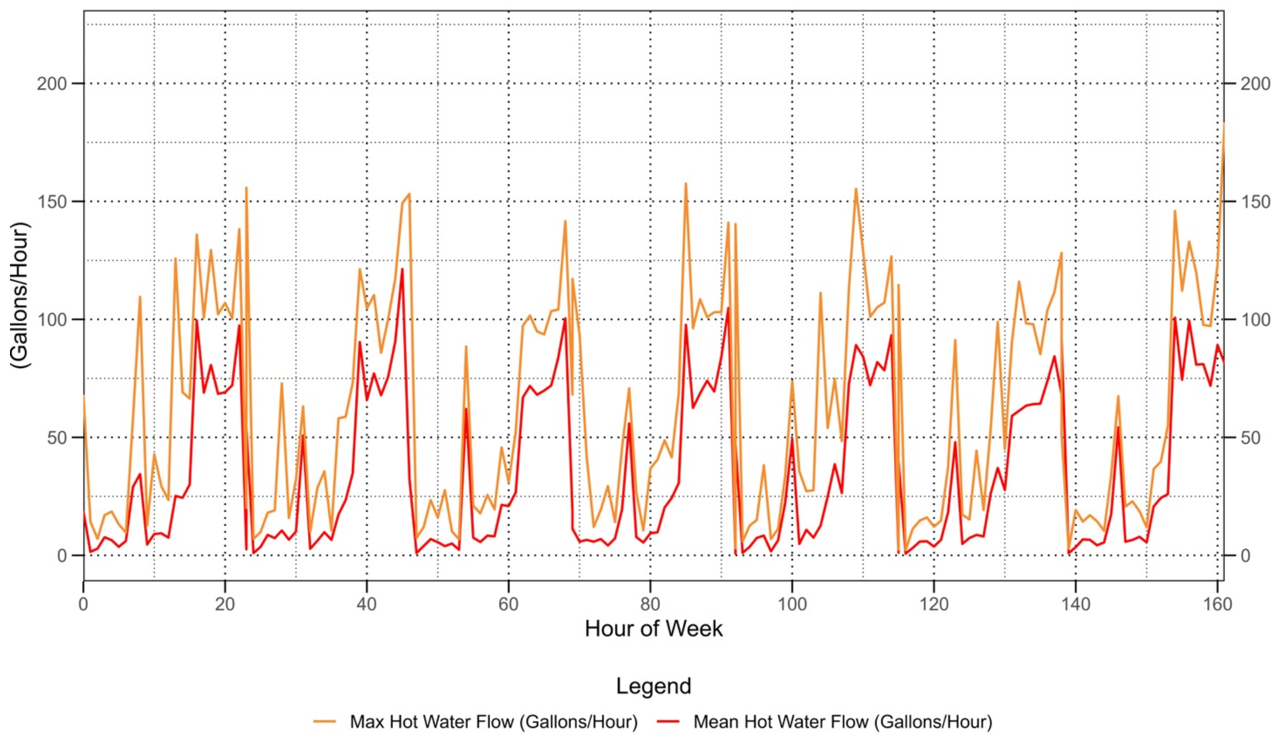


Figure 14: Site 2 maximum and mean weekly hot water draw.

Figure 15 shows the weekly draw profile for Site 3, which highlights the low usage on Sunday, when the site is only open for lunch service, and on Monday, when it is closed. The Tuesday through Saturday draw pattern was characterized by more consistent usage between 10:00 a.m. and 9:00 p.m. due to the lunch and dinner services; this site is open from 11:00 or 11:30 a.m. to 9:00 p.m. each day. Aside from partial or no operation days, the site had lower than average hot water usage on Friday and Saturday, with Tuesday having the largest average daily draw profile.

This site had much more variability between the average and maximum draw than Sites 1 and 2. Even Sunday and Monday had select peak draw days, which the research team presumes is related to the site hosting private events. Excluding Sunday and Monday, maximum peak draws occurred between 175 to 230 GPH, while average daily peaks were 110 to 150 GPH. This site may be more representative of typical restaurants that have varied customer demand each week, as seen in Figure 3, which shows FSRs having peak daily draws 40 to 90 percent higher than their average daily draw.

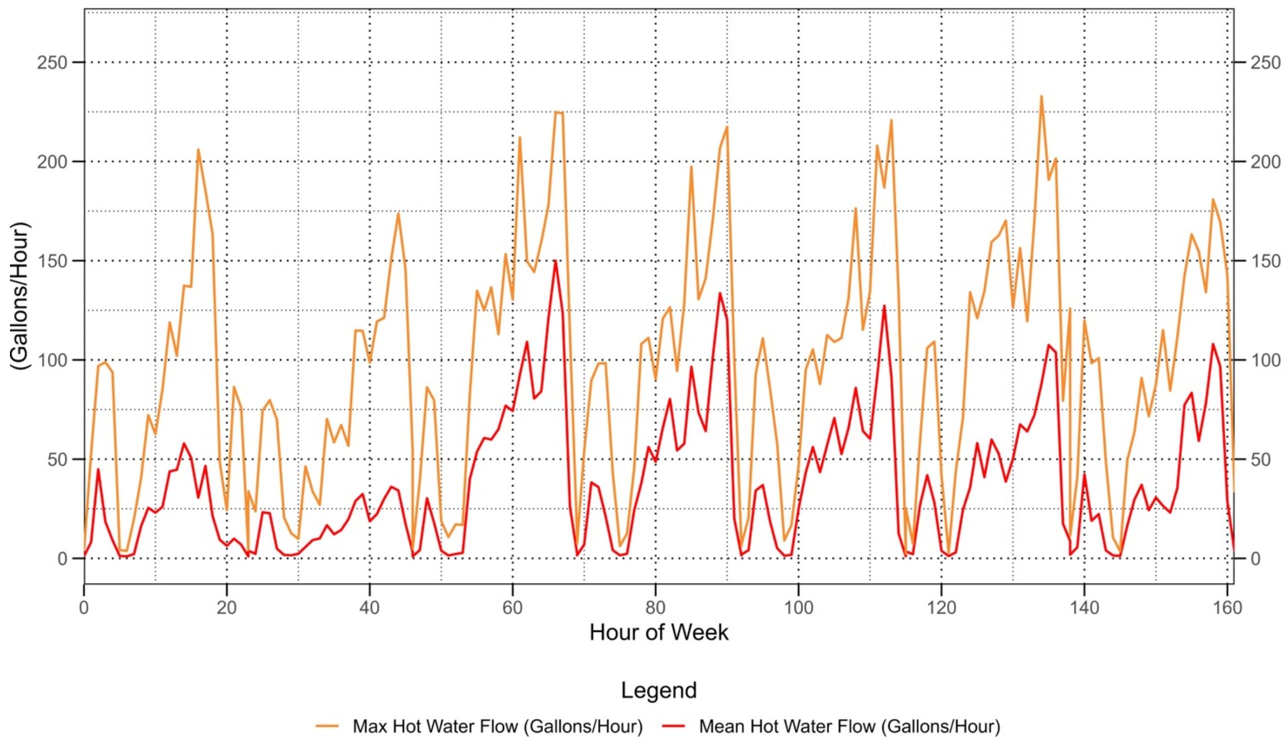


Figure 15: Site 3 maximum and mean weekly hot water draw.

Hot Water Hourly Draw Profile

Figure 16, Figure 17, and Figure 18 characterize the daily hot water draw per hour through boxplots, or box and whisker plots. The following three plots identify the median value of the hourly data in the middle of the box, and the first and third quartiles—the 25th and 75th percentiles—in the lower and upper areas of the box, respectively. The minimum and maximum values are identified by the whisker attached to the box, and outliers are plotted individually. The boxplot format highlights the spread or variability of the hot water use in gallons per hour and makes it easier to identify peak usage hours and the frequency with which they occur.

Site 1, as shown in Figure 16, has a narrower spread of hot water use per hour early in the day, and greater variability in hot water use per hour between 6:00 p.m. and 11:00 p.m. Figure 17 shows Site 2 usage, which has slightly narrower hot water use distribution for most morning hours, until 4:00 p.m. through 12:00 a.m., where hot water use varies more. In Figure 18, Site 3 shows different results, which mirror findings from the weekly hot water draw analysis. Again, hot water use per hour has much more variability than Site 1 and 2; Figure 18 is also on a larger y-axis. This figure excludes Sunday and Monday and is representative of days with lunch and dinner service.

Another key observation from these three plots is the notably wide spread of hot water use in the last hour of hot water consumption, occurring between 10:00 p.m. and 12:00 a.m., depending on the site. This is partially due to the different closing hours for the restaurants, but could also be due to different closing practices and different amounts of hot water use by different staff members.

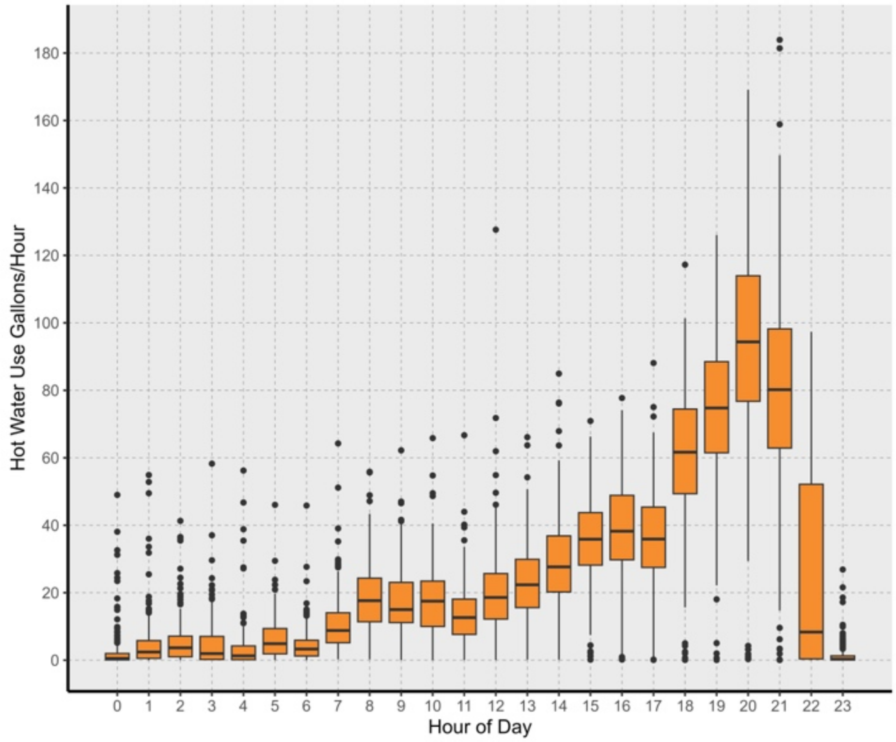


Figure 16: Site 1 hot water draw profile.

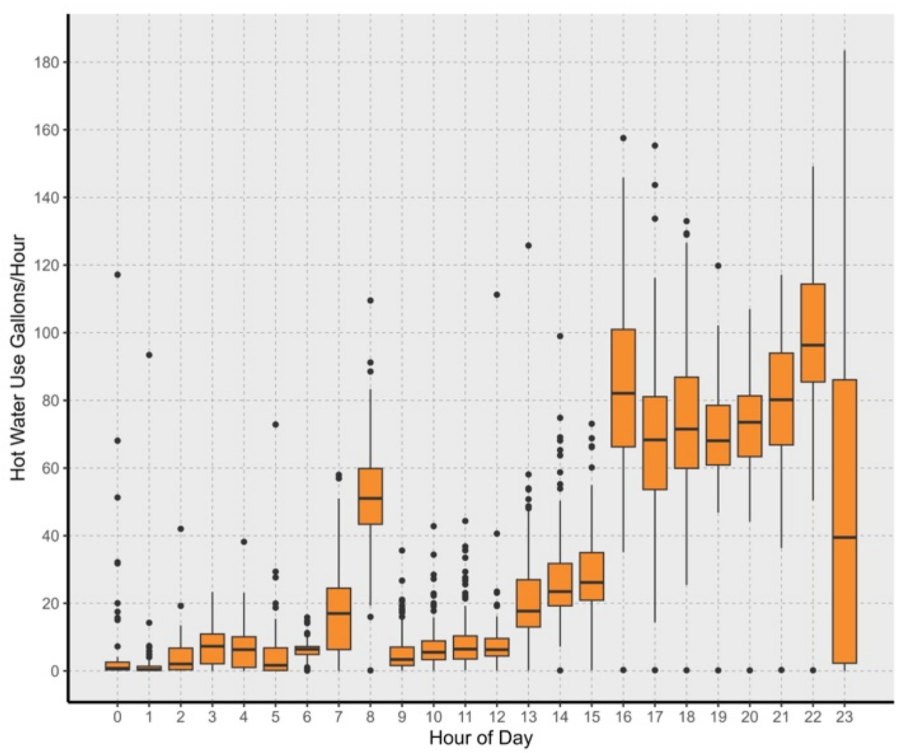


Figure 17: Site 2 hot water draw profile.

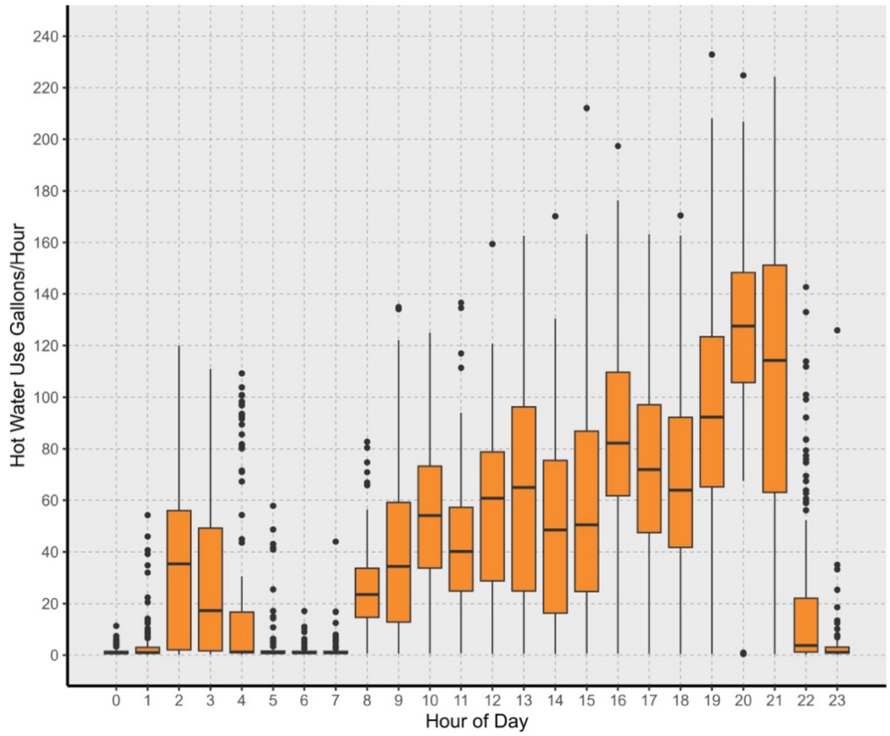


Figure 18: Site 3 hot water draw profile.

Dishmachine Disaggregation

Table 8 outlines the dishmachine specifications for Sites 1 and 3, which were included in the dishmachine disaggregation analysis. Site 1 has two single-rack machines: an Auto-Chlor A4 low-temperature, door-type dishmachine for the entire facility, and an Auto-Chlor U34DD low-temperature, undercounter dishmachine at the bar. The unit specifications for the A4 dishmachine show a rated hot water use of 1.09 gallons per cycle and a rating of 41.3 GPH.

Site 3 has a CMA B-2 low-temperature, double-rack, door-type dishmachine for the entire facility, and a CMA GL-X low-temperature, undercounter dishmachine at the bar. The unit specifications for the CMA B-2 dishmachine show a rated hot water use of 1.94 gallons per cycle and a rating of 77.6 GPH. The dishmachines at Sites 1 and 3 have similar hot water use specifications, if viewed on a per-rack basis. One distinction between the products is the rinse flow rate control type: the A4 product has a pressure regulator, while the B-2 does not have any pressure regulator and uses the pressure from the city or water main.

Table 8: Dishmachine specifications.

	Dishmachine Data Point	Site 1	Site 3
	Make and Model	Auto-Chlor A4 Single Rack Machine	CMA B-2 Two Rack Machine

	Dishmachine Data Point	Site 1	Site 3
Primary Door-Type Dishmachine	Details	Chemical sanitizing 90 second cycle 37 rack/hr	Chemical sanitizing 90 second cycle 80 racks/hr
	Rinse Flow Rate Control Type	Pressure regulator	City Pressure (15-65 PSIG)
	Rated Gallons Per Cycle (Gallons)	1.09	1.94
	Rated Gallons per Hour (GPH)	41.3	77.6
Bar, Under counter Dishmachine	Make and Model	Auto-Chlor U34DD Single Rack Machine	CMA GL-X Single Rack Machine
	Details	Chemical sanitizing 90 second cycle 30 racks/hr	Chemical sanitizing 120 second cycle 30 racks/hr
	Rinse Flow Rate Control Type	Pressure regulator	City Pressure (15-65 PSIG)
	Rated Gallons Per Cycle (Gallons)	1.09	1.7
	Rated Gallons per Hour (GPH)	32.7	51

Table 9 outlines collected data from each dishmachine. During a spot check by the field research team, the Site 1 primary dishmachine used 1.2 gallons, only 10 percent higher than the rated value of 1.09 gallons. It is not surprising that pressure-regulated dishmachines ran slightly or moderately over specification, as the water pressure can be adjusted upward from the recommended 15 to 20 psi, based on manufacturer recommendations. In contrast, the Site 3 door-type dishmachine used 4.3 gallons, 122 percent higher than the rated value of 1.94 gallons. Surprisingly, models can be sold without any pressure regulation, which means real-world rinse water use can vary considerably based on cold water supply pressure, which normally ranges from 45 to 65 psi.

Water pressure can vary in a restaurant based on coincidental water use in the building, such as filling a compartment sink and flushing of toilets. A dishmachine without pressure regulation or pumped rinse will flow at full flow rate for the duration of rinse time, with only the wash tank water volume being reclaimed for the subsequent dishmachine wash cycle; overflow water goes down the drain after further diluting the wash tank chemicals.

At Site 1, both dishmachines used an average of 272 gallons per day for 242 cycles per day. Comparatively, both Site 3 dishmachines used an average of 518 gallons per day for 142 cycles per day, though it should be noted that the primary dishmachine served two racks per cycle while the Site 1 dishmachine served one rack per cycle.

On average, dishmachine hot water use was equal to 43 to 49 percent of the total hot water use at each site. On the peak hot water consumption day, the dishmachines accounted for 24 percent and 58 percent of the total site hot water use at Site 1 and 3, respectively. During the peak one-hour draw at the site, the dishmachines used 75.7 GPH and 198.9 GPH, accounting for 41 percent and 79 percent of the total draw that hour at Sites 1 and 3, respectively. These values are higher than the rated GPH.

Table 9: Dishmachine disaggregation results.

Dishmachine Data Point		Site 1	Site 3 [A]
Spot Measured Gallons per Primary Dishmachine Cycle (Gallons)		1.2	4.3
Estimated Peak GPH Per Total Dishmachines During Site Peak 1-hour Draw[B]		75.7 (12/23/2024, 8:35-9:35pm)	198.9 (3/25/2025, 8:34-9:34pm)
Estimated Mean Gallons per Total Dishmachine Cycle (Both Dishmachines) [B]		1.1	3.5
Spot Measured Maximum Dishmachine GPM		4.1	9.8
Disaggregated Number of Cycles per Day	Minimum	142	22
	Mean	241	142
	Maximum	354	310
Disaggregated Dishmachine Use per day (Gallons)	Minimum	117	75
	Mean	272	518
	Maximum	622	1,202
Percent of Dishmachine Use of Total Hot Water Use (%)	Minimum	20	32
	Mean	43	49
	Maximum	72	69
	Peak Day	24	58

[A] Analysis excludes data from Sunday and Monday, which are single meal service and closed days respectively, to better compare to site 1 which has two meal services each day.
[B] Includes usage from both dishmachines as outlined in the Methodology and Approach section.

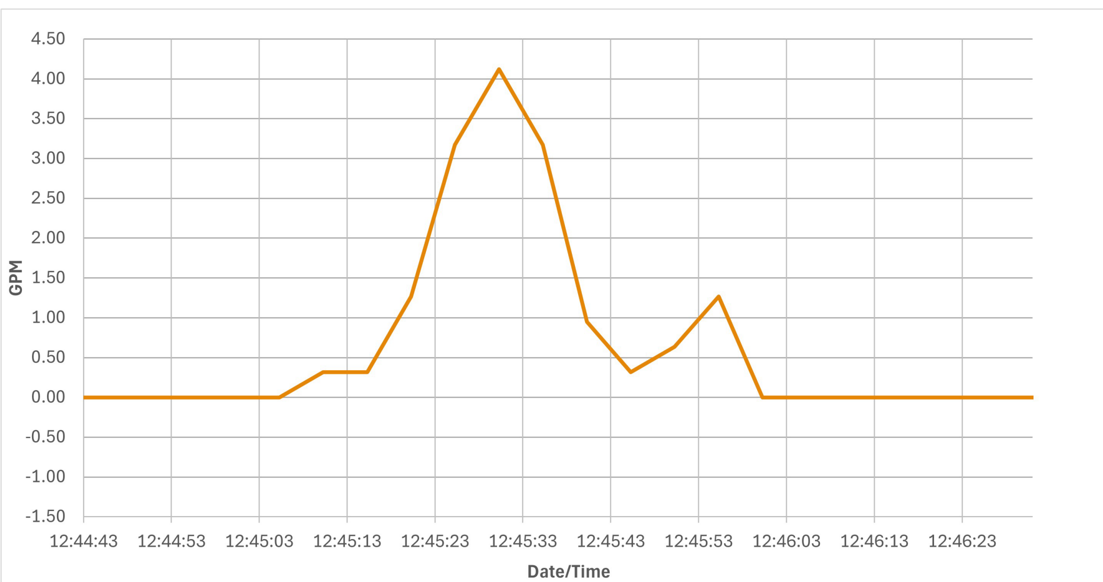


Figure 19: Site 1 spot measured primary dishmachine hot water draw.

Figure 19 and Figure 20 show the field observed hot water draws from the primary dishmachines at each site, with chart vertical lines marking 10-second increments. The Auto-Chlor A4 unit has an

NSF-listed 24-second rinse time, which is corroborated by the big peak and time increment in Figure 19. Similarly, the CMA B-2 machine has a rated rinse time of 45 seconds, which is well represented in Figure 20.

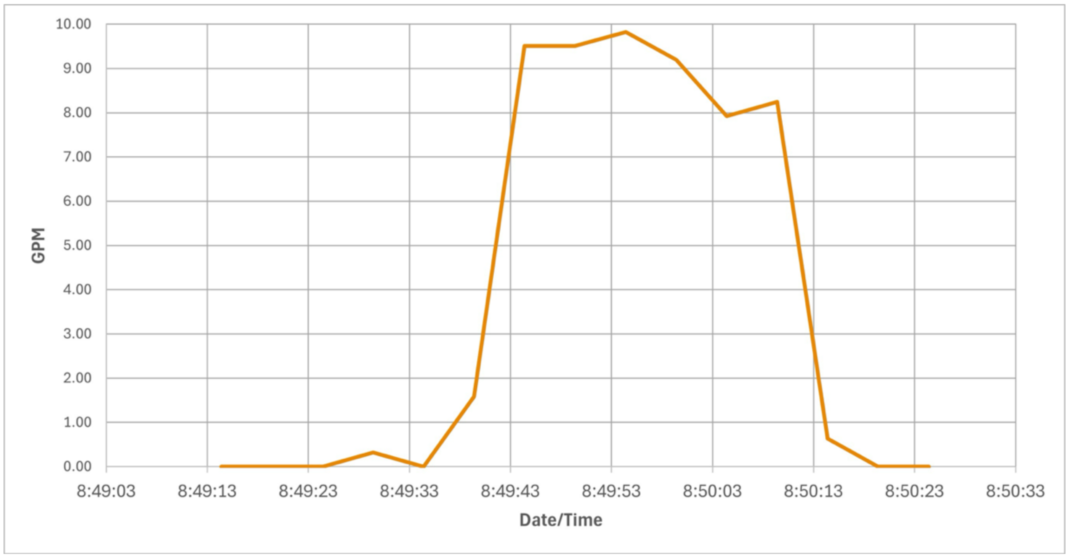


Figure 20: Site 3 spot measured primary dishmachine hot water draw.

Discussion

The following discussion section outlines observations related to the potential for HPWHs in FSRs, a holistic HPWH design approach considering TOU, Guideline revision recommendations, and a re-evaluation of the CCDEH sizing compared to field observations.

Potential for HPWHs in FSRs

A key question throughout this study was, can HPWHs meet the daily HW load of an FSR? In the absence of directly comparable benchmarks or demonstration projects, we reference HPWH systems serving a similar hot water demand, such as multifamily buildings, to help assess whether HPWH technology can effectively support daily FSR loads.

Figure 21 below shows the daily hot water load for an array of FSRs. Restaurants A-F represent prior field data collected by Frontier as outlined in the Hot Water Peak and Hourly Demand Profile section, and Sites 1 through 3 were collected through this CalNEXT field study. Sites A through F are all traditional, chain restaurant, high-volume FRSs and 1 through 3 are small-scale fine dining FRSs: due to the variation in restaurant scale and number of individuals served, they use very different amounts of daily hot water: sites A through F using 2,100 to 5,310 gallons of hot water per day on average, and sites 1 through 3 using 629 to 1,115 gallons of hot water per day on average.

Recent multifamily HPWH system demonstrations have proven that HPWHs can meet daily hot water loads of up to 3,700 gallons, indicating a strong potential for HPWHs to meet the needs of the FRS sector (Valmiki, et al. 2023). However, to gain industry support, the research team suggests starting HPWH split-system demonstrations at FSRs that are lower volume and have one to two meal services, such as fine-dining restaurants. This smaller scale of hot water demand has also already been proven in the field: Multifamily buildings with similar daily loads and water heater setpoints as those in fine dining foodservice—1,198 gallons per day and 147 °F, respectively—are currently being served by HPWH system designs (Banks, Grist and Heller 2020).

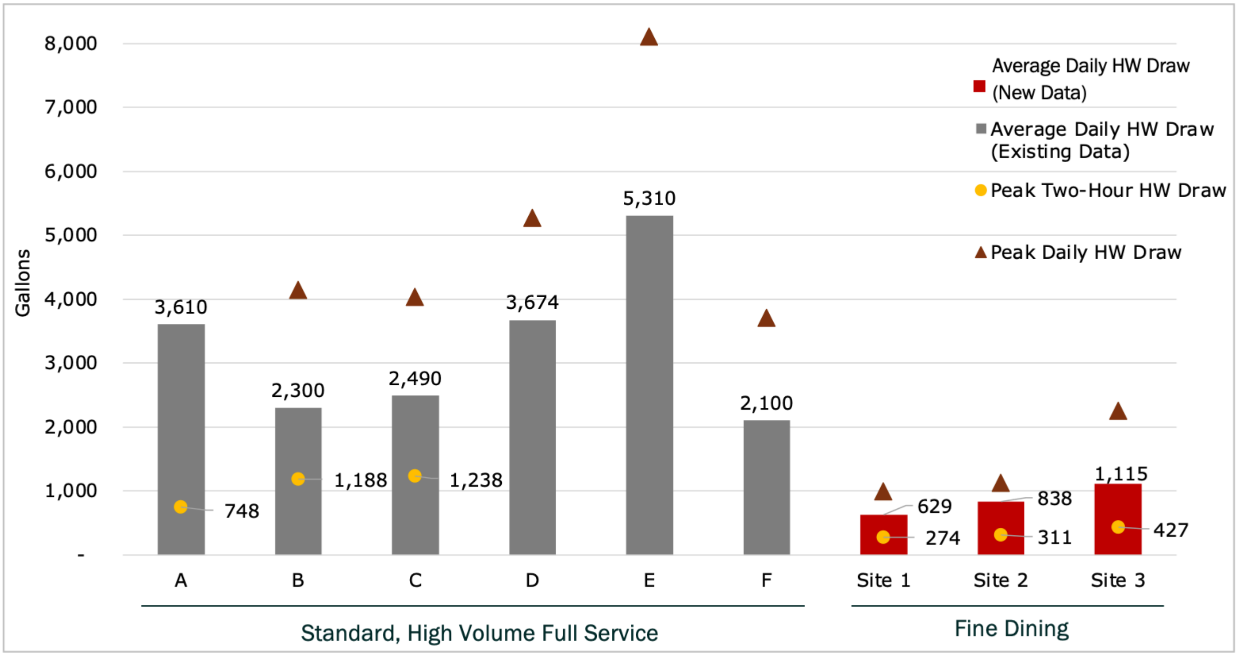


Figure 21: Average daily hot water use across full service restaurants.

HPWH Design: TOU Considerations

The typical commercial or business electric TOU rate period is 4:00 p.m. to 9:00 p.m. in California, where customers see higher peak energy and demand charges. Figure 22 below shows the average draw profiles across different types of full-service restaurants. While the draw profiles are at different scales, the peak hot water demand consistently sits between 4:00 p.m. and 9:00 p.m., coinciding with the peak electric rate, which is highlighted in yellow. This emphasizes the importance of considering how to design HPWH systems for restaurants to minimize peak electric demand and subsequent utility charges.

It is also important to note that the second highest hot water use period for restaurants is the hours before the 4:00 p.m. to 9:00 p.m. period. One way to minimize peak electric demand is by strategically utilizing thermal energy storage to shift load from peak to off-peak hours. This is achieved by a split-system design, where the heat pump and storage tanks are separate and filling (or charging) storage tanks with hot water throughout the day during lower hot water draws and off-peak-TOU rate hours, and discharging the hot water during the peak draw and peak-TOU rate period.

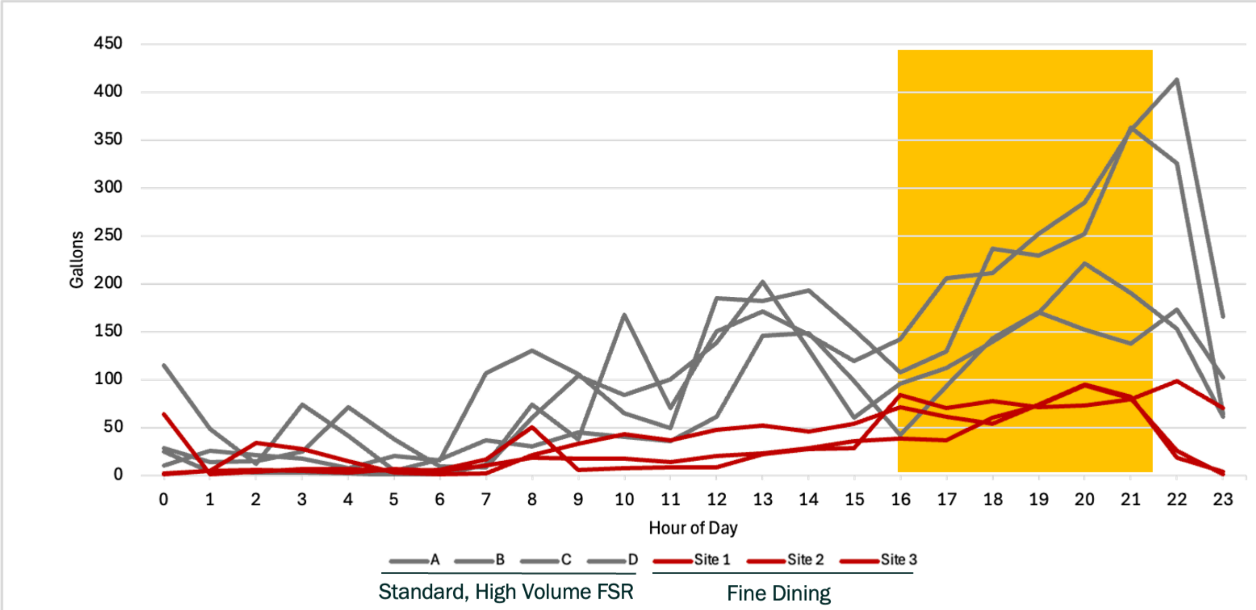


Figure 22: Hot water draw profile comparison across FSRs.

CCDEH Guideline Recommended Revisions

The research team initially anticipated that environmental health departments and CCDEH would only be interested in the simplistic approach of updating the CDDEH Guidelines PDF. However, from Fall 2024 to present, the research team has worked with a group of environmental health department leaders to identify a path forward to updating the existing Guidelines and introducing a calculator tool. As part of this research effort, the team held semi-regular meetings with key stakeholders to mark up the existing Guidelines with recommended revisions to support HPWHs, as well as develop a proof-of-concept Excel-based calculator tool. A mark-up version of the CCDEH Guidelines can be found in Appendix D, and the proof-of-concept sizing calculator is in Appendix D: Proposed Water Heater Sizing Calculator Structure. However, both versions incorporate the same changes, and the following section outlines each suggested change and the reasoning behind it.

The benefit of the calculator tool is that it automates the look-up tables and allows for the user to enter fewer inputs, streamlining plan checker review. The research team recommends the calculator be configured for gas, electric resistance (ER), and HPWH systems to increase accuracy and reduce user error for all system sizing.

This project scope included developing suggested Guideline revisions, the project team was also able to lay out the calculator pathway as a proof of concept. However, the Guidelines need a champion to continue this work to develop further iterations of the Guideline with HPWH revisions and ultimately gain CCDEH approval. In addition, the research team strongly recommends the proof-of-concept calculator is built out, including fully executing the COP lookup tables using available lab testing data and developing the sizing calculation.

Proposed Changes to the CCDEH Guidelines

RIGHT-SIZE SYSTEMS

Increase accuracy for temperature rise. Currently, a 70°F design cold water supply temperature and 120°F or 140°F hot water supply temperature is used for calculating the temperature rise in the CCDEH guidelines. Incoming water from the utility is typically 45 to 60°F for many regions in California; using a higher cold water temperature may lead to under-sizing the gas, ER, or HP water heaters in many colder parts of the state during the winter season. Additionally, it is commonplace for restaurants to set heater setpoints nominally 5°F higher than the targeted delivered hot water temperature, which is typically a minimum of 120°F at the sink or equipment, which accounts for a 5°F hot water temperature drop from distribution losses.

Therefore, the research team suggests the CCDEH Guidelines provide a lookup table for cold water temperatures based on county or climate zone, one good data source is the water main temperatures used in the Title 24, Part 6 ACM. Additionally the Guidelines should encourage using known hot water setpoints, or provide default setpoints of 125°F in all restaurants and 145°F for FSR with dishwashers requiring hot water.

SUPPORT HPWH SYSTEMS

Add equation for HPWHs using a COP with supporting lookup or reference tables. The research team suggests adding two formulas for HPWHs: one for HPs installed indoors and one for HPs installed outdoors. The formula should mirror what gas and ER systems use, as those are most familiar to plan checkers; the main difference for HPWHs will be the use of COP. HPWH COP should be provided by lookup tables in the appendix and determined by refrigerant type, distribution type, water heater setpoint temperature, restaurant type, and design-day winter ambient air temperature (a few reference points should be provided).

HPWHs installed outdoors should use design-day winter outdoor air temperatures to properly size systems; cities within Climate Zone 9 and 16 (CZ 9 and CZ 16) are good examples of weather extremes to compare for HP sizing. A city in CZ 9 has an extreme winter temperature of 38°F and design temperature (0.6%) of 43°F, whereas a city in CZ 16 has an extreme temperature of -10°F and design temperature of 0°F. Using Figure 23 and Figure 24 below for an R134a model HPWH and CO_2-based HPWH, it is evident that the R134a model with a minimum operating temperature of 40°F is barely suitable for the warmer climate design-day condition of 43°F, but may not require backup electric resistance heater to meet the extreme day temperature since it likely occurs overnight. Nonetheless, sizing for heating capacity shall occur at the 43°F design-day condition, yielding a capacity of 35 kW (120,000 Btu/h) at a COP of approximately 2.8, as previously shown in Figure 8. Similarly, on the SanCO_2 unit's design day, the unit will yield a capacity of 4.5 kW (15,354 Btu/h) at a COP of 3.0, as shown in Figure 24 below.

In a colder climate, the R134a-based HPWHs are not suitable for year-round operation if exposed to outdoor air temperatures. A CO_2 refrigerant unit is viable to be placed indoors if it is low noise and compact in size, or outdoors if it operates down to -14°F. At a design temperature of 0°F, the unit will yield a heating capacity of 4.4 kW (15,013 Btu/h) at a COP of 2.2. The same approach can be taken with integrated hybrid heat pumps that use the heat pump as a primary source and electric resistance as back-up capacity.

For the CCDEH Guidelines, the research team recommends providing a COP lookup table based on available lab testing data and accopmanying reference tables, including one for the design-day winter outdoor air temperature. One suitable resource is 2022 Title 24 Reference Ace v2.8, which is used for Title 24, Part 6 compliance and is updated every three years.

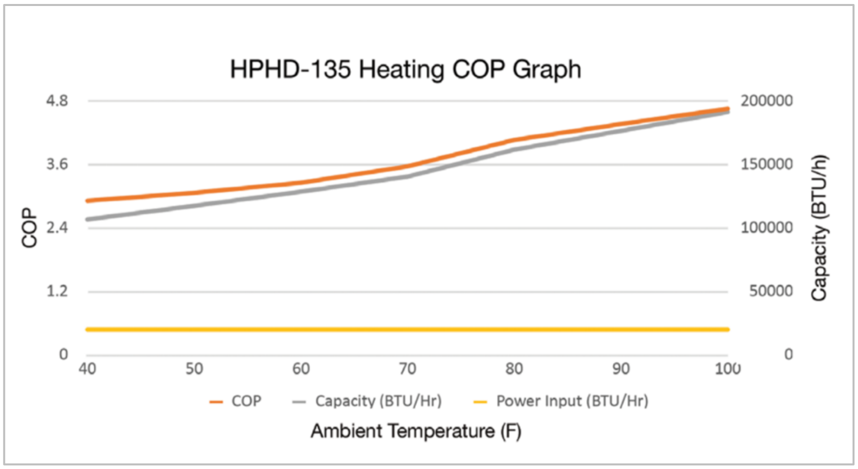


Figure 23: Example performance curve, HPWH with R134a refrigerant.

Source: Rheem.

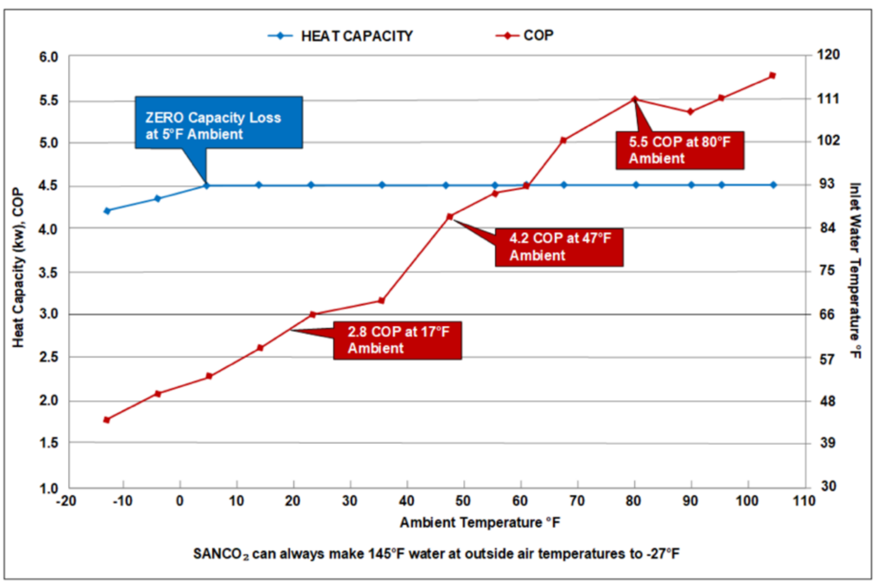


Figure 24: Example performance curve, CO_2.

Source: $SANCO_2$

Additional Recommended Revisions

The research team was able to integrate a number of critical recommendations into the proposed revisions in Appendix C: CCDEH Water Heater Sizing Guideline Recommendations and Appendix D: Proposed Water Heater Sizing Calculator Structure. However, additional steps should be taken to further improve the Guidelines, including the following:

- **Increase accuracy of GPH calculation.**
  - Update sizing values for pre-rinse spray valves, three-compartment sinks, hand sinks, and other fixtures using data—such as operating duration or fill time per peak hour—gathered from peak hot water use monitoring at field sites.
  - Look at adding a GPH penalty factor for dishmachines that use no rinse flow regulation or pressure regulator and gauge-based control, as demonstrated by previous and new field findings.
  - If dishmachines account for roughly 50 percent of usage, consider a probability factor for each end-use sink or equipment to right size for peak hot water use, similar to plumbing code methodology for sizing pipe diameters.
- **Support additional water heating system configurations, including:**
  - Storage tank capacity for load shifting capability.
  - Additional HPWH configurations and COP lookup table advancement.
- **Add minimum storage volume chart:**
  - Add reference table of minimum storage volume table, accounting for type of facility and type and size of water heater, which will support sizing that limits hot water runouts (especially during sanitation activities after working hours) and reduced life of storage heaters from thermal shock of components, such as thermally induced stress cycling.
  - Add ability to reduce or increase the required input rate of primary heater based on storage volume selected; therefore, a facility can choose the existing methodology with a minimum storage volume requirement or oversize the storage volume and reduce the input rate requirement

CCDEH Sizing vs. Field Observations

To better evaluate the accuracy of the CCDEH peak GPH sizing, the research team calculated the CCDEH peak GPH sizing for each location based on actual on-site equipment and compared that value to the field-measured maximum one-hour draw (peak demand). The results are shown in Table 10 and are varied: the CCDEH sizing was 9 percent, 45 percent, and 67 percent larger than the field-measured peak demand at Sites 2, 3, and 1, respectively. It should be noted that Site 2 had more variability in peak demand compared to Sites 1 and 3; Site 2's peak demand occurred only a handful of times during late night clean-up on Saturday night. Health departments are concerned with peak demand during meal periods, so the 9 percent oversizing in Site 2 is conservative. The typical daily peak demand was closer to 160 GPH, whereas Sites 1 and 3 had consistent daily peaks ranging 160 to 190 and 200 to 250, respectively. More detail is provided previously in Figure 13, Figure 14, and Figure 15.

Table 10: Measured versus CCDEH calculated peak demand.

Site	Field Measured Peak Demand (GPH)	Calculated Health Dept Demand (GPH)	Percent Oversized
1	186.3	312	67%
2	218.5	238.7	9%
3	251.8	364.6	45%

Water Heater Sizing Examples

To further demonstrate the difference between the sizing of a gas, electric, and heat pump water heater under the CCDEH Guidelines, the research team prepared Table 11 below. This iterates upon a similar table prepared for the Technical Design Guide for Advanced Water Heating within the Foodservice Industry, Edition 3 (Design Guide).[4] This report's version is designed around Site 3 from this study.

Configuration A and B sizes a gas and HPWH system based on the existing CCDEH sizing approach, using the CCDEH peak demand and typical default CCDEH setpoints. Configurations C and D size HPWHs using a sizing approach proposed by the research team as outlined in Proposed Changes to the CCDEH Guidelines section. Configurations C and D use the field measured peak demand and more accurate cold and hot water temperature setpoints, which aligns with suggestions to right-size the CCDEH peak demand calculator and temperature rise calculation. All configurations use the water heater efficiency listed in the "Design Day System Efficiency with Recirculation" row, which aligns with the suggestion to use a design-day HPWH COP. Although suggested by the research team, the calculation does not factor in hot water storage tank capacity or load shift ability.

[4] Technical Design Guide for Advanced Water Heating within the Foodservice Industry 3rd Edition 2023. The Design Guide, authored by TRC Companies and Frontier Energy, Inc., discusses strategies to implement an advanced commercial foodservice hot water system that meets the health department's hot water sanitation requirements of the facility while optimizing equipment performance, water efficiency, energy efficiency, and decarbonization. The most recent edition of the Design Guide was funded by the CalNEXT program and is hosted on caenergywise.com under the auspices of the California Public Utilities Commission.

Table 11: Full-service restaurant water heater sizing example.

Site	SITE 3			
Configuration	A	B	C	D
Water Heater Sizing Approach	CCDEH	CCDEH	Proposed	Proposed
WH Type	Gas WH	Split HPWH	Integrated HPWH	Split HPWH
Recovery Rate (GPH)	365	365	252	252
Design Day Cold Water Temperature (°F)	70	70	50	50
Hot Water Supply Temp (°F)	120	120	145	145
Sizing Calculator Minimum Input (kW)		**45.41**	**38.93**	**18.25**
Sizing Calculator Minimum Input (Btu/h)	**189,820**	**154,961**	**132,847**	**62.272**
Water Heater Quantity, Type and Configuration	(1) Unitary Gas 80% TE, 200k Btu/h, 100-Gal Gas-Fired	(6) Split HP with (2) 119-Gal Storage Tanks in Series or Parallel & (1) 99% TE ERWH 119-Gal 40 kW at 208V in Series	(4) Unitary HP/ER Hybrid in Parallel 119-Gal 2.8 kW HP at 4.2 COP & 9 kW ER at 208V	(6) Split HP (2) 119-Gal Storage Tanks in Series or Parallel & (1) 99% TE ERWH 119-Gal 15 kW at 208V in Series
System Design Day Input Rate (kW)	-	**45.70**	**47.36**	**20.70**
System Design Day Input Rate (Btu/h)	**199,900**	**155,934.80**	**161,599**	**70,631**
Design Day Ambient Air Temp	-	31 [A]	50 [B]	31 [A]
Recirculation Pump Type	ECM Pump or 3-Speed with Timer			
Design Day System Efficiency With Recirculation	**0.8**	0.98	**1.3**	**3.2**

Site	SITE 3			
Configuration	A	B	C	D
Water Heater Sizing Approach	CCDEH	CCDEH	Proposed	Proposed
WH Type	Gas WH	Split HPWH	Integrated HPWH	Split HPWH
Est. Design Day Output from **Primary** Heat Source (kW)	-	19	49	19
Est. Design Day Output from **Secondary** Heat Source (kW)	-	41	35	15
Est. Design Day Output from **Primary** Heat Source (Btu/h)	159,920	65,513	166,512	65,513
Est. Design Day Output from **Secondary** Heat Source (Btu/h)	-	138,192	120,380	50,158
Total Est. Design Day Output (Btu/h)	**159,920**	**203,705**	**286,893**	**115,672**
Electrical Infrastructure Requirements (Assumes 208V Single Phase)	N/A	2 pole 15A x6 2 pole 250A	2 pole 90A x4	2 pole 15A x6 2 pole 90A
Footprint Indoor Including Clearances	30.5" x 30.5"	103.5" x 35.5"	192" x 45.17"	103.5" x 35.5"
Footprint Indoor Including Clearances (Total Square Feet)	6	26	60	26
Space Ventilation Requirements	N/A	N/A	6,400 to 12,800 ft^3	N/A
Footprint Outdoors	N/A	153" x 44"	N/A	153" x 44"
Estimated Equipment and Labor First Cost [C]	$7,500	$48,100	$64,500	$43,500

[A] Ambient temperature representative of outdoor installation winter design condition.
[B] Ambient temperature representative of indoor installation in a winter condition, assuming a temperature drop with four units located next to each other at the back of the restaurant.
[C] Includes estimated equipment cost plus tax, labor, and installation materials. Excludes electric infrastructure upgrade costs.

The estimated cost includes equipment, tax, labor, and installation materials, and excludes electric infrastructure upgrade costs. This cost would likely be significant for all HPWH systems, but more so for the CCDEH HPWH sizing scenario. Utility or other incentive programs could defray the equipment or infrastructure upgrade costs, making the first cost more achievable.

The scope of this research project did not include an analysis of HPWH operational costs; however, the research team is aware existing utility rates structures play a key role in the payback period when a site is transitioning from natural gas to an electric HPWH. Utility rates that offer lower cost during off-peak hours for sites with HPWHs could play a key role in supporting the uptake of HPWHs.

Key Findings and Recommendations

Key Findings

- At 16 existing sites and 3 field-collected restaurants, the average hot water daily consumption ranged from 80 to 170 gallons for cafés, 470 to 690 gallons for fast casual, 1,450 to 1,900 gallons for fast food, and 629 to 5,310 gallons for full service. The data shows the near-overlap in consumption across categories, indicating that the standard foodservice categories are too simplistic and not a good indicator of hot water consumption. Facility practices and end-use equipment are better indicators than the restaurant category of a site's hot water consumption and load profile.
- Decarbonizing foodservice hot water systems will require a holistic approach that considers all end uses, and will include leveraging high-efficiency appliances and low-flow fixtures to reduce hot water demand. At two field sites, the dishmachine use accounted for 40 to 50 percent of total daily hot water use on average, indicating the potential to pair HPWHs with heat recovery dishmachines that only use a cold water supply connection to reduce hot water load and thereby reduce the HPWH system capacity and the first cost.
- The literature and data review confirmed that decarbonizing commercial foodservice sector water heating systems offers a significant emissions reduction opportunity, particularly in the full-service restaurant sub-sector. Additionally, there is high potential for HPWHs in cafés and small quick-service restaurants, since hot water loads are low, there is limited use of continuous recirculation systems, and one-for-one storage water heater replacement is viable.
- There is also high potential for HPWHs in the fine-dining FSR sub-type category, with data from this study's three field sites indicating this restaurant category could be well served by HPWHs. Fine-dining restaurants—or restaurants or supermarkets with similar loads—are good candidates for demonstrating HPWH systems and growing acceptance for the technology in the foodservice sector. However, HPWHs have certain design and installation barriers, meaning there is no simple drop-in replacement for larger hot water load in the foodservice sector. Additional technical product advancement and plumbing design resources and calculators will be essential for a smooth transition to all-electric HPWH installations in foodservice facilities.
- The research team's water heater sizing comparison results show that using a more accurate peak hot water demand and HPWH system COP —rather than the original CCDEH Guideline approach— provides equipment first cost savings and reduces the required electric panel capacity, limiting the scale of the panel or building electrical infrastructure upgrade.

Recommendations

CCDEH Guidelines

The research team recommends CCDEH adopt revisions to the Guidelines that increase sizing accuracy and support efficient decarbonization technology. In addition, the team recommends utilizing a calculator tool similar to the one outlined in Appendix D: Proposed Water Heater Sizing Calculator Structure. A version of the Guidelines with draft mark-up is included in Appendix C: CCDEH Water Heater Sizing Guideline Recommendations

. The proposed water heater sizing guideline revisions and future recommendations seek to "right size" for hourly hot water demand and water heater input requirements.

Immediate Guideline recommendations include:

- Increase accuracy for temperature rise, including providing a lookup table for cold water design day and default hot water supply temperatures.
- Add HPWH sizing equations. The estimated COP calculation should be based on:
  - Refrigerant type
  - Water heater setpoint
  - Design day intake air and cold water temperature
  - Whether it has a continuous recirculation system

Ongoing and Future Research

The research team recommends future research that builds upon the draft suggestions presented in this report, refining the Guidelines and building out a comprehensive water heater sizing calculator, and ultimately gaining approval and adoption by CCDEH. It's critical that future versions of the Guidelines and calculator include increased accuracy of the peak demand calculation by updating the GPH default values for fixtures such as pre-rinse spray valves, three-compartment sinks, dishmachines, and hand sinks. In addition, they should support additional HPWH system configurations, such as using storage tanks in series and providing sizing considerations around load shifting.

This work is underway, funded by PG&E's Code Readiness Subprogram and is in collaboration with another Code Readiness study that is lab testing HPWHs under foodservice draw profiles to learn about the performance impacts under different typical foodservice configurations. The Code Readiness Guideline and calculator research effort aims to develop a working version of the sizing calculator in early 2026 and gather feedback from engineers and plan checkers before presenting it to additional committees as necessary to gain CCDEH approval.

Building Codes and Appliance Standards

The research team recommends additions to Title 20 appliance standards to require pressure regulation or pumped rinse of commercial dishmachines, preventing the installation of units that operate at unregulated city water pressures.

Lastly, large heat recovery dishmachines should be added as a prescriptive requirement under Title 24, Part 6 (Title 24) and small heat recovery dishmachines should be added to the compliance model as a performance credit under Title 24. The requirement would apply to heat recovery dishmachines that use cold-water supply for undercounter and door-type dishmachines and cold water for the rinse operation of conveyor dishmachines. This type of equipment has the potential to greatly downsize the centralized water heater, reduce hot water set points, reduce pipe heat losses, and make heat pumps much more cost effective—as well as reducing the electrical capacity, size, installation and operating costs, and weight barriers.

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Appendix A: ComStock Service Hot Water Flow Fraction Schedules

The following charts and table excerpts were referenced by the research team to compare against draw profiles collected through data review and field data collection. They are sourced from "Comstock Reference Documentation: Version 1" and were prepared by NREL (Parker et al 2023).

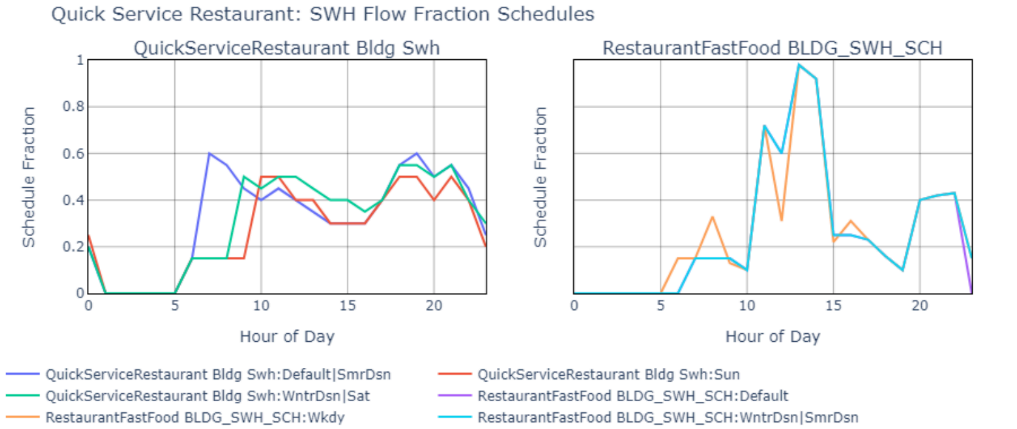

Figure 57. SWH heating usage schedule for quick service restaurant.

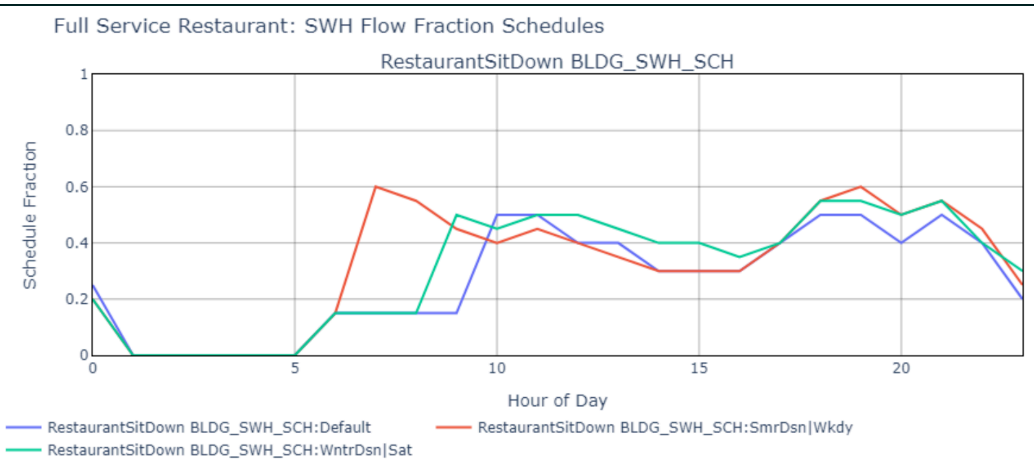

Figure 49. SWH heating usage schedule for full service restaurants.

Table 68. Service Water Heating Flow Rate and Schedule Assignments Based on Template, Building Type, and Space Type (Part 1 of 3)

Template	Building Type	Space Type	Service Water Heating Peak Flow per Area (gal/h*ft^2)	Service Water Heating Schedule
All	FullServiceRestaurant	Kitchen	0.08861	RestaurantSitDown BLDG_SWH_SCH
Pre 90.1-2004	QuickServiceRestaurant	Kitchen	0.032	QuickServiceRestaurant Bldg Swh
90.1-2004 and Later	QuickServiceRestaurant	Kitchen	0.032	RestaurantFastFood BLDG_SWH_SCH

Appendix B: Recirculation Loop Load Evaluation

The research team completed an additional analysis reviewing the total hot water flow going through the hot water supply pipe, meaning the hot water used plus the recirculation loop hot water load. The results are interesting: Site 1 had a high recirculation pump flowrate of 5.7 GPM, while Site 2 had a more standard recirculation pump flowrate of 1.01 GPM. This yielded very different constant or "baseline" recirculation loads gallons of hot water circulating through the water heater distribution system. Site 1 has a baseline recirculation load of about 340 gallons per hour, while Site 2 has one of about 60 gallons per hour.

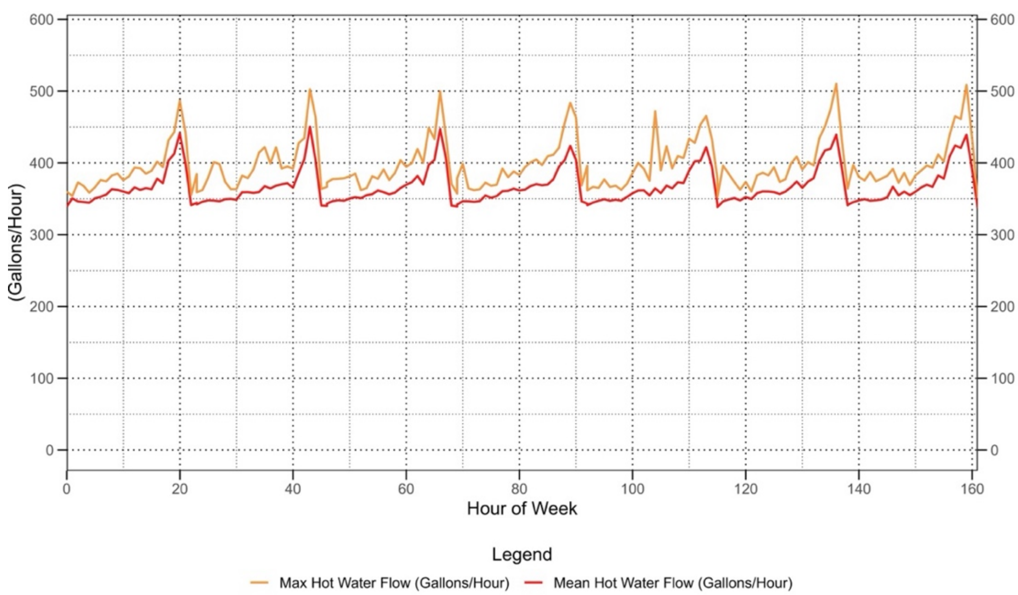

Figure: Site 1 mean and max total supply hot water weekly draw profile.

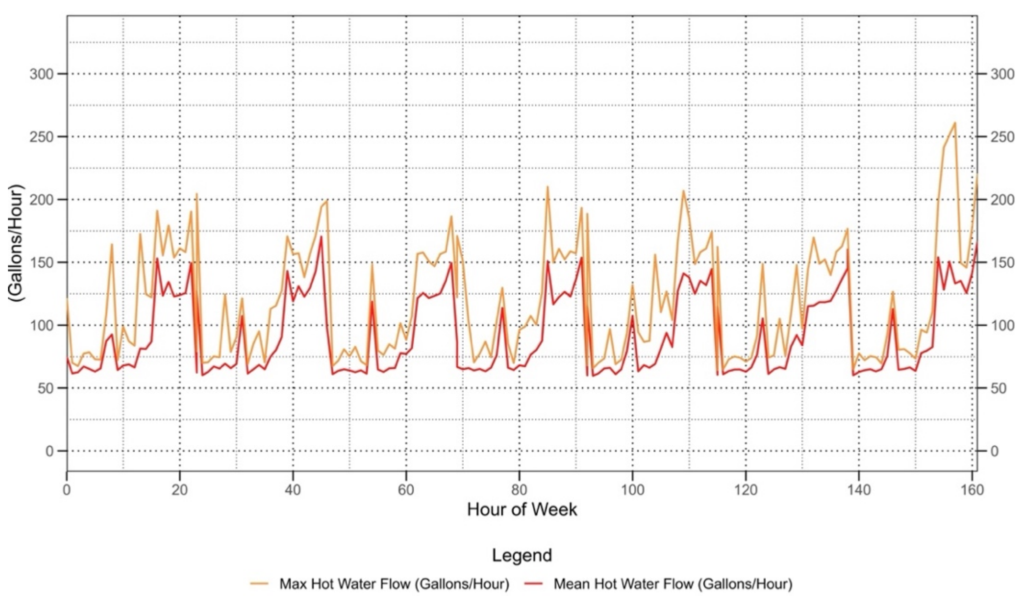

Figure: Site 2 mean and max total supply hot water weekly draw profile.

Appendix C: CCDEH Water Heater Sizing Guideline Recommendations

The following is a first draft mark-up version of the CCDEH Water Heater Sizing Guideline with the research team's recommendations.

GUIDELINES FOR SIZING WATER HEATERS

I. BACKGROUND

A critical factor in preventing foodborne illnesses in a food facility is the provision of an adequate supply of hot water for the washing of hands, utensils, equipment, and the facility itself. The installation of a properly sized water heater will ensure that a sufficient amount of hot water will be available at all times.

II. PURPOSE

The purpose of these guidelines is to provide a set of criteria that will assist architects, designers, contractors, and owners in properly sizing water heaters to adequately meet the anticipated hot water demands of food facilities in California.

Food facilities with water heaters sized according to these criteria should be capable of complying with the requirements for providing an adequate hot water supply as required by the California Retail Food Code.

III. LEGAL AUTHORITY

California Health and Safety Code, Division 104, Part 7.

IV. DEFINITIONS

A. **Booster Heater:** An instantaneous water heater designed and intended to raise the temperature of hot water to a higher temperature for a specific purpose, such as for the sanitizing rinse on a high temperature automatic dishmachine.

B. **BTU (British Thermal Unit):** The quantity of heat required to raise the temperature of one pound of water one (1) degree Fahrenheit.

C. **GPH (Gallons Per Hour):** The amount of water, in gallons, that is capable of being used each hour by the plumbing fixtures and equipment, such as dishmachines.

D. **GPM (Gallons Per Minute):** The amount of water, in gallons, capable of flowing through a plumbing fixture or through an instantaneous water heater per minute.

E. **HPWH:** Heat Pump Water Heater, a type of water heater that electricity to transfer heat from the surrounding air to heat water in a tank, rather than generating heat directly from a fuel.

F. **Instantaneous Water Heater:** A water heater that generates hot water on demand.

G. **KW (Kilowatt):** A unit of electric power equal to 1,000 watts.

H. **Rise:** The temperature of water as it leaves the water heater minus the temperature of the water entering the water heater.

I. **Storage Water Heater:** A water heater that incorporates a thermostat, a storage tank, and a burner or heating elements, to heat and maintain the water within the tank at a specific temperature.

J. **Thermal Efficiency:** The measure of the overall efficiency of the water heater, taking into consideration loss of energy due to combustion, radiation, convection, and conduction of heat

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from the unit.

V. <u>GENERAL REQUIREMENTS</u>

A. A water heater shall be provided which is capable of generating an adequate supply of hot water, at a temperature of at least 120°Fahrenheit (F), to all sinks, janitorial facilities, and other equipment and fixtures that use hot or warm water, at all times.

B. Water heaters and their installation must be in compliance with all local building code requirements.

C. Water heaters that use reclaimed heat from equipment to heat water shall be evaluated on a case by case basis.

VI. <u>SIZING REQUIREMENTS FOR STORAGE WATER HEATERS</u>

A. For food facilities that utilize multiservice eating and drinking utensils, the water heater shall have a recovery rate equal to or greater than 100% of the computed hourly hot water demand, in GPH.

B. For food facilities that use only single-service eating and drinking utensils, or don't use utensils at all, the water heater shall have a recovery rate equal to or greater than 80% of the computed hourly hot water demand, in GPH.

C. For food facilities that handle and sell only prepackaged foods, a water heater with a minimum storage capacity of ten gallons shall be provided.

D. The hourly hot water demand for the food facility, in GPH, is calculated by adding together the estimated hot water demands for all sinks and other equipment, such as dishmachines, which utilize hot water. The estimated hot water demands for sinks and other equipment that utilize hot water are listed in Appendix I. The hot water demands for automatic warewashers, such as dishmachines, glasswashers, and potwashers are found in the listing established by a nationally recognized testing laboratory for that particular piece of equipment.

E. The following examples are provided to explain how to calculate the total hourly hot water demand:

1. Food facility that utilizes only single service eating and drinking utensils.

Assume:

Number	Type	Demand
1	Three compartment sink (18"x18")	42 GPH
2	Hand lavatories	10 GPH (5 GPH each)
1	Janitorial sink	15 GPH
	Total	**67 GPH**

67 GPH X 80% allowance for single service utensils = 54 GPH. For the food facility in this example, a water heater would be required which will recover 54 GPH.

2. Food facility that utilizes multiservice eating and drinking utensils:

Assume:

Number	Type	Demand
1	Three compartment sink (18"x18")	42 GPH
1	Automatic dish machine	80 GPH
1	Hand spray	45 GPH

1	Food prep sink	5 GPH
2	Hand lavatories	10 GPH (5 GPH each)
1	Janitorial sink	15 GPH
	Total	**197**

Since the food facility in this example uses multiservice eating and drinking utensils, 100% of the computed hourly hot water demand must be provided. Therefore, a water heater would be required which will recover 197 GPH.

F. To compute a BTU or KW rating for the required hourly hot water demand found in example #1, the following formulas should be used:

Formula 1 (for gas water heaters):

$$BTU\ Input = GPH\ X\ °F\ Rise^1\ X\ \frac{8.33lb}{gallon} \div Thermal\ Efficiency^2$$

BTU Input = 54 GPH X 50°F X 8.33 lb/gallon / 0.75 = 29,988 BTU

[1] ~~The average temperature of tap water varies throughout the State depending upon the location, elevation, and time of year. In order to properly size the water heater check with your local health agency to determine the required rise. For the purposes of these guidelines, a tap water temperature of 70°F will be used. Therefore, to achieve a temperature of 120°F at the faucet, the required rise would be 50°F.~~

Temperature rise is hot water (HW) outlet temperature (at HW supply or after mixing valve) minus the cold water winter design day supply temperature. The hot water outlet temperature is either specified on the design drawings or may be found in Appendix IX. The cold water winter design day supply temperature is either measured and provided by the municipality water department or found in Appendix V.

[2] The thermal efficiency for gas water heaters, unless otherwise listed by a nationally recognized testing laboratory, will be ~~assumed to be 75%~~ gathered from the following table:

Types of Gas Water Heaters	Piping distribution has recirculation pump?	Cafe	Quick Service	Full Service
Primary Gas 80% TE Storage Heater or Boiler	Yes			
	No			
Primary Gas 90% + TE Storage Heater or Boiler	Yes			
	No			

Formula 2 (for electric resistance water heaters):

$$KW\ input = GPH\ X\ °F\ Rise\ X\ \frac{8.33lb}{gallon\ of\ water} \div Thermal\ Efficiency^1\ X\ 3412\frac{BTU}{KW}$$

KW input = 54 GPH X 50°F X 8.33 lbs / 0.98 X 3412 BTU/KW = 6.7 KW

[1] The thermal efficiency for electric water heaters, unless otherwise listed by NSF International or other nationally recognized testing laboratories, will be assumed to be 98%.

Sizing tables for gas and electric water heaters are found in Appendices II and III respectively.

Formula 3 (for electric heat pump water heaters [HPWH] that interact with indoor air): Use this formula for HPWHs that are installed indoors or intake conditioned or semi-conditioned indoor air.

KW_{input} = (GPH X °F $Rise$[1] X 8.33 lb/gal) / (COP[2] X 3412 BTU/kW)

KW_{input} = 54 GPH X (130°F - 50°F) X 8.33 lbs / 2.5 (CO_2 HP at 20°F Air Temp on design day in return to primary configuration with no recirculation) X 3412 BTU/KW = 4.22 KW[3]

[1] Temperature rise is hot water (HW) outlet temperature (at HW supply or after mixing valve) minus the cold water winter design day supply temperature. The hot water outlet temperature is either specified on the design drawings or may be found in Appendix IX. The cold water winter design day supply temperature is either measured and provided by the municipality water department or found in Appendix V.

[2] The coefficient of performance (COP) for HPWHs interacting with indoor air can be found in Appendix VI.

[3] kW_{Input} required from manufacturer's spec sheet is calculated in Appendix VIII if it is not provided by the manufacturer in their specification sheets.

Formula 4 (for electric heat pump water heaters [HPWH] that interact with outdoor air): Use this formula for HPWHs that are installed outdoors, or integrated HPWHs with intake and exhaust air ducted to the outdoors.

KW_{input} = (GPH X °F $Rise$[1] X 8.33 lb/gal) / (COP[2] X 3412 BTU/kW)

KW_{input} = 54 GPH X (130°F -50°F) X 8.33 lbs / 2.0 (CO_2 HP at 20°F Air Temp on design day in return to primary configuration with no recirculation) X 3412 BTU/KW = 5.27 KW_{input}[3]

[2] The coefficient of performance (COP) for HPWHs interacting with outdoor air can be found in Appendix VII.

[3] kW_{Input} required from manufacturer's spec sheet is calculated in Appendix VIII if it is not provided by the manufacturer in their specification sheets.

VII. SIZING REQUIREMENTS FOR TANKLESS/INSTANTANEOUS WATER HEATERS

A. INTRODUCTION

Tankless (instantaneous) water heaters produce hot water by passing water through a heat exchanger. For proper heating of the water, water must flow through the tankless water heater slowly to allow for adequate heat transfer from the heat exchanger to the water. Therefore, the quantity, or rate at which the hot water is delivered can be significantly less than that provided

No revisions were suggested for the following pages, pages 3 through 12 of the current approved version of the Guidelines, so the unrevised pages are excluded here for brevity. The research team recommends the following appendices are added to support HPWH COP calculations.

Appendix V

Winter Design Day Cold Water and Air Supply Temperature

Search the following table by city name to identify the Heating Design Drybulb Temperature (outdoor air supply Temperature) and Water Main Temperature (Design Day Cold Water Temperature).

Note: The research team recommends a table similar to the one below be developed on a zip code or city basis.

City & Zip Codes	Design Day Cold Water Temperature (°F) [1]	Design Day Cold Air Intake Temperature (°F) [2]
Arcata		
95518 | 95521|95524		
Anaheim		
92804 | 92805 | 92801 | 92802 | 92806 | 92807 | 92808		
Bakersfield		
93307 | 93306 | 93312 | 93309 | 93308 | 93313 | 93304 | 93311 | 93305 | 93314 | 93301		
Burbank		
91501 | 91502 | 91504 | 91505 | 91506		
Chula Vista		
91911 | 91910 | 91913 | 91915 | 91914		
Corona		
92882 | 92880 | 92879 | 92883 | 92881		
Coachella		
92236		
Eureka		
95501 | 95502 | 95503 | 95524| 95564		
Fontana		
92355 | 92336 | 92337		
Fremont		
94536 | 94538 | 94539 | 94555		
Fresno		
93722 | 93727 | 93720 | 93702 | 93726 | 93706 | 93711 | 93705 | 93703 | 93710 | 93704 | 93725 | 93728 | 93723 | 93730 | 93701 | 93721 | 93650		
Fullerton		
92833 | 92831 | 92832 | 92835		
Garden Grove		
92840 | 92843 | 92841 | 92844 | 92845		
Glendale		
91205 | 91206 | 91201 | 91202 | 91204 | 91208 | 91203 | 91207 | 91210		
Huntington Beach		
92647 | 92646 | 92648 | 92649		
Irvine		
92620 | 92618 | 92612 | 92604 | 92614 | 92602 | 92606 | 92603 | 92617		
Long Beach		
90805 | 90813 | 90806 | 90815 | 90802 | 90804 | 90808 | 90810 | 90803 | 90807 | 90814 | 90822 | 90831		

Appendix VI

Indoor Heat Pump Coefficient of Performance

Use the following table to determine the HPWH COP for indoor HPWHs. The Water Heater Setpoint Temperature is either specified on the design drawings or may be found in Appendix IX.

Note: The research team recommends a table similar to the one below that should be filled out based on laboratory and field-testing results. Heat pumps with new refrigerants such as 454b and propane will be listed as they become available on the market and 3rd-party test results become available.

			Design Day COP			
			130°F Water Heater Setpoint			150°F Water Heater Setpoint
Heat Pump Configuration	Refrigerant Type	Piping distribution has recirculation pump?	Full Service Indoor Air Temp 50°F	Quick Service Indoor Air Temp 60°F	Cafe Indoor Air Temp 70°F	Full Service Indoor Air Temp 50°F
Single-Pass Primary HPWH System with Electric Resistance Heater	CO_2 (5kW or less Rated Heating Output per heat pump unit)	Yes				
		No				
Single-Pass Primary HPWH System		No				
Hybrid Heat Pump with Electric Resistance Integrated Storage	134a	Yes				
		No				

Appendix VII

Outdoor Heat Pump Coefficient of Performance

Use the following table to determine the HPWH COP for indoor HPWHs. The Water Heater Setpoint Temperature is either specified on the design drawings or may be found in Appendix IX.

Select the correct "Design Day DB Air Temp X°F" by searching in Appendix V and identifying the design day outdoor air temperature for the closest city. Then round to the nearest design day value offered in the table below.

Note: The research team recommends a table similar to the one below that should be filled out based on laboratory and field-testing results. Heat pumps with new refrigerants such as 454b and propane as they become available on the market and 3rd-party test results become available.

				Design Day COP					
Heat Pump Configuration	**Refrigerant Type**	**Piping distribution has recirculation pump?**	**Building Type**	**130°F Heater Setpoint**			**150°F heater Setpoint**		
				DB Air Temp 0°F	**DB Air Temp 20°F**	**DB Air Temp 40°F**	**DB Air Temp 0°F**	**DB Air Temp 20°F**	**DB Air Temp 40°F**
Single-Pass Primary HPWH System	**CO2 (5kW or less Rated Heating Output)**	No	Café						
			Quick Service						
			Full Service						
	CO2 (Larger than 5kW Rated Heating Output)		Café						
			Quick Service						
			Full Service						
	134a, 513a		Café						
			Quick Service						
			Full Service						
Single-Pass Primary HPWH System with Electric Resistance Heater	**CO2 (5kW or less Rated Heating Output)**	Yes	Café						
			Quick Service						
			Full Service						
		No	Café						
			Quick Service						
			Full Service						
	CO2 (Larger than 5kW Rated Heating Output)	Yes	Café						
			Quick Service						
			Full Service						
		No	Café						
			Quick Service						
			Full Service						
	134a, 513a	Yes	Café						
			Quick Service						
			Full Service						
		No	Café						
			Quick Service						

			Full Service						
Multi-Pass Return to Primary HPWH System	134a, 513a	Yes	Café						
			Quick Service						
			Full Service						
		No	Café						
			Quick Service						
			Full Service						
Multi-Pass Return to Primary HPWH System with Electric Resistance Heater	134a, 513a, 410a	Yes	Café						
			Quick Service						
			Full Service						
		No	Café						
			Quick Service						
			Full Service						

Appendix VIII

HP KW_{Input} Table

HP Make and Model	Rated Electric Resistance Heating Output (BTU)	Rated Heat Pump Heating Output (BTU)	Rated COP	Resistance Electricity Input (KW)	Heat Pump Electricity Input (KW)	Total Electricity Input (KW)
SanCO2 Eco2						
AO Smith CHP-120						
Lochinvar AHP060						
Lochinvar AHP140						

Appendix IX

Default Water Heater Setpoint

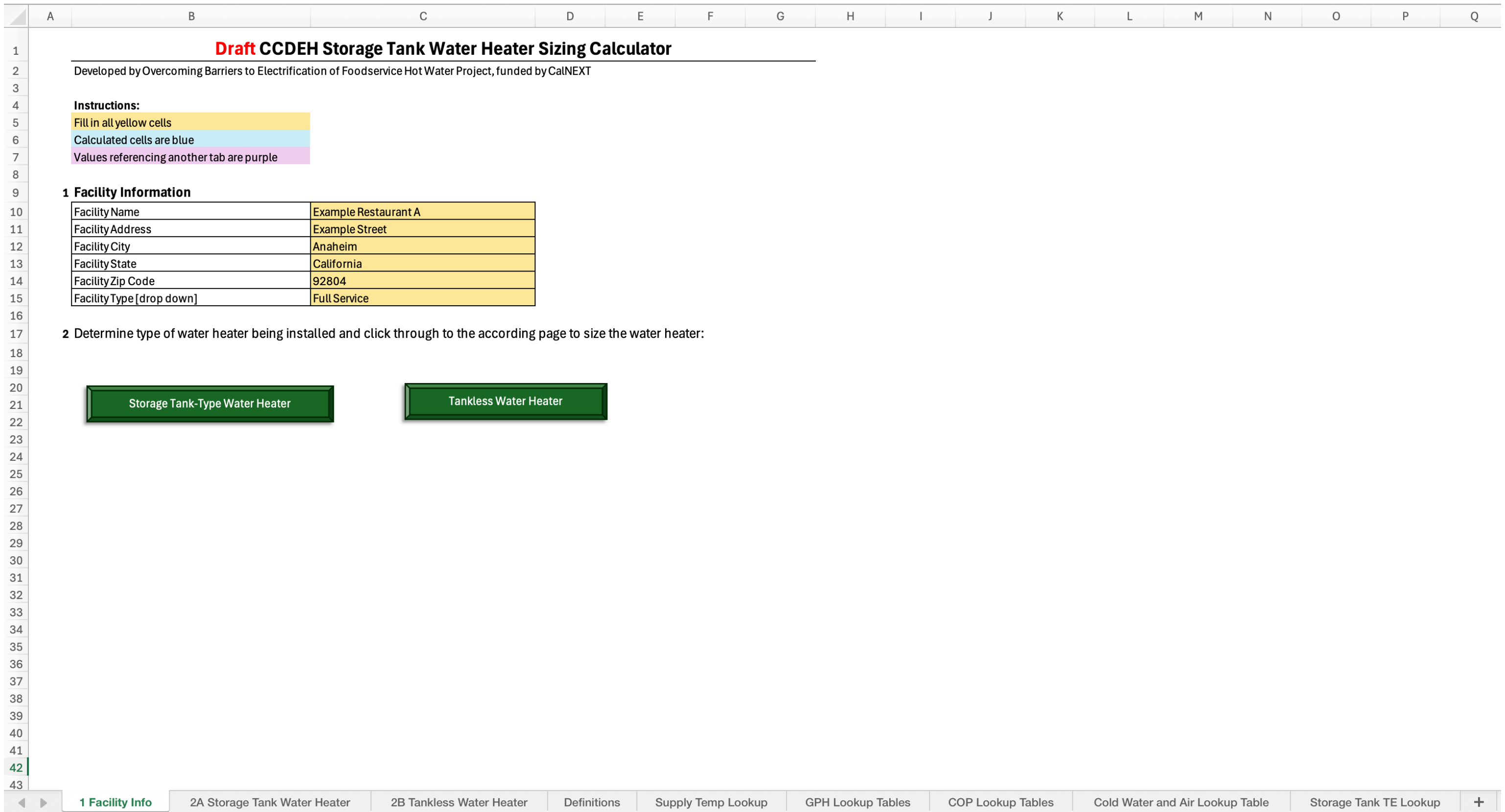
The following table identifies the minimum water heater setpoint temperatures in various types of foodservice facilities with standard distribution and recirculation systems.

	Minimum Heater Setpoint with Standard Distribution System	Minimum Heater Setpoint with Recirculation
Cafe	**130°F**	**125°F**
Fast food restaurant	**130°F**	**125°F**
Sit down restaurant with dishwasher	**150°F**	**145°F**
Sit down restaurant with high temp heat recovery dishwasher with cold water connection only	**130°F**	**125°F**

Appendix D: Proposed Water Heater Sizing Calculator Structure

The research team outlined the following proof-of-concept water heater sizing calculator for use by CCDEH.

Tab 1, “1 Facility Info,” gathers key details and guides the user to select a storage or tankless water heater option, regardless of fuel used.



Draft CCDEH Storage Tank Water Heater Sizing Calculator

Developed by Overcoming Barriers to Electrification of Foodservice Hot Water Project, funded by CalNEXT

Instructions:

Fill in all yellow cells

Calculated cells are blue

Values referencing another tab are purple

1 Facility Information

Facility Name	Example Restaurant A
Facility Address	Example Street
Facility City	Anaheim
Facility State	California
Facility Zip Code	92804
Facility Type [drop down]	Full Service

2 Determine type of water heater being installed and click through to the according page to size the water heater:

Storage Tank-Type Water Heater

Tankless Water Heater

1 Facility Info | 2A Storage Tank Water Heater | 2B Tankless Water Heater | Definitions | Supply Temp Lookup | GPH Lookup Tables | COP Lookup Tables | Cold Water and Air Lookup Table | Storage Tank TE Lookup

Tab 2, “2A Storage Tank Water Heater,” shows the first of two options for gas, ER, and HPWH system sizing. First, the user enters all equipment to calculate the recovery rate needed.

Draft CCDEH Storage Tank Water Heater Sizing Calculator

Developed by Overcoming Barriers to Electrification of Foodservice Hot Water Project, funded by CalNEXT

Instructions:

- Fill in all yellow cells
- Calculated cells are blue
- Values referencing another tab are purple

2 End-Use Equipment

Sinks: enter the description, number compartments, and compartment size

Sink name	Description	Compartment Dimensions [drop down]	Number of Compartments	Total Gallons Per Hour (GPH)
Example Sink 1	2 compartment sink	18" x 18"	2	28
Example Sink 2	3 compartment sink	18" x 24"	3	57
				0
				0
				0
				0
				0
				0

Other Equipment: enter the description, quantity, and estimated gallons per hour (GPH) usage

Equipment Name	Quantity	Gallons Per Hour (GPH)	Total Gallons Per Hour (GPH)
Bar Sink	2	6	12
Food prep sink	2	5	10
Janitorial sink	1	15	15
Hand sinks	6	5	30
Pre-rinse hand sprayer	1	45	45
			0
			0
			0

Dishmachines: enter the description, quantity, and estimated gallons per hour (GPH) usage for equipment that uses hot water

Equipment Name	Dishmachine Type [drop down]	Quantity	Gallons Per Hour (GPH)	Total Gallons Per Hour (GPH)
Dishmachine 1	High temp or low temp (140F required)	1	60	60
Dishmachine 2: bar dishmachine	High temp or low temp (140F required)	1	32.7	32.7
				0
				0

Total Recovery Rate Needed (GPH):	290

3 Water Heater and Distribution System Information

Instructions:

Water heater type [drop down]	Heat pump water heater

1 Facility Info | 2A Storage Tank Water Heater | 2B Tankless Water Heater | Definitions | Supply Temp Lookup | GPH Lookup Tables | COP Lookup Tables | Cold Water and Air

In the Tab 2 second option, the user enters in systems details, including the fuel and distribution type and water heater setpoint. Certain values may be automatically pulled because the user has already entered the facility location. By entering all information on this tab, the user yields the minimum input required.

3 Water Heater and Distribution System Information

		Instructions:
Water heater type [drop down]	Heat pump water heater	
Water heater distribution type [drop down]	Yes has recirculation pump	
Facility Type [drop down]	Full Service	Value is pulled from 1 Facility Info Tab
Hot water supply temperature (F)	140	Value automated by facility type and distribution type selections. See Supply Temp Lookup Table Tab.
Enter custom supply temp (use if facility type is Other), enter hot water supply temperature (F)		
Winter Cold Water design day temperature (F)	56	Value is based on zip code, pulled from Cold Water and Air Lookup Table Tab
Temperature Rise	84	

The following questions are for a heat pump water heater (HPWH), if not applicable, skip to 4.

If a HPWH, select system type [drop down]	Split HPWH: Single-Pass	Click here to find integrated and split HPWH definitions
If a HPWH, does system utilize a supplemental heating source? [drop down]	Yes electric resistance back-up	*[this input does not currently impact the efficiency]*
If a split HPWH, select heat pump installation location [drop down]	Outdoor	Split heat pumps are typically located outdoors, interacting with outdoor air temperatures. If installing heat pump indoors without ducting to the outdoors, then the heat pump will interact with indoor air temperatures. This selection will impact the estimated HPWH COP auto-calculated and found in section 4.
If an integrated Hybrid HPWH, select equipment location and ventilation configuration [drop down]		Click here to find HPWH ventilation definitions
If a HPWH, select refrigerant type [drop down]	Carbon Dioxide, CO2, R744	Select the refrigerant used in the selected HPWH product. This information can be found on a product specification sheet.

4 Heater Efficiency

Natural Gas (Thermal Efficiency)	N/A
Electric Resistance (Thermal Efficiency)	N/A
Heat pump water heater (COP)	2.00

5 Heater Minimum Input Required:

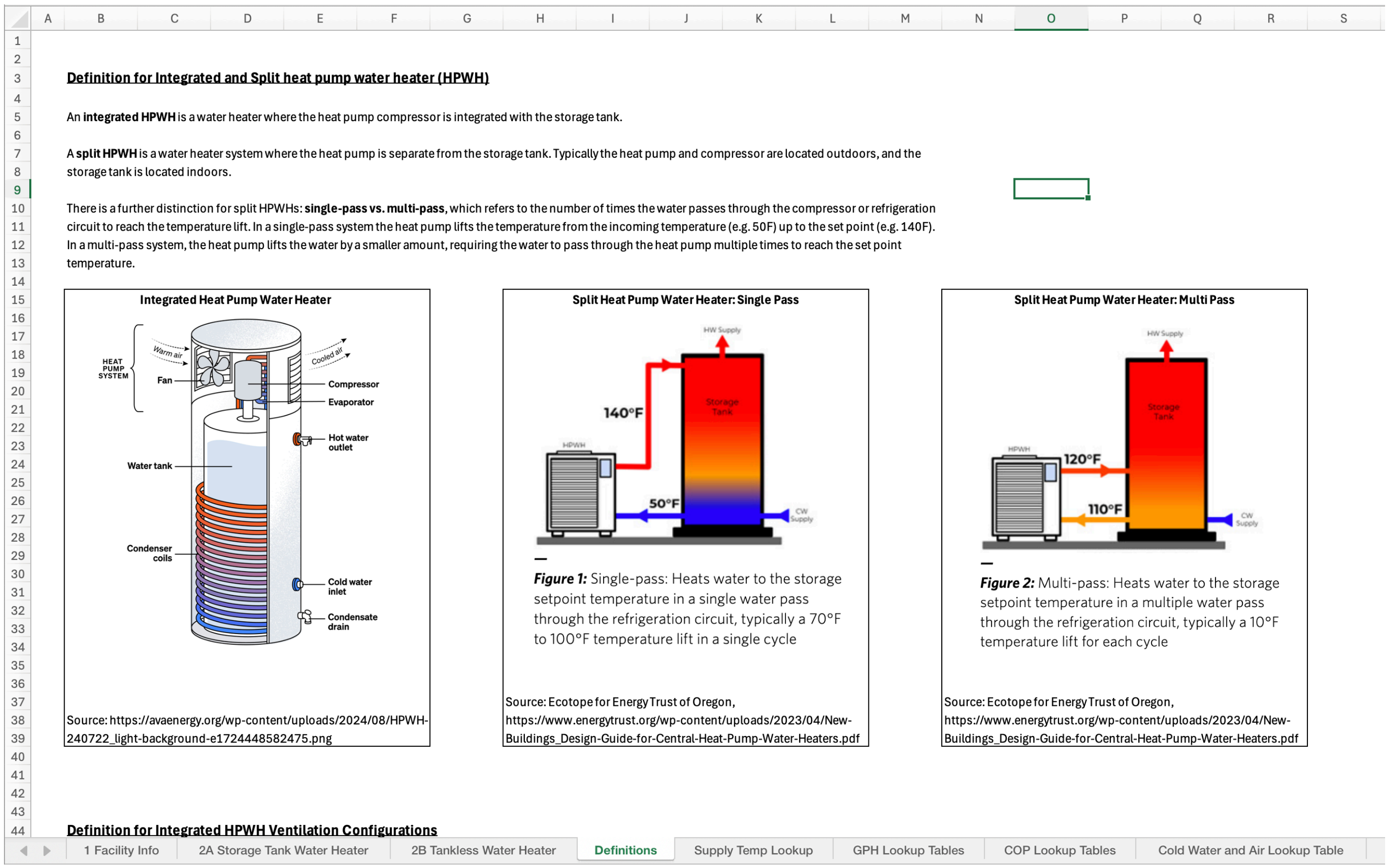
		Formula Reference:
Natural Gas Minimum Input		
Btu		BTU input = GPH X Temperature Rise X 8.33 lb/gal / Thermal Efficiency
Electric Resistance Minimum Input		
Btu		KW input = GPH X Temperature Rise X 8.33 lb/gal / TE X 3412 BTU/KW
kW		
Heat Pump Water Heater Minimum Input		
Btu	101,354	KW input = GPH X Temperature Rise X 8.33 lb/gal / COP X 3412 BTU/KW
kW	29.7	KW input = 289.7 x 84F x 8.33 lbs/gal / 2 x 3412 BTU/kW

Print Water Heater Sizing Summary as a PDF

1 Facility Info | 2A Storage Tank Water Heater | 2B Tankless Water Heater | Definitions | Supply Temp Lookup | GPH Lookup Tables | COP Lookup Tables | Cold Water and Ai

Tab 3, “Tab 2B Tankless Water Heater,” is not yet developed but is recommended so that all water heater sizing can occur in the same calculator. The structure should mirror the Storage Tank Water Heater calculator approach.

Tab 4, “Definitions,” provides an overview of key HPWH terminology and system descriptions. To future-proof this tool, this information could simply link to a webpage where the information could be updated more frequently.



Definition for Integrated and Split heat pump water heater (HPWH)

An **integrated HPWH** is a water heater where the heat pump compressor is integrated with the storage tank.

A **split HPWH** is a water heater system where the heat pump is separate from the storage tank. Typically the heat pump and compressor are located outdoors, and the storage tank is located indoors.

There is a further distinction for split HPWHs: **single-pass vs. multi-pass,** which refers to the number of times the water passes through the compressor or refrigeration circuit to reach the temperature lift. In a single-pass system the heat pump lifts the temperature from the incoming temperature (e.g. 50F) up to the set point (e.g. 140F). In a multi-pass system, the heat pump lifts the water by a smaller amount, requiring the water to pass through the heat pump multiple times to reach the set point temperature.

Integrated Heat Pump Water Heater

Source: https://avaenergy.org/wp-content/uploads/2024/08/HPWH-240722_light-background-e1724448582475.png

Split Heat Pump Water Heater: Single Pass

Figure 1: Single-pass: Heats water to the storage setpoint temperature in a single water pass through the refrigeration circuit, typically a 70°F to 100°F temperature lift in a single cycle

Source: Ecotope for Energy Trust of Oregon, https://www.energytrust.org/wp-content/uploads/2023/04/New-Buildings_Design-Guide-for-Central-Heat-Pump-Water-Heaters.pdf

Split Heat Pump Water Heater: Multi Pass

Figure 2: Multi-pass: Heats water to the storage setpoint temperature in a multiple water pass through the refrigeration circuit, typically a 10°F temperature lift for each cycle

Source: Ecotope for Energy Trust of Oregon, https://www.energytrust.org/wp-content/uploads/2023/04/New-Buildings_Design-Guide-for-Central-Heat-Pump-Water-Heaters.pdf

Definition for Integrated HPWH Ventilation Configurations

Definition for Integrated HPWH Ventilation Configurations

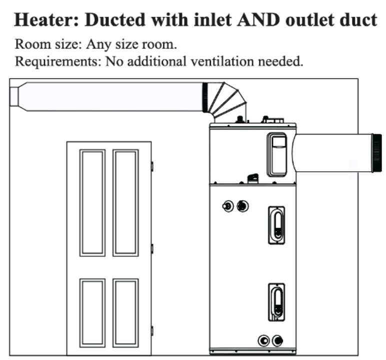
There are a variety of ways to configure ventilation for an integrated HPWH:

Indoor (non-ducted intake or exhaust air)
HPWH is installed indoors and does not use ducting. The heat pump is therefore interacting with indoor air. The photos below represent this scenario:

Source: https://pureplumbingcompany.medium.com/efficient-and-eco-friendly-a-guide-to-heat-pump-water-heater-installation-db5c4a759fdb

Source: https://www.contractormag.com/hydronics/article/55236261/california-hotel-converts-to-heat-pump-water-heaters

Indoor (intake and exhaust air is ducted to exterior)
HPWH is installed indoors and ducts the intake and exhaust air streams to the exterior. The heat pump is therefore interacting with outdoor air. The diagram below represents this scenario:

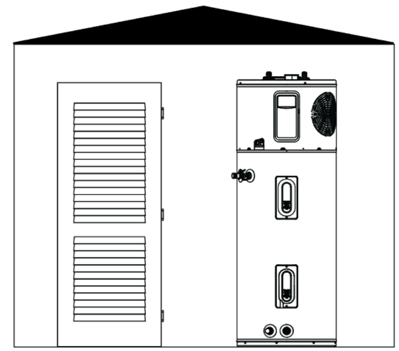


Source: https://media.rheem.com/blobazrheem/wp-content/uploads/sites/36/2024/07/AP23657-Rev-01-Manual-HPWH-GEN-V-UNIVERSAL-CONNECT-ENGLISH_HALF-SIZE-3.pdf

Source: https://plumbingandhvac.ca/todays-heat-pump-water-heaters/

Outdoor
HPWH is installed in an outdoor closet (withadequate ventilation openings). In this scenario is HPWH is interacting with outdoor air. Below is an example of this scenario:

Example: HPWH installed in an outdoor shed



Source: https://media.rheem.com/blobazrheem/wp-content/uploads/sites/36/2024/07/AP23657-Rev-01-Manual-HPWH-GEN-V-UNIVERSAL-CONNECT-ENGLISH_HALF-SIZE-3.pdf

1 Facility Info | 2A Storage Tank Water Heater | 2B Tankless Water Heater | **Definitions** | Supply Temp Lookup | GPH Lookup Tables | COP Lookup Tables

Tab 5, “Supply Temp Lookup,” provides a set of default setpoints if the user is uncertain what to enter.

Supply Temperature Lookup Table

	Minimum Heater Setpoint with Standard Distribution System	Minimum Heater Setpoint with Recirculation
Cafe	**130°F**	**125°F**
Fast food restaurant	**130°F**	**125°F**
Sit down restaurant with dishwasher	**150°F**	**145°F**
Sit down restaurant with high temp heat recovery dishwasher with cold water connection only	**130°F**	**125°F**

1 Facility Info | 2A Storage Tank Water Heater | 2B Tankless Water Heater | Definitions | Supply Temp Lookup | GPH Lookup Tables

Tab 6, “GPH Lookup Tables,” are where all equipment GPH lookup tables could be located. An example for different compartment sink options is provided below.

Compartment GPH Lookup Table

Compartment Size	Gallons per Compartment
16" x 20"	14
18" x 18"	14
18" x 24"	19
18" x 26"	20
18" x 30"	23
20" x 28"	24
24" x 24"	25
24" x 30"	31

1 Facility Info | 2A Storage Tank Water Heater | 2B Tankless Water Heater | Definitions | Supply Temp Lookup | GPH Lookup Tables | COP Lookup Tables

Tab 7, COP Lookup Tables," is where the HPWH COP calculator would be located. The research team recommends having an interim calculator so the user can trace the calculation, as well as the source lookup tables, along with outdoor and indoor installation options. This structure aligns with the suggestions for the PDF version of the CCDEH Guidelines.

COP Interim Calculator

Purple cells are data pulled from "Storage Tank Heater Tab"

Facility Zip Code	92804
Facility Type [drop down]	Full Service
Water heater distribution type [drop down]	Yes has recirculation pump
Water heater type [drop down]	Heat pump water heater
Hot water supply temperature (F) Used in Calculations:	140
If a HPWH, select system type [drop down]	Split HPWH: Single-Pass
If a HPWH, does system utilize a supplemental heating source? [drop down]	Yes electric resistance back-up
If a split HPWH, select heat pump installation location [drop down]	Outdoor
If an integrated Hybrid HPWH, select equipment location and ventilation configuration [drop down]	0
If a HPWH, select refrigerant type [drop down]	Carbon Dioxide, CO2, R744
Winter Cold Water design day temperature (F)	56
Winter Cold air design day intake temperature (F)	45
Estimated COP	2.0

Outdoor HPWH COP Look-up Table

				Design Day COP					
				130°F Heater Setpoint			150°F heater Setpoint		
Heat Pump Configuration	Refrigerant Type	Piping distribution has recirculation pump?	Building Type	DB Air Temp 0°F	DB Air Temp 20°F	DB Air Temp 40°F	DB Air Temp 0°F	DB Air Temp 20°F	DB Air Temp 40°F
Single-Pass Primary HPWH System	CO2 (5kW or less Rated Heating Output)	No	Café						
			Quick Service						
			Full Service						
	CO2 (Larger than 5kW Rated Heating Output)		Café						
			Quick Service						
			Full Service						
	134a, 513a		Café						
			Quick Service						
			Full Service						
	CO2 (5kW or less Rated Heating Output)	Yes	Café						
			Quick Service						
			Full Service						
			Café						

Indoor HPWH COP Look-up Table

			Design Day COP			
			130°F Water Heater Setpoint			150°F Water Heater Setpoint
Heat Pump Configuration	Refrigerant Type	Piping distribution has recirculation pump?	Full Service Indoor Air Temp 50°F	Quick Service Indoor Air Temp 60°F	Cafe Indoor Air Temp 70°F	Full Service Indoor Air Temp 50°F
Single-Pass Primary HPWH System with Electric Resistance Heater	CO_2 (5kW or less Rated Heating Output per heat pump unit)	Yes	2.5	3.3	3	
		No	3.5	3.5	3.2	
Single-Pass Primary HPWH System		No	3.7	4.5	4.5	
Hybrid Heat Pump with Electric Resistance Integrated Storage	134a	Yes	1.3	1.6	1.8	
		No	1.6	1.9	2.7	

1 Facility Info | 2A Storage Tank Water Heater | 2B Tankless Water Heater | Definitions | Supply Temp Lookup | GPH Lookup Tables | COP Lookup Tables | Cold Water and Air Lookup Table | Storage Tank TE Lookup | +

Outdoor HPWH COP Look-up Table

Heat Pump Configuration	Refrigerant Type	Piping distribution has recirculation pump?	Building Type	Design Day COP: 130°F Heater Setpoint: DB Air Temp 0°F	130°F Heater Setpoint: DB Air Temp 20°F	130°F Heater Setpoint: DB Air Temp 40°F	150°F heater Setpoint: DB Air Temp 0°F	150°F heater Setpoint: DB Air Temp 20°F	150°F heater Setpoint: DB Air Temp 40°F
Single-Pass Primary HPWH System	CO2 (5kW or less Rated Heating Output)	No	Café						
			Quick Service						
			Full Service						
	CO2 (Larger than 5kW Rated Heating Output)		Café						
			Quick Service						
			Full Service						
	134a, 513a		Café						
			Quick Service						
			Full Service						
Single-Pass Primary HPWH System with Electric Resistance Heater	CO2 (5kW or less Rated Heating Output)	Yes	Café						
			Quick Service						
			Full Service						
		No	Café						
			Quick Service						
			Full Service						
	CO2 (Larger than 5kW Rated Heating Output)	Yes	Café						
			Quick Service						
			Full Service						
		No	Café						
			Quick Service						
			Full Service						
	134a, 513a	Yes	Café						
			Quick Service						
			Full Service						
		No	Café						
			Quick Service						
			Full Service						
Multi-Pass Return to Primary HPWH System	134a, 513a	Yes	Café						
			Quick Service						
			Full Service						
		No	Café						
			Quick Service						
			Full Service						
Multi-Pass Return to Primary HPWH System with Electric Resistance Heater	134a, 513a, 410a	Yes	Café						
			Quick Service						
			Full Service						
		No	Café						
			Quick Service						
			Full Service						

Indoor HPWH COP Look-up Table

Heat Pump Configuration	Refrigerant Type	Piping distribution has recirculation pump?	Design Day COP: 130°F Water Heater Setpoint: Full Service, Indoor Air Temp 50°F	130°F Water Heater Setpoint: Quick Service, Indoor Air Temp 60°F	130°F Water Heater Setpoint: Cafe, Indoor Air Temp 70°F	150°F Water Heater Setpoint: Full Service, Indoor Air Temp 50°F
Single-Pass Primary HPWH System with Electric Resistance Heater	CO_2 (5kW or less Rated Heating Output per heat pump unit)	Yes	2.5	3.3	3	
		No	3.5	3.5	3.2	
Single-Pass Primary HPWH System		No	3.7	4.5	4.5	
Hybrid Heat Pump with Electric Resistance Integrated Storage	134a	Yes	1.3	1.6	1.8	
		No	1.6	1.9	2.7	

1 Facility Info | 2A Storage Tank Water Heater | 2B Tankless Water Heater | Definitions | Supply Temp Lookup | GPH Lookup Tables | COP Lookup Tables | Cold Water and Air Lookup Table | Storage Tank TE Lookup

Tab 8, “Cold Water and Air Lookup Table,” provides an example of the lookup table structure for the winter cold water and air intake temperatures by city, county, or municipality.

Winter Design Day Cold Water and Air Supply Temperature

<table>
<tr><th>City & Zip Codes</th><th>Winter Cold Water Temperature (°F)</th><th>Winter Cold Air Intake Temperature (°F) (0.2% of days)</th></tr>
<tr><td>Arcata</td><td></td><td></td></tr>
<tr><td>95518 | 95521|95524</td><td></td><td></td></tr>
<tr><td>Anaheim</td><td></td><td></td></tr>
<tr><td>92804 | 92805 | 92801 | 92802 | 92806 | 92807 | 92808</td><td></td><td></td></tr>
<tr><td>Bakersfield</td><td></td><td></td></tr>
<tr><td>93307 | 93306 | 93312 | 93309 | 93308 | 93313 | 93304 | 93311 | 93305 | 93314 | 93301</td><td></td><td></td></tr>
<tr><td>Burbank</td><td></td><td></td></tr>
<tr><td>91501 | 91502 | 91504 | 91505 | 91506</td><td></td><td></td></tr>
<tr><td>Chula Vista</td><td></td><td></td></tr>
<tr><td>91911 | 91910 | 91913 | 91915 | 91914</td><td></td><td></td></tr>
<tr><td>Corona</td><td></td><td></td></tr>
<tr><td>92882 | 92880 | 92879 | 92883 | 92881</td><td></td><td></td></tr>
<tr><td>Coachella</td><td></td><td></td></tr>
<tr><td>92236</td><td></td><td></td></tr>
<tr><td>Eureka</td><td></td><td></td></tr>
<tr><td>95501 | 95502 | 95503 | 95524| 95564</td><td></td><td></td></tr>
<tr><td>Fontana</td><td></td><td></td></tr>
<tr><td>92355 | 92336 | 92337</td><td></td><td></td></tr>
<tr><td>Fremont</td><td></td><td></td></tr>
<tr><td>94536 | 94538 | 94539 | 94555</td><td></td><td></td></tr>
<tr><td>Fresno</td><td></td><td></td></tr>
<tr><td>93722 | 93727 | 93720 | 93702 | 93726 | 93706 | 93711 | 93705 | 93703 | 93710 | 93704 | 93725 | 93728 | 93723 | 93730 | 93701 | 93721 | 93650</td><td></td><td></td></tr>
<tr><td>Fullerton</td><td></td><td></td></tr>
<tr><td>92833 | 92831 | 92832 | 92835</td><td></td><td></td></tr>
<tr><td>Garden Grove</td><td></td><td></td></tr>
<tr><td>92840 | 92843 | 92841 | 92844 | 92845</td><td></td><td></td></tr>
<tr><td>Glendale</td><td></td><td></td></tr>
<tr><td>91205 | 91206 | 91201 | 91202 | 91204 | 91208 | 91203 | 91207 | 91210</td><td></td><td></td></tr>
<tr><td>Huntington Beach</td><td></td><td></td></tr>
<tr><td>92647 | 92646 | 92648 | 92649</td><td></td><td></td></tr>
<tr><td>Irvine</td><td></td><td></td></tr>
<tr><td>92620 | 92618 | 92612 | 92604 | 92614 | 92602 | 92606 | 92603 | 92617</td><td></td><td></td></tr>
<tr><td>Long Beach</td><td></td><td></td></tr>
<tr><td>90805 | 90813 | 90806 | 90815 | 90802 | 90804 | 90808 | 90810 | 90803 | 90807 | 90814 | 90822 | 90831</td><td></td><td></td></tr>
<tr><td>Long Angeles</td><td></td><td></td></tr>
<tr><td>90011 | 90044 | 90003 | 90026 | 90019 | 90022 | 90037 | 90042 | 90006 | 90004 | 90066 | 90001 | 90034 | 90018 | 90002 | 90063 | 90046 | 90024 | 90057 | 90047 | 90025 | 90065 | 90032 | 90033 | 90023 | 90016 | 90059 | 90027 | 90043 | 90007 | 90045 | 90005 | 90020 | 90031 | 90036 |</td><td></td><td></td></tr>
</table>

Definitions | Supply Temp Lookup | GPH Lookup Tables | COP Lookup Tables | Cold Water and Air Lookup Table | Storage Tank TE Lookup

Tab 9, “Storage Tank TE Lookup,” provides a reference for default thermal efficiencies for gas and ER systems. This tab could also provide a reference table for tankless water heaters, once developed.

Natural Gas Look up Table

Water heater type	Recirculation Type	Default TE
Natural gas (standard 80% rated TE)	No recirculation pump	0.8
Natural gas (standard 80% rated TE)	Yes has recirculation pump	
Natural gas (condensing 92%+ rated TE)	No recirculation pump	0.92
Natural gas (condensing 92%+ rated TE)	Yes has recirculation pump	

Electric Resistance Look up Table

Water heater type	Recirculation Type	Default TE
Electric resistance	No recirculation pump	0.98
Electric resistance	Yes has recirculation pump	

Definitions | Supply Temp Lookup | GPH Lookup Tables | COP Lookup Tables | Cold Water and Air Lookup Table | Storage Tank TE Lookup