Market Potential for Heat Pump Assisted Hot Water Systems in Foodservice Facilities

Final Report

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Executive Summary

Electrifying the building sector is a critical step toward meeting California's decarbonization goals. Gas-fired water heating for foodservice applications represents 340 million therms of consumption per year, presenting a significant electrification opportunity through the application of electric air-source heat pump water heaters (HPWH).

Currently, HPWH used in new buildings or replacement applications in existing foodservice facilities face extensive regulatory barriers. Heat pump water heating is a fairly new technology, and state, county, and city health departments may effectively disallow their use due to out-of-date sizing guidelines. These government entities may allow a facility to use a HPWH if it is oversized 300 percent to 400 percent beyond the heating output requirements of conventional heaters. Using a heat pump and storage tank upstream, in series with the existing approved conventional water heater in an "assist" fashion, is one way to overcome current regulatory barriers in most foodservice facilities with medium to large hot water loads. In facilities with small hot water loads, there is a regulatory path to use large, residential 80 gallon or light, commercial 120 gallon integrated heat pump/electric resistance hybrid water heaters.

The Research Team interviewed seven subject matter experts (SMEs) and three restaurant owner/operators who provided the following key drivers and barriers for adopting heat pump water heating in foodservice facilities:

- Drivers: Heat pump water heating provides a path to electrification which aligns with some companies' sustainability goals as the discharge cooled air released by HPWHs can be used to cool the kitchen, increase resiliency,[1, 2] and (particularly if the existing technology is electric resistance water heating) lower operating costs.
- Barriers: Heat pump water heating often has higher upfront costs. It requires additional equipment space (particularly in an assist scenario) and can increase noise. The health department regulation barrier could be lower for a heat pump assist configuration, as it overcomes the output temperature limitation of a "heat pump only" hot water system.

The SMEs suggested that high upfront costs (heat pump equipment, electrical upgrades, etc.) are potential barriers for hard-to-reach (HTR) foodservice operators and owners and those from disadvantaged communities. Both restaurant operator interviews also indicated a lack of awareness of the costs and benefits of heat pump technology.

The interviews and the literature review conducted by the Research Team provided information on how foodservice facilities can incorporate heat pump water heating technology, either independently or in an assist configuration. The literature review and interviews also identified a selection of case

1 Applies only to HPWH "assist" scenarios only.

2 "Energy resilience" is "the ability to avoid, prepare for, minimize, adapt to, and recover from anticipated and unanticipated energy disruptions in order to ensure energy availability and reliability sufficient to provide for mission assurance and readiness, including mission essential operations related to readiness, and to execute or rapidly reestablish mission essential requirements" (10 USC § 101(e)(6) 2022).

studies where facilities have installed, or plan to install, a HPWH; some of these case studies reinforced the aforementioned barriers to HPWH adoption since in some cases, the HPWH installation was ultimately denied by local code officials.

Certain types of foodservice facilities are well-positioned to overcome barriers, though, or be particularly motivated by the drivers including facilities with abundant extra space, very small hot water loads, spare electrical capacity, high radiant cooking loads, or owners/operators who are committed to acting on their sustainability goals. New construction facilities are most likely to be the best positioned to use a heat pump assisted water heater (HPaWH) system, because the facility could be designed to accommodate the space requirements and electrical needs of the system, and could also use an integrated design approach that downsizes the gas water heater and makes use of the waste heat from the HPWH to cool the kitchen. For existing facilities, a minority of facilities have characteristics of likely early adopters, which include those with electric resistance water heaters, abundant space and spare electrical capacity, small water heating needs (such as coffee shops or delis), and those that consider sustainability in decision making processes.

While HPWH systems were cited by several SMEs as an ultimate goal, a HPaWH system takes a step closer to full decarbonization as the industry transitions from full dependency on conventional water heaters. Emphasizing the HPaWH alternative to full HPWH adoption provides health departments, utilities, municipalities, and the state time to increase familiarity with heat pump hot water heating, reduce installation and operating costs, and address other barriers to market adoption in this challenging sector. Field demonstration projects could provide an important example to illustrate benefits and better characterize costs, and—in the long term—utility programs and rebates would be important to accelerate adoption.

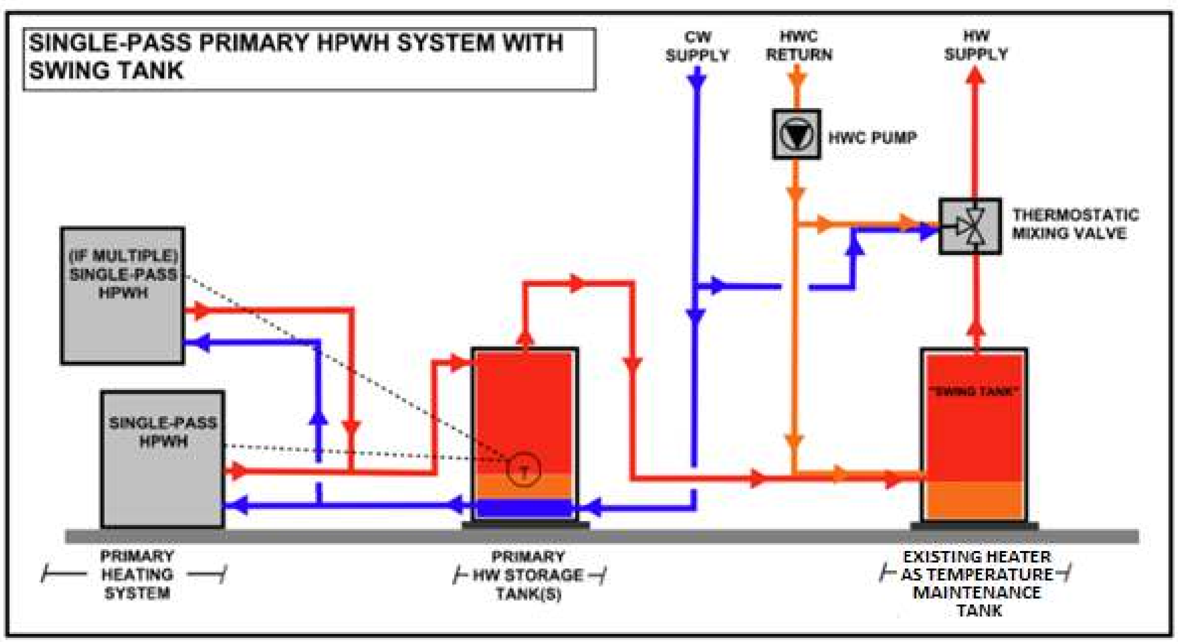

Figure 1: Example heat pump hot water assist system

Source: (Ecotope 2020)

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Abbreviations and Acronyms

Acronym	Meaning
Btu	British Thermal Unit
CEC	California Energy Commission
CCDB	Compliance Certification Database
COP	Coefficient of Performance
CPUC	California Public Utilities Commission
Cx	Building Commissioning
DAC	Disadvantaged Communities
dBa	A-Weighted Decibels
DEER	Database of Energy Efficiency Resources
DOE	Department of Energy
EIA	Energy Information Administration
EUI	Energy Use Intensity
GHG	Greenhouse Gas
GPH	Gallons Per Hour
GWP	Global Warming Potential
HPaWH	Heat Pump Assisted Water Heater
HPWH	Heat Pump Water Heater
HTR	Hard-to-Reach
HVAC	Heating, Ventilation, and Air Conditioning
IOU	Investor-Owned Utility
PG&E	Pacific Gas and Electric
SCE	Southern California Edison

Acronym	Meaning
SDG&E	San Diego Gas and Electric
SME	Subject Matter Expert
TOU	Time of Use
ZNE	Zero Net Energy

1 Background

This section provides:

- Context on the impact of foodservice water heating on total statewide energy use in California.
- The methods the Research Team used to collect data for this research.
- An overview of conventional water heaters, heat pump water heater (HPWH) technology, and a heat pump assist water heater (HPaWH) system.
- A comparison of products that could be used as a standalone HPWH or as part of a HPaWH system.

1.1 Impact of Foodservice Water Heating and Potential Benefit of Electrification

According to the report *Energy Efficiency Potential of Gas-Fired Commercial Water Heating Equipment in Foodservice Facilities* (Delagah and Fisher 2009), water heating for foodservice applications represents 340M therms of gas consumption annually in California, representing 16 percent of commercial gas usage statewide. Based on qualitative experience and industry judgement, the Research Team estimates that total statewide foodservice hot water usage has likely decreased from the estimates in this report due to the increased efficiency of dishwashers and a combination of factors stemming from the COVID-19 pandemic.[3] However, while exact trends are still emerging, data within this report indicate that water heating in foodservice facilities remains high.

When comparing the median energy use intensity (EUI) of various property types, foodservice buildings are among the most high intensity energy users on a per square foot basis. Based on energy modeling published in the *Zero Net Energy Commercial Market Characterization* report (TRC 2019), restaurants have a much higher EUI than other commercial building types, as shown in Figure 2 below. This figure presents results by building vintage and for a zero net energy (ZNE) existing building efficiency target (the “ZNE EB Eff Target” series), which includes high efficiency measures. While there is a slight reduction in newer vintages, and for the ZNE EB Eff Target series, restaurant EUI is two to three times higher than other commercial building types in California.

[3] COVID-19 has impacted the foodservice industry through both the shift away from full service restaurants and the trend of more people working from home and dining out less (Marchesi and McLaughlin 2022).

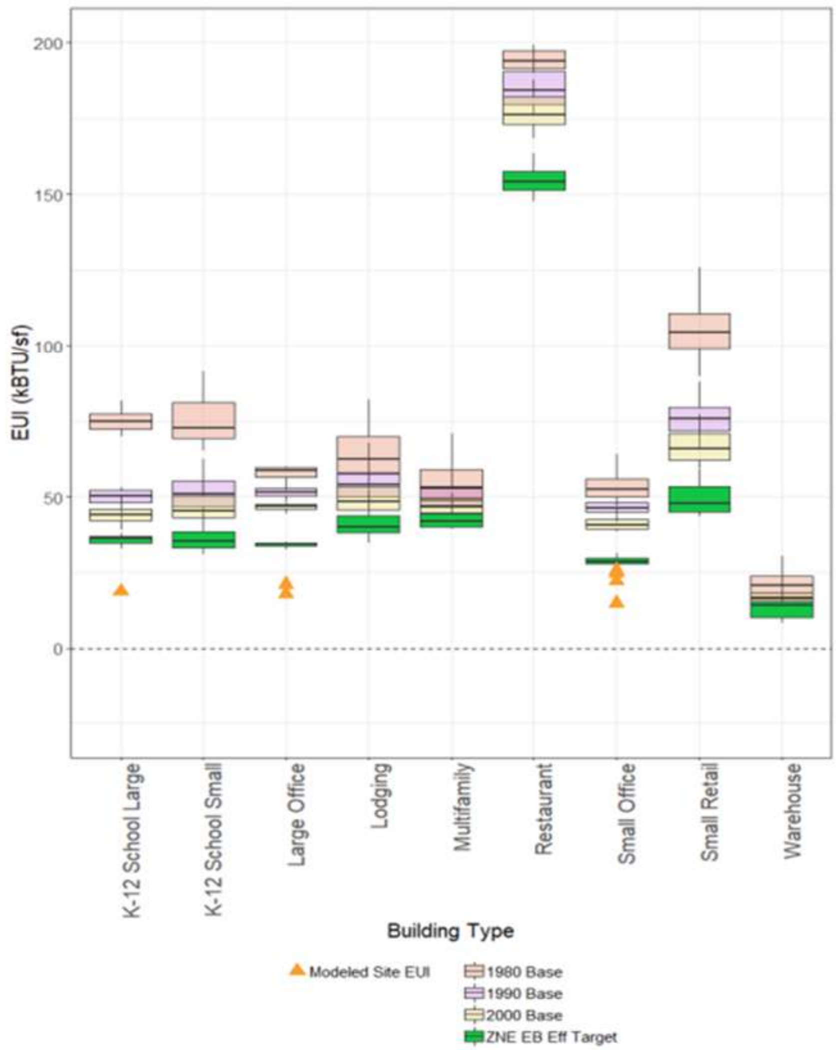

Figure 2: Comparison of restaurant EUI compared to other California commercial building types and by building vintage

Source: (TRC 2019)

Nationally, fast food restaurants rank higher than any other subcategory listed by ENERGY STAR® Portfolio Manager, with a site EUI of 402.7 one kilo of British Thermal Units (kBtu)/square feet (US Department of Energy 2021). Restaurants not classified as fast food rank second at 325.6 kBtu/square feet. For comparison, general medical and surgical hospitals, also high intensity energy users, have a median site EUI of only 234.3 kBtu/square feet (US Department of Energy 2021). On a per building basis, sectors like health care and lodging used much more electricity than foodservice in 2012, but on a per square footage floorspace basis, the opposite is true (EIA 2012). A study found that the total gas load of foodservice establishments approaches 40 percent of the overall commercial gas consumption in the state (Spoor, Zabrowski and Mills 2014).

From 2004 to 2019, fast food (also referred to as 'quick service') restaurants have only seen a 20.9 percent reduction in site energy in the United States, the lowest percent energy savings of any sector evaluated in a Pacific Northwest National Laboratory presentation (Cejudo 2021). Full service restaurants saw a site energy reduction of only 28.5 percent over the same period, significantly lower than the national weighted average of 37.6 percent energy savings (Cejudo 2021). Hot water heating represents a large portion of this high intensity energy use. Another study, *Characterizing the energy efficiency potential of gas-fired commercial foodservice equipment* (Spoor, Zabrowski and Mills 2014), found that hot water heating can represent up to 20 percent of the total energy consumption and up to 50 percent of the total gas consumption in full service and industrial kitchens.

Electrifying the building sector is a critical step towards meeting California's decarbonization goals and all of these sources highlight the importance of reducing the energy use and greenhouse gas (GHG) impact of foodservice water heating as critical to meeting statewide goals. Increasing market penetration of HPaWH systems in foodservice presents a significant electrification opportunity through the application of heat pump assistance.

In addition to their high energy use, water heaters in foodservice facilities significantly impact grid demand, as their use spikes at specific times—including peak times when the grid is stressed. Electric air-source HPWHs and HPaWHs also offer the potential for load flexibility and greater resiliency. Using grid-connected controls, if a power shortage is predicted, controls can call on a HPWH to pre-heat water prior to the event and "coast" through the outage period with little or no usage. A HPaWH system offers even greater resiliency—if integrated with a gas-powered water heater—because it can fluctuate between using the electric HPWH when the grid demand is low and using the gas-powered water heater when grid demand is high. Load flexibility and resiliency are becoming more important as the "duck curve" becomes more pronounced.[4] Figure 3 illustrates the duck curve and its evolution over time for a day in January for the California grid (TRC 2021).

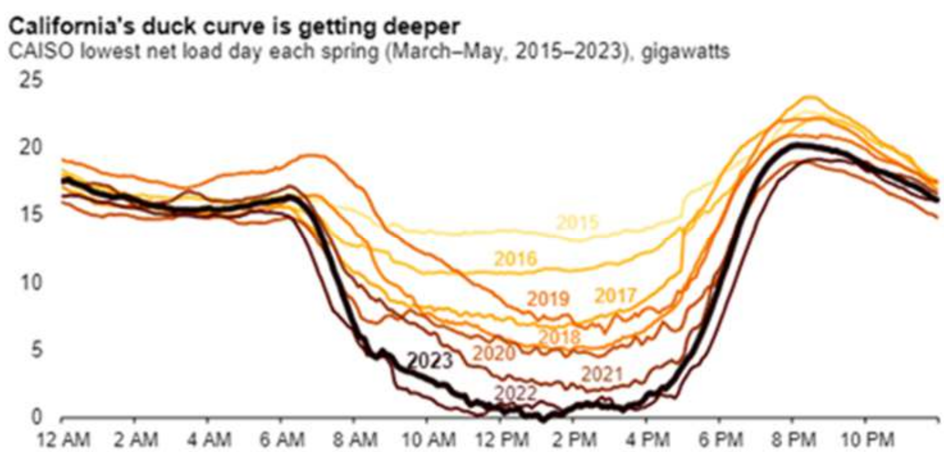

Figure 3: Net load curve for Spring study period for years 2015 through 2023

Source: (EIA 2023)

[4] The duck curve refers to the difference between grid demand and solar power generation over a typical day.

1.2 Methods

For this study, the Research Team reviewed currently available HPWH technologies that could be used in foodservice facilities, investigated the market barriers and opportunities for adoption of a HPWH (either independently or in an assist fashion), and identified potential early adopters. The scope included a literature review and interviews with subject matter experts (SMEs) and restaurant owners/operators.

1.2.1 Literature Review

The Research Team conducted a literature review for baseline information, including the scale and relative intensity of hot water energy usage in foodservice, current heat pump technological specifications, relevant health codes, and applicable rebates. The Research Team reviewed the literature for other published articles on heat pumps in restaurants and foodservice facilities. Literature resources reviewed and report content supported by each source is listed in Table 1.

Table 1: Literature Sources Reviewed

Source Reviewed	Report Content Supported by Source
(A Noisy Planet 2019)	Byproduct Cooling
(California Public Utilities Commission 2022)	Appendix - methodology to calculate operating cost estimate
(CCDEH 2020)	Overview - sizing calculations
(Cejudo 2021)	Impact of Foodservice Water Heating and Potential Benefit of Electrification
(CLEAResult 2022)	Methods of Increasing Feasibility
(Delagah and Fisher 2009)	Impact of Foodservice Water Heating and Potential Benefit of Electrification; Typical Sizing and Water Heating Needs
(Department of Industrial Relations 2022)	Health and Safety Guidelines
(Ecotope 2020)	HPaWH Systems - Diagram
(EIA 2012)	Impact of Foodservice Water Heating and Potential Benefit of Electrification; Likely Attributes of Early Adopters
(Energy Solutions 2021)	Methods of Increasing Feasibility
(Environmental Health Services Division 2020)	Overview - sizing calculations

(Feng 2021)	Methods of Increasing Feasibility
(GTI 2021)	Byproduct Cooling
(Paisan 2022)	Health and Safety Guidelines
(PG&E Company and Fisher-Nickel 2013)	Likely Attributes of Early Adopters
(Seattle City Light 2021)	HPWH Systems - Diagram
(Spoor, Zabrowski and Mills 2014)	Impact of Foodservice Water Heating and Potential Benefit of Electrification
(TRC 2019)	Impact of Foodservice Water Heating and Potential Benefit of Electrification
(TRC 2021)	Impact of Foodservice Water Heating and Potential Benefit of Electrification
(US Department of Energy 2021)	Impact of Foodservice Water Heating and Potential Benefit of Electrification

1.2.2 Interviews

The Research Team interviewed seven SMEs and three restaurant owners/operators, as described below.

- Seven SMEs:
  - Four mechanical and plumbing engineers.
  - One restaurant designer.
  - One senior executive at a manufacturer of heat pumps for commercial facilities that include foodservice facilities.
  - One California investor-owned utility (IOU) project manager.
- Three operator/owners:
  - One chain restaurant director of operations.
  - One franchise restaurant owner.
  - One hard-to-reach (HTR) restaurant owner.

1.3 Overview of Conventional Water Heaters, HPWHs, and HPaWH Systems

1.3.1 Conventional (Gas and Electric Resistance) Water Heaters

Figure 4 shows conventional storage water heaters used in foodservice facilities. California state, county, and city health department sizing guidelines exist for these types of water heaters.

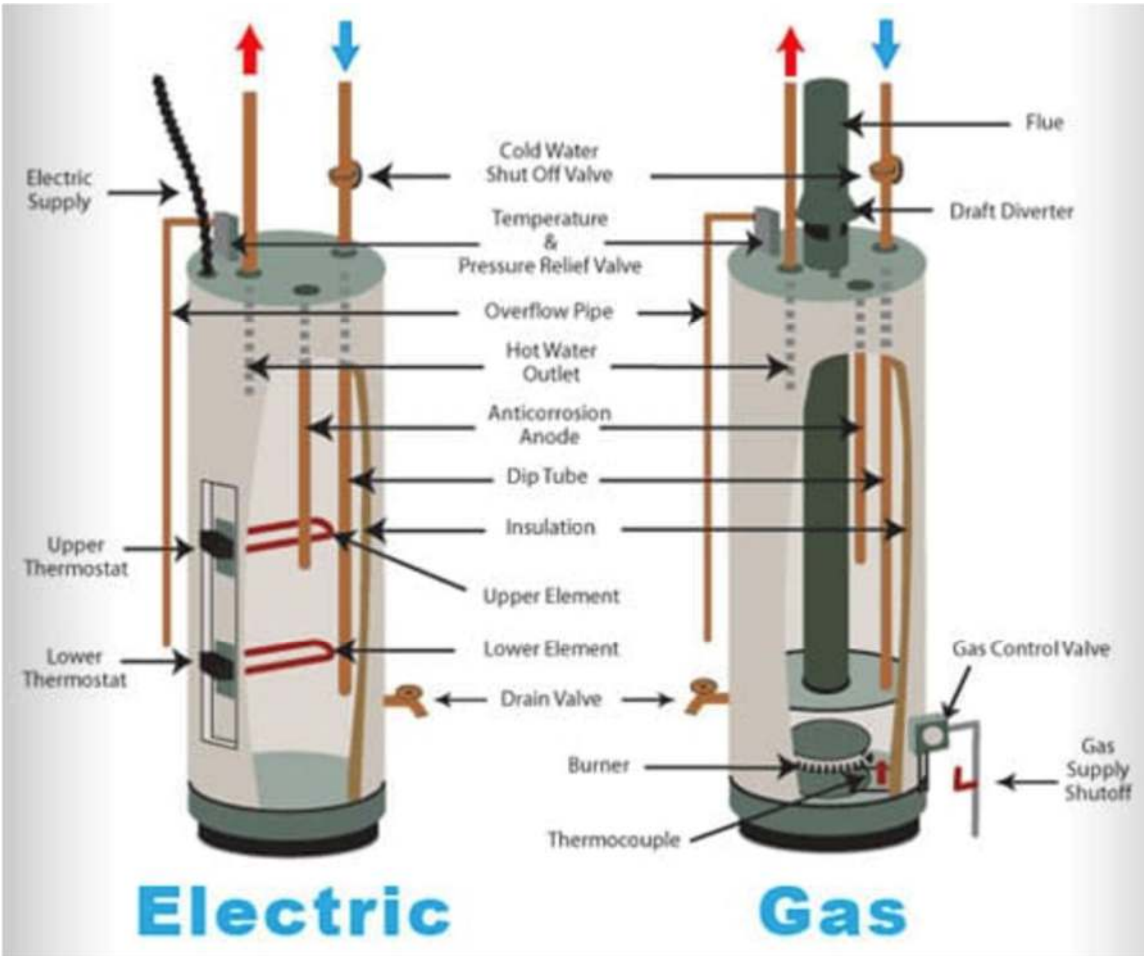

Figure 4: Schematic of conventional gas-fired and electric resistance storage water heaters

Source: InterNACHI.

1.3.2 HPWH Systems

Figure 5 shows a common application of an indirect or split heat pump paired with a hot water storage tank. In this figure, "HW" refers to hot water and "CW" refers to cold water. This figure shows a common commercial HPWH system setup that is useful to most foodservice facilities. In light commercial buildings, including very small foodservice facilities, it is possible to utilize integrated storage hybrid water heaters due to the inherent benefits of their being a single piece of equipment (not pictured).

Note that California state, county, and city health department sizing guidelines do *not* exist for these types of water heaters.

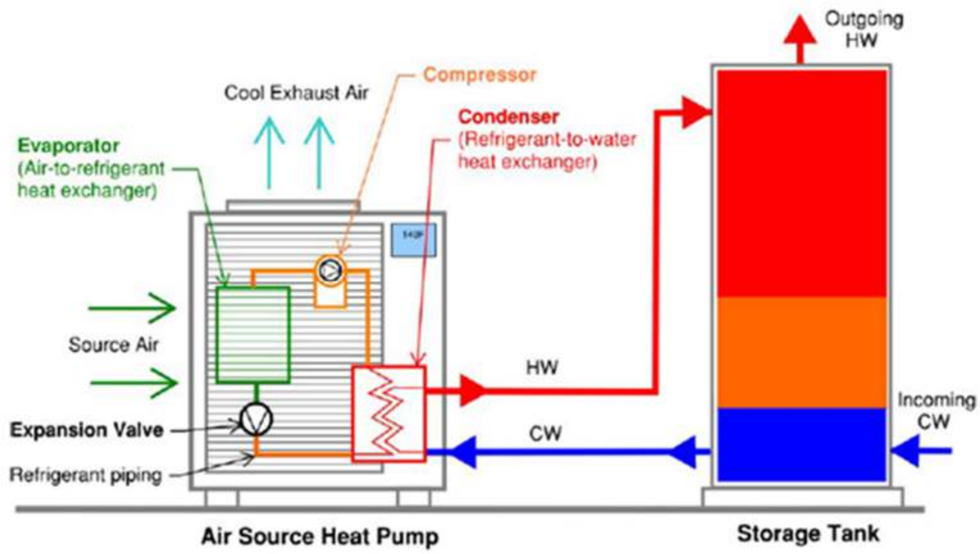

Figure 5: Typical air source heat pump with storage tank

Source: Seattle City Light 2021.

One technical constraint of a HPWH with relatively smaller heating capacities is that they need much longer run times and a larger storage tank to store heat compared to gas water heaters. While an electric resistance heater with large heating elements could fulfill the first hour of hot water demand without a significant storage tank, a heat pump cannot. Similarly, if the system has a hot water storage tank, but it is emptied in the first hour of demand, an electric resistance system can recover relatively quickly to operating temperature, but a heat pump cannot recover in the same time period. Neither electric resistance heaters nor HPWHs have the capabilities of a gas water heater, which can meet business needs with a smaller storage tank while offering much quicker recovery rates. Long recovery time to meet continuous demand is a significant technological constraint for a HPWH if an owner wishes to maintain a reasonable footprint and reduce installation costs.

1.3.3 HPaWH Systems

Figure 6 shows one way to configure a HPaWH system. Note that the primary HPWH and hot water storage tank are upstream in series with the existing water heater (electric-resistance heater shown), which is commonly a gas-storage heater. During low or no-draw periods, the existing heater activates to maintain recirculation loop temperature. Existing heater energy use is minimized by maintaining the primary storage tank at an elevated water temperature of 150°F. In this illustration, the primary storage tank feeds the existing storage heater during medium to high draw periods and elevates the storage heater average water temperature above its 125°F setpoint during moderate to high draw periods. The existing storage heater in this application is defined as a “swing tank,” as the tank temperature is allowed to swing up to 140°F and down to 125°F during low or no-draw periods. This configuration with the cold water entering the lower part of the primary storage tank ensures that temperature stratification is maintained for high efficiency heat pump operation and reliable application of single-pass heat pumps that otherwise would be sensitive to warm inlet temperatures.

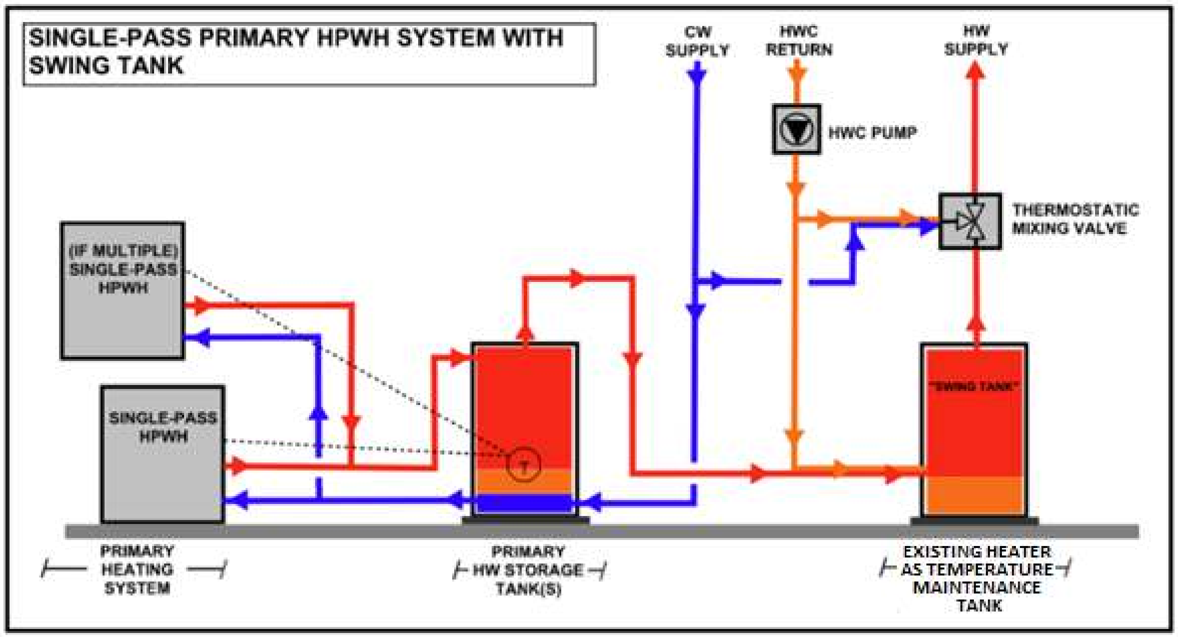

Figure 6: Example heat pump hot water assist system

Source: (Ecotope 2020).

Since the existing heater was sized to meet the full load during meal periods, the option is available to undersize the primary HPWH system to fit the space, electrical, purchase, installation, cost, or miscellaneous limitations, especially in an existing facility. The benefit of this approach is that the undersized heat pump can maintain a high duty cycle of up to 19 hours of operation without impacting the facility in a negative way. The ability of this configuration to operate during off-peak periods of between 9:00 p.m. and 4:00 p.m. maximizes heat pump operational efficiency (by maintaining lower average cold water supply temperature into the heat pump), reduces the first cost hurdle, reduces electrical capacity requirements, reduces space requirements further, and maximizes the payback period.

The master mixing valve ensures circulation of hot water into the distribution loop at the desired lower setpoint temperature to allow for the heat pump to be the primary heater when sized accordingly. The mixing valve ensures that most of the recirculation return water coming back through the circulation pump recirculates through the mixing valve, and a smaller portion goes through the storage heater, which helps improve gas storage heater efficiency and reduces burner activations. State, county, and city health departments in California typically require 120°F water at sinks in restaurants. In larger restaurants that have commercial dishwashers that require 140°F water, two options are available to ensure outlet temperature setpoints from the swing tank remain at 125°F. These existing commercial dishwashers can employ a booster heater to elevate inlet water temperature to the desired freshwater rinse temperature. The recommended option is to install a high-efficiency commercial dishwasher with a heat recovery system that operates only on the cold-water supply by preheating it from the heat exhausted from the prior dishwashing cycle. This eliminates the biggest hot water draw on the heating plant, reduces hot water supply and return loop heat loss and allows the HPWH to heat a larger portion of the heating load.

In addition to energy benefits, one benefit of a HPaWH system is that current health code requirements make a HPWH (heat pump only, not assisted) infeasible for commercial foodservice facilities in California. The subsection Cost Effectiveness Challenges within the Market Drivers and Barriers section describes the health code requirement challenge. In general, health code requirements call for three to four times oversizing of the heat pump input rate, which adds a huge purchase and installation first cost and significantly increases space requirements. It is for this reason that the Research Team supports incorporating a heat pump assist approach into the heat pump water heating systems to meet the current health code requirements in a foodservice facility.

1.4 Typical Sizing and Water Heating Needs

Table 2 shows the typical storage capacity in gallons and the typical rated capacity in Btu/hour for gas water heaters by type of foodservice segment. The Research Team provides this table for gas water heaters only, because—to date—they are the most commonly used, and past sizing research has focused on this technology. As shown, a coffee shop has the smallest capacity (50 gallons and 60,000 Btu/hour), followed by a deli or a bar (75 gallons and 75,000 Btu/hour). A quick service restaurant has a medium rated capacity (100 gallons and 150,000 Btu/hour) and a full service restaurant has the highest capacity (150 gallons and 400,000 Btu/hour).

Table 2: Typical Storage Capacity and Input Rating for Water Heaters by Type of Foodservice Facility

Foodservice Segment	Typical Gas Input Rate (Btu/hour)	Typical Storage Capacity (gallons)	Typical Gallons Per Day	Typical Distribution System
Coffee + Specialty	50,000	50	150	Simple Distribution Line
Deli + Sandwich	75,000	75	100	Simple Distribution Line
Bar + Tavern	75,000	75	200	Simple Distribution Line
Quick Service	100,000	100	500	2 Simple Distribution Lines
Full Service	150,000	150	2000	Recirculation System

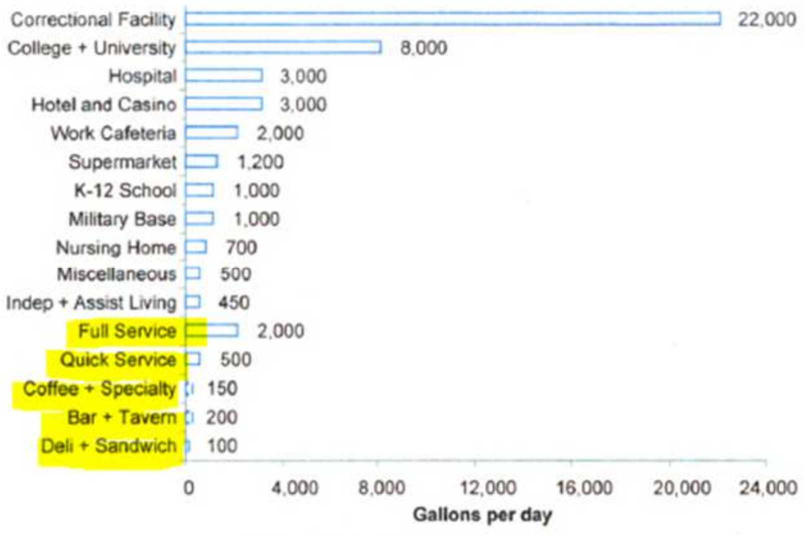

Figure 7: Approximate daily hot water use by type of foodservice facility

Source: Adapted from (Delagah and Fisher 2009).

Similarly, as shown in Figure 7, the daily hot water use is lowest with a deli (approximately 100 gallons/day) and highest with a full service restaurant (2,000 gallons/day). Additionally, Figure 8 shows the annual gas use by foodservice segment when the daily hot water use values are combined with the number of facilities operating in California, annual days of operation, heater temperature setpoint, and heater operating efficiency. Combined quick and full service restaurant gas load is 259 million therms, or 76 percent of the total gas load in the foodservice segment. Thus, restaurants are the main focus area in the wider foodservice industry to transition from gas-fired to electric HPWH systems.

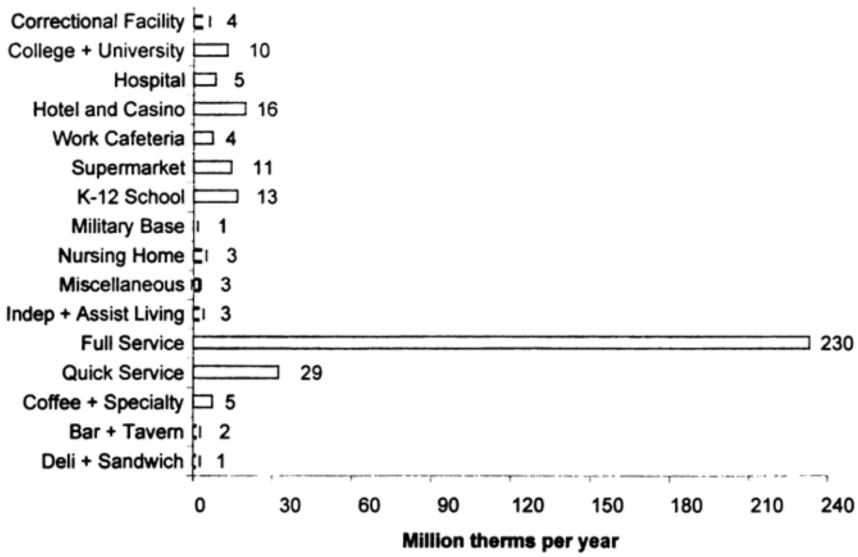

Figure 8: Approximate annual natural gas use by type of foodservice facility

Source: Adapted from (Delagah and Fisher 2009).

1.5 Comparison of HPWH and HPaWH Products

Table 3 provides key criteria for a sample of HPWH products, including heating capacity, size, and refrigerant. Many of these are split heat pumps potentially applicable in a HPaWH system configuration with the addition of storage tanks. But a few—the Rheem 80 gallon hybrid and the A.O. Smith CAHP 120, for example—are integrated heat pump electric resistance water heaters for direct replacement of existing gas or electric water heaters in facilities with small hot water demands. Table 3 illustrates the range of potential products and is not an exhaustive list. Table 3 also highlights many of the key criteria that are important to owners. This includes:

- **Heating capacity:** A higher capacity HPWH in this assist application will generate a larger volume of hot water to meet a larger portion of the hot water load for the facility, thus the existing lower efficiency water heater will operate less to meet the remainder of the load. Other factors in estimating the fraction of the hot water load that the HPWH will offset include the volume of the storage tank, tank setpoint temperature, and the heating loads placed on the heating plant including hot water draws and maintaining the temperature of the recirculation loop in the hot water distribution system.
- **Heat pump size, install location, and ventilation needs:** These criteria indicate the space needed for the HPWH.
- **Output temperature:** Most foodservice facilities with commercial dishwashers need an output temperature of 145°F. Those without dishwashers or with small undercounter dishwashers, such as some coffee shops and delis, need an output temp of 125°F.
- **Single-pass HPWH Systems:** Can heat supply water to the setpoint temperature in a single-pass at low flow rates with higher coefficient of performance (COP) as long as the supply water temperature is lower than 110°F to 125°F depending mainly on the refrigerant type)

- **Multi-pass HPWH Systems:** Will heat water gradually at a typical 10°F temperature rise per pass at much higher water flow rate until reaching setpoint temperature without limitations on maximum supply temperature.
- **Voltage (V) and Amps (A):** These criteria indicate the electrical needs for the HPWH. Most restaurants have heavy duty appliances that require 208V or 240V electrical supplies and single phase HPWHs at 120V, 208V, or 240V can readily be installed as long as the buildings electrical system has available capacity in amps. Many modern restaurants have access to 480V three-phase power that can be utilized to power large kitchen appliances and the largest HPWH, or with the use of a transformer stepped down to 208/120V to connect to the smaller HPWHs. The 480V three-phase power systems are the most cost-effective solution when specifying HPWHs in new build and retrofit applications due to reduced construction and retrofit costs.
- **Refrigerant:** Many facilities are searching for refrigerants with lower global warming potential (GWP) to reduce their carbon footprint. Examples of low GWP refrigerants for water heating applications are R-744, better known as CO_2, which sets the benchmark for low GWP at one. R-513a is a medium GWP refrigerant at a lower GWP and has been developed as a direct replacement to R-134a.
- **Sound**: Since noise can be a deterrent, Table 2 includes the typical sound level in decibels (dBa) of the HPWH, where available.[5] HPWHs operating at 60 dBA or below for this application are considered to be quiet. Generally, the larger the heat pump, the higher the dBA rating, and likelihood that the unit is designed for an exterior or rooftop application. Restaurant interiors are already noisy with dining areas typically registering at 75 dBA. Thus heat pumps are not a deterrent since they are typically installed far away from the dining area and many units operate at a dBa below this rating. A noisy HPWH can be problematic if installed in the kitchen, as prolonged periods of any sound at or above 85 dBA is more likely to cause damage to staff member's hearing over time if they are working next to the unit (A Noisy Planet 2019). The last consideration is if the restaurant has a patio where normal conversation is at 60 dBA; anything louder may be considered noisy. Designers would have to factor in the proximity of the HPWH and the direction of the fan. Note: acoustic materials can be used to shield or redirect the noise.

5 A-weighted decibels (dBA) are an expression of the relative loudness of sounds in air as perceived by our ears. https://hearinghealthfoundation.org/decibel-levels

Table 3: Key Criteria for a Sample of HPWH Products

Model	Heat Pump Size (L x W x H)	Rated Heating Capacity: (Btu/hour)	Rec. Storage Tank (gallons)	Heating (COP)	Max Output Temp	Operating Temp Range	Single-pass or Multi-pass Heating	Install Location	Ventilation and Air Flow Rate	Voltage (V)/ Phase	Amps (A)	Refrigerant (GWP)	Sound (dBa)
Nyle E8	21 ¾" x 21 1/16" x 18 3/8"	6,700 at 100°F inlet 113°f outlet water, 70°f ambient Air DB	80	2.7	145°F	38°F	Both	• Indoor wall • Rack • Overhead mount	Minimum room space 700 cubic feet, No ducting option, maximum 400 CFM	120V/1 (shared outlet)	15A, maximum power draw 900W- Can be used on shared circuit	R-513A (GWP = 573)	62
Nyle E360	40" x 72" x 99 ¼"	287,000 at 60°F inlet 140°f outlet water, 70°f ambient air DB, 50% RH	800	3.4	160°F	10°F	Multi-pass	• Indoor/ outdoor ground mount	16,000 CFM	208-230V/3 or 440-480V/3	RLA 106A 208-230, 52A 440-480V	R-513A (GWP = 573)	78
Colmac CxV-5	34" x 47" x 45"	68,400 at 70°F inlet 140°f outlet water, 70°f ambient Air DB, 50% RH	250	3.2	140°F	10°F for 140°F hot water output; -4°F for 120°F hot water output	Multi-pass	• Indoor/ outdoor ground • Rack mount	No ducting option, minimum 4,000 CFM	208-230V/1	FLA 41.5A	R-410A (GWP = 2,088)	72
Colmac CxA-15	36.5" x 39" x 72" 88"H Ducted	203,700 at 70°f inlet 140°f outlet water, 75°f ambient air DB, 50% RH	500	4.2	160°F	35°F	Both	• Indoor/ outdoor ground mount	Ducting option, 5,000 CFM	208-230V or 460V	FLA 55.2A at 230V, 27.6A at 460V	R-134a (GWP = 1,430)	76-85

Model	Heat Pump Size (L x W x H)	Rated Heating Capacity: (Btu/hour)	Rec. Storage Tank (gallons)	Heating (COP)	Max Output Temp	Operating Temp Range	Single-pass or Multi-pass Heating	Install Location	Ventilation and Air Flow Rate	Voltage (V)/ Phase	Amps (A)	Refrigerant (GWP)	Sound (dBa)
SanCo2 (formerly Sanden)	35 1/8" x 15" x 26 3/8"	15,000 at 70°F inlet 140°F outlet water, 70°F ambient air DB, 50%RH	120	5.1	150°F	Minimum - 25°F, maximum 104°F	Single-pass	• Indoor/ outdoor ground • Rack mount	No ducting option, 800 CFM	208-230V/1	15A breaker, 7.2A MCA	R-744 (GWP = 1)	37
Mitsubishi Heat2o	48" x 30" x 72.5"	136,500 at 63°F Inlet 150°F outlet water, 61°F ambient air DB	400	4.1	176°F	Minimum - 13°F, maximum 109°F	Single-pass	• Indoor/ outdoor ground mount	No ducting option, 7,770 CFM	208-230V/3	67 MCA, 110 MOP, 70 recommended fuse	R-744 (GWP = 1)	60
Rheem Performance Platinum Hybrid 80	Combined with tank: 27.5" x 24.6" x 74.25" (91"H Ducted)	4,200 HP, 15,360 electric, 19,560 combined	72	3.2	140°F	Minimum 37°F, maximum 109°F	Multi-pass	• Indoor ground mount	Ducting option, 200 CFM	208-230V/1	Max 21A, breaker 30A	R-134a (GWP = 1,430)	50
A.O. Smith CHP-120	Combined with tank: 31" x 40" x 70"	33,700 HP, 40,900 electric, 74,600 combined	112	4.2	150°F HP 180°F element	Minimum 40°F, maximum 110°F	Multi-pass	• Indoor ground mount	No ducting option, Min. 4,000 CFM	208-240V/1	80A or 90A power supply, 67A MOC	R-134a (GWP = 1,430)	59

Source: Manufacturer specification sheets.

2 Market Drivers and Barriers

2.1 Overview

Table 4 and Table 5 summarize drivers and barriers to HPWH and HPaWH system adoption based on interviews conducted directly with restaurant owners/operators and with SMEs regarding their views on owners' and operators' drivers and barriers. Note that these tables focus on drivers and barriers to the market (e.g., restaurant owners and operators), since they are the decision makers.

Table 4: Drivers to HPWH and HPaWH System Adoption

Drivers	Top Drivers from Restaurant Owners/Operators	Top Drivers from SMEs
Decarbonization (Societal Benefit)	X	X
Byproduct Cooling, Possibly Useful for Space Conditioning Kitchen	X	X
Getting Ahead of Regulation	X	X
Improved Energy Efficiency (Societal Benefit and Contributes to Reduced Energy Costs)		X
Possibly Lower Long-Term Energy Costs	X	
Increased Hot Water System Resiliency	X	

Source: ET22SWE0019 Project Team.

Table 5: Barriers to HPWH and HPaWH System Adoption

Barriers	Top Barriers from Restaurant Owners/Operators	Top Barriers from SMEs
Higher Upfront Costs	X	X
Lack of Available Space in the Facility	X	X
Increased Noise	X	X
More Equipment and Complexity Leads to More Maintenance (Increased Down-Time and Costs)	X	X
Electrical Panel Amperage Upgrade and Wiring/Conduit/Subpanel may be Required	X	X
Lack of Trust or Familiarity with Technology	X	

Source: ET22SWE0019 Project Team.

Based on interview responses and industry knowledge, the Research Team found that several drivers are likely to be more relevant to specific foodservice segments or business types. For example:

- Decarbonization is an especially relevant driver for chain businesses and large companies, as these businesses are more likely to hold this as a priority.
- Long-term energy costs are an especially relevant driver for businesses with existing electrical resistance water heater systems. The Research Team believes this to be more common in coffee shops.

Similarly, for barriers:

- Higher upfront costs are an especially relevant barrier for quick and full service restaurants, as a smaller integrated/hybrid HPWH is not an option for these larger hot water users.
- Electrical panel upgrade and wiring is an especially relevant barrier for any foodservice business with a current gas water heater, but especially for coffee shops with gas, which are likely to be using many electrical appliances already.
- Space is an especially relevant barrier for quick service restaurants.
- Health department regulations are a major barrier for installing a HPWH. Using a HPaWH system can address this barrier.
- Code Challenges

One of the key barriers to installing a HPWH-only system is the challenge of meeting health code standards that do not accommodate this technology. A HPaWH system may help address these challenges, at least partially, as described in this section.

Health department requirements for food facility water heater sizing are meant to ensure adequate hot water supply for facilities with single-use or multi-use plates and utensils. They achieve this by calculating the maximum hourly hot water demand in gallons per hour (GPH) based on the installed sinks and sanitation equipment. However, the guidelines have no sizing calculations specific to electric HPWH systems. Instead, the guidelines require a calculation (Figure 9) based on the thermal efficiency of electric resistance water heaters (CCDEH 2020) for electric water heater input rate (kilowatt [KW] input) sizing—regardless of storage volume:

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

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%.

Figure 9: Calculation of thermal efficiency of electric resistance water heaters.

This interpretation is based on a lack of familiarity with HPWH technology. In past discussion with the Research Team, health departments have provided two options for a HPWH in a foodservice facility. They can either ban the use of a HPWH in their municipalities until they are proven, or they can interpret the existing guideline conservatively to allow their use if they meet the input rate of conventional electric resistance water heaters. The health department assumes a 98 percent thermal efficiency—equivalent to a COP approximately equal to 1—for the heat pump and severely discounts actual HPWH performance benefits, which typically have a COP of 3 or 4 (see Table 3).

Following this logic, a foodservice facility would have to upsize the water heater by a factor of three to four times compared to what is required from an engineering perspective, solely to meet the health departments' sizing guidelines. The health departments' sub-optimal COP causes heat pump heating capacity sizing requirements to be excessive, making heat pump retrofits cost prohibitive. Additionally, an oversized HP system would cause short cycling and lower HP operating COP.

The stringent sizing calculations that dictate tank storage volume are not always followed outside of California. Codes and regulations in Washington State simply require that "the water heater must be large enough to meet the peak hot water needs of the facility." In addition, the plan drawings for restaurants and other commercial facilities in Washington are reviewed by the city planning and permits department. Foodservice permit applicants must provide only basic information about the unit (Environmental Health Services Division 2020).

2.2 Cost Effectiveness Challenges

Because first costs were identified as a major barrier—and potential operating cost savings were identified as a potential driver—this study provides high level estimates for both. However, it is challenging to estimate first costs of a HPWH or HPaWH system, since they are so rare for foodservice facilities and because there are multiple ways to design a system. Similarly, operating costs may vary based on utility rate structure, other loads in the facility, and other factors. Consequently, the costs below are high level approximations and not exact figures.

First Cost: SME's interviewed first costs as a top barrier to foodservice owners and operators using a HPaWH system. Experts cited high upfront equipment and installation cost, as well as possible costs associated with an electrical infrastructure upgrade, and/or structural infrastructure upgrades for facilities with space constraints.

One study conducted by TRC for a community choice aggregator (unpublished) analyzed the initial cost of replacing a gas water heater with a HPWH in a multifamily building, using cost estimates from contractors. While this is not an estimate for a HPWH installation for a foodservice facility—nor does it include a HPWH installed in an assist scenario—it does use commercial HPWH equipment, so it gives some basic insight into the scale of potential costs for a foodservice application. A contractor estimated the cost of a retrofit for a 120 MBH to 500 MBH capacity system,[6] typically designed as four to six centrally located heat pump water heaters installed in series, with separate hot water storage. This retrofit was estimated to cost between $97,500 and $350,000 in Climate Zone 3 (reference city of Oakland/San Francisco), with the major factor being the size of the system equipment. Equipment cost was estimated to represent 77 percent to 85 percent of total first cost, with labor and materials making up the remainder.

[6] MBH = a thousand Btus per hour

This designed output rate range of 120 MBH to 500 MBH roughly equates to an input rate for a gas heater of 150 MBH to 625 MBH, with an assumed efficiency of 80 percent. A full service restaurant typically requires an input rate of approximately 400 MBH, which falls within this range. Using a linear equation based on the range of system sizes (150MBH to 625 MBH input) and first costs ($97,500 – 350,000), a 400 MBH input HPWH system retrofit would be expected to cost approximately $230,000.

However, this hypothetical system design would not meet the health department requirements previously mentioned, which assume a COP of approximately 1 (instead of the true COP of a HPWH which is 3 to 4). The HPWH system would need to be upsized by a factor of three or four to meet the health department requirements, which would be prohibitively expensive. Therefore, for medium and large foodservice facilities, the most practical approach to incorporate a HPWH would be in an assist scenario. For a HPaWH system, an owner could put in a smaller HPWH; it does not need to meet health department requirements, because the existing (typically gas fired) water heating system is meeting the load. However, the HPaWH system then represents an *additional* cost because a facility owner would install it in addition to the existing system. In the case of a HPWH, the owner could install it at time of replacement, *instead of* a standard water heater.

Operating Cost: While operating cost savings was cited less frequently as a motivation than three other drivers (decarbonization, using the byproduct cooling, and getting ahead of regulation), two interviewees did report that operating cost savings were drivers for a HPWH and a HPaWH system.

This analysis included an estimate of billing impacts, detailed in the Appendix A: Estimate of Bill Impacts. The analysis used load profiles for foodservice water heaters from the Database of Energy Efficiency Resources (DEER) and assumed energy prices of $1.75 per therm for gas and $0.29 per kWh for electricity. At these rates, an electric HPWH system with storage is estimated to have energy costs 36 percent to 51 percent higher than a gas fired water heater with storage. However, the cost effectiveness results in this analysis may underestimate savings from a HPWH or HPaWH system for reasons that include:

- By assuming an electricity cost of $0.29/kWh, the results do not factor in time of use (TOU) rates and opportunities for reducing energy bills through load shifting, particularly in a HPaWH that could shift from electric to gas during peak electricity times.
- The modeling does not include recirculation systems and added hot water load related to full service restaurant application, nor does it include "free cooling," which is a byproduct of a HPWH that could be used to cool kitchen staff.
- Only one light commercial hybrid heat pump is listed in the database used, with the rest representing residential hybrid heat pumps.
- The commercial heat pump split system that was available for analysis does not have built-in electric resistance.
- The analysis does not factor in heating plant design.

Despite these limitations, the overall conclusions support that:

- For an electric resistance heater versus a HPWH, there is significant cost savings for moving to a HPWH.
- For a gas water heater versus a HPWH, operating costs are in the same ballpark. Under certain assumptions (such as load flexibility and TOU rates), a HPWH could generate some cost savings, but under other assumptions, a HPWH is more expensive to operate than a gas storage water heater.
- In order to keep costs down of a HPaWH based system in new facilities, a comprehensive design to size down the hot water system to utilize HPaWH, heat recovery ventless dish machine (roughly the same installed cost as non-heat recovery model that requires vent hood installation), master mixing valve and other design elements that save energy and installed cost by reducing hot water use from end-use equipment and sinks, reduce pipe heat losses by reducing the distribution footprint, reduce the distribution water temperature, and reduce the pipe diameter in some combination may overcome or offset the operating cost and installation costs barriers.

A simple analysis of costs and hypothetical real world efficiencies supports this conclusion, as shown in Table 6. Based on industry knowledge, the Research Team selected 60 percent and 80 percent efficiency for gas water heaters to be a reasonably expected range of real world daily efficiencies for gas water heaters. Also based on industry knowledge, The Research Team selected 2 COP to 4 COP to be a reasonably expected efficiency range for a HPWH. The lower end represents systems placed outdoors or in less efficient heating plant setups while meeting a large portion of the primary heating load. The upper end represents near ideal conditions in a consistently warm or hot environment with a heat pump purposely undersized with moderate storage tank volume to support a smaller portion of the total water heating load. The high COP setup relies on maintaining low inlet water supply temperatures to the heat pumps for most of the operating time.

Assuming the same gas and electricity costs ($1.75/therm and $0.29/kWh), the cost of electricity to generate one Metric Million British Thermal Unit (MMBtu) of heat with a hypothetically less efficient HPWH (real world operating efficiency of 2 COP) would be much more than the cost of gas to generate the same amount of heat, even compared with an inefficient gas water heater—roughly 1.5x the cost of the 60 percent efficiency gas water heater. However, if the real world COP of the HPWH is 4, the energy costs are even less than a gas water heater operating at 80 percent efficiency to generate the same amount of heat.

Table 6: Parametric Examination of the Effect of Equipment Efficiency on Cost

Option	Cost of 1 MMBtu Heat Generation at $1.75/therm and $0.29/kWh
Gas water heater with 60 percent real world efficiency	$29.17
Gas water heater with 80 percent real world efficiency	$21.88
HPWH with 2 real world COP	$42.50

HPWH with 4 real world COP	$21.25

Source: ET22SWE0019 Project Team.

As shown, a HPWH with a low efficiency (COP of 2) is much more expensive than a gas water heater, but a HPWH with a high efficiency (COP of 4) is cheaper to operate. There are various factors influencing operating costs, and this analysis explored just one of them (equipment efficiency). The results illustrate the range of operating costs under different assumptions.

2.3 Electrical Capacity

Another key barrier to a HPWH or a HPaWH system is sufficient available electrical capacity (electrical panel and/or service). The SME interviewees estimated that 0 percent to 20 percent of foodservice facilities have extra existing electric panel capacity. The Research Team concluded that implementing a HPaWH system may require a panel upgrade in approximately 80 percent to 100 percent of existing foodservice facilities. SME interviewees mentioned physical space for breakers as a limiting factor above and beyond electrical panel capacity.

Regarding the utility service to the panel, one SME interviewed considered a 200A service too small for restaurants but considered it viable for sandwich and coffee shops that are commonly using 9kW electric resistance water heaters. Quick service restaurant amperage service ranges from 400A to 600A service (208V, three phase) with no spare capacity or breaker space. Full service restaurants were estimated in the 600A to 800A service range with some spare capacity and breaker space.

Of the three restaurant owners and operators interviewed, one owner indicated that there was no extra space on the electrical service panel that could serve a HPWH, and the other two were not sure.

> **Electrical service and panel constraints are also limiting utility efforts to implement all-electric kitchens.**

2.4 Barriers for DAC/HTR Populations

Foodservice facility owners who are HTR or are located in disadvantaged communities (DAC) are of particular importance when considering drivers and barriers to adoption of technologies such as a HPWH and HPaWH systems.

- HTR is not defined by the California Public Utilities Commission (CPUC) specifically for foodservice facilities. The Research Team defined it here to include owners of minority business enterprises, owners with language barriers, owners in rural areas, or owners of locally owned facilities with limited time to research options.
- The CPUC defines DACs as those populations that suffer most from a combination of economic, health, and environmental burdens—including high pollution levels—and designates them based on CalEnviroScreen criteria (CPUC 2018).

This research effort investigated drivers and barriers that might be specific to HTRs and DACs by interviewing SMEs and asking how these owners or communities might be uniquely affected. In addition, the Research Team interviewed one owner of a barbeque restaurant which, as a locally owned and Black-owned business, is considered a HTR business. While the responses cannot be generalized to all DAC/HTR foodservice operators, the information provides anecdotal data of unique barriers to DAC/HTR owners and operators.

All SMEs listed financial barriers first when asked about barriers for HTR and DACs. However, the SMEs also identified knowledge of the capabilities of the new technology and awareness of HPWHs as DAC/HTR barriers. The barbeque owner was unfamiliar with HPWH technology. Although the business likely had extra space for a HPWH, the concept did not immediately appeal to the barbeque owner, because the current propane water heater was not a large expense to the business, and the existing electric panel likely did not have extra capacity. The owner was much more concerned about his high electric bills. This corresponds to two expected common barriers to DAC/HTR businesses hypothesized by SMEs—financial barriers and unfamiliarity with the technology.

2.5 Owner/Operator/Customer Drivers

Table 7 identifies the primary drivers to adopting a HPWH and a HPaWH system identified by interviewees. As shown, many of the drivers are the same for a HPWH as a HPaWH system, but a key additional driver for a HPaWH system is that it circumvents state, county, and city health department sizing guidelines.

Table 7: Customer Drivers for Installing a HPWH or HPaWH System Based on Interviews

	Efficient System	Circumventing Health Department Sizing Guideline	Decarbonization	Byproduct Cooling	Getting Ahead of Energy Regulations	Less Fuel Cost	Adding Capacity
HPWH	✓		✓	✓	✓	✓	
HPaWH	✓	✓	✓	✓		✓	✓

Source: ET22SWE0019 Project Team.

Drivers for installing or retrofitting a HPWH or HPaWH system in a foodservice facility varied, with energy efficiency being just one of several reasons. It should be noted, however, that foodservice facility owners, operators, and by extension utility customers do not usually have a way for distinguishing gas usage for water heating from their energy bill or hot water usage from their water bill.

2.5.1 Byproduct Cooling

Many commercial kitchens are hot year-round, especially when working with heavy duty cooking equipment such as charbroilers, woks, or numerous heat-emitting units used simultaneously in small spaces such as cafés. A benefit of heat pumps to cool cooklines and maintain thermal comfort for staff was noted as very motivating by several interviewed operators and SMEs. A California Energy Commission (CEC) field demonstration project in two Los Angeles restaurants found significant air conditioning savings from natural gas HPaWH systems (GTI 2021).

Unfortunately, manufacturers have not marketed this cooling and dehumidification attribute or developed their heat pump products directly for this sector. Such improvements would include providing ducting and air inlet filter kits to ensure better utilization and reliable indoor operation. Nonetheless, a few commercial heat pumps can be ducted to easily integrate into existing space conditioning, makeup air systems, or operate independently to provide beneficial cooling of cooklines, condensing units for ice machines, and walk-in and reach-in refrigeration units. Other more compact heat pump can be positioned to provide cooling to the back-of-the-house space.

2.5.2 Health and Safety Guidelines

Additionally, the California Division of Occupational Safety and Health has been working on mitigating indoor heat hazards. Restaurants in the future may be subject to California's Indoor Heat Illness Prevention Standard, which in draft form mandates rules for sites that exceed 87 °F when employees are present or 82°F in high radiant work areas. These factors illustrate the potential for heat pumps to provide non-hot water heating energy savings and thermal comfort benefits to foodservice operators (Paisan 2022) (Department of Industrial Relations 2022).

2.5.3 Energy Resilience

Owners and operators may be motivated to install a HPaWH system to add energy resiliency to their existing gas-fired hot water system. If one heater malfunctions, then second heater is available to get the customer through the event. Or if the utility has issues with gas or electricity supplies, the restaurant can continue to provide hot water for sanitization and operate with the dual energy hot water system.

2.5.4 Methods of Increasing Feasibility

Utility programs could increase drivers for HPWH or HPaWH system adoption. The California Foodservice Instant Rebates Program offers instant rebates on qualifying commercial foodservice equipment—including gas, electric, and dual fuel products (Energy Solutions 2021). However, it does not currently include any water heaters (of any type) in the eligible equipment list. Many California commercial customers are also eligible for instant savings on qualifying high-efficiency water heating equipment through the Statewide Midstream Water Heating Program, but all of the HPWH types listed are residential size (50 gallons) and would not be appropriately sized for restaurants (CLEAResult 2022). These 50 gallon systems could be appropriate for small facilities, such as delis or coffee shops, but expanding the eligible product list to include larger systems will offer greater benefit to commercial foodservice facilities.

Lastly, the HPWH in a HPaWH system application can be operated in a cost-effective way through several options:

- HPaWH operators can schedule the on/off operation of the heat pump to ensure it is not operating during peak pricing periods—typically from 4 p.m. to 9 p.m.— and relying on the existing gas heater during those hours. Operators can take advantage of fixed peak pricing periods of the utility based on the rate schedule selected and operate their unit on a set schedule as desired to minimize operating costs. Manufacturers can easily provide this feature with a software update with the existing technology built into the central processing units of these heaters.
- Most heat pumps have CTA-2045 compliant ports,[7] and others have the communication module integrated so the water heater can communicate with external systems like a utility or a third-party to control the operation and setpoint of the heater. Communication infrastructure for HPWHs is a rapidly emerging field and HPaWH are ideal candidates to take advantage of TOU and other communication methods to operate as cost effectively as possible. Through grid connectivity and operator participation in incentive based load management programs, HPaWHs would have the ability to power down and idle when a demand response event

[7] American National Standard (ANSI)/CTA-2045 specifies a modular communications interface (MCI) to facilitate communications with devices for applications such as energy management. Source.

occurs, which may include Flex Alerts.[8] There are a variety of load management programs available that could use HPWHs (Feng 2021). In addition, this technology creates the possibility for new programs suited for this HPaWH application to power down as needed or when generation costs are high, and power up when excess renewable generation is placed on the grid or when electricity generation costs are low.

3 Current Market Penetration, Early Adopters, and Market Potential

3.1 Current Market Penetration

Significant installation and operating costs, as well as equipment footprint and regulatory barriers, have limited implementation of HPWH systems to far less than one percent of existing foodservice facilities. However, the Research Team identified a few case studies of foodservice facilities that have installed, or plan to install, a HPWH or a HPaWH system.

Based on interviews, a designer in Washington State was involved with one new café build that incorporated heat pumps and a chef training kitchen that was in the build phase. The designer was not aware of any foodservice retrofit projects with a HPWH. One kitchen designer in California knew of several foodservice projects in the design phase where a HPWH was being considered.

According to one SME, with gas prices typically being half of electricity prices and payback times exceeding 10 years, finding market traction for HPWH adoption is difficult. A review of electricity and gas rates for foodservice establishments shows that electricity prices per unit of energy are four times greater than gas in Southern California Edison (SCE) territory, seven times greater in San Diego Gas and Electric (SDG&E) territory and four and half times greater in Pacific Gas and Electric (PG&E) territory. Application of a HPWH versus a conventional gas water heater baseline shows slight operating cost savings or cost offset in most parts of the state (See Appendix A: Estimate of Bill Impacts for more information). A HPWH in certain areas of the state may be more appealing in cases where more weight is given to non-energy benefits such as carbon reduction.

3.2 Likely Attributes of Early Adopters

Most facilities are likely to encounter at least one major hurdle such as major electrical upgrades, space constraints for an add-on or replacement HPWH, or high incremental cost. But based on the literature review and interviews, the following types of facilities may have reduced barriers, and could be early adopters:

- Facilities where space is not a major concern, such as:
    - Small full-service restaurants with spare or unused space for mechanical equipment

[8] Flex Alerts, issued by the non-profit California Independent System Operator (ISO) public benefit corporation, are "a call for consumers to voluntarily conserve electricity when there is an anticipated shortage of energy supply, especially if the grid operator needs to use reserves to maintain grid integrity" (Flex Alert 2023).

- Cafés with significant space in the back of the house
- Foodservice facilities with very small hot water loads, such as sandwich and coffee shops.
    - However, as shown in Figure 8, delis and coffee shops represent a small percent of the annual gas usage of foodservice facilities.
    - In these facilities, the use of hybrid integrated storage water heaters that use an electric resistance storage water heater with integrated heat pump is a viable solution approved by some health departments for new and existing facilities. A study by the United States Energy Information Administration (EIA) reported this ten years ago (EIA 2012), and a few case studies on cafés support the concept that these types of facilities could be early adopters.
- Facilities where decision makers consider sustainability a priority, including:
    - Big companies with declared decarbonization goals that impact their decision making.
    - State or federally funded educational institution kitchens and foodservice facilities.
- Facilities that use electric resistance space heating since these have greater operating cost savings compared to gas water heaters.
    - However, this is a minority of facilities. Roughly 85 percent of foodservice facilities in California use gas-fired heaters, followed by electric resistance and propane that make up the additional 15 percent of facilities (PG&E Company and Fisher-Nickel 2013).
- Facilities with spare electrical capacity.
    - This is uncommon in existing facilities, although new construction could address this by providing an electrical panel with spare capacity.
- Facilities where limited lease terms are not a major concern, including:
    - Restaurants that own their own building or corporate/university campuses with cafeterias or restaurants.
    - Facilities with a longer locked-in lease term.
- New construction facilities which could install a HPaWH system.
    - While the number of newly constructed facilities is much smaller than existing facilities, installing a HPaWH system would be easier in a new building. The facility could be designed to accommodate the space and electrical needs of the system. Designers could also consider how to thoughtfully integrate both parts of the HPaWH system—including a gas water heater and the HPWH—so they complement each other, (such as by downsizing the gas water to reduce costs), and they design the system to make use of the waste heat from the HPWH to cool the kitchen.

The examples provided in the section, Case Descriptions from Interviews and Literature Review, show that at least a few restaurant owners, builders, or designers are installing or considering installing a HPWH or HPaWH system.

3.3 Market Potential

In California, there were slightly more than 68,000 existing commercial food service facilities in 2017 (Statista 2022). Based on the characteristics of likely early adopters supplied by interview participants, the following types of food service facilities could be early adopters:

- Coffee shops or delis
- Facilities with electric resistance water heaters.
- Facilities with spare electrical capacity.
- Facilities where sustainability influences decision making.

In each case, the number facilities as a percentage of the total is low, likely lower than ten percent.

4 Case Descriptions from Interviews and Literature Review

The following case studies of HPWH and HPaWH systems provide insight into barriers encountered implementing heat pump technology in actual facilities. Included are facilities that have been built, are in progress, or are proposed but have been denied approval. Many of these studies illustrate how a design incorporating a HPWH was ultimately denied by the local code officials.

4.1 Small Café: Case #1

A San Francisco Bay Area energy consulting firm is working with the San Francisco Department of Environmental & Public Health on a small fast service coffee and bakery. The customer site already has an electric water heater for service hot water needs. The site does not have a huge water demand, but it does want more hot water storage capacity for dishwashing and sanitation. There is no existing gas connection and no room in the electrical panel for another breaker. The customer would consider a full HPWH solution, and the energy consultant has already specified a plug and play 120V Nyle unit. However, health department hot water system design constraints are too difficult to overcome. A HPaWH retrofit with storage to supplement the existing electric water heater is a viable option to increase hot water capacity without adding electrical capacity.

4.2 Small Café Franchise Location: Case #2

Design in progress. Electrical resistance heating is the base case and GE® small capacity hybrid heat pump with solar water heating is the proposed retrofit.

4.3 Small Café Franchise Location: Case #3

The site is part of a small chain of coffee shops, and is located in Long Beach, California. Long Beach Health Department concerns are pushing the retrofit in the direction of tankless electric resistance water heating instead of a heat pump assist solution. This case illustrates how local health departments have the final say on foodservice hot water systems in their jurisdiction.

4.4 Small Café Franchise: Case #4

An Oregon chain is establishing 52 new locations in California. An all-electric store is their first choice. Their leadership is asking the design team to plan on 200A service for kitchen and an additional 200A service for water and space heating. They are a good candidate for a HPWH or HPaWH system.

4.5 University Café: Case #5

A San Francisco Bay Area design firm was working with a Bay Area County Department of Environmental Health on a high efficiency electrification of a café that is a part of a larger building. The design firm submitted plans for a HPWH or separate HPWH system to meet the needs of the café and adjacent restrooms. The site has a relatively low water demand. The health department water heater sizing guidelines require that the electric heater is sized based on input capacity for a 98 percent efficient electric resistance heater, and they do not recognize or have a sizing guideline for HPWHs that can operate at nominally 300 percent efficiency or COP of 3. The health department reached out to other counties/agencies and learned that no other department had reviewed nor approved HPWHs. They recommended that the design firm consider traditional tank/tankless water heaters. The design team had to scrap their plans for a HPWH after several attempts and went ahead with designing with two electric resistance storage water heaters to keep the project on schedule.

4.6 Full-Service Restaurant

A full-service restaurant chain with two sites in Los Angeles installed a heat pump (with storage tank) assisting a gas water heater. The residual cooling from heat pump operations is ducted back into kitchen. The resultant heating, ventilation, and air conditioning (HVAC) cooling setpoint adjustment saved 20 percent energy of cooling energy over the pre-retrofit base.

4.7 Fast-food Franchise Location: Case #1

In another case (Lindsey, 2022), a field demonstration of an integrated HPWH for a McDonalds in southern Mississippi showed an estimated yearly water heating energy savings of 11,500 kWh compared to the previous water heater. Average daily savings were 42.5 kWh, and the heat pump operated at a COP of 1.9. The facility is open 24 hours with average hot water draw of 420 gallons/day. An A.O. Smith CHP-120 HPWH replaced a malfunctioning electric resistance three-phase (208V, six 3kW elements), 80-gallon water heater. The CHP-120 unit can be appropriate for similar fast-food applications.

4.8 Fast-food Franchise Location: Case #2

Design in progress. The base case is an 9kW electric resistance water heater. This site is a good candidate for HPWH or HPaWH because no electric infrastructure upgrades are needed.

4.9 Fast-food Franchise Location: Case #3

Design in progress. Electrical resistance heating is the base case. This site is a good candidate for HPWH or HPaWH because the site will not require electric infrastructure upgrades.

4.10 Fast-food Franchise Location: Case #4

Design in progress. Because the base case is an all-electric kitchen, except for water and space heating, a HPWH or HPaWH is an easier retrofit, because electric infrastructure is already in place.

5 Future Research

This study identified the following opportunities for future research:

- A field demonstration study of a HPaWH system in a foodservice facility, which could provide data on installation costs, operation costs, energy savings, GHG savings, and potentially load flexibility opportunities with retrofitting a conventional hot water system. Ideally, the study would document savings from the heating plant and the addition of a heat recovery commercial dishwasher and master mixing valve separately and combined to showcase the impact of each measure.
- Expanding the California EnergyWise sponsored Design Guide on Improving Commercial Kitchen Hot Water System Performance by adding a HPaWH system section. This could leverage lessons learned and performance results from the field demonstration study.
- A thorough update on restaurant hot water system information as an update to the CEC hot water system characterization report *Energy Efficiency Potential of Gas-Fired Commercial Water Heating Equipment in Foodservice Facilities* (Delagah and Fisher 2009). This would increase stakeholder understanding of the potential statewide benefits and impacts of HPWH and HPaWH systems.

- Funding to expand advocacy of HPWH and HPaWH systems to county environmental health departments and statewide California Directors of Environmental Health Food Policy Committee. The goal would be to expand their understanding of these systems and build support to allow for the approval of HPWH systems in more jurisdictions. Eventually, the goal is to suggest revisions to the state water heater sizing guidelines for hybrid electric resistance/heat pump integrated water heaters and indirect HPWH systems.

6 Conclusions

While there is limited market penetration of HPWH or HPaWH systems in foodservice facilities, this technology represents large energy savings potential given the high intensity water heating energy usage in the foodservice industry. In addition, case studies identified through the literature review and in interviews indicate that adoption of heat pump technology can be implemented.

Potential drivers noted among SME and industry interviewees included:

- Societal benefits of decarbonization.
- The potential for byproduct cooling of the kitchen.
- Avoiding future regulation challenges. Potentially getting ahead of an upcoming standard that would regulate the temperature in commercial kitchens (the Indoor Heat Illness Prevention standard).
- Operating costs. Only a few interviewees mentioned operating cost savings as a driver—aligning with operating cost estimates done by the Research Team—which did find energy cost savings were possible for a HPWH system compared to an electric resistance water heater, but essentially no operating cost savings compared to a gas water heater.

Primary adoption barriers identified by SME and industry interviewees included:

- Higher upfront costs are a significant barrier to adoption of these technologies, but the possibility of lower energy costs are a potential driver in some circumstances—particularly for facilities where the legacy equipment is electric resistance water heaters.
- Physical constraints (lack of available space) also arose as one of the barriers for both foodservice operators and SMEs.
- Lack of existing electrical capacity is another key barrier identified by designers and SMEs for existing facilities for which a costly service upgrade, subpanel install, wiring, and possibly a panel upgrade could greatly diminish the retrofit viability.
- Increased noise, maintenance, and complexity concerns were a concern for a few interviewees as well. .

A few types of facilities are well positioned to overcome these barriers and/or may be especially motivated by the drivers, namely those with abundant extra space, very small hot water loads, spare electrical capacity, high radiant cooking loads, or that make purchasing/installation decisions based on their sustainability goals.

New construction facilities are the best positioned to use a HPaWH system because they could design the facility to accommodate the space requirements and electrical needs of the system, could use an integrated design approach to the system that downsizes the gas water heater, and synergistically make use of the byproduct cooling from the HPWH to cool the kitchen.

Conversely, existing facilities have few characteristics of likely early adopters. Many of these facilities lack the space and electrical capacity required to support heat pump system adoption and have legacy gas water heaters instead of electric resistance water heats, which does not provide an enticing payback incentive. These facilities also prioritize other business expenses over sustainability measures due to limited funds.

To demonstrate the feasibility of heat pump technology adoption, field demonstration projects should be prioritized to illustrate the benefits of HPWH and HPaWH systems and provide the opportunity to better characterize costs. Steps should also be taken to add large commercial HPWH and HPaWH systems to the qualifying equipment lists of utility programs as rebates and incentives will be an important method to accelerate adoption.

While several SMEs cited full HPWH system adoption as the preferred path to support California's energy goals, HPaWH systems offer a more accessible step closer to full decarbonization as the industry transitions from full dependency on conventional water heaters. The HPaWH alternative provides health departments, utilities, municipalities, and the state time to increase familiarity with heat pump hot water heating, reduce installation and operating costs, and address other barriers to market adoption in this challenged foodservice sector.

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8 Appendix A: Estimate of Bill Impacts

Results of the Bill Impacts Estimate

The Research Team estimated energy bill costs for each equipment type in each climate zone, by assuming electricity costs of $0.29/kWh and gas costs of $1.75/therm. As noted in Cost Effectiveness Challenges, the cost effectiveness results in this analysis may underestimate savings from a HPWH or HPaWH system for a variety of reasons already listed.

Table 8: Results for Usage Corresponding to a Sit Down (Full Service) Restaurant

Climate Zone	Electric Resistance Water Heater with Storage	Electric HPWH with Storage	Gas-fired Tankless Water Heater	Gas-fired Boiler – Instantaneous	Gas-fired Water Heater with Storage
1	$14,218	$5,254	$3,605	$3,310	$3,789
2	$13,152	$4,937	$3,334	$3,060	$3,501
3	$13,137	$4,895	$3,329	$3,054	$3,499
4	$12,495	$4,705	$3,166	$2,904	$3,325
5	$13,134	$4,905	$3,328	$3,054	$3,498
6	$12,118	$4,459	$3,069	$2,815	$3,224
7	$12,084	$4,452	$3,061	$2,807	$3,216
8	$11,781	$4,402	$2,984	$2,736	$3,133
9	$11,877	$4,534	$3,008	$2,759	$3,159
10	$11,829	$4,522	$2,998	$2,749	$3,146
11	$12,067	$4,660	$3,059	$2,805	$3,211
12	$12,489	$4,716	$3,166	$2,904	$3,323
13	$11,755	$4,492	$2,979	$2,732	$3,127
14	$12,131	$4,871	$3,076	$2,821	$3,228

Climate Zone	Electric Resistance Water Heater with Storage	Electric HPWH with Storage	Gas-fired Tankless Water Heater	Gas-fired Boiler – Instantaneous	Gas-fired Water Heater with Storage
15	$10,051	$3,992	$2,545	$2,329	$2,671
16	$13,989	$5,543	$3,549	$3,259	$3,724

Source: ET22SWE0019 Project Team.

Table 9: Results for Usage Corresponding to a Fast Food (Quick Service) Restaurant

Climate Zone	Electric Resistance Water Heater with Storage	Electric HPWH with Storage	Gas-fired Tankless Water Heater	Gas-fired Boiler – Instantaneous	Gas-fired Water Heater with storage
1	$7,754	$2,810	$1,967	$1,804	$2,068
2	$7,173	$2,638	$1,819	$1,667	$1,910
3	$7,165	$2,619	$1,816	$1,665	$1,910
4	$6,815	$2,515	$1,727	$1,583	$1,815
5	$7,163	$2,629	$1,816	$1,664	$1,909
6	$6,610	$2,388	$1,675	$1,534	$1,760
7	$6,591	$2,385	$1,670	$1,529	$1,755
8	$6,426	$2,355	$1,628	$1,491	$1,710
9	$6,479	$2,427	$1,641	$1,503	$1,724
10	$6,452	$2,420	$1,635	$1,498	$1,717
11	$6,581	$2,490	$1,669	$1,529	$1,752
12	$6,812	$2,518	$1,727	$1,583	$1,813
13	$6,411	$2,397	$1,625	$1,489	$1,733
14	$6,616	$2,611	$1,678	$1,537	$1,748
15	$5,483	$2,139	$1,389	$1,269	$1,458

Climate Zone	Electric Resistance Water Heater with Storage	Electric HPWH with Storage	Gas-fired Tankless Water Heater	Gas-fired Boiler – Instantaneous	Gas-fired Water Heater with storage
16	$7,628	$3,019	$1,936	$1,776	$2,032

Source: ET22SWE0019 Project Team.

Method to Calculate Operating Cost Estimate:

Calculation Tool

The Research Team used a CPUC approved DEER water heater calculator to determine operating cost estimate for different hot water heating technologies.

Building Hot Water Load Profiles

The calculator contains 8,760 hour hot water load profiles (in gallons of hot water) for 23 commercial and three residential DEER building types. The Research Team extracted load profiles from DEER DOE2 building prototypes.

Table 10: The Research Team Selected the Two Following Commercial Building Types

				Total Capacity			Sizing Factor		
Building	Tank T (°F)	Frac Resist	Total Vol	Gas (kBtu/h)	Elec (kW)	Peak GPH Load	Gas	Elec	Building Area (square feet)
Sit Down Restaurant	135	0.5	62.4	90.9	21.3	94.8	1.2	2	2,000
Fast Food Restaurant	135	0.5	60	87.5	20.5	55.1	1.2	2	4,000

Source: (California Public Utilities Commission 2022).

Technologies

The tool has a total 95 different hot water technologies. The water heater calculator used the following residential and commercial water heater sources for technology input paraments:

- AHRI database, February 2020
- CEC database, March 2020
- DOE Compliance Certification database (CCDB), March 2020

The following technologies cover different water heater types:

- Electric Resistance Water Heater with Storage
- Electric HPWH with Storage
- Gas-fired Tankless Water Heater
- Gas-fired Boiler—Instantaneous
- Gas-fired Water Heater with Storage

For each water heater type, the following technologies over different storage capacities and efficiencies:

- Electric Resistance Water Heater with Storage
  - Stor_UEF-Elec-030gal-MD-0.92UEF
  - Stor_UEF-Elec-040gal-MD-0.92UEF
  - Stor_UEF-Elec-050gal-MD-0.92UEF
  - Stor_EF-Elec-060gal-0.89EF
  - Stor_EF-Elec-075gal-0.87EF
- Electric HPWH with Storage
  - Stor_UEF-ElecHP-050gal-3.30UEF
  - Stor_UEF-ElecHP-050gal-3.50UEF
  - Stor_UEF-ElecHP-050gal-3.75UEF
  - Stor_UEF-ElecHP-065gal-3.75UEF
  - Stor_UEF-ElecHP-080gal-3.75UEF
  - Stor_COP-ElecHP-120gal-4.3COP
- Gas-fired Tankless Water Heater
  - Inst_TE-Gas-lt200kBtuh-0.80Et
  - Inst_TE-Gas-gte200kBtuh-0.80Et
- Gas-fired Boiler—Instantaneous
  - Blr_TE-Gas-gte300kBtuh-0.84Et
- Gas-fired Water Heater with Storage
  - Stor_UEF-Gas-030gal-MD-0.60UEF
  - Stor_UEF-Gas-040gal-MD-0.58UEF
  - Stor_UEF-Gas-050gal-MD-0.56UEF
  - Stor_TE-Gas-gt75kBtuh-0.80Et

California Climate Zone

The tool has the option to select any zone out of total 16 climate zones for California.

Calculation Process

Step 1: Selected Sit-Down Restaurant (RSD) as building type from dropdown menu.

Step 2: Selected "Stor_UEF-Elec-030gal-MD-0.92UEF" technology from dropdown menu.

Step 3: Selected California climate zone "CZ01" from dropdown menu. Repeat to examine all climate zones.

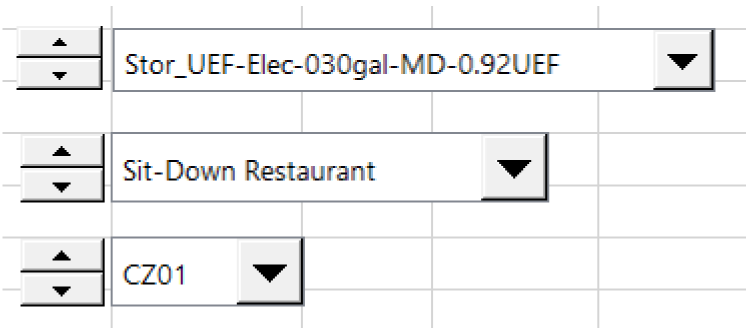

Figure 10: Dropdowns

Step 4: Extracted 8760 load profile from the tool.

Step 5: Repeated four steps mentioned above to extract 8760 load profiles for different technologies.

Step 6: Selected Sit-Down Restaurant (RSD) as building type from dropdown menu.

Step 7: Repeated steps 2,3,4 and 5 mentioned above to extract 8760 load profiles for different technologies.

Step 8: Developed summary table to compare annual utility consumption for different water heater types.

Step 9: Multiplied average utility consumption for different water heater types with average utility rate to determine yearly operating cost for different water heater types.

9 Appendix B: Interview Questions

9.1 Interviewee background

1. What is your title and role?

9.2 Current market penetration of HPWHs in food service

2. Chain Operator and Owner: What type of water heater do you use in your facility? If, no idea or not clear, not a good candidate for this interview.
    - Gas-fired storage heater (atmospheric 80% efficient)
    - Gas-fired condensing storage heater (fan assist 95% efficient)
    - Gas-fired Tankless atmospheric
    - Gas-fired Tankless condensing
    - Gas-fired split system (Boiler/storage tank)
    - Electric resistance storage tank
    - Electric resistance tankless

3. Chain Operator and Owner: Before we talk about heat pump water heaters, let's take a step back. Are you familiar with HPWH technology? This isn't meant be a quiz. We are trying to get a sense of the market's understanding, so it's fine if you're not familiar with them.
   Here's some background: heat pump water heaters (HPWH):
    - **Use electricity to move heat** from the outside or room to the water stored in the tank.
    - **Discharge colder air,** which can be useful for cooling off hot kitchens.
    - Are typically **3-5x times more efficient than traditional, gas-fired** water heaters.
    - Require **input power much lower than electric resistance heaters**, so have lower amperage requirements and less impact on peak kW power use.
    - Need **long run times and larger storage tanks** to store the heat compared to gas water heaters

Here is a diagram of a HP system (Show diagram).

4. Chain Operator and Owner: Have you considered or installed a HPWH for your business? Why or why not?

5. SME: Are you aware of food-service facilities that have considered or installed a HPWH? If so, please describe which facilities, and what type of HPWH they're using.

9.3 HP Assist Water Heaters in Food Service

6. All: A HPWH is a standalone system. A HP **Assist** HW system is a heat pump connected to a conventional, fossil-fuel fired system. A HP Assist HW system consists of **adding a HP, storage tank and mixing valve to an existing hot water system** with recirculation loop (Show diagram).

   The HP system is added upstream and pre-heats the water (set point ~125 F). The existing storage water heater serves as a backup heater and maintains adequate water temperature (~150F) in the recirculation loop. This configuration below depicts operation.

As hot water is consumed, hot water flows from the primary tank to the swing tank to add heat to the lower temperature setpoint swing tank to minimize the conventional heater's operation. This setup maximizes the high efficiency operation of the HP. With controls, the HP can turn off during peak periods when electricity costs are high.

A HP assist WH also **circumvents the problem of a HPWH on its own, which California health departments don't allow** for food service facilities. [If they ask, the reason why some health codes don't allow it is they're new, and don't exist in sizing guidelines. It's typically county-wide requirements but based on CA statewide guidelines.]
We'll be discussing this technology during the interview, including your expectations for drivers and barriers to its adoption. Before we get to those questions, do you have any high-level questions about how HP Assist WHs operate?

7. SME: Do you know of any existing HP **Assist** type of system in use in food service facilities in California? If so, please describe it.

8. SMEs: What about outside of California: do you know of either HPWH products or HP Assist WHs products in use for foodservice application?

9.4 Market Drivers

9. Chain Operator and Owner: Some benefits of a HP Assist Water Heater are the following:
    - Energy bill savings
    - Lower carbon footprint
    - Back-up if the gas water heater fails
    - Meeting a hot water demand that's not currently met during meal periods or during after-hours cleanup
    - Increasing the life of the existing water heater through reduced operation
    - Reducing instances of thermal shock when the heater is depleted of hot water
    - Providing a chain operator with an option to design an all-electric restaurant in locations where this is desirable, such as an all-electric strip mall, rural locations using propane, and out of state to locations where electricity rates are low

    Which of these, if any, would be motivating to you for considering a HP assist water heater? Do you see any other benefits for installing a HP assist water heater?

10. Chain Operators and Owners: What percent energy bill savings would a Heat Pump Assist Water Heater need to provide for you to consider installing one?

    SMEs: What percent energy bill savings would a Heat Pump Assist Water Heater need to provide for most food service facilities to consider installing one?

11. SME: What do you see as the primary benefits to foodservice owners and operators in using HPWHs?

12. SMEs: Same question but for HP Assist WHs: What do you see as the primary benefits to foodservice owners and operators in using HP Assist WHs?

9.5 Market Barriers

13. SME: What do you see as the biggest barriers to foodservice owners and operators using HP Assist WHs? [If needed, probe for cost, lack of space, adding power, venting or making holes in the wall for outdoor install, and noise?]

    Chain Operator and Owner: What would be your primary concerns about using a HP assist WH for your business? [If they ask about first cost, note that the cost would be higher because it adds electrical and plumbing labor and material costs, and commissioning costs.]

14. SME: How do you think the operating costs of a HP Assist HW system compare to an all-gas system for foodservice facilities? Feel free to provide qualitative responses if you can't estimate numbers. [Skip if they have no idea.]

15. One possible barrier we're exploring to HP Assist Water Heaters is space constraints.

    Chain Operator and Owner: Would your facility have space to add a HP or a HP assist water heater? You'd need to add the heat pump, primary hot water tank, and mixing valve, in addition to maintaining your current water heater. The heat pump could be outdoors. The hot water tank would need to be in a location with a floor drain.

    SMEs: Would most food service facilities have space for adding a HP water heater for a Heat Pump Assist WH? What type(s) of facilities do you think would have a space constraint? They'd need to add the heat pump and the primary hot water tank, in addition to maintaining your old hot water tank. The heat pump could be outdoors. The hot water tank would need to be in a location with a floor drain

16. Another potential barrier we want to explore is electrical capacity for adding a heat pump. Chain Operator and Owner. Please answer to the best of your knowledge, but feel free to tell me if you can't answer knowledgably.

    - What amperage service is your electrical panel(s)?
    - Do you have spare capacity in your main electrical panels?
    - Do you have spare in your main electrical panels?

    SMEs:

    - What is the typical amperage service in terms of electrical panels for food service facilities? Feel free to provide a range or different estimates depending on different types of facilities.
    - Approximately what fraction of food service facilities do you think would have spare capacity in their main electrical panels when built and as found operating?
    - Approximately what fraction of food service facilities do you think would have spare physical space for breakers in their main electrical panels?

17. SMEs: Do you think there would be any greater barriers, or additional barriers specific to hard-to-reach food service facilities? The term "Hard-to-reach" includes owners that may have language barriers, be located in rural communities, or owners of locally-owned facilities with limited time to research options. If so, please describe.

18. SMEs: Do you think there would be any greater barriers, or additional barriers specific to food service facilities in disadvantaged communities? The CPUC defines disadvantaged communities as those that most suffer from a combination of economic, health, and environmental burdens, including high pollution levels.

9.6 Early Adopters

19. Chain Operator and Owner: Would you consider installing either a HPWH or HP Assist WH for your business? [If they're not]: What data or information would you want to see before considering it for your business?

20. SMEs: What types of food service facilities do you think would be most interested and able to install a HP Assist WH?

21. Do you have any final questions or comments about this technology?