Achieving Central Heat Pump Water Heater Optimization through Contractor Training and Design Side Incentives

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ABSTRACT

Traditional sizing methodologies for central domestic hot water (DHW) systems in multifamily housing rely heavily on assumptions around hot water usage and pre-date the widespread adoption of water conservation and energy efficiency measures. This means, historically, DHW systems have been oversized to compensate for the uncertainty in the load. Using these assumptions for central heat pump water heater (CHPWH) retrofits leads to systems that are infeasible to install due to electrical, space, and cost constraints. Therefore, CHPWH systems tend to be sized with an emphasis on primary storage capacity over primary heating capacity. However, there is a need for more data from existing buildings to guide system designers on how to use CHPWH-specific sizing tools effectively, especially for buildings that have atypical loads or usage patterns. This design practice also makes CHPWH systems much more susceptible to the comfort and efficiency impacts of distribution issues as compared to gas systems, so these issues must be diagnosed and repaired prior to retrofit.

This paper will present a summary of DHW monitoring data from twenty-one multifamily buildings in California and discuss the large variability in demand profiles and recirculation loads. It will also highlight the prevalence of distribution issues in existing buildings. Finally, this paper will present a comprehensive strategy to build capacity within the market to advance effective and efficient CHPWH retrofits. This strategy includes contractor training and support, tiered DHW investigation protocols, and enhanced incentives.

Introduction

Buildings contribute to 24% of California's greenhouse gas (GHG) emissions (CPUC 2026). A report funded by the California Energy Commission (CEC) states that DHW heating alone accounts for one third of the gas energy usage in multifamily buildings and that central DHW systems were present in 50% of these buildings (Ahmed and Krause 2022). This means electrification of existing gas water heating in multifamily housing provides a huge opportunity for the state to meet its GHG reduction goals. This is why incentive programs target this measure via rebates (CPUC 2026). Achieving these expected emissions reductions is only possible if the CHPWH retrofits are affordable, operate efficiently, and provide satisfactory hot water delivery for tenants, all of which rely on proper sizing and design of the proposed system.

Plumbing codes do not provide specific calculation methodologies for how to properly size central domestic hot water heating systems. The International Plumbing Code (IPC), adopted by 36 states, simply requires the system designer choose a system that will meet the hot water demands of the building (Fasel 2026). The Uniform Plumbing Code (UPC) that is adopted by 14 states, including California, similarly does not provide guidance on how to size central domestic hot water heaters (IAPMO 2023). Even the American Society for Plumbing Engineers (ASPE) admits that sizing DHW systems “is as much an art as a science” because engineers are left to choose one of the many sizing methodologies in hopes that it will accurately reflect the usage in the building (2010). Inefficient distribution system design causes further uncertainty around the total DHW load at a building. The lack of accurate information for sizing means that existing gas DHW systems are oversized and end up masking distribution issues.

However, oversizing CHPWH due to uncertainty in loads is not a strategy that will lead to widespread adoption of this technology in multifamily retrofits. Many existing multifamily buildings do not have the electrical capacity to support such a large CHPWH system, and electrical service upgrades often render projects infeasible. The upfront cost of installing an oversized system is simply too high for most owners, even when accounting for electrification rebates. Furthermore, an oversized system that is compensating for a poor distribution system will not perform efficiently, leading to high on-going operational costs. Therefore, installing smaller, more efficient, and more cost-effective CHPWH systems is critical for project feasibility and to enable climate, grid and owner benefits.

Central DHW Loads and Sizing

The sizing of a central DHW plant must consider two loads: demand and recirculation. The demand load in a building is the hot water that is consumed. Understanding the demand load means understanding how much water is being used and when. Many multifamily buildings with central DHW systems will also have a recirculation system. Its purpose is to reduce wait times for hot water in the units further away from the water heating plant by circulating hot water throughout the building. Smaller buildings may have a single recirculating loop, while larger buildings tend to have more complex distribution systems with circulated risers. A recirculation pump is responsible for moving the hot water throughout the distribution system. The recirculation load is the amount of energy needed to maintain temperature in this loop. As soon as hot water leaves the DHW plant, it begins to lose heat. The amount of heat lost is a function of the temperature difference between the supply and return and the volume of hot water in the distribution system. Determining the actual amount of heat loss in the distribution system is difficult and can be exacerbated by the presence of distribution issues.

Demand Loads

Sizing for the demand load requires the designer to make three decisions: how many people are going to be in the building, how much water each person is going to use, and when the hot water is used. There is no single agreed-upon source for determining the number of occupants in a building. The California Building Energy Code Compliance (CBECC) software uses occupancy rates that differ from the low-income occupancy rates specified by the California Tax Credit Allocation Committee (CTCAC). The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) provides yet another set of occupancy rates for both market rate and low-income properties. Table 1 below shows the variability in these different sources.

Table 1. Occupancy rates

	CBECC	CTCAC	ASHRAE-Market Rate	ASHRAE-Low Income
Studio	1.37	1	1.49	1.69
1 bedroom	1.74	1.5	1.93	2.26
2 bedroom	2.57	3	2.39	2.83
3 bedroom	3.11	4.5	2.84	3.40
4 bedroom	4.23	6	3.29	3.97

The number of people per apartment type varies based on the source. *Source:* Ecotope 2020

Determining the amount of hot water each person will use is also an important decision in sizing a system. ASHRAE and ASPE provide a source for the number of gallons per person used for several time intervals and per day (ASPE 2010). As shown in Table 2 below, the usage rates are determined based on low users, medium users, and high users. ASPE offers some guidance around selecting the usage rate. For example, seniors, tenants who are employed, and middle-income tenants are expected to be low users (ASPE 2010). Conversely, families, low-income tenants, and unemployed tenants are expected to be high users (ASPE 2010).

Table 2. Gallons of hot water per person

	5min	15min	1hr	3hr	Daily
Low	0.4	1.0	2.8	6.1	20
Medium	0.7	1.7	4.8	11.0	49
High	1.2	3.0	8.5	19.0	90

Gallons of hot water consumed per person across different time intervals. *Source:* ASPE 2010

There are several issues when it comes to choosing an occupancy rate and a usage level. The first is that occupancy rates and types will vary over time. This means designers need to choose a conservative occupancy rate to ensure the system will always be able to meet the hot water demand. The second issue is that the usage rates predate the widespread adoption of low flow fixtures, so they overestimate the amount of hot water usage (Ecotope 2020). Another issue with these calculations is determining the load profile. Occupants will use hot water throughout the day, and the system needs to be sized to cover the expected peak load. The peak load is when the largest volume of hot water is being used in a given time period, usually one or three hours. The designer must choose their peak timeframe, a demand factor to represent how many people will use water during the peak, and what the hot water consumption will look like during the rest of the day. Uncertainty around these considerations and overestimation of flow rates drives the oversizing of existing DHW systems to ensure they will always cover the load.

Recirculation Loads

The magnitude of the recirculation load is driven by the amount of heat loss in the distribution system. California first adopted an energy code, Title 24, in 1978 (DGS 2026). This means buildings constructed prior to 1978 are unlikely to have fully insulated DHW distribution systems. Existing buildings are also likely to have oversized distribution piping. Since the 1940's, Hunter's Curve has been used to size DHW distribution piping, but it overestimates peak demand flow because it uses outdated fixture flow rates and incorrect assumptions around concurrent usage (IAPMO 2024). IAPMO developed a study on water demand and created a more updated sizing methodology that results in smaller pipe sizes (2024). However, this calculation was only adopted as a voluntary alternative pipe sizing method into California's Plumbing Code (CPC) in 2024 and has yet to be adopted by every local jurisdiction in the state (CALWEP 2023). Therefore, existing buildings will have significantly higher rates of heat loss than new construction.

Recirculation loads can be further inflated by the presence of distribution issues like crossover and imbalance. These issues may not always be present during the construction of the building and may only become apparent with time. Distribution issues can also increase the demand load. When distribution issues cause long wait times for hot water or fluctuating water temperatures, occupants may end up using more hot water as a result.

Crossover. Crossover is the unintended mixing of hot and cold water within the domestic hot water distribution system. A CEC-funded study of 100 multifamily buildings with central DHW found that crossover occurred in 52% of them. (Ayala and Zobrist 2016). Most commonly, crossover occurs at failed shower mixing cartridges (Ayala and Zobrist 2016). When the seals inside the cartridge begin to fail after a few years of use, cold water leaks through the cartridge and can flow into the hot water supply line. Crossover can also occur, but is less common, at mop sinks, laundry machines, or incidental plumbed cross-connections in the building.

When crossover occurs in a building, the downstream tenants will often report fluctuating hot water temperatures due to the cold-water slugs in the distribution line. In response to the complaint, recirculation speed is simply increased and water heater setpoints are raised. Higher supply temperatures and higher flow rates create more mixing of the hot and cold water, which masks the issues for tenants. This intervention increases the recirculation load, but existing gas DHW systems can cover this load because they are so oversized.

Imbalance. Imbalance can occur in buildings that have multiple recirculation loops or circulated risers. Water in the distribution system will take the path of least resistance, which is the shortest loop back to the water heater. This means the loops or risers closest to the water heater see much more flow than the loops or risers further from the water heater, as shown in Figure 1 below. Imbalance can be inherent in the building due to poor distribution design. Even systems that had balancing valves installed on the loops can be susceptible to imbalance due to improper commissioning of the valves or site staff adjusting the valves later on.

Imbalance can become more severe when there is a larger number of risers or recirculation zones. Buildings that have risers for each individual fixture rather than each stack of apartment units have a higher opportunity for imbalance and a higher overall amount of heat loss from the piping.

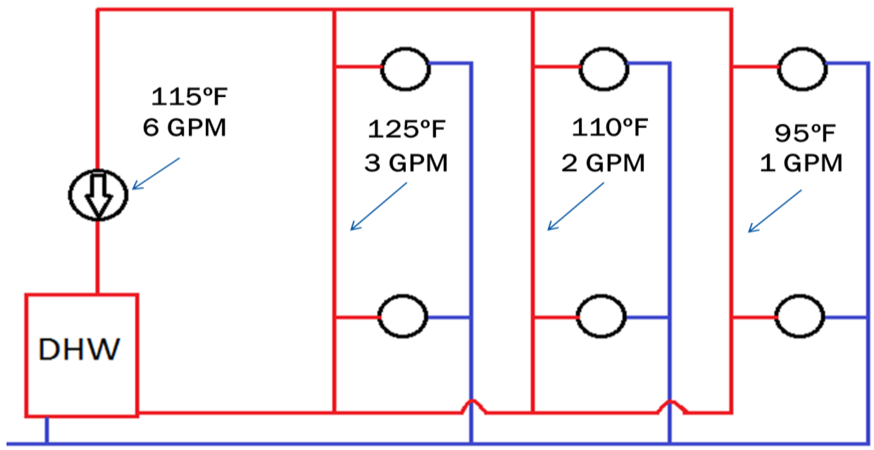

Figure 1. Example of an imbalanced distribution system with circulated risers.
Source: Association for Energy Affordability

Imbalance is symptomatic for tenants who live the furthest away from the DHW plant. They often report long wait times for hot water, especially if they are the first users after a period of low to no hot water use. As in the crossover case, building staff often simply increase water heater setpoints and increase the recirculation pump speed to try and force more hot water to the far away loops, which in turn increases the recirculation load. The oversized gas water heater will have to work harder and will cost more to operate, but it will be able to continue to produce sufficient hot water.

Central Heat Pump Water Heater Context

Using traditional sizing methodologies for CHPWH plants will result in systems that are oversized even beyond redundancy. These systems require electrical and space capacity that is not present at existing multifamily buildings. Accommodating the electrical and space demands of such an oversized system adds significant cost to retrofit projects that many multifamily property owners are simply unable to cover. To ensure CHPWH retrofits are cost efficient, emphasis is placed on larger primary storage volumes and smaller primary heating capacities as compared to gas DHW systems. However, this sizing practice can make CHPWH systems more susceptible to the impacts of inflated recirculation loads as compared to traditionally oversized systems.

System Design

Many CHPWH systems are designed with a swing tank for recirculation temperature maintenance, which can either be an electric resistance water heater or a heat pump water heater (HPWH). Figure 2 below shows this plant design and how the recirculation water is piped into the swing tank, not the primary storage tank(s). The swing tank is piped in series with the primary storage tank(s), meaning some of the recirculation load can be offset by the high temperature water that was heated by the heat pumps (Brooks, Neal, and Young 2024). However, during periods of low or no DHW consumption, only recirculation water is cycling through the swing tank, so all the recirculation load is on the swing tank. Any inflation of the recirculation load due to distribution issues will cause even more reliance on the swing tank.

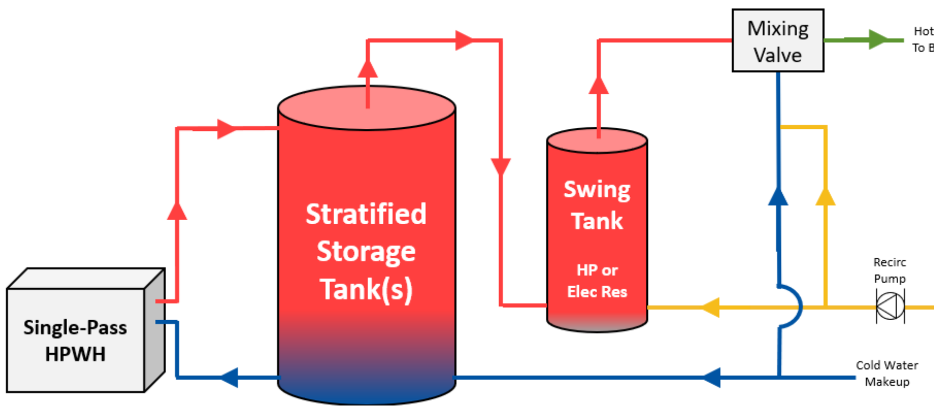

Figure 2. CHPWH plant design with single-pass HPWH and a swing tank for recirculation maintenance. This is the approved design for prescriptive California Energy Code compliance. *Source:* Association for Energy Affordability

While the swing tank helps to keep distribution issues from impacting tenant comfort, over-reliance on them will have severe efficiency and operational cost impacts, especially when the swing tank is electric resistance. EnergyStar's criteria for certifying commercial HPWH equipment is a minimum coefficient of performance (COP) of 3.0, although higher COPs have been published by many manufacturers (EnergyStar 2026). In comparison, the COP of an electric resistance swing tank is effectively 1.0, so excessive usage of the swing tank will significantly reduce the overall plant COP. Lowering the existing recirculation flow rate to lower the swing tank runtime is a common strategy in designing CHPWH plants. However, doing so can uncover distribution issues that were masked by the existing high flow rate. If these issues are not repaired prior to retrofit, there will be a tradeoff between tenant comfort and cost-effective, efficient operation.

Some CHPWH plants are designed without swing tanks, but this does not mean they are safe from the impacts of inflated recirculation loads. Single-pass CHPWH plants without swing tanks may fail to provide hot water entirely if the distribution issues are severe because they do not operate efficiently with high incoming water temperatures (Ecotope 2023). A low-income senior building in San Francisco had such severe crossover that the installed demand controls were bypassed; the site staff needed to improve tenant comfort with a higher, constant recirculation speed that would keep the delivered water temperatures higher (Aitchison, Neal, and Kumar 2020). After this action, the heat pumps were unable to handle the load and the building had to revert to their gas boiler system (Aitchison, Neal, and Kumar 2020).

Another strategy is to design CHPWH systems with multi-pass heat pumps as the primary heating source or as a swing tank because they are better able to handle higher incoming water temperatures as compared to single-pass heat pumps (Ecotope 2023). However, using multi-pass heat pumps still requires repairing distribution issues for efficient operation. The higher the exiting water temperature, which is directly correlated with incoming water temperature, the lower the capacity and efficiency of the HPWH (Rheem Water Heating 2025).

Design Optimization

To optimize performance of the new CHPWH while also delivering adequate hot water, it is essential to size the system properly, which means shifting away from traditional sizing methodologies and assumptions towards methodologies that will prioritize the storage capacity over the heating capacity. The primary storage is sized to cover the peak load, with the heating capacity sized to recover the storage during the off-peak hours. Thus, it is essential to make the correct determinations around the peak load and the shape of the load profile in the building. The Ecosizer, which is the most widely used sizing tool for CHPWH systems, provides alternate consumption rates and load profiles to optimize the sizing of these systems (Ecotope 2020). However, even these updated metrics are still based on limited data. Per Ecosizer's manual, their default peak demand value of 25 gallons per person per day is based on one 118-unit building that was part of a study of three market-rate multifamily buildings in Seattle (Ecotope 2020). Ecosizer assigns a default load shape to its calculations that was also based on the 118-unit building (Ecotope 2020). There is also an option to choose a California specific mode that determines usage rates and load profiles from CBECC (Ecotope 2020). While these metrics are significantly updated as compared to traditional sizing methodologies, they are still based on limited data and may not be accurate for all multifamily buildings. To allow for more custom sizing, the tool does accept a custom hourly load profile, but this requires the building to be monitored prior to using the tool.

Optimizing the design of a CHPWH plant also involves properly sizing the recirculation maintenance component of the system. As discussed, the most common CHPHWH plant designs cannot mask distribution issues the way gas DHW systems do without significantly compromising performance or tenant comfort. To properly size the temperature maintenance, it is essential to choose an estimate for the heat loss in the building while also repairing distribution issues to reduce the existing recirculation load as much as possible. The Ecosizer defaults to a recirculation load of 100 watts per unit with a safety factor of 75% (Ecotope 2020).

Pilot and Evaluation

Since 2016, the Association for Energy Affordability (AEA) has provided technical support on over 200 multifamily CHPWH system retrofits. Given the issues in applying traditional sizing methodologies to CHPWH retrofits, AEA began implementing pre-retrofit monitoring on some of these projects. The purpose of this monitoring was to determine if there were atypical consumption patterns that would require a different sizing strategy and if there were distribution issues that required repair prior to retrofit. Pre-retrofit monitoring activities include time to temperature testing throughout the building, pressure gauge crossover testing, and temperature and flow monitoring in the boiler room.

The Technology Equipment for Clean Heating (TECH) program funded a pilot to monitor additional projects and to compile and analyze data collected by AEA. The intent of the analysis was to understand the ubiquitousness and impact of distribution issues to inform program requirements, incentive levels, and training needs. The data gathered through this monitoring helped project teams identify the existence of distribution issues in the buildings so that they could be repaired prior to CHPWH retrofit. It also helped project teams adjust CHPWH sizing calculations to more accurately reflect the actual demand and recirculation loads at the buildings.

Findings

The TECH pilot included evaluating the data across CHPWH retrofit projects that were monitored by AEA, with a subset also receiving TECH incentives. Out of these, data from twenty-one multifamily buildings was determined to be of good enough quality for inclusion in the pilot's analysis. The buildings ranged from eight to 154 units and were two to ten stories tall. The study included market rate, low-income, and low-income senior buildings. These properties were located throughout California and were enrolled in various energy-efficiency and electrification programs administered by AEA including the Low-Income Weatherization Program (LIWP), Bay Area Multifamily Building Enhancements (BAMBE), the Tri-County Regional Energy Network's Multifamily Home Energy Savings program (3C-REN MHES), and the Comprehensive Affordable Multifamily Retrofits Program (CAMR). Under the TECH pilot, the data was summarized and analyzed to understand the prevalence of distribution issues in existing buildings and how real DHW loads deviate from traditional assumptions.

Recirculation Loads

The pilot study found that, on average, recirculation loads accounted for 39% of the total DHW load with an average of 144 watts per unit. The study also found significant variability in the recirculation load from building to building with a range of 18 watts per unit to 270 watts per unit. While units can vary in size across different buildings, watts per unit was chosen as the evaluation metric to align with sizing methodologies. The analysis found that recirculation loads tended to be higher in buildings that are greater than four stories versus buildings that were less than four stories. Larger buildings have more opportunity for crossover to occur, they have more imbalance potential due to more complex distribution systems, and there is more overall piping, all of which contribute to high heat loss. The large variability in recirculation loads can be seen in Figure 3 below.

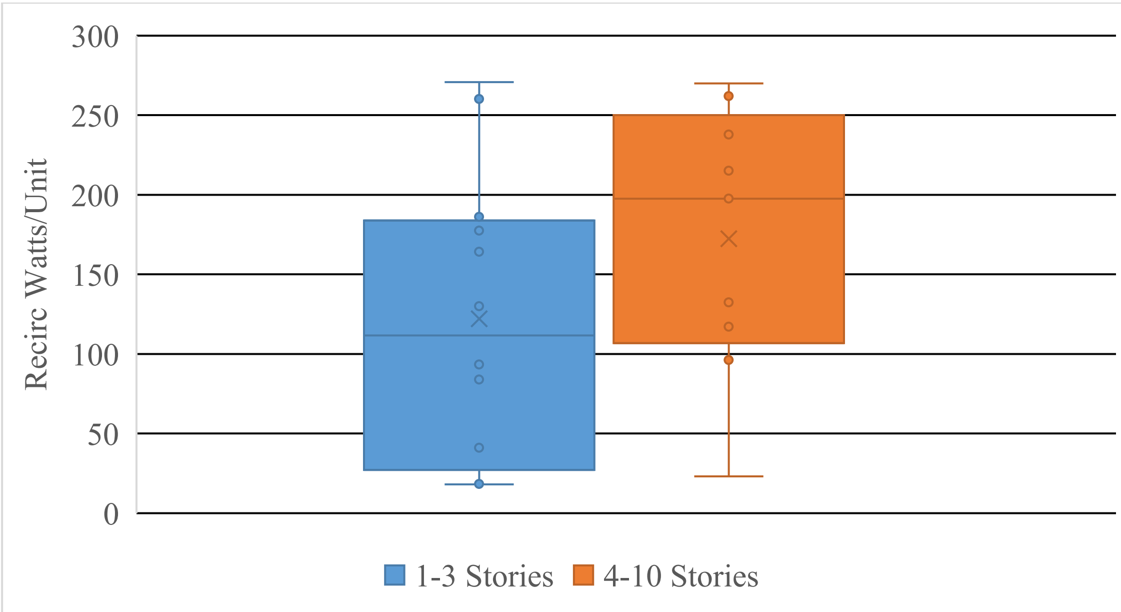

Figure 3. Recirculation watts per unit. The average recirculation load for 1-3 stories was 122 watts per unit and the median was 112. For 4-10 stories the average load was 172 watts per unit and the median was 198.

Demand Loads

The pilot analysis also looked at the demand loads at the buildings and assessed both the peak gallons per person per day (GPD) during the monitoring period and the usage profile. The study found that there was an average peak consumption of 25 GPD when calculated using CBECC occupancy rates. However, as was the case with recirculation loads, the study found significant variability in peak consumption rates across buildings, ranging from 5.25 to 62 GPD. The analysis also showed that seniors consumed less hot water than buildings occupied by families; senior-occupied buildings showed an average peak of 20 GPD as compared to an average peak of 28 GPD for the other buildings. Additionally, the study found variability in draw profiles, and that many buildings did not follow the expected morning/evening peak pattern.

Figure 4 below shows the average daily draw profile across a one-to-two-week monitoring period for eight deed-restricted low-income properties. Not all the buildings had clearly defined three-hour peak draw events, which would typically be used to size a CHPWH system. Additionally, the buildings that did show peak draw events still had high levels of consumption during the off-peak hours.

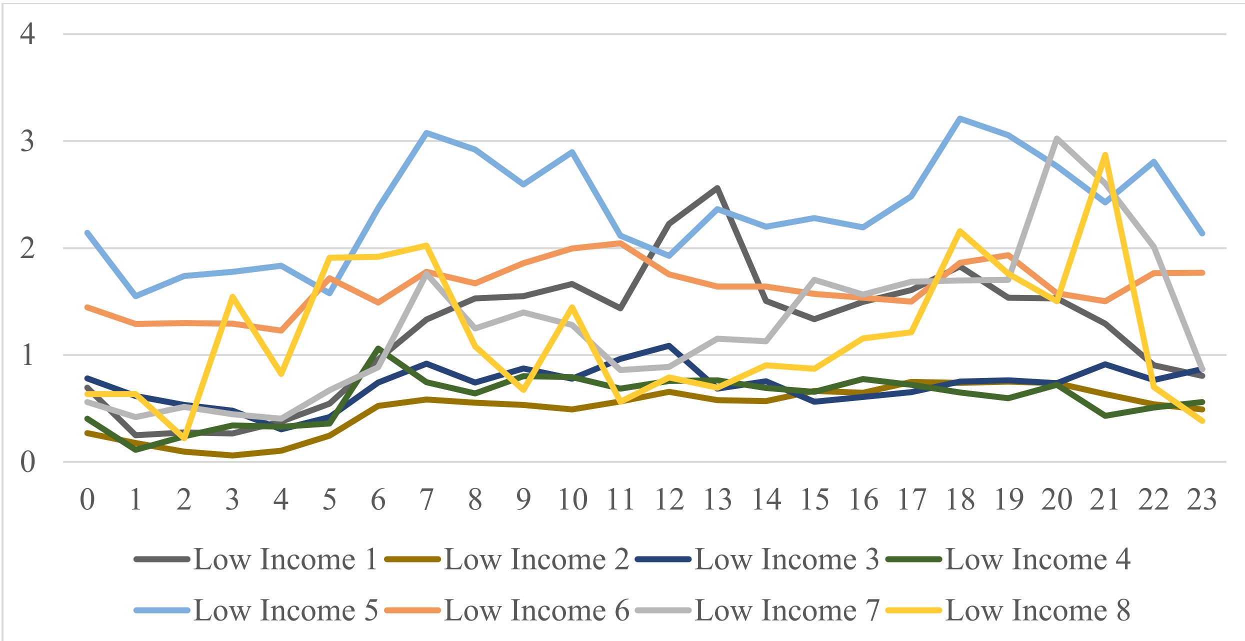

Figure 4. Draw profiles in low-income multifamily buildings showing average gallons per person per hour during the monitoring period. CBECC occupancy rates were used.

It should be noted that this short-term monitoring only provides insight into the hot water consumption at a building for a limited time. These data points can help provide guidance on whether the sizing methodology may need slight adjustments to account for higher than assumed occupancy rates or atypical usage patterns. However, sizing a system based solely on the monitoring data may lead to a system that is not appropriately sized for the 99th percentile peak usage in the building. Occupancy and vacancy rates in multifamily housing can change significantly over time. Additionally, hot water consumption can vary seasonally; data gathered in the summer will likely underestimate the amount of hot water used by tenants in the winter.

Recommendations

Based on the results of the TECH pilot analysis, the team concluded that traditional sizing methodologies have too much uncertainty to allow for proper sizing of a CHPWH plant. The analysis also found that there is a lack of industry data to inform how to properly size systems for existing buildings that have atypical DHW loads and how to identify if a building falls into this categorization. The team has also concluded that identifying distribution issues and repairing them prior to retrofit is critical to ensure the system can operate effectively. To this end, the Central Heat Pump Water Heater Optimization Enhanced Support Pathway (CHPWHO ESP) was developed under TECH. The purpose of this ESP is to expand contractor capacity to install successful and well-performing CHWPH retrofits to avoid negative responses from buildings owners to CHWPH attributed to poor performance and high utility costs. The ESP is working to achieve these goals with two main strategies. The first strategy is to provide resources for contractors on how to properly investigate distribution systems pre-retrofit and understand if mitigation strategies have been successful. These resources will be made publicly available for contractors outside the program and the state of California. The second strategy is to continue to gather information from existing buildings so that CHPWH sizing tools can be used more effectively. Projects enrolled in the ESP will receive additional incentives to support these strategies beyond the standard incentives TECH provides for CHPWH electrification retrofits.

Contractor Resources

The ESP involved the deployment of a tiered investigation approach for CHPWH retrofits. Three tiers were developed to utilize time and resources effectively for the contractor, owner, and technical assistance provider. The goal of this approach is to understand if there are inefficiencies in the distribution system so they can either be repaired or accounted for in the system design. The contractor shall start with Tier 1 investigation and shall proceed to subsequent monitoring tiers as needed.

Tier 1. The first tier of the investigation approach involves collecting information during the contractor's initial visit to the property. If any of the following conditions are true, it may indicate an inflated recirculation load is present at the property, and further monitoring described in Tier 2 should be undertaken to determine if there is a distribution issue that needs to be repaired.

Boiler Room Investigation:

- There is a larger temperature difference between the supply and return with a large recirculation pump.
  - >20 units: pump >65 watts, temperature difference >5°F
  - 20-60 units: pump >125W, temperature difference >10°F
  - 60+ units: pump >250W, temperature difference >10°F
- The water heater setpoint is greater than 140°F.
- There are multiple recirculation pumps for a single plant.
- The recirculation controls have been bypassed.
- The piping is undersized based on conventional sizing methodology.
- The building failed a pressure gauge crossover test.
- The recirculation flow rate exceeds the maximum velocity for the pipe material.

Distribution System Investigation:

- There is underground piping.
- The distribution piping is uninsulated.
- There are multiple risers for each apartment.
- There are existing balancing valves that have been adjusted or bypassed.

- There are isolation valves that have been manually throttled on the risers.
- There are leaking fixtures or fixtures with handles that are hard to turn.
- The time to reach 110°F in any of the sampled apartments was greater than 1 minute.
- The time to reach 110°F varies by more than 30 seconds across the sampled apartments.
- The maximum temperature reached in the apartments varies by more than 5°F.

Anecdotal Investigation:

- There are complaints from tenants about water temperatures, consistency in hot water delivery, and/or wait times.
- Site staff have made adjustments to the plant (i.e. increased recirculation speed, increased water heater setpoint, added recirculation pumps).

Preliminary System Proposal:

- The proposed system will not include a swing tank.
- The proposed system will include a demand-controlled recirculation pump.

Tier 2 monitoring. If there are any red flags raised in Tier 1, there may be an inflated recirculation load at the property, so the contractor should proceed to Tier 2. Tier 2 involves installing temperature sensors and flow meters on the hot water supply, cold water make up, and recirculation return lines in the boiler room for a two-week monitoring period. Figure 5 below shows a diagram of a typical set up.

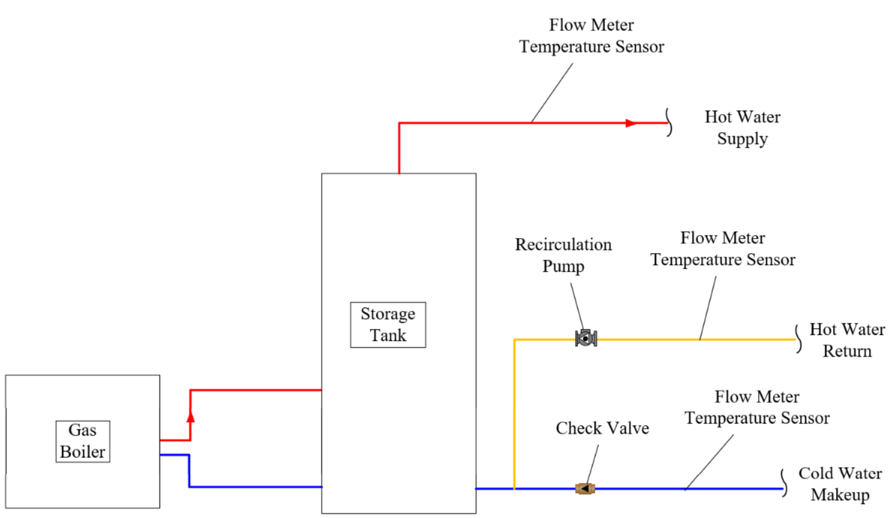

Figure 5. Monitoring installation diagram for Tier 2. If two flow meters are installed, the third flow can be calculated. However, it is best practice to install all three flow meters to ensure good data quality and to verify that measured values are accurate.

The data collected in Tier 2 monitoring can be used to calculate the contributions of the recirculation load and the demand load to the total domestic hot water load. It can also be used to understand the amount of hot water being used at the property, and if there is a significant deviation from the assumptions the sizing methodology would make. Based on the results of the monitoring study, the TECH team identified results of Tier 2 monitoring that could indicate the presence of a distribution issue and would require further investigation. If any of the following conditions are true, there could be a significant distribution issue:

- The recirculation load is greater than 30% of the total DHW load and/or the recirculation load is greater than 100 watt per unit.
- The return temperature fluctuates when the supply temperature does not, indicating crossover.
- The return temperature drops significantly during periods of low/no hot water usage while the supply temperature remains steady, indicating imbalance.
- Hot water consumption at the building is more than 35 gallons per person per day during the monitoring period.
- The recirculation velocity regularly exceeds the maximum allowable velocity for the pipe material.

Any of the above conditions indicate that the recirculation load is inflated and mitigation steps may need to be taken to ensure a successful CHPWH retrofit. However, while the conclusions drawn in Tier 2 may indicate the presence of a distribution issue, they may not necessarily provide insight into where the issue is located, the type of issue, or how to mitigate the issue. For this reason, it is recommended that contractors proceed to Tier 3.

Tier 3 monitoring. More detailed monitoring may be required to finalize a distribution repair plan. The third tier of the investigation protocol is to install temperature sensors on the supply and return of three different risers that are spread throughout the building in addition to the main hot water supply and recirculation return in the boiler room. Investigating the temperatures on individual risers can provide insight into what the distribution issue is and where it is located. For example, imbalance may be revealed from Tier 3 monitoring if one riser's return temperature drops during times of low to no usage when other risers' temperatures do not.

Once contractors have completed the necessary tiers of monitoring, they should be able implement a repair plan for any distribution issues. They will also have the necessary data to customize the inputs to CHPWH sizing tools so they can accurately size the system. After necessary distribution repairs have been completed, the contractor should re-monitor the DHW system briefly to confirm that repairs were successful.

Monitoring training. A set of two training courses were held for contractors who were accepted into the CHPWHO ESP and will be released to the public. The first training focused on the background behind the development of the tiered monitoring protocols and provided step-by-step guidelines for how to proceed through the protocols. The training also included a case study showing how the protocols were used on a previous CHPWH retrofit and how they lead to the diagnosis and repair of severe crossover. A second training course was held which discussed how to interpret monitoring data. It also provided strategies for understanding data quality and how to make corrections to bad data so that it could still be used for calculations and analysis.

Enhanced Incentives

Undertaking monitoring activities has an initial cost that may be required to determine if the CHPWH project is feasible and within budget. Thus, the ESP is providing a $5,000 incentive to contractors to offset this labor cost. The actual monitoring equipment package costs can range from $3,000 to over $6,000 depending on the equipment needed, so the ESP provides a $5,000 incentive for contractors to purchase equipment. Because monitoring equipment can be re-used on projects, this is a one-time incentive per contractor enrolled in the program. Implementing distribution repairs can also significantly impact the project cost. AEA projects have seen shower cartridge replacements ranging from $200 to $1,000 per replacement depending on the type of repair and thermostatic balancing valve installation costs of roughly $1,200 per valve. There is a $17,000 per HPWH plant incentive (up to two plants) for the repair of identified distribution issues for projects enrolled in the ESP, capped at actual costs. Finally, there is $5,000 incentive for post-retrofit monitoring activities to ensure that the installed CHPWH is performing optimally.

Current ESP Projects

To date, two contractors who have projects enrolled in the ESP have completed their investigation into the existing system. Building 1, located in Concord, CA is a 42-unit low-income property with a non-complex distribution system. An analysis of Building 1 found that the recirculation load was 71% of the total DHW load. Tier 1 investigation of the building helped draw the conclusion that this inflated load was due to a fully uninsulated distribution loop located in the carport. Approximately 700 linear feet of DHW piping will be insulated as a distribution repair effort. Building 2, located in San Francisco, CA is a 12-unit owner-occupied building. An analysis of the building found that the recirculation load was approximately 430 watts per unit. Investigation into the system revealed a complex distribution system with many return loops. Once building plans are sourced from the city and the exact locations of the returns are confirmed, the system can be balanced to improve the recirculation load.

Conclusions

CHPWH retrofits are a critical climate change mitigation strategy for multifamily buildings, and it is important to keep public perception of these systems positive to encourage continued adoption. This means installing systems that operate efficiently and at low cost, provide proper hot water to tenants, and are not dismantled or replaced by owners. To do this, CHPWH systems must be sized properly, not using the outdated traditional sizing methodologies. Thus, continuing to gather data on existing DHW systems is essential to expand the customization options and provide better guidance on how to use sizing tools in a way that accurately reflects the existing conditions. In addition to understanding the actual load conditions at a building, it is also essential to investigate distribution systems and repair distribution issues prior to retrofit. Incorporating additional incentives for DHW investigation and distribution repair into program design will increase the number of CHPWH retrofit projects that are doing these activities and will lead to more successful installations. Finally, it will be important to continue to expand contractor capacity to investigate distribution systems and make accurate determinations on how to use sizing tools. After the conclusion of the CHPWHO ESP, the team will survey participating contractors and report out on learnings about the impact of the training courses, investigation protocols, and incentives on these projects.

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