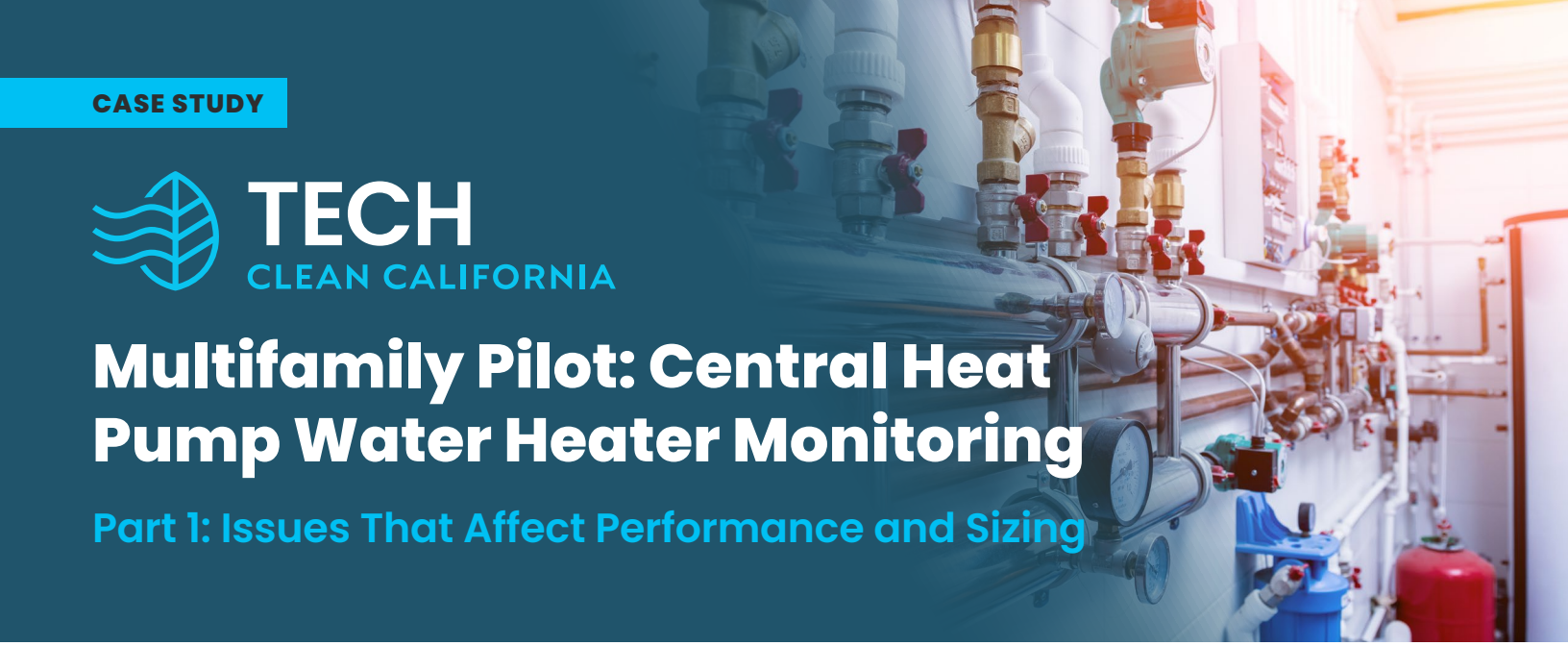
CASE STUDY

TECH
CLEAN CALIFORNIA



Multifamily Pilot: Central Heat Pump Water Heater Monitoring

Part 1: Issues That Affect Performance and Sizing

The TECH Clean California Multifamily Pilot includes components to evaluate barriers to overcome in the electrification of space and water heating. One component provides pre- and post-retrofit equipment monitoring for central domestic hot water (DHW) plant retrofits. Pre-retrofit monitoring efforts to date have illuminated the importance of monitoring distribution loads both as a core component for sizing central heat pump water heating systems and as a means of uncovering distribution issues that affect system performance and customer satisfaction.

Differences in Central Domestic Hot Water System Operations

It is essential to understand how both central gas boiler systems and central heat pump water heater systems operate when investigating the feasibility of replacing a central domestic hot water gas boiler system with a central heat pump water heating system. Central heat pump water heating systems are sized differently than gas boilers because they operate differently. Gas boilers are typically sized for faster recovery (greater heating capacity/BTU) and lower storage than a central heat pump system. Central heat pump water heating should be sized for more storage to be most effective and efficient, meeting demand with lower energy output.

Given the differences in how gas boilers and central heat pump water heater systems operate, actual distribution loads, as well as distribution issues, should be evaluated ahead of system design to optimize performance of the central heat pump water heating system. Distribution issues can result in longer wait times for hot water, water that does not get sufficiently hot, and/or unexpected water temperature fluctuations. Gas boilers can mask these issues while also resulting in higher bills. All these factors can lead to resident dissatisfaction, increased water consumption, and higher utility costs that may be more evident with a heat pump system.

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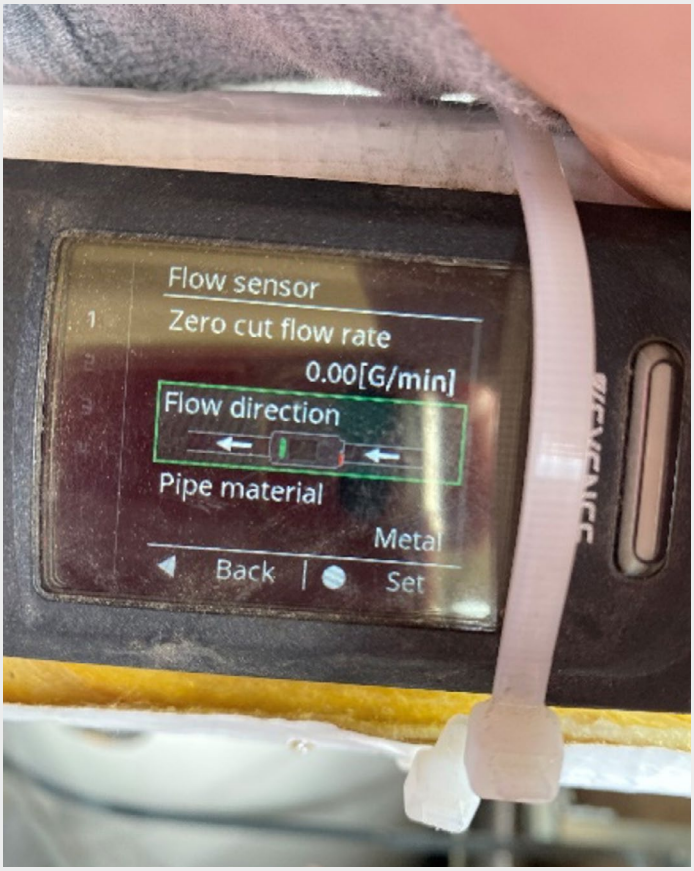
Sizing Central Heat Pump Water Heaters

There are two different types of hot water loads in central heat pump water heater systems: consumption load and distribution load.

Consumption load: Sizing to meet consumption load[1] is the way that gas water heaters and boilers have been sized. There are many different sizing methods within this category, and each has pros and cons. Different sizing methods work better for different building types and occupancies – there is not one consumption load sizing method that applies to all occupancies. Key factors in estimating hot water demand include occupancy, fixture flow rate, and design temperature.

Distribution load: Sizing to meet distribution load[2] is uncommon for gas water heaters and boilers. Gas systems have faster recoveries and are typically oversized. However, not considering distribution load for central heat pump water heater systems can result in inefficient hot water and higher utility costs. There are only two sizing methods for distribution load for new construction based on calculations, and neither are appropriate for existing buildings.



Digital sensor assisting in water flow and distribution diagnostics. Photo credit: AEA

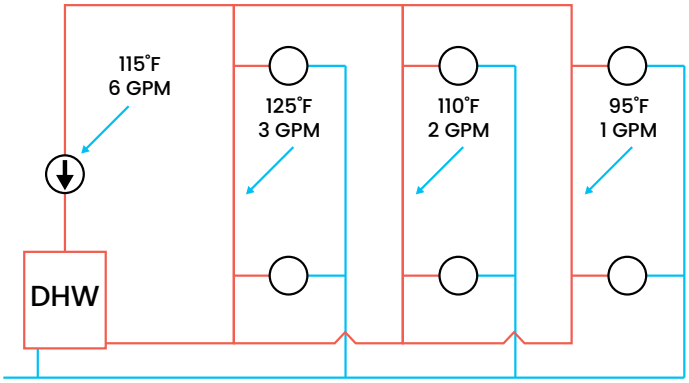
Electronic monitoring of water heater load. Photo credit: AEA

Domestic hot water load monitoring has proven to be an effective way to determine what consumption-load sizing method is most appropriate for a particular building and has been the most accurate way to size distribution load of existing systems. Domestic hot water load monitoring should be conducted for at least two weeks and should take into consideration the time of year and building vacancy rate. Domestic hot water load monitoring is valuable for system sizing even in well-performing buildings, and it has an added critical value of uncovering distribution issues before a new system is installed.

1 Hot water demand of a building based on the number of units, occupancy, fixture, and design temperature.
2 Hot water load associated of distribution piping, pumps and recirculation loops, also called temperature maintenance load.

Distribution Issues

Below are examples of issues that can result in inflated distribution load in multifamily buildings. These issues can vary in severity over time, which is why it is important to monitor the domestic hot water load to understand the distribution load under current conditions and not to design a system based on the distribution load when the building was built.



Imbalance illustration created by AEA.

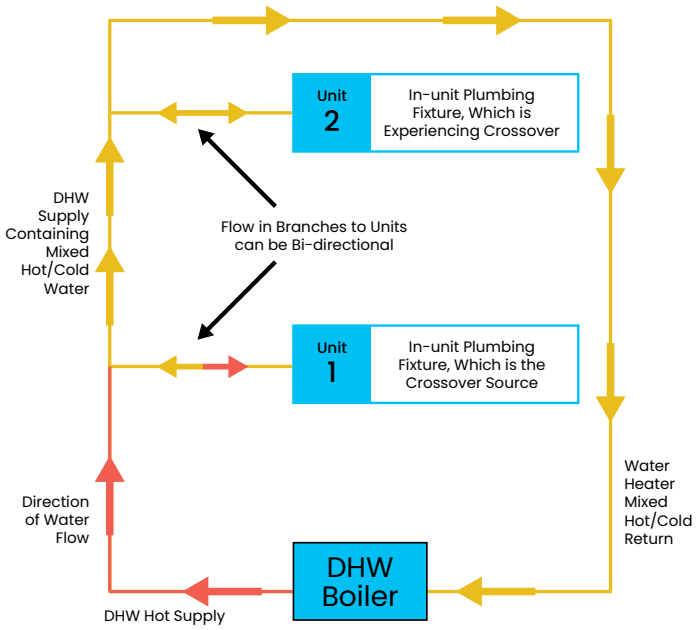
Imbalance

Distribution systems often have several recirculation zones and loops of varying sizes. Water travels through the path of least resistance and smaller loops have less resistance. As a result, dwelling units on longer recirculation loops may receive inadequate hot water and experience longer wait times for hot water.

Crossover report[3]

Crossover is the unintended mixing of hot and cold water, which occurs at fixtures where hot and cold water is mixed.

Crossover results in lower water temperatures returning from the distribution system, inflating distribution load. It also causes inadequate hot water temperatures, which maintenance staff often respond to by increasing set point temperatures and overriding recirculation pump controls, actions which can increase the system's energy use and operating cost.



Crossover illustration created by AEA.

Pressure differential

This is defined as pressure differences between hot and cold lines. Pressure differential and changes in pressure due to usage can result in the improper mixing of hot and cold water at a mixing valve or water fixture mixing cartridge. Improper mixing results in water that is to hot causing scolding risks and water that is to cold causing tenant dissatisfaction. Pressure can drop in hot water lines due to mineral sediment that can build up and restrict water flow. Pressure can also be impacted by improper valve operationn.

For example, if this is occurring at the mixing valve, then there could be either too hot or too cold water supplied to building as the water is not mixing evenly.

Piping heat loss

Underground or uninsulated pipes result in higher heat loss as water is distributed throughout the property or building, resulting in larger distribution loads.

3 Crossover: Testing Solutions and Assessing Savings for Water and Energy in Low-Income Multifamily Affordable Housing

Field Activity

Project examples below show how factors described above have played out in a variety of multifamily property types.

65-unit, two-story multifamily building in climate zone five

Initial Consumption Sizing: The manufacturer used a standard gas boiler sizing methodology using peak demand and a low (cold) design temperature. The recommendation resulted in an oversized system with an infeasible amount of heat pumps - six heat pumps totaling 464,646 BTU/h and 2500 gallons of storage, which is a moderate amount of storage.

Monitoring: Monitoring was recently completed at the design stage. While analysis is not complete, it is providing more insight into consumption and distribution loads. This data will allow a consumption sizing approach to determine how much storage is needed to float through minimal cold design periods. This will result in a more financially feasible system.

Findings: This example illustrates the implications and differences in sizing methodologies and prioritizing power with no storage vs. storage and better operating costs.

248-unit, two-story project comprised of 16 buildings with eight central plants each serving two buildings in climate zone 10

Initial Consumption Sizing: Contractor employed peak hot water demand defined by ASHRAE standard (2015 ASHRAE HVAC Applications). Distribution load was calculated based on standard new construction approach and did not consider existing conditions.

Monitoring: Distribution issues were discovered after the installation due to inflated utility costs, resident complaints, and the central heat pump water heater system not meeting the load. Monitoring the central heat pump water heating system showed signs of crossover, imbalance, pressure issues and heat loss associated with underground piping.

Findings: Monitoring is underway, and corrections are being implemented to address distribution issues. At completion, we should have insight as to how much the corrective actions reduced the distribution load. We intend to use monitoring equipment data to further investigate distribution issues and to correct sizing issues at the property. In addition, the monitoring data will show the effect on utility consumption and hot water delivery satisfaction if these distribution issues had been mitigated prior to the central heat pump water heating system installation. These results will be shared out to demonstrate differences and impacts in sizing methodologies to contractors and affordable housing owners.

The TECH Clean California Multifamily Pilot under Association for Energy Affordability is continuing to monitor properties installing central heat pump water heating systems to support pre-installation sizing and post-installation performance, monitoring, and troubleshooting. Results from these efforts will inform industry practices and program incentive design.

Learn More

Central Heat Pump Training on the **Electrification Knowledge HUB**
aea.us.org/electrification-knowledge-hub