

Packaged Central Heat Pump Boiler Project

Small Planet Supply

Quick Start Grant Final Report

Albert Rooks

Small Planet Supply

August 3, 2023



Executive Summary

There is a lack of industry knowledge and experience in designing and installing central heat pump water heaters in California. The current practice requires the creation of a custom engineered design for each individual building. To add to the complexity, the design of central heat pump water heater systems consists of heat pumps, tanks, controls, service power, and piping from separate manufacturers. This piecemeal approach to decarbonization will not scale due to the highly customized requirement of both engineering, design, and installation.

As part of TECH Clean California's Quick Start Grants, Small Planet Supply set out to address this barrier by developing a standardized, modular, pre-packaged central heat pump water heater to minimize the design requirement, installation, cost, and challenges inherent to the existing practice. By creating pre-engineered systems and providing all equipment through a single source, the process becomes a simple plug and play approach that allows scaling production volume to meet the market demand.

The system concept is based on the interactive relationship of how buildings use potable hot water, and how that hot water can be most efficiently generated by heat pumps and stored for future building use. The amount of hot water that a building requires is based on a simple calculation of the number of occupants in the building, their typical usage per day, and the typical time of day that it's used. These relationships are predictable across the varying types and sizes of buildings and can be served by a set of equipment packages that are designed and pre-manufactured to fit the appropriate range of both existing and new buildings. Market scale can be reached by having these pre-engineered packages available for purchase as simple catalog items are available from local plumbing equipment supply stores.

To prove the validity of this concept, Small Planet Supply designed and installed pre-packaged WaterDrop central heat pump system in five separate buildings at the Parkside Apartments in Delano, California. To account for the increased spatial requirements of central heat pump water heater systems relative to gas boilers, the Small Planet Supply design team designed a flexible modular system that was able to adapt to fixed space constraints of the pilot buildings.

Having successfully equipped the buildings with the pre-engineered central heat pump water heater systems, the project demonstrated an alternative solution to replace incumbent natural gas boiler systems.

The original gas boiler design demonstrated another common barrier to address for both new and existing buildings—central heat pump water heaters require more space than gas boilers which are typically placed in small mechanical areas. The design team was able to overcome this additional barrier by designing a flexible modular system that was able to adapt to the fixed space restraints of the building, while still maintaining standardization and scalability across the market.

The five central heat pump water heater systems are installed and operate in all five buildings with no complaints about the hot water temperatures or availability. The successful operation of the central heat pump water heater systems validates the WaterDrop load sizing and equipment concept as well as provides a demonstration to inform future building code development in support of the transition to heat pumps. The planned 2023 to 2024 post-installation central heat pump water heater systems monitoring of all five buildings will specifically inform code and energy modeling development for minimum code capacities and Title 24 load sizing.

WaterDrop equipment packages are now available at select California plumbing supply houses for both new construction and existing building boiler replacement. The pre-engineered, pre-manufactured nature of WaterDrop allows for a quick turnaround in both equipment selection and delivery to the site. Small Planet Supply has appointed leading manufacturer representatives to support the market adoption of the plug-and-play product range. This simplified approach to providing hot water to both new and existing buildings reduces cost of central heat pump water heater systems by reducing design complexity for the engineering community, building owner, and the installation time required to craft individual custom installations by the contractor. In reducing complexity and speeding up installation, the building owner benefits by having simple tools available and being ready to support the transition to heat pumps.

Scaling the pre-packaged central heat pump water heater concept will require a dedicated effort to address the sales process, incentive structures, and contractor education. Given the niche market this product can support, the concept is crucial for fuel-switching and achieving California's decarbonization goals.

Project Description

Project Team

Small Planet Supply is a company dedicated to the supply, education, and training in the use of energy-efficient building materials and practices. The project installed heat pumps in a regulated affordable housing development that is restricted to low-income farmworker families.

Market Barrier

There is a lack of both design knowledge and available product offerings to serve small multifamily buildings seeking to use central heat pump water heaters for domestic hot water. The industry is not positioned to make the necessary decarbonization shift away from incumbent natural gas boilers to central heat pump water heaters or to leverage the potential benefits of future load shaping using central heat pump water heaters without solutions that simplify specifying, installing, commissioning and operation of central heat pump water heater systems.

The typical pathway to design and install a central heat pump water heater in a multifamily building requires a project engineer to properly size and meet the building load through a multitude of individual components. These may include heat pumps, primary storage tanks, loop tanks, mixing valves and recirculation pumps, piping, or parts for new power requirements. The components must then be placed into a schematic design that is submitted for permitting and provided to installing contractors for pricing.

The current design process can take months in development before it goes out to pricing by installing contractors. Once the design is received, bidding contractors will begin pricing the components and estimating the installation time to develop a project bid. Once the bid to procure and assemble the design onsite has been awarded, the work can then be scheduled.

This results in each central heat pump water heater design being a unique assembly of individual components designed by one group and installed by another. In addition, each group has varying degrees of prior experience with central heat pump water heaters. This shortcoming becomes apparent at system



TIMELINE:

January 2022 –
February 2023



HOUSING TYPE:

Multifamily



EQUITY SEGMENT:

Affordable Housing



TECHNOLOGY:

Central Heat Pump
Water Heaters



LOCATION:

Delano, CA



start up where errors in design or installation that necessitate repairs are commonly found. Furthermore, most building inspectors aren't familiar with how central heat pump water heaters work which can create inspection challenges for inspectors trying to understand a custom design. All of these steps compound to create what is essentially a custom crafted solution for each building, adding cost to the project in both fees and project duration.

Proposed Solution

This project seeks to address these challenges by removing the need for custom designs and shortening the installation time of central heat pump water heaters. The project team designed a pre-packaged, modular central heat pump water heater for this building size that can be applied as a drop in domestic hot water system. The standardized central heat pump water heater product doesn't require any customization and is ready for purchase and installation like any other off-the-shelf product.

The project team reviewed the five targeted workforce buildings and designed a modular pre-packaged central heat pump water heater to fit each building size, between four to eight apartments per building. The project team then progressed from system design to system manufacturer and built the system in its factory then shipped the system to site for installation by a local contractor. The system was installed and commissioned in all five buildings in late 2022 and has been continuously operating and supplying the occupants with reliable hot water for domestic use.

Theory of Change and Scalability

The project team's intent was to create a scalable solution to fill the application experience and system availability gap. This innovation, which delivers heat pump boilers as a pre-engineered, factory-completed package that can be easily installed, could be key to the expansion of heat pump boilers into the gas boiler market.

Program Changes and Evolution

From a technical development perspective, generally, the original concept is consistently tracked toward the final product design solution. The changes and adaptations experienced were primarily focused on adapting equipment form factors to fit the wide variety of building



types found in these five sites and the broader California small multifamily market. The project progressed, albeit with significant changes due to the building being under construction and the difficulty of coordination. These challenges were met, and the final result is a product design that is both modular and adaptable to the wide range of building forms typically encountered in the small multifamily market.

Project Goals and Achievements

Summary of Project Goals and Achievements

| Goal | Metric | Data Source and/or Analysis Approach | Project Results |
|---|-----------------------------------|--|------------------|
| Reduce customer cost per WaterDrop system | Cost per unit | Pre-engineered and pre-fabricated Droplet compared to same custom engineered and site construction | 32% cost savings |
| Performance assessment | Coefficient of Performance (COP) | Field data collection of temperature, water volume and energy use | N/A |
| Energy bills are equivalent or better than typical gas system | Annual energy costs | Pre- and post-installation bill comparison | N/A |
| Reduce GHG emissions from refrigerant leakage | Percent of annual CO2e reductions | Based on industry norm for standard HFC refrigerants used in a typical heat pump | 100% |

Reduce Customer Cost Per WaterDrop System

Pricing established in the wholesale market meets this requirement. Local California sales rep Flowtech currently manages the small building sales channel to the wholesale industry. The simplified central heat pump water heater product is available from the wholesale industry and a specially trained sales channel, addressing one of the largest market barriers to heat pump adoption in this building range. The simplified piping, power, and control modifications removed yet another market barrier by eliminating the need for a specially trained installer. This enables the existing plumbing industry to size, recommend, install, and start up a central heat pump water heater for small California multifamily buildings. Documenting overall project savings from eliminating or reducing the engineering and contractor costs associated with the design, installation and operation is an additional research area.

Performance Assessment

This project is the subject of a long-term study by SoCal Edison and Redwood Energy to determine the WaterDrop system coefficient of performance and provide a full performance report. More measurement and verification data on this will be available in 2024 aimed at informing future building codes for multifamily buildings. Based on prior experience and monitoring of site-built systems, it is expected that the pre-packaged system will perform predictably and achieve a coefficient of performance greater than three. The measurement and verification conducted on these five buildings will confirm the system capacity meets the building load. Actual occupant domestic hot water use compared to modeled estimates will be used to help properly size loads of future projects and may present opportunities for load shifting through demand response.

Energy Bill Reductions

This information will be evaluated and reported in the above-mentioned study to be published concurrently in 2024.

Reduce Green House Gas Emissions from Refrigerant Leakage

This goal has been met. The installed system uses the R744 refrigerant (CO₂) which has a global warming potential of 1.0. Additionally, the WaterDrop system is a monoblock heat pump that wholly contains the small charge of refrigerant in the unit. The low global warming potential of the R744 refrigerant is a key pathway to feasibly meet the state's refrigerant goals.

Key Publications

Small Planet Supply has developed the WaterDrop product group website to support the product line. Small Planet Supply will continue to develop additional resources on the website for small building sizing, selection, where-to-buy, and system start-up support. Please see the Droplet two and Droplet four products at waterdropsystems.com/waterdrop-product-line.

As highlighted above, Southern California Energy and Redwood Energy will assess and document system performance in a future evaluation report of the WaterDrop system in 2024.

Key Learnings

The technical challenge of developing a product design to both meet a site-based application load and scale into a standardized product offering for small multifamily buildings was complex. Small Planet Supply generated several lessons applicable to the future development of this concept and broader market transformation.

Size constraints of mechanical rooms in small multifamily buildings necessitate a flexible product design and sales process. A key learning came from having to satisfy five buildings under construction that were already designed for gas boilers. Due to required setbacks from windows and pedestrian pathways, the buildings did not have enough space available to install a central heat pump water heater in the mechanical room or outside of the mechanical room. This project uncovered that skidded solutions with all the heat pumps, tanks, and accessories will not fit projects with space constraints. Projects like this will require the highest flexibility to break apart the functions into separate component groups while retaining the pre-packaged approach to both system sizing and installation.

From a product design standpoint, Small Planet Supply gained more insights from this project that resulted in the development of a more flexible product line. Small Planet Supply created a new mix and match menu of heat pumps and tanks to make it easier for wholesalers and installers to select and create a system. This flexibility made the system more adaptable to work within the parameters of existing infrastructure compared to typical, rigid product designs and specifications that require building modifications designed around it.

Tools to properly size central water heater systems must be refined for small multifamily buildings. An additional learning that came out of this project is related to Ecosizer, a tool used to size central heat pump water heaters in multifamily buildings.¹ The multifamily buildings in this project were smaller than Ecosizer was designed for. For that reason, Small Planet Supply ran additional sizing calculations to validate the loads. The additional one-year measurement and verification study will help to confirm the sizing range of the product. It's worth noting that simplified sizing for both new and existing buildings removes a significant market barrier by using external sizing resources. The project team strongly suggests further investigation into sizing tools for small buildings.

Industry education is crucial for central heat pump water heater inspections. When the project reached the start-up phase, a significant knowledge gap of central heat pump water heater operation became evident. Central heat pump water heaters behave differently from boilers at start up and occupancy of a new building. Buildings with a recirculation system and boilers tend to have hot water at the fixture prior to occupancy. Comparatively, buildings with central heat pump water heaters are typically a single pass design with a swing or loop tank to isolate the recirculation loop from the stratified primary storage tank. When a building has not been occupied and the domestic hot water system is being inspected, the fixture temperatures will be an inaccurate representation of system operation from lack of occupant usage. In an occupied building, there is a daily load cycle that keeps the system hot while reducing waste loss in primary storage and the recirculation lines by isolation. In this small building, the fixture temperatures were found to be low at inspection, and the perception was that there was something wrong. This created doubt and concern that a central heat pump water heater would work in this building and took repeated attempts of education and instruction at inspection for turnover. The solution was simply running 50 gallons through the system to charge the distribution lines. Once completed, the central heat pump water heater operated normally and read appropriate fixture temperatures. Industry education that covers how to inspect central heat pump water heater systems of unoccupied buildings is needed to ensure unnecessary inspection failures.

Recommended Next Steps

This project demonstrated the effectiveness of pre-packaged central heat pump water heater products as a decarbonization solution. In particular, this product tackles notoriously challenging market segments in multifamily buildings and retrofitting existing structures.

¹ ecosizer.ecotope.com/sizer



With some assistance, this product can be readily scaled into the broader market to aid in California's decarbonization goals.

Expanding the market reach of pre-packaged systems will require partnerships with local distributors. The WaterDrop model is available for purchase from plumbing supply wholesalers in California and is supported by a dedicated sales representative and distributor. Further marketing efforts should continue fostering the partnership with distributors rather than property owners. Installing contractors are ultimately the ones who drive the decision-making process and leverage existing relationships they have with distributors presenting a pathway to rapidly increase market demand.

Additional product refinements will allow for seamless integration into demand response programs. Development of an upgraded controller has begun, making system start up simpler and not requiring a factory start-up agent to travel to the site. This upgrade, available in later 2023, will also make the system operation visible in a cloud operation and add a CT 2045 Eco Port as a standard feature. It's important to note that this step of actual product availability would not have been possible without the Quick Start Grant funding.

Streamlining incentives is critical to scaling. Financial incentives are necessary for heat pump water heater competitiveness with gas boilers. Existing incentives, however, are complicated to navigate. The funding is often restricted geographically by utility territory based on storage, building type, and may have other contingencies, such as load shifting capabilities. Further, funding must be consistently and reliably available. Small Planet Supply has held conversations with various stakeholders to introduce the product line, but scaling the concept needs additional support.

Contractor education of small multifamily buildings is a necessary component. This project focused on the unique market of small multifamily buildings. Large buildings receive the skill and attention of project engineers, whereas small buildings have a limited budget for professional consultation. An educational campaign directed at the installation contractors that work on these smaller buildings would be effective in bringing immediate results. The ideal campaign partners would include the California Energy Commission, TECH Clean California stakeholders, utilities, and local plumbing wholesale supply.



This program is part of the TECH Quick Start Grants (QSG) program, designed to fund targeted, innovative projects that test approaches to overcoming market barriers to heat pump space and water heating adoption.

If you have questions about this report's findings or seek additional support assessing lessons learned for scaling project concepts, please contact the TECH Clean California Team at tech.info@energy-solutions.com.