BONNEVILLE POWER ADMINISTRATION

Emerging Technologies

WaterDrop Feasibility Study

March 2022

WaterDrop Feasibility Study

Prepared for
Karen Janowitz, Project Principal Investigator
Washington State University Energy Program
Under Contract to Bonneville Power Administration

Prepared by
Erik Turner, Evan Green, Jonathan Heller
Ecotope, Inc.

The following report was funded by the Bonneville Power Administration (BPA) to assess emerging technology topics that have the potential to increase energy efficiency. BPA is committed to identify, assess, and develop emerging technologies with significant potential for contributing to efficient use of electric power resources in the Northwest.

BPA does not endorse specific products or manufacturers. Any mention of a particular product or manufacturer should not be construed as an implied endorsement. The information, statements, representations, graphs, and data presented in these reports are provided by BPA as a public service. For more reports and background on BPA's efforts to "fill the pipeline" with emerging, energy-efficient technologies, visit the ET website at http://www.bpa.gov/energy/n/emerging_technology/.

Contents

Table of Figures iv
Acronyms iv
Executive Summary 1
Background 2
Market Landscape 2
Domestic Hot Water HPWH System Design 2
Purpose 2
Codes and Certifications 3
Codes 3
Federal Safe Drinking Water Act 4
Energy Code 4
Mechanical Code 4
Plumbing Code 4
Advanced Water Heater Specification 5
Electrical Code 5
Fire Code 5
System Components 6
Points of Connection 9
Cold Weather Package 9
Performance Assessment 9
Architecture 9
Engineering 10
Structural 10
Mechanical / Plumbing 10
Electrical 10
Plumbing 10
Controls 10
Owners 11
End Users 11
Cost and Constructability 11
Retrofit Feasibility 12
Maintenance and Service Assessment 12
Conclusions and Recommendations 12
Utility Recommendations 14
Applications Testing Topics for Investigation 14
Works Cited 15

Table of Figures

Figure 1. Multifamily energy savings with heat pump water heater 2
Figure 2. *WaterDrop* schematic simple 7
Figure 3. WaterDrop rendering showing interior (top) and exterior (bottom) 8

Table of Tables

Table 1. Temperature points 9

Acronyms

AHJ	Authority Having Jurisdiction (local / regional code enforcement body)
AHWS	Advanced Water Heating Specification
BPA	Bonneville Power Administration
CHPWH	Commercial Heat Pump Water Heater
COP	Coefficient of Performance
DHW	Domestic Hot Water
HPWH	Heat Pump Water Heater
IECC	International Energy Conservation Code
IMC	International Mechanical Code
IPC	International Plumbing Code
NEC	National Electrical Code
NFPA	National Fire Protection Agency
NSF	National Sanitation Foundation
OAT	Outdoor Air Temperature
OEESC	Oregon Energy Efficiency Specialty Code
SDWA	Safe Drinking Water Act
TIM	Technology Innovation Model
UPC	Uniform Plumbing Code
WSEC	Washington State Energy Code

Executive Summary

Domestic water heating is the largest single use of energy in multifamily new construction in the Northwest. The *WaterDrop*, built by Small Planet Supply with the SANCO2 heat pump at its core, will offer a fully packaged, energy efficient, cost effective and grid responsive option for heating domestic water that can help Bonneville meet its energy efficiency goals and address the electrical usage peaks identified in its resource plan[i].

This study is the first step in BPA's Technology Innovation Model (TIM) – assessing certifications, system components, performance, cost, constructability, and maintenance. While we have recommendations around documentation, standardization, and process to ensure the product successfully makes it to market, we believe the *WaterDrop* is ready to move on to Applications testing.

Codes and Certifications: No issues are foreseen for compliance with building code requirements. Small Planet Supply plans to provide the *WaterDrop* with an external electrical panel built in a UL shop, which will streamline electrical inspections.

Codes and Certifications:
Small Planet Supply should develop documentation showing the portion(s) of the product that will come with UL listing, and a plan to streamline plan review and inspections.

Performance: The performance of the heat pump and ancillary components have been showcased extensively in the marketplace. The novel skid-based delivery of the *WaterDrop* will provide this same performance in a single package.

Cost: Comparative price estimates to date have placed the *WaterDrop* at parity with a field-built system of similar size. Small Planet Supply intends for more aggressive pricing as manufacturing ramps up.

Constructability: The skid-mounted equipment should allow for a more predictable construction schedule as the entire hot water plant will be installed as a single product. This delivery method will allow more risk to be taken on by the manufacturer, thus alleviating concerns by contractors regarding implementing new technologies.

Maintenance: Regular maintenance includes clearing debris from evaporator coils on exterior units and clearing bag water filters within the primary skid. Small Planet Supply is still developing maintenance plans through its coordination with SANCO2.

The combination of design support from Small Planet Supply for nascent engineers together with the skid-based approach easing construction and coordination difficulties for contractors promises to provide a streamlined and proven pathway to increase the use of heat pump water heating for domestic water heating.

Background

Market Landscape

Domestic water heating is the largest single use of energy in multifamily new construction in the Northwest; responsible for 25 to 30 percent of the energy use of a typical apartment building. In new apartments, domestic water heating has an EUI of 8-10 kBtu/SF/yr. Figure 1 shows the typical market rate apartment energy end use EUI breakout.[ii]

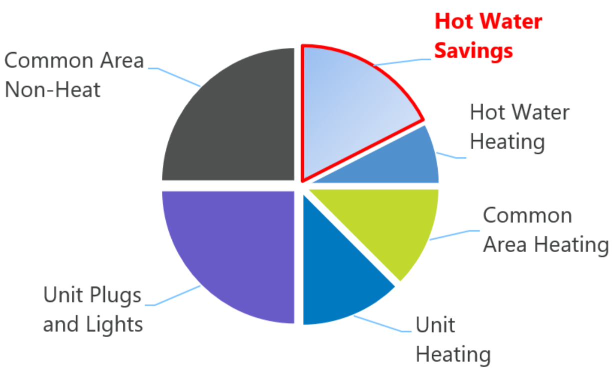

Figure 1. Multifamily energy savings with heat pump water heater

Water heating can be divided into two distinct loads: 1) the heating of cold city water entering the system and 2) temperature maintenance of circulating water. Approximately one-third of energy is used to maintain the water temperature in the distribution piping.

HPWHs have the potential to reduce the energy used for water heating by approximately a factor of three if properly designed. Figure 1 shows an energy use pie chart of a typical multifamily building and the savings that can be expected from a correctly designed and operated HPWH system. Heating domestic hot water (DHW) with central heat pumps can reduce the total energy usage controlled correctly, the 12-16 hour run period can avoid peak times and flatten overall grid load.

Domestic Hot Water HPWH System Design

HPWHs can be single-pass or multi-pass and come as a standalone unit or be integrated into a tank as a unitary system. Single-pass systems heat water in one pass and require a high-temperature lift to operate efficiently, whereas multi-pass units heat water in several passes with low lift and can accept warmer water temperatures.

The SANCO2 R-744 (CO_2) heat pumps which make up the heart of the *WaterDrop* product are small-scale single pass heat pump water heaters. To date, these heat pumps have been manifolded together using ad hoc controls in order to meet the demands of commercial buildings.

Purpose

This feasibility study is meant to access the fully packaged, skid based *WaterDrop* serving multifamily water heating needs in the Pacific Northwest efficiently.

This study focuses on the base design which was created for the first projects where this product is to be deployed. Small Planet Supply has been expanding upon this base system with various permutations of storage tank sizes, overall storage volume, number of heat pumps, and even heat-pump-only skids to be used with remote storage tank options. These design options are still being developed and are not discussed in length in this report.

This study is the first step in the TIM, which is designed to take a technology through a series of stage gates representing different areas of inquiry to ensure that the product can be safely and cost effectively applied in a manner that ensures performance and savings in the marketplace.

Key stage gates for the TIM include:

1) Feasibility Study
2) Applications Testing
3) Demonstration Project
4) Measurement and Verification (M&V)
5) Design Guidelines

Codes and Certifications

This section reviews the fully packaged *WaterDrop* systems compliance with federal, state, and local codes and standards (the components of the system have the necessary certifications and compliance). The Energy Code addresses operational efficiencies and controls; the Mechanical Code addresses allowable refrigerant charge and certification requirements; the Plumbing Code addresses condensate management and drinking-water quality standards; and the Electrical Code addresses the design of electrical connections to and within the skid.

A challenge for skid-mounted equipment is conformance with various codes to allow for approval in multiple jurisdictions without extensive customizations that would slow production and lead to longer production schedules. Skid-mounted equipment is common but is often provided in more simplified packages such as water pressure boost pumping or chemical water treatment. A domestic hot water plant is more complicated and requires careful attention such that the equipment will be acceptable for installation in a wide variety of locations.

The *WaterDrop* must comply with the following codes to be a viable product in the Northwest and California. This section identifies any unmet requirements and Small Planet Supply's responses to date.

Codes

FEDERAL LAW

- The Safe Drinking Water Act (SDWA) Section 1417

ENERGY CODE

- International Energy Conservation Code (IECC) (Includes Idaho and Montana)
- Washington State Energy Code (WSEC)
- Oregon Energy Efficiency Specialty Code (OEESC)
- Title 24 (in California)

MECHANICAL CODE

- International Mechanical Code (IMC)

PLUMBING CODE

- Uniform Plumbing Code (UPC)
- International Plumbing Code (IPC)

ELECTRICAL CODE

- National Fire Protection Agency (NFPA) 70 – National Electrical Code (NEC)

FIRE CODE

- NFPA 13 - Standard for the Installation of Sprinkler Systems

Federal Safe Drinking Water Act

The SDWA requires all products in contact with potable water be tested through NSF 372 to prove they are lead-free, meaning they contain less than 0.025% lead at wetted surfaces. All piping, equipment and ancillary equipment that will be in contact with potable water during normal operation of the *WaterDrop* have been tested and comply with NSF 372.

Energy Code

Minimum performance of water heating equipment is covered in table C404.2 of energy codes based on the IECC. Heat pump equipment with less than or equal to 24 amperes must be tested by DOE 10 CFR Part 430 and show compliance with table C404.2. The *WaterDrop* product amperage rating will depend on exact configuration, but at a minimum will have (4) heat pumps that would total 28.8 amperes. The *WaterDrop* would therefore not need to comply with table C404.2 requirements. Recirculation loop performance has also been introduced to some Energy Code requirements. Updated control strategies for the recirculation pump control and installation standards to help remove air from the piping system are among new requirements being introduced in Title 24. The *WaterDrop* features all the necessary sensors and controls capability to meet these requirements, but final verification of these sequences needs to be done in Applications Testing.

Mechanical Code

The *WaterDrop* must be UL certified to be accepted under the mechanical code by local Authorities Having Jurisdiction (AHJ). Small Planet Supply has opted to showcase UL certification by showing all *WaterDrop* components are UL certified. More detail about UL certification can be found in the Electrical Code section.

Refrigerant charges are also limited per IMC, which outlines requirements for maximum amount of refrigerant that could leak into a given sized room volume. The *WaterDrop* will need to be located either on the exterior where these requirements are not applicable, or within a very large interior area such as a parking garage, where the concentration of refrigerant will not pose any compliance issues. These locations are where designers would already be looking to locate heat pump equipment, therefore refrigerant charge issues for code compliance will not be an issue.

Plumbing Code

The UPC has two requirements the *WaterDrop* must address. The first is UPC 603.5.4, which requires double-wall heat exchangers to protect potable water from the heat transfer medium by providing a space between the two walls that is vented to the atmosphere. This is applicable only to the SANCO2 heat pump unit's gas cooler, which has connections for both refrigerant (R-744, CO_2) and potable drinking water – and is compliant with the requirement.

The UPC also requires NSF certification for products in contact with potable water – UPC sections 415.1, 417.1, 604.1, 604.9, 606.1, 607.2, and 608.2. NSF is used to show the product is lead-free and meets the Federal SDWA Section 1417. While all applicable components that come into contact with potable water will be NSF certified, AHJs might look for certification of the *WaterDrop* itself since it is being marketed as a single product. Small Planet Supply should consider obtaining documentation showcasing the NSF certification of all its components and provide this information, along with technical documents, for the *WaterDrop* on its website.

Advanced Water Heater Specification

The Advanced Water Heating Specification (AWHS) v8.0 (https://neea.org/our-work/advanced-water-heating-specification) is a draft reference tool that lays out proven pathways and recommendations for successful residential and commercial HPWH system installations. Version 8 is still in draft form, but it is anticipated that the AWHS will include the *WaterDrop* on the Qualified Products List and that it will receive a Tier 2 rating (with a System COP about 0.5 higher than the entry-level Tier 1 systems). A Tier 2 rating in the AWHS may allow a smoother pathway for acceptance in future codes and programs that may require compliance with the AWHS.

Electrical Code

The electrical code dictates requirements for conduit routing, wire sizing, panel locations and circuiting of equipment within the skid(s), which the *WaterDrop* will meet.

Small Planet Supply plans to have the single point of connection high voltage (208V or 480V/ 3ph) electrical service third-party inspected at the factory and carry a UL certification. Field wiring will need to be performed from this panel to all the loads within the skid. This field wiring will be subject to AHJ review, as is typical with all other field-wiring on a construction project. This strategy has been coordinated with and accepted by the AHJ reviewing the first *WaterDrop* project that has gone through permit review.

Field inspection of all field wiring within the skid adds coordination tasks during design work, and complexity to the install. Therefore, Ecotope recommends Small Planet Supply standardizes their equipment selection for the *WaterDrop* and investigates cost-effective ways to increase the scope of the UL listing such that the entire skid can be delivered pre-wired and with a UL rating.

Fire Code

The main compliance question for the *WaterDrop* in reference to fire codes is whether the interior of the skid enclosures will need to be sprinkled. NFPA 13 requires that mechanical rooms have sprinklers, but they aren't required within equipment that isn't intended for occupancy.[1] The key question here is whether the *WaterDrop* is more similar to a mechanical room, since it contains equipment that typically get installed within one, or if it is more similar to a piece of mechanical equipment due to its size and the fact that it's not occupiable. Initial discussions with code officials have indicated that the *WaterDrop* more closely aligns with the requirements of mechanical equipment and will therefore not need to be sprinkled. The fire protection engineer should confirm this with local AHJs to avoid issues during construction.

System Components

System Component Assessment identifies the equipment needed for a complete water heating system deployment.

The *WaterDrop* utilizes single-pass SANCO2 heat pumps, storage tanks piped in series, and a swing tank for temperature maintenance. The SANCO2 heat pumps utilize CO2 as the refrigerant in a transcritical refrigeration cycle. It efficiently heats incoming city water (40 °F to 70 °F) to a hot storage water temperature (130 °F to 160 °F). As the water recirculates through the building, the hot water piping loses heat to its surroundings and the water cools. If water is sent to the building at 125 °F, it may return at a temperature closer to 115 °F. Using a swing tank to efficiently reheat this water allows the primary single-pass HPWH to only heat incoming city water to a storage temperature above the building's hot water setpoint temperature. The standard design is discussed in detail in the section below.

As shown in Figure 2, the standard *WaterDrop* offering features two skids, each containing four single-pass SANCO2 Gen4 heat pump hot water heaters mounted on the exterior. All points of connection (POC) interface with the primary skid. There are separate conduit connections for power and communications and three pipe connections: (Cold Water, Hot Water, Hot Water Circulation).

Additionally, each skid will have a single combined condensate drain adjacent to the heat pump rack.

[1] Chapter 8 Section 8.1.1 states that *"Sprinklers shall not be required to be installed within electrical equipment, mechanical equipment, or air handling units not intended for occupancy."*

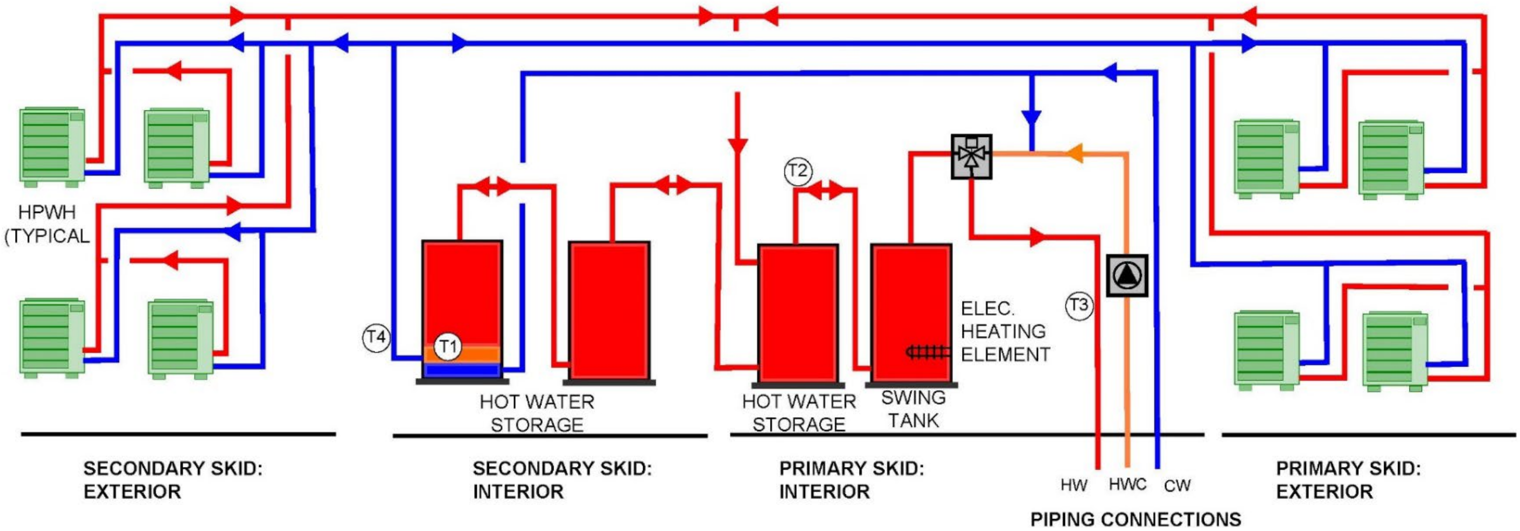

Figure 2. *WaterDrop* schematic simple

The primary skid (Figure 3, left) contains a 285-gallon storage tank, a 120-gallon “swing tank”, the thermostatic mixing valve, controls enclosure, recirculation pump, water filter, and expansion tank. Expansion tanks are sized to absorb the pressure of expanding water as it is heated. The expansion tank on the primary skid is sized for the expansion of distribution piping throughout the building and the storage volume within the primary skid. An electrical panel is located on the exterior and feeds all loads within the primary and any secondary skids. This primary skid is sized to provide DHW for approximately 50 people.

The secondary skid (see Figure 3, right) contains two 285-gallon storage tanks and an expansion tank sized for the expansion of the storage in the secondary skid. The secondary skid is sized to provide added capacity for approximately 50 more occupants.

Piping connections between the skids consist of two 1” heat pump supply and return headers, one 2” cold water make up, and a 2” pipe that joins the storage tanks together in the series configuration. These piping connections are provided via flanged connection, which ships with blanks installed and will require a plumber to connect them with flexible connectors. Three 1” flexible electrical conduits will feed power and control to the secondary skid and will also need to be field installed by an electrician. Small Planet should develop standard details showing these connections and clearly label what scope is required of the installing contractors to avoid change orders in the field.

The controls enclosure in the primary skid can receive signals from flow meters, current transducers, and temperature sensors. Sensors noted as “required” are necessary for the system to operate and will be provided as part of the *WaterDrop*. The additional sensors can be used for additional alarming or measurement and verification purposes.

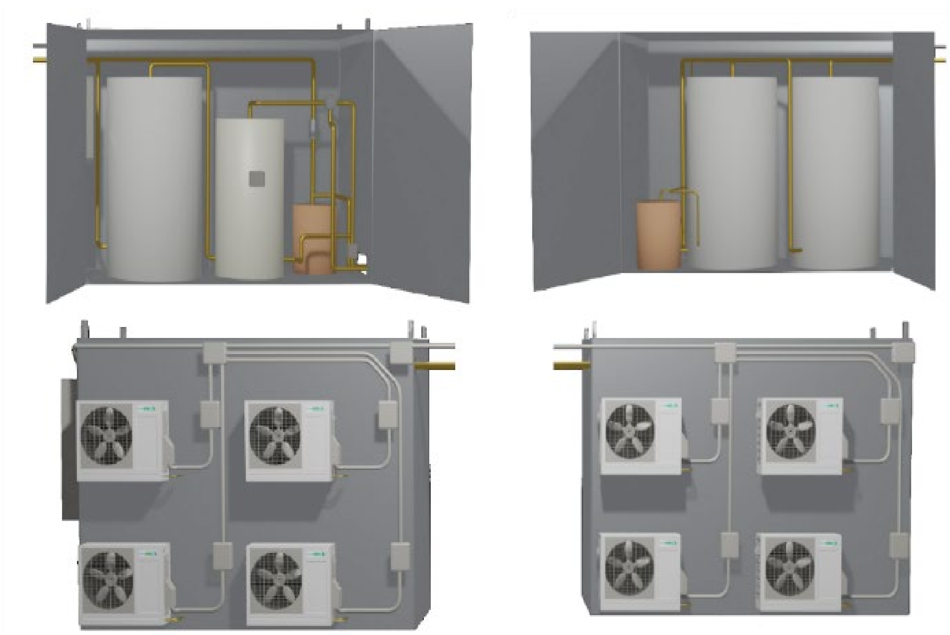

Figure 3. WaterDrop rendering showing interior (top) and exterior (bottom)

Table 1. Temperature points

Sensor #	Service	Required	Optional
T-0	Incoming cold water temperature		
T-1	ST-1 tank temperature	x	
T-2	ST-2 tank temperature		x
T-3	ST-3 tank temperature		x
T-4	Heat pump return temperature	x	
T-5	Primary Storage Outlet temperature		x
T-6	Swing Tank Outlet temperature		x
T-7	Outgoing hot water temperature	x	
T-8	Recirculation return water temperature	x	

Points of Connection

Main building connections will be made via side connections out of the *WaterDrop* to make it easier for the plumbing contractor to connect the building piping to the wet points of connection: Cold Water, Hot Water and Hot Water Circulation. Experience with other skid-based equipment has showcased the importance of manufacturer-provided details for all points of connection to ensure easy coordination and reduce field change orders. Small Planet Supply should provide details for the wet points of connection per plant, electrical power feed per plant, condensate discharge per skid and communication conduit per plant. Details should also be developed for all connections between skids.

Cold Weather Package

As with any heat pump product, it's important to adjust for colder climates in which the outdoor coil can freeze. Small Planet Supply should include a "cold weather package" that would provide heat trace powered from the *WaterDrop*'s main electrical panel. Control set-points should be verified to ensure that heat-trace is only activated when it is required.

Performance Assessment

The following sections will confirm the *WaterDrop* will have adequate performance to gain acceptance from designers and users.

Architecture

The *WaterDrop*'s compact and predictable package will streamline architectural coordination by providing a more precise estimate of space required for it within the building. Especially in urban locations, locations for mechanical equipment at grade is difficult, and therefore the best location for equipment of the *WaterDrop*'s scale will be an enclosed parking garage or on the roof. Rooftop installations may require mechanical screening, which will add cost.

Engineering

Structural

Utilizing a skid-based product with predictable and well-documented equipment lists and weights will help right-size structural components early on and avoid pain points later in the design process. The Primary Skid weighs roughly 5,000 pounds dry and 8,500 pounds when full of water. Due to increased volume of water storage, the Secondary Skid weighs approximately 4,700 pounds dry and over 9,500 pounds when full. Small Planet Supply should develop details to completely describe the requirements for pad or curbs, structural supports, and anchorage.

Mechanical / Plumbing

The *WaterDrop* dramatically reduces the need for specialized knowledge Small Planet Supply will be able to size the heat pump capacity, storage, and recirculation pump to meet the domestic hot water demands of the building based on number of occupants and type of development, which should lower temperature maintenance losses.

Electrical

Electrical requirements will depend on the number of heat pumps employed, as well as the swing tank size. Both factors are driven by the building size and usage type. Small Planet will provide electrical requirements to the designer at the time of equipment selection, which will accommodate 208 or 480 V, 3-phase power. The *WaterDrop* will have a single power connection to a service panel that distributes power to all the individual components on the skid.

Since the *WaterDrop* may require field wiring between its internal components to satisfy local AHJ's, wire sizing and installation scope should be coordinated early on with the electrical designer and installer. Load requirements will be provided by Small Planet Supply at the time of equipment sizing.

Plumbing

By designing and pre-packaging all the DHW plumbing components, Small Planet Supply is making it easy for plumbing designers and installers to put in a heat pump hot water system. The designer will no longer need to worry about the design of the interconnecting piping between storage tanks and heat pumps, nor the controls essential for successful and reliable heat pump operation. Design resources will now shift to correctly sizing the equipment by considering such things as peak building flow rate, occupancy, and usage patterns, and examining the requirements of the building outside of the heat pump water heater plant, such as the distribution piping. The *WaterDrop* will have a single point of connection to drain condensate that includes freeze protection; however, freeze protection downstream must be supplied by the plumbing installer to prevent freezing of field-installed condensate pipes when exposed to freezing conditions.

Controls

The *WaterDrop* will have an on-board controller that carries out a factoryspecified sequence of operation to ensure reliable HPWH operation that satisfies the building load. In the event of a HPWH failure, the on-board controller will transmit external alarm notifications to the local building management system, or through a local internet connection.

More information about the controller and its specifications can be found in the *ECO2 Heat Pump Water Heater Controller: Feasibility Study & Applications Testing* report due out later in March 2022.

Owners

Building owners want equipment with high reliability, low upfront cost, and reasonable, predictable cost of maintenance. The *WaterDrop* is expected to ensure consistently reliable operation because the whole system is factory-built and designed for optimal HPWH operation. Post-installation factory startup, which is required by Small Planet Supply, will ensure the system was installed per the manufacturer's requirements. The upfront cost of the *WaterDrop* is similar to a custom engineered HPWH system. Small Planet will provide maintenance recommendations but has not fully developed a national network of technicians to maintain and repair the *WaterDrop*.

End Users

End users are concerned about the consistent delivery of hot water. The *WaterDrop* will allow for greater reliability of hot water delivery because it will be properly sized and have redundancy. Small Planet Supply can provide sizing with redundancy in mind and size the plant for "n+1" number of HPWH units.

Cost and Constructability

The Cost and Construction Assessment confirms challenges associated with acquiring and installing the product.

The *WaterDrop* will be assembled in Small Planet Supply's factory located in Tumwater, Washington using stocked components. They have not yet built the first *WaterDrop,* but they have worked closely with Ecotope to design its first iteration for installation at 4 multi-family projects in Menlo Park, CA utilizing a total of 17 *WaterDrop*s. These projects are set to begin construction in 2022. Small Planet Supply has not yet finalized the sales network to bring the *WaterDrop* to market. Initially, Small Planet Supply is targeting a lead time of 4-5 months, with a goal to decrease this to 3 months after a year of production.

The *WaterDrop* will be shipped to the jobsite via flatbed truck and will require equipment with payload capacity greater than 5,000 lb for placement. No over height, wide load or special shipping considerations need to be made, as it can be shipped via standard freight. Since it is a single assembly, coordination must be made to transport the *WaterDrop* to its final installation location. There may be clearance issues, for example, if it must be transported through mechanical room doors or through a low-ceiling parking garage.

Once in place, installation involves securing it to the ground via steel tabs and connecting the electrical and plumbing. Due to its height, the need for seismic restraints will need coordinating with local jurisdictions.

Retrofit Feasibility

The *WaterDrop* is a good candidate for retrofit, but several considerations must be made for its success. It consumes much more power than a conventional gas water heater, thus in retrofit applications electrical supply panels may need to be up sized when replacing gas water heating systems. If the original system is electric resistance, this is not a concern. More space is often required for the installation of the *WaterDrop* because the location of its components is not flexible. One can picture the *WaterDrop* as a large box that is carried in and placed in the middle of the mechanical room, compared to several small boxes that can be placed around the room to accommodate existing equipment. Large water storage volume in the *WaterDrop* means a relatively small area must accommodate a lot of weight. Installation outside, on grade could mitigate a lot of the challenges associated with a retrofit installation of the *WaterDrop*. It is designed for outdoor use, and the SANCO2 HPWH's can operate outdoors down to -14°F.

Maintenance and Service Assessment

WaterDrop will require a factory startup service to ensure proper installation, performed by Small Planet Supply in the near future. During time of startup, they will offer free maintenance personnel training. Their extended service network for maintenance and startup is not yet developed. Small Planet Supply will offer a six-year warranty on all the components of the WaterDrop except the swing tank, which will carry a three-year warranty. This level of warranty is likely to comply with Advanced Water Heating Specification requirements for commercial systems. Final version of the specification is still being written at time of writing of this report. The WaterDrop will require the same maintenance as any other HPWH system. Regular maintenance is required on all the components, with a list of maintenance requirements provided by Small Planet. The WaterDrop sales channels are not yet developed, so they have not coordinated maintenance contracts with regional representatives. If there are performance issues with the WaterDrop, Small Planet Supply will provide remote troubleshooting.

Conclusions and Recommendations

The WaterDrop will provide the gains in performance of a heat pump hot water heating plant with the ease of design and installation of a packaged system. Small Planet Supply's support during design efforts will help engage design teams who don't have the specific knowledge or tools required to provide a fully functional HPWH design. Packaging of an entire hot water plant within a skid will ease construction schedule coordination and allow for more predictable and verifiable operation. The WaterDrop will give building owners, contractors, and utility representatives confidence that the promise of highly efficient hot water production will be realized.

The following recommendations are being made in order to ease the widespread market adoption of the WaterDrop.

Recommendation 1:
Small Planet Supply should communicate clearly in its documentation which portions of the *WaterDrop* will come UL listed and investigate ways to expand the scope of the UL listing to decrease the design phase coordination required between plumbing and electrical designers, and to increase the amount of wiring that can be provided at the factory.

Response:
Small Planet Supply states that "[they] will start with base UL process (as described in report) and will look at UL for the skid [as a package] once volume of production is known".

Recommendation 2:
Small Planet Supply should develop standard connection details for all the points of connection:

PLUMBING

- (4) plumbing main points of connection (HW, HWC, CW, Condensate)
- (3) plumbing points of connection for joining of skids (HPWH supply, HPWH return, CW, Storage tank connection)

ELECTRICAL

- (1) Main electrical connection (208V or 480V, 3ph; conduit)
- Distribution electrical feed between skids (208V/480V, 3ph; conduit)

COMMUNICATIONS

- (1) Main communications line (conduit)
- (1) Distribution communications line between skids (conduit)

STRUCTURAL

- Pad / Curb detail
- Anchorage
- Lift points

Recommendation 3:
Development of a standard cold-weather package to protect against damage in severe conditions.

Response:
Small Planet Supply states that "*[they] are developing a cold climate package as an upgrade. [Cold weather package] to include integrated pan heaters and heat trace*".

Recommendation 4:
Small Planet Supply should formalize maintenance capabilities.

Response:
Small Planet Supply states that "*[they] are [developing the process of employing*

SANCO2 sales reps in a cost-effective manner]".

Recommendation 5:
Small Planet Supply should continue to develop standard product documentation to describe the capabilities of all design options of the *WaterDrop*. Install, operation and maintenance (IOM) documentation should be created for the *WaterDrop* and all its constituent parts.

Response:
Small Planet Supply states that this work is underway.

Utility Recommendations

The *WaterDrop* has enormous potential to provide energy savings by helping introduce heat pump water heating solutions via a well-designed packaged system. It is recommended the product move forward in the TIM to Application Testing. Typically, Application Testing is undertaken prior to field demonstration, but due to the size of the equipment, and the fact that the *WaterDrop* is a combination of proven pieces in a single package, the Application Testing is likely to occur at one of the early sites where the product is already being carried as basis of design equipment. A preliminary list of concerns to be addressed during applications testing is below. Applications Testing timeline is driven by project schedules and will be either late 2022 or early 2023.

Applications Testing Topics for Investigation

A subset of the following topics will be investigated during applications testing.

- Onboard M&V and calculation of system COP.
- Ability of thermal storage system to remain stratified.
- Error codes and alarming provided by equipment through controller and broadcast out to listed email/SMS.
- Ability of the equipment to log data. Can the equipment provide accurate internal data logging that can be used for diagnostic and performance verification?

Works Cited

[i] 2020 Resource Program, Pg. (15-18)
https://www.bpa.gov/p/Power-Contracts/Resource-Program/Documents/2018%20Resource%20Program.pdf

[ii] Heller, Jonathan, K. Geraghty, and S. Oram. *Multifamily Billing Analysis: New Mid-rise Buildings in Seattle*. December 2009. Prepared by Ecotope for Seattle Department of Planning and Development.