CG-2575

A Simplified Utility Program to Fight Climate Change

Prepared for:

Tacoma Power

March 27, 2023

Utility Name and Address

Tacoma Power
3628 South 35th Street
Tacoma, WA 98409

Utility Description

Tacoma Power is a municipal electric utility that has been operating since 1893. Tacoma Power currently delivers power to an area of approximately 180 square miles with 2,387 miles of transmission and distribution lines to 183,524 customers, including 163,870 residential customers, served by 783 employees. Tacoma Power generates 46% of its electricity from eight hydroelectric facilities and acquires nearly all of the remaining power (53%) from the Bonneville Power Administration, which is almost entirely hydroelectric. In 2021, Tacoma Power delivered approximately 6,510,000 MWh to our customers, including 1,939,000 MWH to residential customers, 308,000 MWh to commercial customers, and 1,889,000 MWh to industrial customers. In addition, 97% of our power is carbon-free. Tacoma Power is a regional Balancing Authority and joined the western Energy Imbalance Market in March 2022.

Tacoma Power is part of Tacoma Public Utilities, including Tacoma Water, which provides water to approximately the same service territory as Tacoma Power, and Tacoma Rail, one of the busiest short-line railroads in the country.

Key Personnel & Telephone

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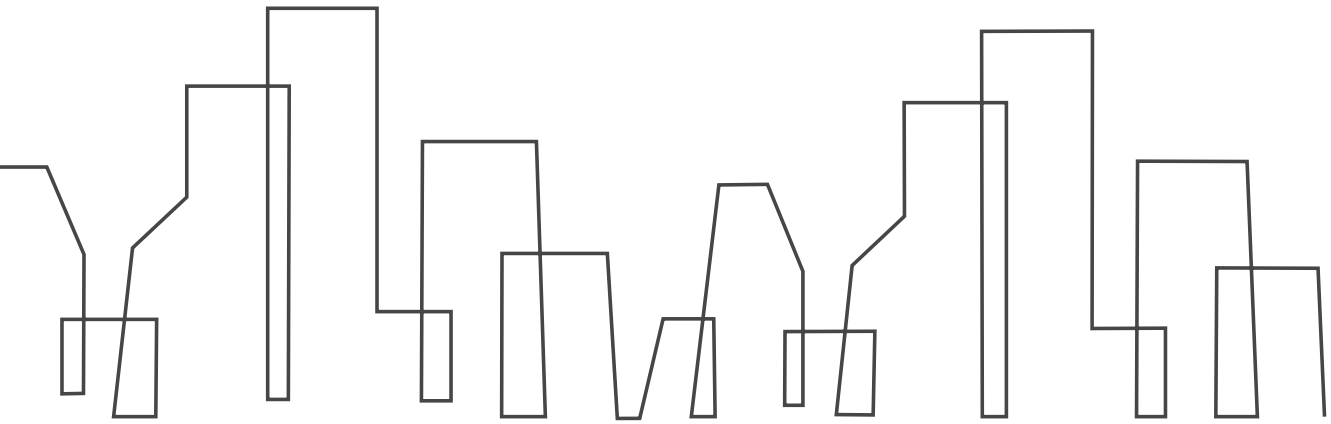


Acknowledgments

The project team extends our thanks to this project's in-kind contributors:

- Jack Zeiger, Energy Conservation Engineer, Tacoma Power
- Robert Weber, Engineering Technical Lead, Bonneville Power Administration
- Christian Douglas, Ptarmigan Consulting (staffing the Regional Technical Forum)

These contributors dedicated more than a year to this effort, significantly improving the generalizability of this project's tools and deliverables. Additionally, this project completes another step toward achieving the strategic market vision for commercial heat pump water heaters, which could not exist without the ongoing support of the Northwest Energy Efficiency Alliance, Bonneville Power Administration, and the Ecotope project team.

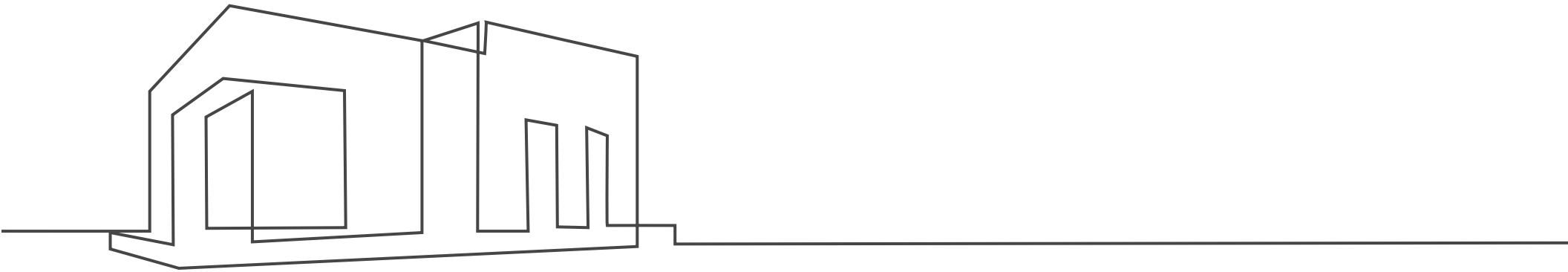
Terms

DHW Usage: Domestic hot water – the amount consumed by the building and its occupants in gallons.

HPWH system: Heat Pump Water Heater – A DHW heating system that uses a heat pump water heater to heat the DHW.

SysCOP: System COP – the coefficient of performance for the entire HPWH system – a measure of how efficiently the heat pump, temperature maintenance system, pumps, circulation losses, and other system components can heat water. It is calculated by dividing the total useful output energy by the total input energy of the entire HPWH system. A higher SysCOP means lower energy consumption and lower operating costs.

TM Heating: Temperature Maintenance Heating-- the heat required to compensate for heat loss in the DHW circulation loop, often a dedicated heater in an HPWH system.



General Overview

Addressing the energy used to heat domestic hot water in the multifamily sector represents an opportunity for an outsized impact on overall energy use. Multifamily domestic hot water (DHW) accounts for a significant portion of total building load – between 25 to 30% of multifamily building end-use energy consumption and a substantial share of daily peak energy use. Daily peak residential hot water loads tend to align with critical utility morning and evening load periods. Additionally, over 75% of all US commercial energy use for DHW production is from four building types: multifamily, food service, grocery, and lodging[1] . Within these four sectors, multifamily buildings represent the most significant single sector for DHW loads, representing over 30% of commercial sector DHW energy use. Converting this sector to central heat pump water heating technologies can significantly reduce total consumption, with feasible reductions of up to 17% of total multifamily building energy use.

Over the past decade, significant progress has been made in developing central heat pump water heating (HPWH) technologies in the market and in developing tools and standards to guide the deployment of this technology. This development has reached a point with this project that provides utilities with an opportunity to deploy a simplified incentive program based on validated performance tools. This program is an alternative to programs that rely on custom analyses for every central HPWH project, developing central HPWH programs that may or may not align with established standards, providing incentives based on appliance efficiency only, or simply choosing to not incentivize central HPWH installations. This project leverages and expands upon several existing standardization and tool development efforts and has developed several new tools to support a reliable efficiency measure framework and savings calculation tool. This standardized approach can deliver predictable savings and a clear program framework for deploying a utility-scale central HPWH incentive program for multifamily buildings.

The modeling and evaluation tools employed in developing this program are recognized as the emerging industry standard in a rapidly evolving marketplace. The Ecosim research tool is a modeling protocol initially developed to evaluate California code compliance strategies and overall system performance. The tool has been subsequently deployed to support the development of system performance predictions for a series of standardized system configurations captured in the Advanced Water Heating Specification (AWHS) and a published Qualified Product List (QPL). The QPL identifies specific system configurations submitted by manufacturers that have been reviewed and verified. Initially, co-funding to support a public release of the Ecosim tool was anticipated during this project, but the co-funding and subsequent release of the Ecosim tool has been delayed. The development of the QPL represents an alternative approach to leverage the functionality of the Ecosim tool to provide standardized system efficiencies (SysCOPs) that form the basis of the incentive program described below. The standardized approach presented in this program provides a mechanism to deploy a simplified incentive program across a wide swath of multifamily project installations. The approach also supports a transition from component-focused custom-designed systems to standardized, fully integrated, and documented central HPWH systems.

1 N. Fernandez, "Impacts of Commercial Building Controls on Energy Savings and Peak Load Reduction," PNNL-25985, 2017, 25985.

General Overview

This project achieved its goals to develop a straightforward utility incentive program for central HPWHs that can be immediately deployed using the tools developed all or in part by the American Public Power Association's Demonstration of Energy & Efficiency Developments funding:

1. The central HPWH Qualified Products List and standardized data collection methodology (**Appendix C**)
2. The central HPWH Performance and Incentive Tool
3. Project Screening and Selection Guidelines for Existing Buildings
4. Utility Program Guidelines

A secondary goal emerged after this project launched: to prepare this measure for review and acceptance by the Pacific Northwest Regional Technical Forum (RTF). The RTF provides standardized incentive calculations, program development, and review for utilities in the Pacific Northwest. The initial meetings for this step in the process have been set, and the project team expects the measure to be adopted as a pre-approved RTF measure in 2023.

Purpose and Applicability

Central HPWHs represent substantial energy savings potential. However, the potential savings from these complex systems can vary broadly without a systems approach to manufacturing, design standardization, energy savings calculations, and load management benefits. This project expands on several existing standardization and tool development efforts to develop a reliable framework and savings calculation tool to deploy a utility-scale central HPWH program.

Energy to supply domestic hot water (DHW) represents 25-30% of the total energy use in typical multifamily buildings. It is the single largest energy end-use in multifamily buildings and a strong candidate for significant savings. Heat pump water heating technologies represent an opportunity to significantly reduce the energy use associated with DHW generation, with reductions of as much as 17% of total building energy use possible. Additionally, over 75% of all commercial energy use for domestic hot water production in the United States is from four building types: multifamily, food service, grocery, and lodging[2] , as shown in Figure 1. Within these four sectors, multifamily buildings represent the most significant single sector for DHW loads, representing over 30% of commercial sector DHW energy use.

In the Pacific Northwest, building characteristics data suggests that in the existing building sector, less than 20% of multifamily buildings currently have central hot water systems for DHW. However, roughly 50% of multifamily buildings nationally have central water heating systems. Few of those buildings have installed heat pumps for this load, making this end-use a significant target for utility programs to deliver efficiency and reduce load. Central HPWHs offer a compelling strategy to reduce overall energy use and peak loads and support emission reduction in multifamily projects. APPA member utilities may use the tools produced by this project to deploy a reliable, utility-scale multifamily central HPWH program.

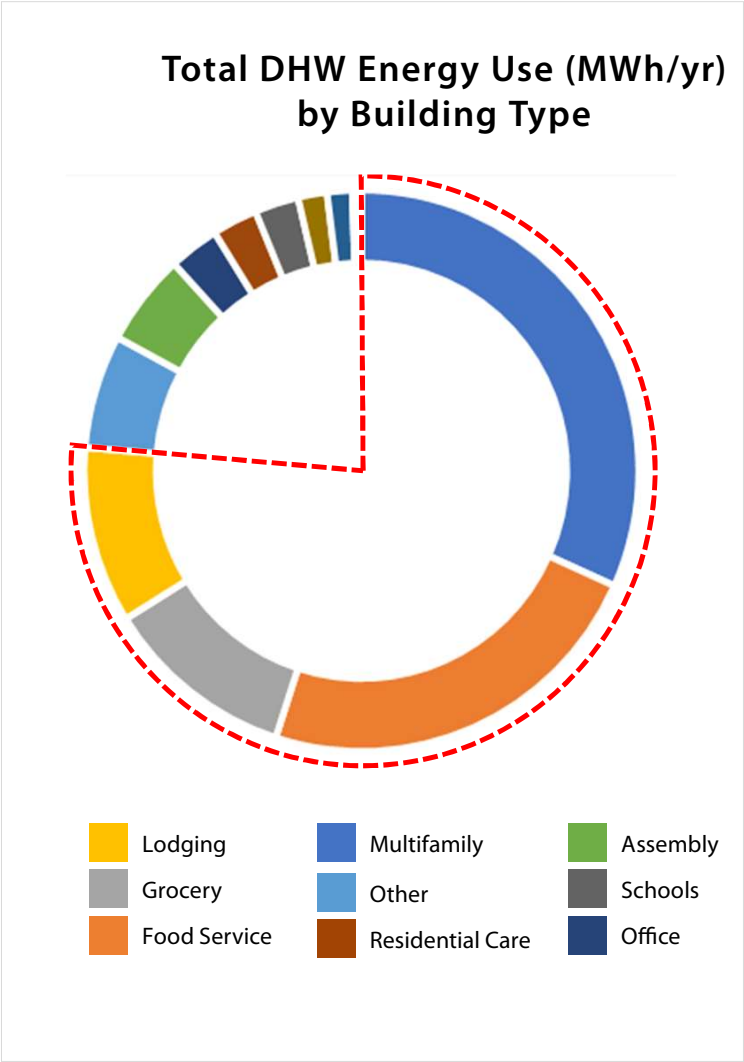


Figure 1: Domestic hot water energy end-use by building type in the United States[2]

2 N. Fernandez, "Impacts of Commercial Building Controls on Energy Savings and Peak Load Reduction," PNNL-25985, 2017, 25985.

Project Description

Over the past decade, significant advances have been made in heat pump water heating technologies. As a result, central HPWH systems are beginning to find traction in this marketplace. Over the same period, Ecotope has worked with utilities, manufacturers, developers, and state agencies to help develop effective design strategies, tools, and performance standards to support broad market adoption of this technology. Ecotope has worked with most manufacturers with products on the market today, designed over 90 central HPWH systems for multifamily buildings, and deployed monitoring and evaluation protocols on dozens of these projects. Governments, utilities, NGOs, developers, and engineers recognize the significant market signals indicating that central HPWH technology is ready for broad adoption in the marketplace and represents an excellent opportunity to develop standardized utility program offerings. The Northwest Energy Efficiency Alliance (NEEA) has committed to a regional goal of attaining 30% market share for HPWHs by 2030 and several specific outcomes to which this project directly contributes[3] , including:

- 60,000 HPWHs sold in the Northwest
- Four product tiers added to the Advanced Water Heating Specification Qualified Products List
- Packaged system HPWH products offered by 100% of HPWH manufacturers

The American Public Power Association's (APPA) Demonstration of Energy & Efficiency Developments (DEED) grant has allowed us to develop a program outline and technical tools to support the deployment of a utility efficiency program offering. This program incentivizes the design and installation of highly efficient central HPWHs to serve multifamily building DHW loads. The program we have developed leverages a number of key tools and resources that Ecotope has already developed with utility and program clients and builds several new tools to directly support utility incentive calculations and project selection criteria in support of program deployment.

The following introduces the tools that were leveraged or built as the primary products of this project; they are then described in detail in the *Results to Date* section.

- **HPWH qualified products list (QPL)[4] and Product Assessment Data Sheet (PADS).** A catalog of central HPWHs, provided by manufacturers via a standardized data request form and analysis protocol established in the PADS. The PADS also provides a standardized protocol for manufacturers to engage with utility program providers via the QPL (a copy of the PADS can be found in **Appendix C**). The QPL provides pre-qualified products and design configurations with predictable performance outcomes, as modeled by Ecosim. In addition, the QPL categorizes the pre-qualified central HPWHs into the four AWHS performance tiers. The QPL process was developed by Ecotope with additional funding from BPA, NEEA, and other utilities and has been leveraged to support program development in this project.

3 "Heat Pump Water Heaters," Regional Energy Efficiency Office, Northwest Energy Efficiency Alliance, accessed March 7, 2023, https://neea.org/success-stories/heat-pump-water-heaters.

4 "Commercial Heat Pump Water Heater Qualified Products List" (Northwest Energy Efficiency Alliance, December 1, 2022), https://neea.org/resources/commercial-hpwh-qualified-products-list.

Project Description

- **Central HPWH Performance and Incentive Tool.** A simple energy savings calculator and project guidance tool with customizable program options and minimal project-owner inputs. This tool accurately produces projected annual energy savings (kWh/yr.) based on the total number of apartments by type (e.g., X number of studios, 1-beds, 2-beds, etc.) to deduce total annual DHW consumption. The tool bases its calculation on a survey and analysis of annual DHW consumption from actual occupancies in California, which incorporate the natural vacancy rates of multifamily dwellings. It serves as the basis of utility program savings and incentive calculations using individual project data and standardized performance data from Ecosim and the QPL.

- **Project Screening and Selection Guidelines for Existing Buildings.** A set of considerations to help program implementers or other utility staff identify good candidate projects for central HPWH retrofits and screen out projects with significant challenges or complications.

- **Utility Program Guidelines.** The framework that explains the implementation of a full-service central HPWH incentive program for multifamily buildings for any utility.

Ecotope is pleased to present this as a comprehensive toolset and documentation to support deploying a prescriptive central HPWH incentive program.

Results to Date

A key aspect of this program is the recognition that central HPWH systems represent a relatively complex set of individual components that function together to deliver a total system efficiency that the efficiency ratings of individual components cannot predict in isolation. Central HPWH systems are configurations of heat pump appliances, storage tanks, a temperature maintenance and distribution system, and associated valves, pumps, and controls that together comprise a complete DHW system in multifamily buildings. Recognizing that the efficiency of these systems is dependent on how well these components are integrated is a fundamental element of an effective central HPWH incentive program.

With strategic collaborators Bonneville Power Administration (BPA), the California Energy Commission (CEC), Northwest Energy Efficiency Alliance (NEEA), and individual utilities, Ecotope has developed tools and metrics to define and determine a system COP (SysCOP), the key efficiency factor, which incorporates all energy inputs and losses for entire central HPWH systems. The SysCOP conforms to standardized design criteria and performance specifications and, together with the tools that inform the metric, form the basis of this program design. The tools we have leveraged in this project include the following:

- The Advanced Water Heater Specification v8.0 (AWHS 8.0)[5]. A set of specifications for system configurations with predictable performance characteristics that guide manufacturers and market actors interested in developing heat pump water heating products capable of high energy performance and user satisfaction in various climates. Additionally, the AWHS provides a robust set of typical system designs and configurations to act as a basis of design for engineering applications. Finally, the AWHS defines an easily referenced set of tiered SysCOP performance levels across system designs, component types, configurations, and climate zones.

- Ecosizer[6]. A tool for sizing HPWH-based central water heating systems in multifamily buildings that helps designers and program implementers identify appropriate system capacity based on building occupancy or the number of apartments. Ecosizer uses multiple heating capacity and storage sizing criteria that adapts to local codes, design standards, and temperature maintenance configurations – and allows users to balance storage and heating capacity where designs are subject to physical building constraints. Finally, as grid-enabled and interactive systems increase in importance and value, Ecosizer can account for user-selected load shift criteria.

- Ecosim Research Tool (Ecosim). Ecotope developed a standalone energy analysis tool that provides a predicted SysCOP for central HPWH systems for various design choices. Initially created for CEC Title 24 compliance, it has also been deployed to predict the sensitivity of SysCOPs as a function of significant variables, such as source water temperature and fixture flows. Importantly, this sensitivity analysis was used to verify the calculation methodology used in the Central HPWH Performance and Incentive Tool (described below). Further development of this tool will allow utility programs to predict SysCOPs for custom HPWH measures.

5 "Advanced Water Heating Specification Version 8.0" (Northwest Energy Efficiency Alliance, March 1, 2022), https://neea.org/img/documents/Advanced-Water-Heating-Specification.pdf.

6 "Ecosizer," Engineering Tool, Ecosizer, accessed March 6, 2023, https://ecosizer.ecotope.com/.

Results to Date

Together these tools provide a standard for performance calculations that can form the basis of a prescriptive utility incentive program. Refining and expanding on these products, this project developed or contributed to the following tools and guidelines as the basis of a repeatable utility incentive program.

Qualified Products List

In collaboration with NEEA and BPA, and with the support of this project, Ecotope developed a data collection method in partnership with several manufacturers: the PADS and QPL framework. This framework ensures system designs align with AWHS 8.0 and ranks system performance across four tiers. Building on the previous body of central HPWH market transformation work, the project team used Ecosim to model the performance of four initial system designs. These designs populated the QPL across performance tiers and International Energy Conservation Code (IECC) climate zones (simplified as hot, mild, cold, and very cold).

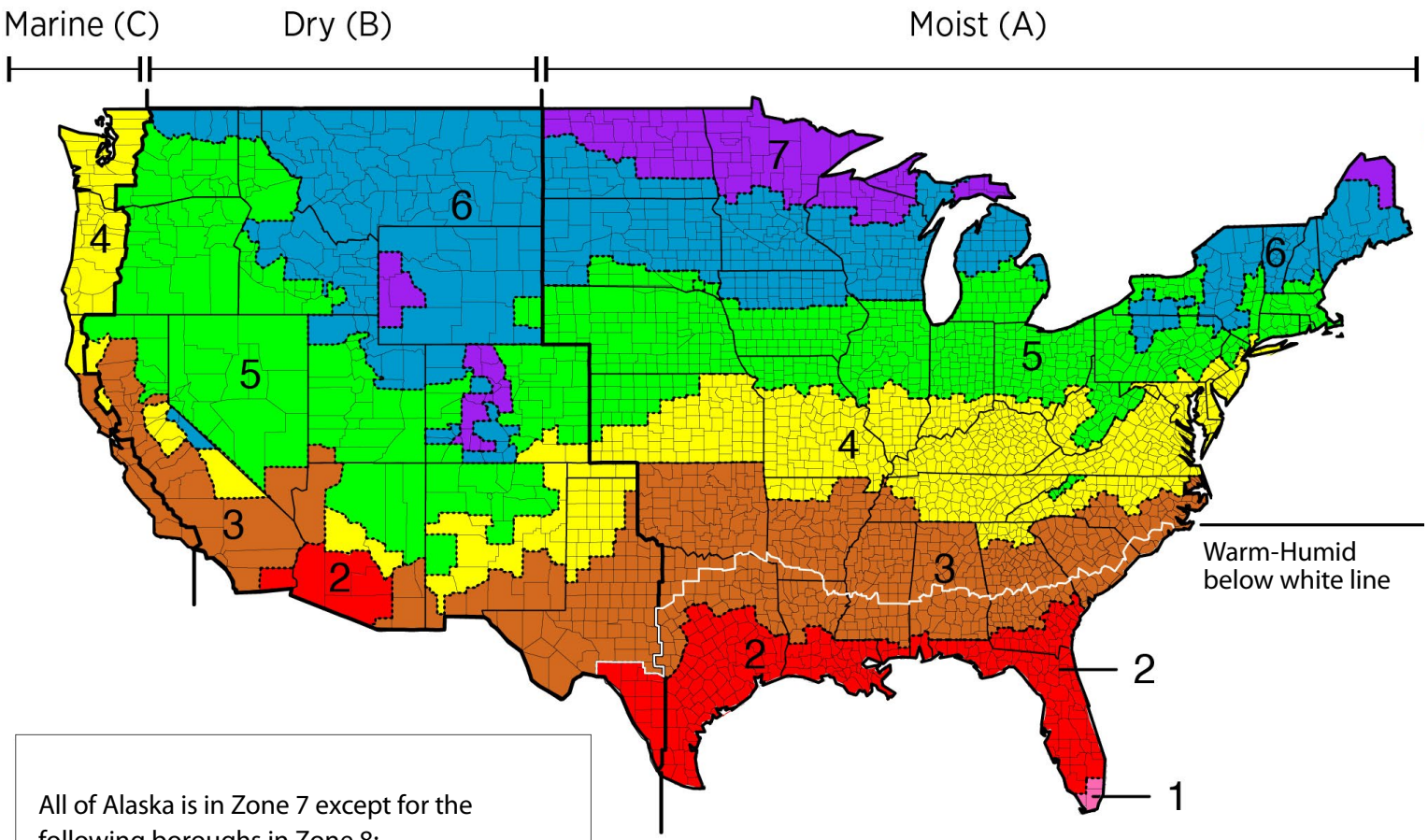
Domestic and international firms are increasing their participation in the PADS/QPL process. As of March 2023, eight of the largest global manufacturers have engaged in the PADS/QPL process with an expectation that their central HPWH products will be pre-qualified via a QPL listing in 2023. NEEA will update and publish the QPL on its website as new systems qualify. The most current version can be found on NEEA's website: Qualified Products List

For each QPL entry, Ecosim has predicted the average annual water heating coefficient of performance for an entire central HPWH system (SysCOP). The SysCOP includes all energy-consuming components of a water heating system and their estimated losses, including circulation loops and storage tanks. The SysCOP modeled for each HPWH product line and configuration may qualify for one of four tiers in the four climate zones to which it is applied. The QPL standardizes the range of system efficiency by categorizing SysCOPs across tiers, which vary between climate zones. The minimum SysCOP required to qualify for each Tier in each climate zone is shown in Table 1. The IECC climate zone map follows in Figure 2.

Table 1: HPWH System Efficiency Tiers

	Minimum SysCOP			
	Hot Climate (IECC Zones 1-2)	**Mild Climate (IECC Zones 3-4)**	**Cold Climate (IECC Zones 5-6)**	**Very Cold Climate (IECC Zones 7-8)**
Tier 1	1.75	1.50	1.25	1.15
Tier 2	2.25	2.00	1.60	1.50
Tier 3	2.75	2.50	2.25	2.15
Tier 4	3.50	3.00	2.75	2.50

Results to Date



All of Alaska is in Zone 7 except for the following boroughs in Zone 8:

Bethel, Northwest Arctic, Dellingham, Southeast Fairbanks, Fairbanks N. Star, Wade Hampton, Nome, Yukon-Koyukuk, North Slope

Zone 1 includes Hawaii, Guam, Puerto Rico, and the Virgin Islands

Figure 2: IECC Climate Zone Map

Results to Date

Cold Climate Operation

The model program can be applied nearly anywhere to incentivize efficient water heating. As described by the HPWH efficiency tiers, several central HPWH systems offer efficient options for almost any climate; many can operate at temperatures as low as -25°F using advanced refrigeration technology.

Central HPWH Performance and Incentive Tool

With the QPL established and published, Ecotope developed Central HPWH Savings Tool that collects several important design data points and calculates energy savings based on annual DHW consumption (in gallons) and SysCOP with prescriptive and custom options for savings and incentive calculations.

Currently, most central HPWHs are custom engineered with off-the-shelf heat pumps. To address these designs, this project initially included a set of tasks to develop the Ecosim Research Tool into a simplified user interface with a method for gathering and inputting the data required to predict SysCOPs for custom project applications. However, the development of the commercial HPWH Qualified Products List (QPL) and the loss of matching funding for these tasks invited an alternative approach. The result is a simplified program that relies on published COPs for entire HPWH systems (SysCOP) on the QPL, eliminating the need for complex modeling tools and associated utility training for custom programs. Ecosim may serve a purpose for especially complex custom projects in the future, but the standardized approach presented in this program is meant to cover most installations. This approach further supports a transition from component-focused custom-designed systems to standardized, fully integrated, and documented central HPWH systems.

The project team met regularly with the broader stakeholder group to encourage a diversity of input while developing the Performance and Incentive Tool. Representatives from BPA, the Regional Technical Forum (RTF), and Tacoma Power provided iterative feedback to refine the product for immediate deployment by Tacoma Power and to prepare this measure for BPA and RTF review and acceptance. As Ecotope developed the calculator, the project team reviewed existing RTF and BPA-approved measures, including the existing RTF-approved residential HPWH measure and the:

- Advanced Rooftop Unit Control (ARC) measure
- Demand Controlled Kitchen Ventilation Standard Protocol
- Compressed Air Standard Protocol
- Commercial Boiler Standard Protocol

Results to Date

Upon reviewing these measures and the variables required to calculate energy savings in central HPWH installations, the project team agreed that a calculator that determines energy savings from occupancy and total annual DHW consumption would be the most straightforward approach. The tool comprises a customer-facing user interface and a back-end for utility fine-tuning and calculations. Ecotope currently hosts this tool as a public resource (Central HPWH Performance and Incentive Tool). The back-end incentive calculations are currently customized to reflect Tacoma Power incentive policies. These values will be updated based on the current RTF evaluation of regional incentive values. In addition, custom modifications to the tool's back-end can be made to reflect individual utility incentive rates and policies as needed by emailing hpwh@ecotope.com.

The *user interface* collects basic data and information about a central HPWH project via **user inputs** and provides several **calculated outputs** calculated in the back-end, bulleted below.

- Baseline Annual Energy Use (kWh/yr.)
- Projected Annual Energy Use (kWh/yr.)
- Projected Annual Energy Savings (kWh/yr.)
- Total Incentive

The **user input collects** basic project information regarding the number of dwelling units and the product selected from the QPL and its Tier (Figure 3). It also allows the project owner or utility representative to enter measured DHW usage and energy data for existing buildings to inform custom energy savings calculations. Finally, the tool records basic AWHS design provisions to demonstrate that the designer has made the considerations necessary to properly size and implement the HPWH system as intended by the AWHS. **Appendix A** provides a detailed explanation of the tool's logic and a user guide.

Results to Date

CENTRAL HPWH PERFORMANCE & INCENTIVE TOOL

User Input
Calculated Output

(1) Building Information:

Project Name:	SAMPLE PROJECT
Project Address:	1917 1ST AVE E
Building Type:	Existing Building
Studios:	25
1-Beds:	25
2-Beds:	25
3-Beds:	25
4-Beds:	0
5-Beds:	0

(2) Usage Data: If submitting for an existing building with measured data, complete the following section.

Was the average daily DHW usage measured?	NO
Was the average DHW circulation heat loss measured?	NO

(3) Equipment: Select a product from the 'Climate Zone Mild' category on the AWHS Qualified Products List and enter its Tier and information below:

Link to QPL: https://neea.org/img/documents/commercial-HPWH-qualified-products-list.pdf

Product Tier:	3
Product Brand:	
Product Model:	
Qualified Piping Configuration:	c. Single Pass, temp. maintenance in series (swing)

(4) Your projected annual energy use and savings for each AWHS performance tier are:

AWHS Tier	Baseline Annual Energy Use (kWh/yr)	Projected Annual Energy Use (kWh/yr)	Projected Annual Energy Savings (kWh/yr)	Total Incentive
1	298,162	178,897	119,265	$27,450
2	298,162	134,173	163,989	$37,700
3	298,162	107,338	190,824	$43,900
4	298,162	89,449	208,713	$48,000

Figure 3: Screenshot—Central HPWH Performance & Incentive Tool User Input

Results to Date

The back-end is the repository for several figures required for accurate energy savings and incentive calculations. It also collects technical baseline and climate inputs and provides detailed information on annual DHW consumption and energy use, temperature maintenance, custom and prescriptive energy savings, and incentive tables. The back-end consists of the following:

- **Static Constants** established by Ecotope to ensure the integrity of the Ecosim model that establishes the SysCOP, alignment with the QPL Tiers, and standard physics and engineering constants.
- **Program Constants**, which utilities must establish, given the unique characteristics of their service territory and their program requirements. Once established, these assumptions should not be changed.
- **Utility Inputs** determined by the utility on a project-by-project basis.
- **Calculated Outputs**, which provide calculations for annual DHW consumption and energy use, temperature maintenance, custom and prescriptive energy savings, and incentive tables.

The savings tool follows a four-step process. For a particular building, the inputs and calculations provide the

1. Determine the annual baseline (existing, like-for-like replacement, or code minimum) energy use for a given DHW system.
2. Determine the annual energy usage for the energy efficiency measure (EEM), a high-efficiency HPWH system.
3. Calculate energy savings by subtracting the baseline system's measured or calculated energy consumption from the proposed EEM's calculated energy consumption.
4. Calculate the total incentive.

Please see **Appendix A** for a full explanation of these steps.

Results to Date

Project Screening and Selection Guidelines for Existing Buildings

Retrofits of multifamily buildings to install central HPWH systems represent a great energy savings opportunity – and a potentially complex design and installation problem. Because not all multifamily buildings are good candidates for a central HPWH retrofit, this project developed a screening tool to help utility program managers identify promising candidates for this incentive program. The Existing Building Screening tool helps utility staff walk through a series of questions about building configuration that can help identify good candidates for central HPWH retrofit and screen out projects with significant challenges or complications.

The success of an HPWH retrofit relies substantially on selecting appropriate candidate buildings. The following categories organize the consideration of each criterion in a stepwise fashion by

1. Evaluating the current water heating system configuration (central or distributed)
2. Developing an accurate DHW load estimate
3. Determining retrofit feasibility given the building's physical layout
4. Develop strategies for adapting to the DHW system's existing fuel source and capacity

These steps are illustrated in Figure 4, which provides visual guidance for screening and selecting good candidate buildings. In addition, **Appendix B** provides detailed screening considerations when considering existing equipment, DHW load, the distribution system, electrical capacity, compressor, and hot water storage locations.

EXISTING MULTIFAMILY BUILDING SCREENING TOOL

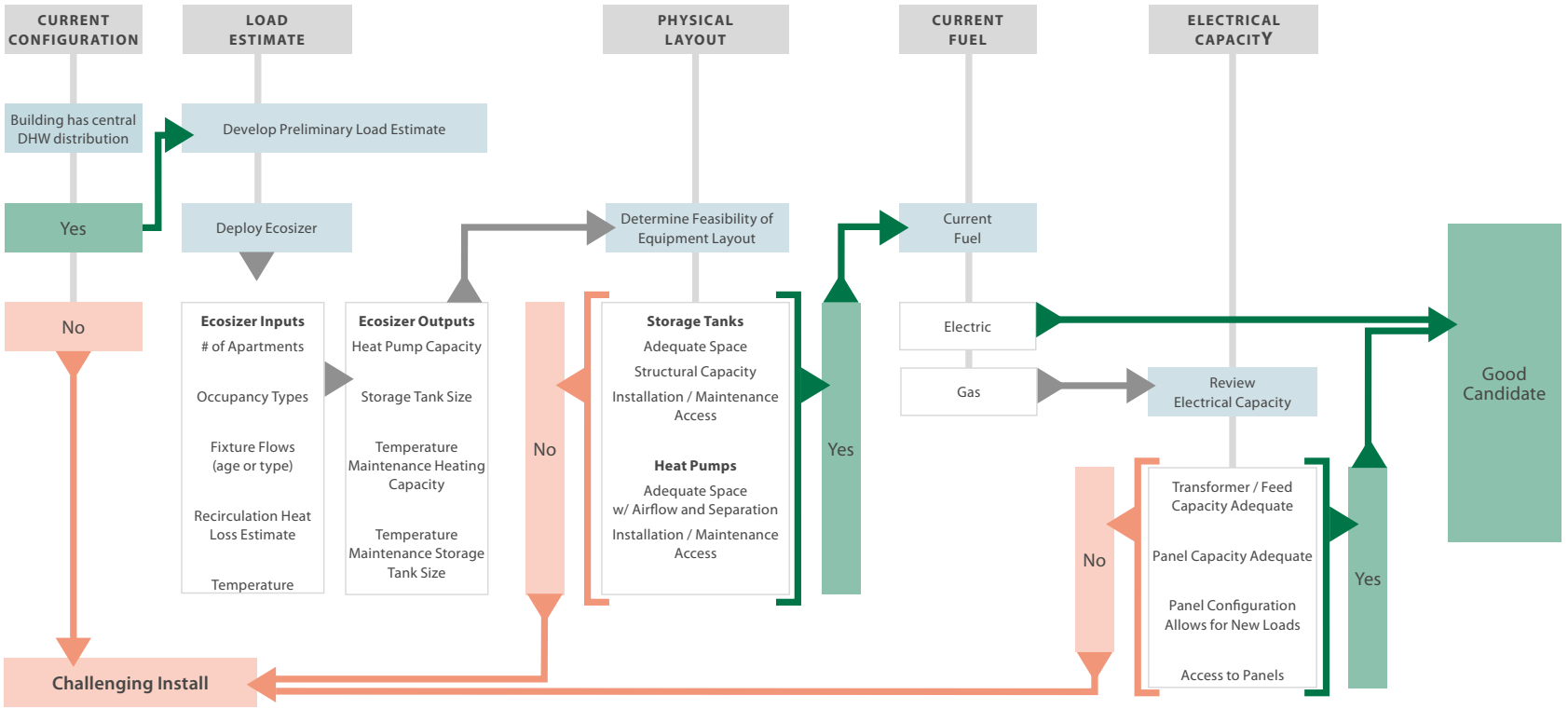


Figure 4: Existing Multifamily Building Screening Tool

Results to Date

Utility Program Guidelines

The tools and resources described in this report provide a practical framework for implementing a full-service central HPWH incentive program for multifamily buildings. The following diagram describes the program visually (Figure 5). It is divided into project Phases, Tasks, and Tools required for each phase and indicates the Responsible Party for each task or phase.

There are four phases to a project:

1. **Identifying the target market.** For this program, only new or existing multifamily buildings qualify. Future expansions to this program could include other target markets, such as lodging, food service, or other commercial buildings.
2. **Design Engagement.** This phase contains two sub-phases:

    A. **Feasibility.** For use with existing buildings only, the included Existing Buildings Screening Tool provides utility programs with guidance on selecting building candidates for retrofit projects. Additional site review steps further improve candidate selection by verifying electric capacity, physical space characteristics, and mechanical systems configuration.

    B. **Design.** Use the Central HPWH Savings and Incentive Tool to calculate baseline energy consumption, potential savings, and incentive (This tool must be operated via computers running Microsoft Windows using Edge or Chrome Browsers. Private Browser modes and Mobile web browsers are not supported at this time). The Central HPWH Savings Tool uses the commercial HPWH QPL tiers for a set of key inputs.

    This tool also prompts the user to record several design characteristics, which allows the program manager or utility engineer to ensure the design aligns with the expectations of the AWHS 8.0. It includes outputs from Ecosizer (ecosizer.ecotope.com) or an alternative sizing method approved by the manufacturer. The sizing calculation determines the required HPWH heating capacity and storage volume according to the characteristics of the HPWH and storage equipment selected by the designer. Future expansions of this program will include a set of calculations to determine the potential impact of Load Shift based on time-of-use energy rates and demand charges and a measurement and verification (M&V) plan for HPWH projects.
3. **Deployment.** The project owner installs the central HPWH system.
4. **Verification.** The utility verifies that the installation meets the requirements agreed upon in the incentive contract.

PROPOSED PROJECT FLOW FOR CHPWH INCENTIVE PROGRAM DEPLOYMENT

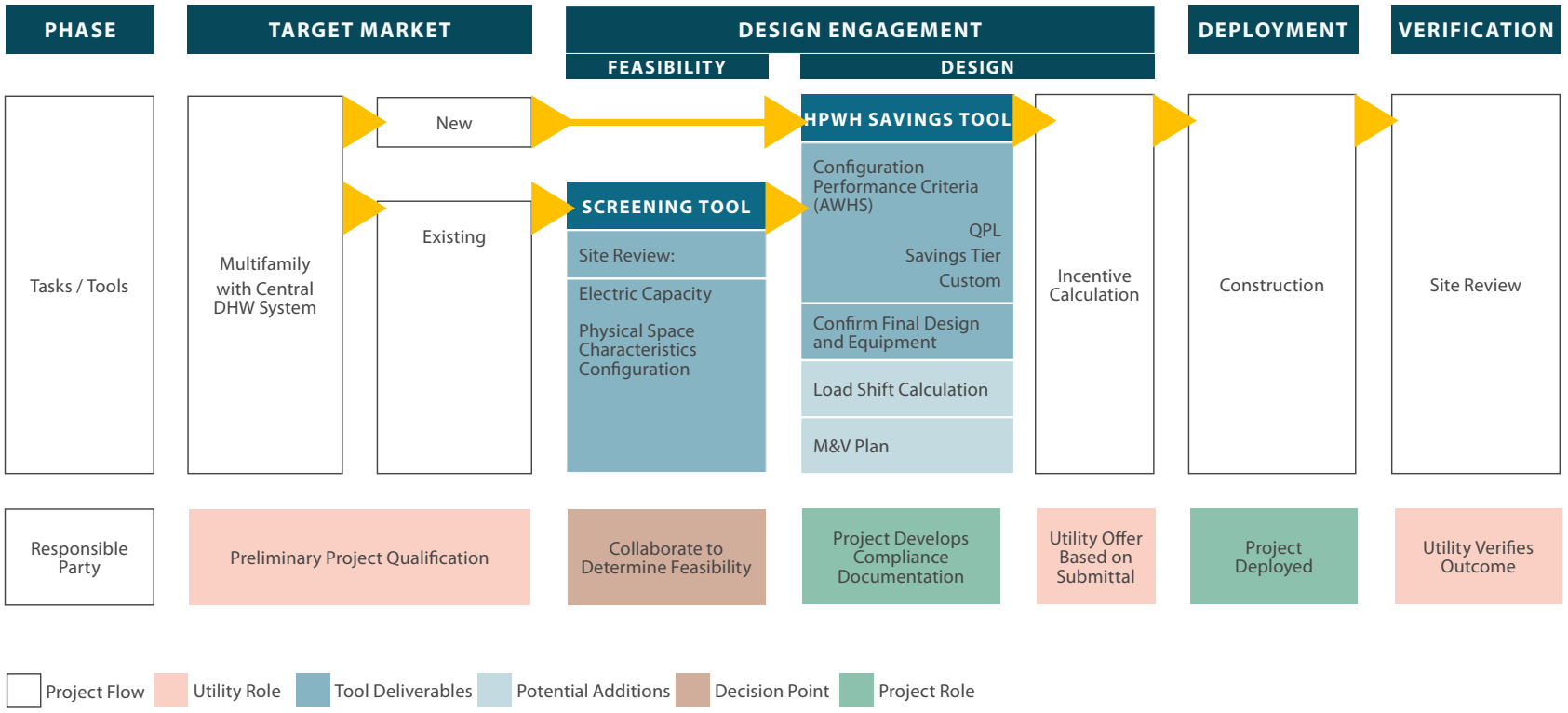


Figure 5: Central HPWH Project Flow

Alternatives

The alternatives to the standardized approach presented in this report include:

1. Creating custom analyses for each central HPWH project using a standard or non-standard modeling protocol or tools on a case-by-case basis to determine savings and incentives.
2. Developing or contracting the development of a central HPWH program that may or may not align with established modeling standards, savings protocols, component definitions, or sizing protocols.
3. Providing incentives based on appliance efficiency only, which does not accurately reflect total system performance and actual savings.
4. Choosing to not incentivize central HPWH installations.

The risks of custom-designed and incentivized central HPWH projects can outweigh their potential benefits when system designers and/or utility programs inexperienced with central HPWHs do not follow established design specifications. Ecotope's extensive experience has revealed that central HPWHs must be considered as a system and that component-based designs and incentives cannot be relied upon. However, these complicated systems can be simplified if standard specifications are followed. Where the AWHS and the related tools and protocols are ignored, significant savings can be missed or over-estimated, and customer satisfaction and system reliability will depend entirely on design engineer expertise.

The program presented in this report captures Ecotope's experience working directly with manufacturers and designing central HPWH systems over the past decade. The program is designed to enable utilities to build on this experience to take a lead in central HPWH market transformation by incentivizing well-designed projects with predictable outcomes rather than incentivizing component-based efficiencies and non-standardized designs.

Future Plans

This project incorporated previous and ongoing work to develop a prescriptive utility incentive program for Tacoma Power and a template that other utilities can use to create program offerings for central HPWHs. It also provides programmatic guidance for central HPWH custom incentive programs. This simplified approach enables utilities to streamline central HPWH energy savings calculations and incentives and avoids potential project audits by state or federal authorities to ensure alignment with accepted methods and tools. It also avoids costly investments for utilities, project owners, and consultants that would result from a patchwork of custom measure approaches across projects and utilities. Such an approach would negatively impact central HPWH adoption by impacting perception and increasing administrative and cost barriers.

Using the framework developed by this project will streamline similar measure development for Technical Reference Manuals used by public utilities nationwide. In pursuit of broad utility adoption, this measure will seek acceptance by the Pacific Northwest Regional Technical Forum as a pre-approved measure, significantly streamlining the process. Longer term, the program could expand into closely related building typologies such as lodging and incarceration with additional research on DHW draw profiles and system design.

Status

Task 1	Support development of QPL with a minimum of four products	Notes
1.1	Assess requirements of PADS submittal process to AWHS QPL	**Completed:** Submittal process defined, and data received from manufacturers.
1.2	Recruit a minimum of 4 manufacturers to submit to QPL	**Completed:** 4 manufacturers recruited: Nyle, Sanden, Mitsubishi, Water Drop
1.3	Workshop PADS. Provide feedback to NEEA for any changes needed	**Completed:** Working draft of PADS completed
1.4	Work with manufacturers to fulfill the PADS requirements defined in the AWHS 8.0	C**ompleted:** 4 MFR submitted PADS; adding more manufacturers
1.5	Form first version of QPL with submitted products	**Completed:** Sept. 2022
1.6	Project management, review, report	**Completed:** March 2022
Task 2	**Create a prescriptive incentive plan for TPU**	**Notes**
2.1	Review existing TPU incentive programs to determine best fit	**Completed:** aligning with RTF process
2.2	Develop recommendations for optimal metrics for prescriptive program (i.e., $/ton, $/apartment, $/SF, $/bedroom)	C**ompleted:** Each occupancy type has an associated dollar figure for each QPL Tier, which varies depending on climate. As Tier increases, so do incentives for each occupancy type.
2.3	Develop calculation procedures for predicting savings and calculating incentive amounts for the prescriptive program	**Completed:** aligning with RTF process
2.4	Project management, review, report	**Completed:** March 2022
Task 3	**Create templates for other APPA members for prescriptive programs**	**Notes**
3.1	Review sample of program offerings from APPA members	**Completed:** aligning with RTF process
3.2	Create a simplified templated program for Prescriptive incentives	**Completed:** March 2022
3.3	Project management, review, report	**Completed:** March 2022

Status

Deliverables

- **HPWH qualified products list (QPL)**[7] and Product Assessment Data Sheet (PADS). A catalog of central HPWHs, provided by manufacturers via a standardized data request form and analysis protocol established in the PADS. The PADS also provides a standardized protocol for manufacturers to engage with utility program providers via the QPL. The QPL provides pre-qualified products and design configurations with predictable performance outcomes, as modeled by Ecosim. In addition, the QPL categorizes the pre-qualified central HPWHs into the four AWHS performance tiers.
- **Central HPWH Performance and Incentive Tool.** A simple energy savings calculator and project guidance tool with customizable program options and minimal project-owner inputs. This tool serves as the basis of utility program savings and incentive calculations using individual project data and standardized performance data from the tools above. This tool is hosted as a web resource.
- **Project Screening and Selection Guidelines for Existing Buildings.** A set of considerations to help program implementers or other utility staff identify good candidate projects for central HPWH retrofits and screen out projects with significant challenges or complications.
- **Utility Program Guidelines.** The framework explaining the implementation of a full-service central HPWH incentive program for multifamily buildings for any utility.

7 "Commercial Heat Pump Water Heater Qualified Products List" (Northwest Energy Efficiency Alliance, December 1, 2022), https://neea.org/resources/commercial-hpwh-qualified-products-list.

Dates

Original Timeline	Final Timeline
Ecosim Research Tool—January 2022	**Completed January 2022**. No timeline adjustment
AWHS 8.0 in effect—January 2022	**Completed January 2022**. No timeline adjustment
Methodology (PADS) and system design for modeling QPL with Ecosim—January 2022	**Completed September 2022**. A key staffing turnover resulted in a significant delay with this, and subsequent steps related to Ecosim modeling.
Products submitted to QPL—March 2022	**Completed November 2022**. Ecotope worked with central HPWH manufacturers to standardize and collect performance data that aligns with AWHS 8.0. Product submittals were completed and modeled in Ecosim in October, and the QPL was published in December 2022.
AWHS tiered structure w/ 4 products on QPL—May 2022	**Completed December 2022**. Ecotope standardized and collected performance data to inform the tiered QPL structure. The QPL can be found here: https://neea.org/resources/commercial-hpwh-qualified-products-list
Model prescriptive program created for Tacoma Power – July 2022	**Completed March 2023**. As this project evolved, the Regional Technical Forum (RTF) and Bonneville Power Administration became involved in aligning the APPA-funded prescriptive program structure with the RTF process with the expectation that the RTF would approve the measure in Q2 2023.
Custom Program Methodology Developed for Tacoma Power – September 2022	**Completed March 2023**. Developed as part of the program flow, screening, and energy savings calculator tools.
APPA generic prescriptive and custom program templates available – September 2022	**Completed March 2023**. Developed as part of the program flow, screening, and energy savings calculator tools.

Budget

ALL TASKS	TASK 1: QPL, TASK 2: INCENTIVE PLAN, TASK 3: APPA TEMPLATES	TOTAL SPEND: $125,000
Task 1	**Support development of QPL with a minimum of four products**	**Total Spend: $56,400**
1.1	Assess requirements of PADS submittal process to AWHS QPL	$2,850
1.2	Recruit a minimum of 4 manufacturers to submit to QPL	$6,350
1.3	Workshop PADS. Provide feedback to NEEA for any changes needed	$10,000
1.4	Work with manufacturers to fulfill the PADS requirements defined in the AWHS 8.0	$24,000
1.5	Form first version of QPL with submitted products	$4,200
1.6	Project management, review, report	$9,000
Task 2	**Create a prescriptive incentive plan for TPU**	**Total Spend: $39,200**
2.1	Review existing TPU incentive programs to determine best fit	$5,600
2.2	Develop recommendations for optimal metrics for prescriptive program (i.e., $/ton, $/apartment, $/SF,	$9,200
2.3	Develop calculation procedures for predicting savings and calculating incentive amounts for the	$16,000
2.4	Project management, review, report	$8,400
Task 3	**Create templates for other APPA members for prescriptive programs**	**Total Spend: $39,200**
3.1	Review sample of program offerings from APPA members	$8,200
3.2	Create a simplified templated program for Prescriptive incentives	$13,500
3.3	Project management, review, report	$7,700

References

"Advanced Water Heating Specification Version 8.0." Northwest Energy Efficiency Alliance, March 1, 2022. https://neea.org/img/documents/Advanced-Water-Heating-Specification.pdf.

"Commercial Heat Pump Water Heater Qualified Products List." Northwest Energy Efficiency Alliance, December 1, 2022. https://neea.org/resources/commercial-hpwh-qualified-products-list.

Ecosizer. "Ecosizer." Engineering Tool. Accessed March 6, 2023. https://ecosizer.ecotope.com/.

Fernandez, N. "Impacts of Commercial Building Controls on Energy Savings and Peak Load Reduction." PNNL-25985, 2017, 25985.

Kruis, Neal, Bruce Wilcox, Jim Lutz, and Chip Barnaby. "Development of Realistic Water Draw Profiles for California Residential Water Heating Energy Estimation – Revised (March, 2019)," 2019. http://www.bwilcox.com/BEES/docs/dhw-profiles-revised3.pdf.

Northwest Energy Efficiency Alliance. "Heat Pump Water Heaters." Regional Energy Efficiency Office. Accessed March 7, 2023. https://neea.org/success-stories/heat-pump-water-heaters.

APPENDICES

Appendix A: Calculator Logic and User Guide

Appendix B: Screening Considerations for Existing Multifamily Buildings

Appendix C: Product Assessment Datasheet Submission

Appendix A: Calculator Logic and User Guide

User Guide

The Central HPWH Performance & Incentive tool calculates the baseline, projected energy savings resulting from a central HPWH installation, and the estimated incentive.

Follow steps 1 through 6 to enter the required information to determine project eligibility and savings.

Terms

DHW Usage: Domestic hot water – the amount consumed by the building and its occupants in gallons.

EEM: Energy Efficiency Measure

HPWH system: Heat Pump Water Heater – A DHW heating system that uses a heat pump water heater to heat the DHW.

TM Heating: Temperature Maintenance Heating-- the heat required to compensate for heat loss in the DHW circulation loop, often a dedicated heater in an HPWH system.

User Guide

The Central HPWH Performance & Incentive tool calculates the baseline, projected energy savings resulting from a central HPWH installation, and the estimated incentive.

Follow steps 1 through 6 to enter the required information to determine project eligibility and savings.

Step 1

Provide information about the building in which the central HPWH will be installed, including:

- Project Name
- Project Address
- Building Type
- Number of units per type (i.e., studio, 1-bed, 2-bed, etc.)

Step 2

If your project will be installed in an existing building (i.e., a retrofit) and you have measured data for average daily DHW consumption and/or average heat losses related to hot water circulation, follow the prompts in step 2 by selecting yes from one or both dropdown menus.

Step 3

Select a product from the appropriate climate zone category on the AWHS Qualified Products List (https://neea.org/img/documents/commercial-HPWH-qualified-products-list.pdf). Then, select the Tier of the product selected from the Product Tier dropdown menu.

Please enter the model and manufacturer brand in the appropriate boxes as they appear in the QPL. Finally, select the AWHS Qualified Piping Configuration you intend to use in central HPWH installation.

Step 4

This step provides the projected annual energy use, projected savings, and estimated incentive for each AWHS performance tier. The highlighted row aligns with the AHWS tier selected for your project.

Appendix A: Calculator Logic and User Guide

Note: Steps 5 and 6 are optional and will not affect the energy savings calculation. However, they are recommended to streamline the process for the utility to confirm that the central HPWH designer covered the considerations necessary to properly size and implement the HPWH system as intended in the AWHS.

Step 5

Size the proposed HPWH system using Ecosizer (https://ecosizer.ecotope.com/sizer/) or a manufacturer-provided sizing software and provide the system design information.

The following inputs verify that the designer has considered the temperatures necessary for proper HPWH system sizing.

- Cold design air temperature:
- Hot design air temperature:
- Storage Tank temperature:
- Temperature maintenance temperature (where applicable):
- DHW supply temperature:

The following values should be gathered from the HPWH system sizing software.

- Primary storage volume required:
- Temperature maintenance storage volume required (where applicable):
- Primary HPWH capacity required:
- Temperature maintenance heating capacity required[1]:

The following values confirm that the selected HPWH and temperature maintenance heater aligns with the system sizing criteria.

- Primary HPWH capacity at cold design air temp (ea)
- Installed quantity of primary HPWHs:
- Temperature maintenance capacity at cold design air temp[1,2] :
- Installed quantity of temperature maintenance heaters[1]:

Step 6

Provide the following design documentation to confirm the DHW system has been sized per the requirements above, the schematic has been produced in alignment with the Qualified Products List Qualified Piping Configuration, and the equipment is scheduled in alignment with both the Qualified Products List equipment selection and the equipment manufacturer's reported performance at the necessary design air temperature.

- DHW plant sizing:
- DHW plant schematic:
- Equipment Schedule:
- HPWH performance sheet (including defrost):

High-Level Process

Note: each value is considered on an annual basis

1. Determine the annual baseline (existing, like-for-like replacement, or code minimum) energy use for a given DHW system.
2. Determine the annual energy usage for the energy efficiency measure (EEM), a high-efficiency HPWH system.
3. Calculate energy savings by subtracting the baseline system's measured or calculated energy consumption from the proposed EEM's calculated energy consumption.
4. Calculate the total incentive.

1 If using return-to-primary configuration, leave this input blank.

2 Equipment performance must include defrost de-rate where applicable.

Appendix A: Calculator Logic and User Guide

These steps are explained in detail below.

1. Annual DHW energy use of the baseline system

    > **Total baseline heating** = baseline DHW heating + baseline TM heating

        - **Total DHW usage** = total counts of each dwelling unit type x assumed occupancy of each unit type
        - **Baseline DHW heating** = total DHW usage x water density x heating constant x (DHW Delivery Temp – DCW Temp)
        - **Baseline TM heating** = assumed heating per dwelling unit x total number of dwelling units

    > **Baseline energy usage** = total baseline heating / baseline system COP

2. Annual DHW energy use of the EEM system (HPWH)

Standard (default) approach. The SysCOP relies on simulated equipment performance, modeled in Ecosim, to assign HPWH systems a minimum SysCOP within a QPL tier. This conservative approach provides an additional backstop to ensure that the modeled SysCOP does not overestimate performance as installations and design configurations vary.

> **Proposed energy use** = total baseline heating / proposed system COP.

> **Proposed system COP** is determined by referencing the qualified products list to align the select system to its QPL tier and the installation's climate zone.

Custom Approach. The custom approach allows users to input DHW usage and TM heat loss values that deviate from the assumptions in Ecosim. However, additional research is necessary to accurately model the TM heat losses for each design configuration.

3. Energy savings

    > **Proposed energy savings** = baseline energy use – proposed energy use

4. Total incentive

    > **Total incentive** = total energy savings x incentive rate per kWh

    > Independent incentive rates exist for each case below:

        - **New construction** (assumes default DHW usage and TM loss values)
        - **Existing building** (assumes default DHW usage and TM loss values)
        - **Custom measure** (allows custom inputs based on measured DHW usage and TM loss)

Appendix A: Calculator Logic and User Guide

Utility Customization

The following provides the options for utilities to customize the Central HPHW Savings and Incentive tool. **Program constants** should be set by the utility program once and then left as a constant for the life of the incentive program. The defaults are Ecotope's recommendations. Utility Inputs are more flexible variables that can be adjust as needed. Ecotope is available to discuss utility approaches to this program and recommend program customizations. Future versions of this tool will be in web-tool format with utility access to customizable inputs.

Program Constant | Calculated Output | Utility Input | Static Constant

ADJUSTABLE INPUTS Consult with Ecotope to adjust these inputs. Email hpwh@ecotope.com			
Occupancy per Dwelling Unit*			
Studio	**1.37**		
1-Bed	**1.74**		
2-Bed	**2.57**		
3-Bed	**3.11**		
4-Bed	**4.23**		
5-Bed	**3.77**		
Building Characteristics			
Assumed Average DHW Usage **	**17**	gallons per occupant per day	
Assumed TM Heat Loss ††	**60**	watts per dwelling unit	

Appendix A: Calculator Logic and User Guide

Program Constant | Calculated Output | Utility Input | Static Constant

Baseline System Assumptions					
	Baseline System COP ††		**0.9**		
	DHW Supply Temp		**120**	°F	
	Avg City Water Temp		**55**	°F	
AWHS Qualified Products List Info					
	Climate Zone		**Mild**		
	Tier 1 COP		**1.5**		
	Tier 2 COP		**2**		
	Tier 3 COP		**2.5**		
	Tier 4 COP		**3**		
Incentive Rates					
	Building Type	**Incentive Rate**			
	New Construction	$ 0.20	$/kWH		
	Existing Building	$ 0.23	$/kWH		
	Measured Building	$ 0.23	$/kWH		
	Building Type Used	Existing Building			
	Incentive Rate Used	$ 0.23			

Appendix A: Calculator Logic and User Guide

Program Constant Calculated Output Utility Input Static Constant

Qualified Piping Configuration		
Configuration		**Excess TM COP Multiplier** [1]
a.	Single Pass, no hot water circulation	**0.8**
b.	Single Pass, temp. maintenance returned to primary storage	**0.8**
c.	**Single Pass, temp. maintenance in series (swing)**	**0.4**
d.	Single Pass, parallel temp. maintenance heated by HPWH	**0.8**
e.	Integrated HPWH, no hot water circulation	**0.8**
f.	Integrated HPWH, temp. maintenance returned to primary storage	**0.8**
g.	Multi Pass, temp. maintenance returned to primary storage	**0.8**
h.	Multi Pass, no hot water circulation	**0.8**

COP vs Climate Zone					
	Climate Zone	**Tier**			
		1	**2**	**3**	**4**
	Very Cold	**1.15**	**1.5**	**2.15**	**2.5**
	Cold	**1.25**	**1.6**	**2.25**	**2.75**
	Mild	**1.5**	**2**	**2.5**	**3**
	Hot	**1.75**	**2.25**	**2.75**	**3.5**

Appendix A: Calculator Logic and User Guide

Program Constant | Calculated Output | Utility Input | Static Constant

Ecosim Model Assumptions				
	Daily DHW Usage	**17**		
	TM Loss	**60**	w/apt	
Physics				
	Days per Year:	**365.25**		
	Water Density:	**8.3**	lb/gal	
	BTU/kWH:	**3412**		
	Hours per Day:	**24**		
	Watts per kW:	**1000**		

*A survey and analysis of DHW draw from actual occupancies in California. Kruis, N., Wilcox, B., Lutz, J., Barnaby, C, (2019) "Development of Realistic Water Draw Profiles for California Residential Water Heating Energy Estimation – Revised (March, 2019)"

** Ecotope's professional experience suggests that 17 gallons per day is an appropriate number for new construction

† Temperature Maintenance load describes the heat loss rate from hot water circulation piping. It is commonly standardized as a heat loss per apartment unit. Here the baseline value is assumed to be 60 W/Apt to allow for a more conservative approach aligning with the Ecosim model, which avoids over-incentivizing temperature maintenance energy that is not covered by the primary heat pump. An Ecotope study (Kintner and Larson, 2019) reveals that 90w/Apt is the median value across existing apartment types, but that the range extend from roughly 40w/Apt to 400w/Apt.

Kintner P., and Larson, B. (2019). Literature Review of Multifamily Central Domestic Hot Water Distribution Losses. Prepared for NEAA.

†† Baseline System COP is the assumed efficiency factor of the existing or baseline system including TM and Tank losses and any other system energy.

(1) TM losses identified here are based on measured and calculated values from Ecotope's project experience. These values are based on limited data, and may not reflect actual conditions based on variability in pipe insulation and support strategies, routing and location, etc. Limited available research into TM losses suggest that a wide range of outcomes are possible, and more research and data on this topic is needed. The multipliers used here represent good practice in new construction, and provide conservative approach for adjusting the fraction of SysCOP contributed by temperature maintenance losses measured in excess of Ecosim's default 60 watts per apartment. Future research would into these values would improve their accuracy.

Appendix B: Screening Considerations for Existing Multifamily Buildings

This document provides guidance on determining the feasibility of a CHPWH installation in an existing multifamily building. These criteria are meant to provide general guidelines to identify likely candidates for CHPWH deployment. All design considerations must be confirmed during the design process to align with actual equipment to be installed. The following conditions should be considered in evaluating existing building conditions.

Load Analysis

Key consideration in load analysis are the gallons per day of hot water demand and the load shape of water use through the day. These are driven primarily by the number and type of occupancy. These variables are accounted for in the Ecosizer tool. In existing buildings, it is recommended that flow meters be deployed to verify hot water demand in the DHW system. This data, in conjunction with temperature sensors can help form the basis of load calculations for both DHW loads and the continuous circulation loop. This data can support more accuracy in evaluating building loads,and can be input directly into the Ecosizer tool to support system sizing calculations. As a guideline, anticipate deploying approximately one ton of HPWH heating capacity for each 5 apartment units. Total capacity can be built up from 1.5, 5, or 10 ton units.

Number of units/occupants – DHW loads can be calculated with information about number of apartments or with more specific occupant numbers. The Ecosizer tool, available to the public on Ecotope's website, allows designers to quickly calculate loads and system capacity requirements for CHPWH DHW systems.

Occupancy type – DHW demand patterns vary by occupancy type, with distinctions between low income, market rate, elderly housing, and hospitality occupancies.

Existing fixture characteristics and flows – older buildings/fixtures may have substantially higher flow rates than new low-flow fixtures. Fixture replacement may represent a cost-effective strategy to reduce overall DHW system capacity requirements.

Special loads – special-case loads, such as commercial kitchen equipment, hot tubs, or other DHW loads need to be identified for inclusion in load calculations.

Distribution System

Continuous circulation – most medium and large multifamily buildings have temperature maintenance systems which circulate hot water back to the DHW plant for reheating to keep hot water near potential fixture loads at all times. In CHPWH systems, it is typically more efficient to use a dedicated temperature maintenance system that is separate from the primary water heating system. The presence and configuration of the existing temperature maintenance system will impact CHPWH configuration options.

Insulation/efficiency – the heat loss characteristics and efficiency of the distribution system impact energy loads and performance of the temperature maintenance system, and overall DHW system performance. Pipe insulation and sizing, and pump characteristics should be evaluated in existing distribution systems.

Pumps/controls – pumps and controls may need to be upgraded to work with the new DHW plant. Configuration options and space constraints need to be evaluated for installation.

Electrical Capacity

If the existing DHW system is served by electric resistance heating, there is almost certainly enough electric capacity in the building to change

Appendix B: Screening Considerations for Existing Multifamily Buildings

over to a HPWH system. As a general guideline, any building with electrical capacity of roughly 1 kW for every 100 gallons of peak daily water demand is probably able to comfortably deploy a CHPWH system, including some electric backup, without additional electrical capacity. Buildings with smaller electrical capacity at the panels or transformers may also be able to deploy CHPWH systems, but more careful evaluation of system electrical capacity needs and configuration will be needed.

Panel and transformer capacity - Heat pump water heating equipment is an efficient use of energy to make hot water, but compressors require adequate electrical capacity for startup and operation. Also, some sort of backup heating system is often desired for redundancy, and this may take the form of electric resistance elements in some of the primary hot water storage tanks, as well as in the temperature maintenance system. A typical electric backup system might be sized to provide temperature maintenance, and redundancy for the daily water production capacity of one of the HPWH compressor units in a staged system. (Data for these calculations can be pulled from on-site flow meter data and/or Ecosozer outputs.)

HPWH equipment may require single phase or three phase power, and usually at least 208/230 volts. Each manufacturer has their own requirements for the amperage required for each heat pump unit, but a general guideline is that single-phase systems require 15-18 amps per ton of installed equipment capacity. And each unit requires it's own circuit breaker in the electrical panel. This requires space panel capacity as well as adequate transformer capacity for new HPWH and backup loads.

Panel Configuration – If existing spare electrical capacity is spread out among multiple electrical panels, some consolidation and reconfiguration may be needed, or a new panel installed to serve the DHW system.

Compressor Location

Available space – Mid-sized and large multifamily buildings are typically served by a bank of HPWH compressors connected as a staged system. In large projects, multiple independent CHPWH plants may be deployed. There are different equipment capacity options to build the system with, depending on the manufacturer selected.

The compressors need to be located in a space that provides good airflow across the coils, and clear maintenance access. Typically the compressors cannot be located in an enclosed room, though some manufacturers allow ducted airflow configurations to connect to outside air.

The ambient temperature under which the units will be expected to operate will impact refrigerant and equipment choice. CO2 refrigerants are able to operate in below freezing conditions, while other refrigerants require milder ambient temperatures such as provided in buffer spaces, and/or additional backup capacity for low temperature operation.

Because all HP compressors draw heat out of the ambient air, the best performance is achieved when the units are located in a buffer space, such as an underground parking garage, to limit exposure to the coldest air temperatures.

Proximity to storage tanks and power – Ideally, compressors should be located near the DHW storage tanks and electrical panels that serve them. Long piping runs between compressor banks and storage systems decrease overall system efficiency.

Noise – Heat pump compressors can be noisy, and they must be located where operating noise will not adversely impact neighbors or occupied spaces.

Appendix B: Screening Considerations for Existing Multifamily Buildings

Storage Tank Location

Available space – CHPWH systems rely on significant hot water storage volumes as part of the system. Most typically these systems deploy several tanks plumbed in series to provide the full storage volume needed. Locating these tanks requires adequate floor area with maintenance and installation access. HP systems rely on roughly twice the storage volumes of a gas boiler system, and therefore typically require more floor space than the gas systems they replace. Tanks should be located indoors and well insulated.

Structural capacity of floor - Hot water storage tanks are heavy, and require structurally adequate floors to support them. Any installation above grade and any framed floor should be evaluated for structural capacity to support hot water storage tanks. As a rough order of magnitude, storage water will weigh nearly 1000 pounds for every 100 gallons stored.

Proximity to distribution system – storage tanks should be adjacent to the pumps and distribution systems that serve the building. Excessively long pipe runs decrease system efficiency.

Temperature maintenance – most medium and large multifamily buildings incorporate a continuous circulation loop to keep hot water near all fixtures in the building and maintain distribution temperatures in the piping. In a built-up CHPWH system this temperature maintenance system is typically served by a separate small storage tank with pumps and mixing valves. When hot water demand is minimal, the temperature in this loop is maintained by an electric resistance coil or a separate small HPHW system. When hot water demand increases, the DHW is supplied from the primary CHPWH system. For unitary systems where the tank and heat pump are integrated into a single unit, recirculation loops are typically piped back directly into the primary unit.

Evaluation of Existing Equipment

Continuous service - In existing buildings it is critical to minimize disruption to DHW supply to occupied apartments as new systems are deployed. Temporary DHW systems can often be deployed to serve DHW loads during new system installation. Sometimes elements of the existing DHW system can be retained as part of the new system, or phased out over time. These issues add complexity to DHW system replacement, and may require the deployment of interim system configurations which relocate or repurpose existing system components. The logistics of an uninterrupted DHW supply during the installation of a new system represents additional design scope independent of the primary system design itself.

Condition/useability – the condition and configuration of existing DHW equipment helps determine its usability in the new system. Storage tanks may sometimes be reconfigured to serve the new system, and elements of the existing system may be repurposed to serve as temporary or permanent backup systems in the new DHW system. Controls and pumps are often difficult to reuse in new configurations.

Appendix C: Product Assessment Datasheet Submission

SYSTEM PERFORMANCE MODELING INPUT PARAMETERS		*Provide information on the following parameters indicated below in sections A-I. The information provided in these sections will be used in the Ecosim commercial heat pump water heating modeling software to predict a System COP for a heat pump water heating product. The System COP will determine what tier of the Qualified Product List a product complies with.*			
SECTION	**PARAMETERS**			***AWHS 8.0 - REFERENCE TEXT***	**MFR NOTES / COMMENTS / QUESTIONS**
A	**Contact Information**	*Provide contact details of person submitting this form*			
1	Name:				
2	Job Title:				
3	Company				
4	Email				
5	Phone				
B	**Equipment Identification**	*Provide information on the product identification for each product line. A completed PADS must be submitted for each product line. Products with accessory packages shall be noted in the 'Accessory Packages' line below and do not require a PADS submission for each product accessory package variation.*			
1	Manufacturer/brand				
2	Model number(s)			**A completed PADS must be submitted for each product line**	
3	Accessory Packages that affect equipment capacity or efficiency (e.g. defrost, supplemental electric resistance, etc..)			*Provide information on accessories that are available with the product line submitted.*	
4	Refrigerant Type	[R410a, R134a, R744, R513a, Other]			
C	**Product Categorization:**	*Provide information on the product categorization to inform if the product a Unitary or Split System HPWH product type.*			
1	Are the heat pump components and storage tank integrated into the same unit?	[Y / N]		*Yes-> Unitary, No -> Split System*	
2	Are all heat pump components in the same unit? (components include: compressor, evaporator, fan, condenser, expansion valve, primary pump)	[Y / N]		**components include: compressor, evaporator & fan, condenser, expansion valve, and water pump**	
3		If no: which components are located remotely from the compressor? Provide a list:	[e.g. evaporator, fan, pump, etc..]	**components include: compressor, evaporator & fan, condenser, expansion valve, and water pump**	
4		Are the remote components provided by the MFR or specified by a third party?	[provided by MFR, 3rd party specified]	**components include: compressor, evaporator & fan, condenser, expansion valve, and water pump**	
D	**General Requirements (Section 3.3.1 of AWHS)**	*Provide information on the HPWH product warranty. No warranty information on accessory components is required.*			
1	Does the HPWH manufacturer provide a minimum 5-year warranty that covers all parts of the HPWH?	[Y / N]		*HPWH manufacturer shall provide a five-year parts warranty on the HPWH that commences on the HPWH system startup date or six months after the HPWH ship date, whichever is earlier.*	
a	HPWH product warranty length:		years		
2	Does the HPWH manufacturer provide a minimum 1-year labor warranty for HPWH system troubleshooting, technical support, and parts replacement that commences on the HPWH system startup date?	[Y / N]		*HPWH manufacturer shall provide a one-year labor warranty for HPWH system troubleshooting, technical support, and parts replacement that commences on the HPWH system startup date.*	
a	HPWH labor warranty length:		years		
b	Provide a link to the warranty terms and conditions.	[link(s)]			
3	Does MFR require HPWH system startup be performed by a manufacturer-authorized service provider?	[Y / N]		*HPWH system startup shall be performed by a manufacturer-authorized service provider.*	
4	Is the HPWH capable of sending alarms to an offsite location if the following events occur?			*HPWH system shall be capable of sending alarms or notifications to an off-site location if the following events occur:*	
a	HPWH fails to start or is forced to shut off before the heating cycle is completed per the HPWH system sequence of operation	[Y / N]		*a. HPWH fails to start or is forced to shut off before the heating cycle is completed per the HPWH system sequence of operation*	
b	Auxiliary electric-resistance heating is activated (excluding swing tank heater or defrost operation)	[Y / N]		*b. Auxiliary electric-resistance heating is activated (excluding swing tank heater or defrost operation)*	
c	Provide a link to a document describing the configuration of these alarms.	[link(s)]			
5	Provide a link that outlines line items that must be purchased if any of the above requirements are not satisfied by the base HPWH offering.	[link(s)]			
E	**Standards Approval and Testing (Section 3.3.2 of AWHS)**	*Provide information on Laboratory Testing in compliance with the AWHS*			
1	Has the HPWH been certified per UL 1995 or UL 60335-2-40 by a Nationally Recognized Testing Laboratory (NRTL), Electrical Testing Laboratories (ETL), CSA International (CSA), or an equivalent third-party agency?	[Y / N]		*The HPWH shall meet UL 1995 and or UL 60335-2-40 through testing by a Nationally Recognized Testing Laboratory (NRTL), Electrical Testing Laboratories (ETL), CSA International (CSA), or an equivalent third-party agency to all standards required by local and national code.*	
2	To the manufacturer's knowledge, does the HPWH comply with the current versions of the International Electric Code, National Electric Code, International Plumbing Code, Uniform Plumbing Code, International Mechanical Code, and all applicable health and safety requirements?	[Y / N]		*The HPWH system shall comply with the current version of the following codes:* *a. International Electrical Code.* *b. National Electrical Code* *c. International Plumbing Code* *d. Uniform Plumbing Code* *e. International Mechanical Code* *f. All applicable health and safety requirements*	
Note: Sections F, G, and the sequence of operation in section H are used for Energy Modelling that drives performance tier assignment. A separate QPL entry will be assigned to each applicable piping configuration.					
F	**HPWH Performance Data (Section 3.3.3 of AWHS)**	*Provide information on HPWH performance in compliance with the AWHS and the California Energy Commission's JA 14*			
1	Has performance data in alignment with the *California Energy Commission's (CEC's) Joint Appendix 14: Qualification Requirements for Central Heat Pump Water Heater System standard (JA14)* been submitted? Provide submission date:	[Y / N]	[Date]	*Manufacturers shall submit performance data in alignment with the California Energy Commission's (CEC's) Joint Appendix 14: Qualification Requirements for Central Heat Pump Water Heater System standard (JA14)*	
a	Is the data provided in the JA14 submission based off simulated, or tested results?	[Tested / Simulated]			
b	Are all energy consuming heat pump components (compressor, fan, controls, pump, etc.) accounted for in the performance map data submitted to the CEC?	[Y / N]		**components include: compressor, evaporator & fan, condenser, expansion valve, and water pump**	
c	If No, list the components not included.	[list components not included]		**components include: compressor, evaporator & fan, condenser, expansion valve, and water pump**	
d	If No, provide the estimated power draw of all components not included.	[Power]	Watts		
e	Do the input power and output capacity in the performance map account for defrost operation?	[Y / N]			

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f	Provide a link to any accessory package line items that are required to achieve submitted performance data.	[link(s)]			
G	**Qualified Piping Configurations (Section 3.3.5 of AWHS)**	***Check all approved system configurations the HPWH unit is supported by the MFR to operate in:***		*Manufacturer-provided HPWH system piping schematics shall align with one or more of the following qualified piping configurations…*	
1	Single-pass HPWH:				
a	Split-system Single Pass: no hot water circulation system	[Y / N]			
b	Split-system Single Pass: hot water circulation returned to the primary storage	[Y / N]			
c	Split-system Single Pass: hot water circulation returned to a temperature maintenance tank in series (swing tank)	[Y / N]			
d	Split-system Single Pass: hot water circulation returned to a temperature maintenance tank in parallel	[Y / N]			
e	Other	[Y / N]	[Description]	*Guidance that does not align with the qualified piping configurations will be subject to review during the PADS process.*	
2	Multi-pass HPWH:				
a	Integrated HPWH: no hot water circulation system	[Y / N]			
b	Integrated HPWH: hot water circulation returned to primary storage	[Y / N]			
c	Split-system Multi-pass: no hot water circulation	[Y / N]			
d	Split-system Multi-pass: hot water circulation returned to the primary storage	[Y / N]			
e	Other	[Y / N]	[Description]	*Guidance that does not align with the qualified piping configurations will be subject to review during the PADS process.*	
Note: Except for the sequence of operation, section H does not drive performance tier assignment, but demonstrates the availability of manufacturer-provided guidance necessary for successful design and installation of their HPWH into a DHW system. If a MFR believes any information requested below does not apply to their product, please explain why.					
H	**Manufacturer-Provided Guidance (Section 3.3.4 of AWHS)**	***Provide links (and section numbers where applicable) to documents that provide the following information for the HPWH model represented in the JA14 performance data submission. If information is dependent on piping configuration, provide a link for each submitted piping configuration.***		*Manufacturers shall provide access to detailed HPWH system design and installation guidance that includes:*	
1	General summary of HPWH operation as part of a DHW system. This can be a high-level summary; specific setpoint temperatures and discrete control operation is covered later in this section.	[link(s)]		*General summary of HPWH system operation*	
2	Detailed piping schematics that align with each piping configuration in AWHS Section 3.3.5 that applies to this HPWH model. Schematics shall include locations of temperature sensors that drive HPWH operation.	[link(s)]		*Detailed piping schematics that align with one or more qualified piping configurations listed in Section 3.3.5. Guidance that does not align with the qualified piping configurations will be subject to review during the PADS process.*	
a	If "other" piping configuration is described in section G, provide a link to be subject to further review.	[link(s)]			
3	Detailed performance specification for all components defined in Section 3.2. This includes:			*Detailed performance specification for all components defined in Section 3.2*	
a	HPWH. Details will be explained in later sections of this document.				
b	Primary storage tanks. Details include temperature sensor locations, DHW inlet and outlet locations, orientation (vertical vs horizontal), HPWH supply and return connection locations.	[link(s)]			
c	Temperature Maintenance System. Where applicable, details include DHW inlet and outlet locations, sensor and electric element locations (where applicable), and HPWH supply and return connection locations (where applicable)	[link(s)]			
d	Controls and Sensors: details include (where applicable) temperature sensor specifications (size and wire type), control wiring requirements, additional controls required to satisfy AWHS general requirements (Section 3.3.1)	[link(s)]			
4	Requirements for additional ancillary HPWH system components including but not limited to mixing valves, check valves, circulation pumps, wye strainers, balancing valves, check valves, air vents. This includes (where applicable): inlet wye strainer mesh size, check valve cracking pressure and/or type, air vent type and location if required, hot water return pump flow or temperature differential limitations.	[link(s)]		*Requirements for additional ancillary HPWH system components, including but not limited to mixing valves, circulation pumps, wye strainers, balancing valves, check valves, and air vents*	
5	HPWH output heating capacity and storage sizing guidelines. This includes:			*HPWH output heating capacity and storage sizing guidelines*	
a	HPWH performance map/table as a function of air temperature that includes capacity de-rate due to defrost operation, or separate table that illustrates capacity de-rate due to defrost operation.	[link(s)]			
b	DHW storage sizing guidelines including storage volume and temperature sensor location as a function of total storage volume (aqua stat fraction).	[link(s)]			
6	Potable water quality, pressure, and flow considerations that affect DHW system piping design. This includes:			*Potable water quality, pressure, and flow considerations that affect DHW system piping design*	
a	minimum potable water quality requirements	[link(s)]			
b	min. and max water pressure allowed at HPWH inlet	[link(s)]			
c	max design water flow through HPWH (using max operating air temp, min TD through HPWH)	[link(s)]			
d	pressure drop associated with max design water flow in units without integrated circ pump, external pressure available during max design water flow in units with integrated circ pump	[link(s)]			
e	min and max water temperatures entering the HPWH.	[link(s)]			
7	Air source design considerations. This includes max air flow through fan coil, external static pressure available, ducting details (where applicable)	[link(s)]		*Air source design considerations*	
8	Electrical specifications. This includes voltage and phase, FLA, MCA, MOP.	[link(s)]		*Electrical specifications*	
9	Sound levels and sound testing method.	[link(s)]		*Sound levels and sound testing method*	
10	Installation specifications and requirements. This includes mounting details, clearance requirements, connection details, and any other information needed to physically install the HPWH.	[link(s)]		*Installation specifications and requirements*	
11	Maintenance requirements. This includes a maintenance schedule with all tasks required to keep the HPWH running long-term.	[link(s)]		*Maintenance requirements*	
12	Equipment operating manuals and warranty documentation.	[link(s)]		*Equipment operating manuals and warranty documentation*	
13	Sequence of operation. This includes any operation that affects air flow, power usage, or potable water flow and must include specific setpoint temperatures (on,off,leaving water temp) and sensor call-outs that align with the detailed piping schematic.	[link(s)]		*Sequence of operation*	

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	Example Sequence of operation: A) Staging of Multiple Heat Pumps: 1) Lead unit is wired to "on1" "on2" and "off" sensors. 2) If "on1" sensor reads less than 110°F, turn on one HPWH with lowest number of run hours. 3)Turn additional HPWHs on as "on" sensor drops in 5°F increments until all HPWHs are running. 4)If "on2" sensor reads less than 105°F, close auxiliary contact to activate P2 and WH2 per detailed piping schematic. 4a. WH2 and P2 shall provide 140°F water to the storage system. 5)If "off" sensor exceeds 125°F, turn off all HPHWs B) HPWH-level sequence of operation: 1) when HPWH is called to run, activate fan and pump at full speed. 2) after fan and pump have run for 1 minute, turn on compressor. 2a. HPWH modulates flow to produce a leaving setpoint temperature of 140°F. 3) if air temp is below 45°F, activate defrost for 10 minutes. 3a. turn pump and fan off during defrost. 4) when "off" sensor rises above 125°F, turn compressor, fan, and pump off.			
14	Is similar manufacturer guidance available for all other models in the product line that is represented in this PADS submission?	[Y / N]		
Note: Capabilities in section I are not required for inclusion on the qualified products list, but may be selectively incentivized or required by specific jurisdictions that wish to reference the AWHS				
I	**Optional HPWH System Capabilities (Section 3.3.6 of AWHS)**		*The following capabilities are not required for inclusion of a product line on the Qualified Products List but can be incentivized or required by local codes as local context deems appropriate:*	
1	Is CTA-2045 port available?	[Y / N]		
2	Does the manufacturer offer a measurement and verification equipment package that aligns with Appendix M of the AWHS?	[Y / N]		
3	Provide a link to any non-standard line items required to enable the capabilities listed above.	[link(s)]		