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Central Heat Pump Water Heaters for Multifamily Supply Side Assessment Study

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Executive Summary

Water heating constitutes the second-largest energy use in U.S. homes, combining with space heating to represent nearly two-thirds of a home's total energy use. In multifamily buildings of five or more units, water heating constitutes the top energy use (32%).[1] More than 11 million housing units in multifamily buildings are served by a centralized domestic hot water system (as opposed to water heaters in every unit). For these multifamily buildings, use of central heat pump water heater (HPWH) systems is a key decarbonization strategy, efficiently providing hot water to occupants with a lower operating cost than traditional systems. This technology provides a decarbonization pathway for a sector predominantly composed of renters, representing a higher percentage of households of color and lower-income households than the single-family sector.

To better understand the current landscape of central HPWH adoption in multifamily buildings in California and the Northwest, the Northwest Energy Efficiency Alliance (NEEA) contracted with New Buildings Institute (NBI) in January 2021 to conduct research and outreach to market actors in the central HPWH supply chain. The key research objectives were to:

- Identify all primary barriers to central HPWH adoption
- Better understand the value propositions (i.e., drivers) for each market actor in the central HPWH supply chain
- Utilize market actor feedback to understand the most effective pathways to increased market adoption of central HPWHs

Research activities included fielding an online survey targeting specifiers and installers and conducting a series of interviews across the supply chain. NBI identified four key findings based on its research activities:

Installation complexity and lack of installer education create barriers across the supply chain.

Market actors largely agreed that the number of installers educated about central HPWH systems is insufficient, specifically contractors with plumbing certification. Moreover, respondents reported that most plumbing contractors are not interested in learning about central HPWHs since they naturally favor the equipment with which they are already familiar and have spent years learning how to install and maintain gas appliances. They may also lack confidence in HPWHs or an understanding of the electrical requirements, making it difficult for them to maintenance the equipment and answer questions. Contractors also charge a premium labor cost for projects that include central HPWHs, and some respondents stated that contractors will make no effort to become familiar with the technology until it is required by code.

Space constraints create early roadblocks to adoption.

Challenges related to space constraints (e.g., "no suitable location to install") were cited as a primary barrier to central HPWH adoption (see Table 1). Central HPWH systems can require

[1] U.S. Energy Information Administration 2015

more space than typical gas boiler systems and have ventilation requirements that traditional systems do not require. Exterior installations are an option for central HPWHs, but this comes with structural or security concerns. Logistics of getting the equipment onsite can also be more complicated than for a typical system. Geographical considerations also come into play; colder ambient conditions affect the system design and efficiency.

Table 1. Summary of Barriers by Market Actor Group

Metric	Supply Chain	Designers	Installers	End Users
Complexity of installation				
No suitable location to install				
Lack of availability (equipment and labor)				
Higher cost				
Lack of confidence in the technology				
Noise concerns				

Notes: Supply chain includes manufacturers and distributors. Designers includes engineers and consultants. Installers includes general contractors and installers. End users includes developers, building owners, and facility managers.

Darker red cells indicate a higher frequency of mentions for the associated barrier. Unshaded cells indicate no mentions of the barrier by the market actor group.

Proper commissioning and building staff handoff are critical to end user satisfaction and operational success.

Commissioning is a critical part of a central HPWH project, especially in multifamily buildings containing many housing units. Incorrect commissioning can result in subpar system performance and decrease building management and facilities staff confidence in the technology —the day-to-day users of the system. Properly educating staff can be a challenge due to language barriers and their bandwidth as part-time employees. System maintenance plans that can be used to enter into service contracts are not always provided to building owners or maintenance staff, leaving them to work directly with the manufacturer to develop the contract or to rely on finding a service contractor who is already familiar with how to service a central HPWH. The shortage of educated service contractors in the market can make establishing a contract difficult and cause delays in addressing issues.

Incentive programs are the number-one driver for adoption, as upfront cost remains top barrier.

Aligned with research findings from other organizations, NBI's interview findings suggest that a downstream delivery method may be the most effective for central HPWHs. Proactive interest in central HPWHs by end users is not yet a primary driver. One developer said they have only general knowledge of the technology systems available to them; they look to the project team to recommend equipment. This speaks to the importance of education for midstream and upstream market actors.

Other costs associated with central HPWH systems, including operations and maintenance, were not included in the installer and specifier survey based on NBI's background research and were rarely mentioned by interview respondents. Thus, this report focuses on the upfront cost, which respondents frequently raised as a key barrier.

A variety of resources, activities and future research can be deployed to overcome barriers.

Based on the barriers outlined by survey and interview respondents, the project team identified the following recommendations to advance market adoption of central HPWH systems:

- **Sharing best practices.** Ensure that lessons learned are well-documented for pilot projects and that technology transfer is included in project budgets. A comprehensive guide to best practices or a central repository of resources containing best practices, segmented by market actor, would be valuable to the market, as would a virtual or in-person forum for knowledge sharing. A research project with the specific focus of gathering best practices could be beneficial.
- **Workforce education, training and awareness-building.** Seek additional opportunities to understand broader drivers and value propositions for installers. Encourage manufacturers and distributors to offer hands-on, product-specific trainings with real-world operational data for installers, reduce the financial barriers for service contractors to participate in these trainings, and provide a maintenance plan and basic troubleshooting guide tailored to building owners and maintenance staff.
- **Increasing access to quantitative data.** The market would benefit from one- or two-page fact sheets, case studies and other easy-to-digest collateral that include quantitative performance data and cost information. Additional research and education into cold-climate performance is also suggested.
- **Promoting the development of packaged systems.** Clearer "apples to apples" cost and performance comparison tools are needed to compare the cost of a packaged central HPWH system with a built-up system and other alternatives such as in-unit HPWHs or traditional gas boilers. Research on the market potential of packaged systems is also needed. Development of a Qualified Products List will make it easier to develop utility programs incentivizing packaged systems.

Introduction

Water heating constitutes the second largest energy use in U.S. homes, combining with space heating to represent nearly two-thirds of a home's total energy use. In multifamily buildings of five or more units, water heating constitutes the top energy use (32%).[2] More than 11 million housing units in multifamily buildings are served by a centralized domestic hot water system (as opposed to water heaters in every unit). For these multifamily buildings, use of central heat pump water heater (HPWH) systems is a key decarbonization strategy, efficiently providing hot water to occupants with a lower operating cost than traditional systems. Central HPWH systems can provide grid flexibility during times of peak load and can be scheduled to operate during times with lower pricing under a time-of-use rate structure. While a variety of residential HPWHs are available to the single-family residential market, central HPWH systems are relatively new technology, with limited models appropriate for use in multifamily buildings. Central HPWHs that use a low global warming potential (GWP) refrigerant are just coming to market and provide the opportunity to increase the efficiency and lower the operating cost of domestic hot water systems across the multifamily sector. This sector, which is predominantly composed of renters, also has a higher percentage of households of color and lower-income households than the single-family sector.[3] This is an important consideration as the sector works toward beneficial and equitable decarbonization.

Central HPWH systems installed in multifamily buildings offer a path to efficiency and decarbonization, but this technology faces a unique set of barriers that present challenges to widespread adoption. Contracted by the Association for Energy Affordability (AEA) and the Northwest Energy Efficiency Alliance (NEEA), New Buildings Institute (NBI) completed supply-side market actor engagement and outreach to help understand the mechanisms that would be most effective to transform the central HPWH market for multifamily applications, specifically in California and the Pacific Northwest. This research identified barriers and drivers in this market to inform future work that will most effectively promote widespread adoption of central HPWH systems in multifamily applications.

NBI undertook this work as a part of the Large Capacity CO2 Central Heat Pump Water Heating Technology Evaluation and Demonstration Project (LC-CO2 Project), led by the AEA and funded through the California Energy Commission (CEC) under the Electric Program Investment Charge Program (EPIC),[4] with matching funding from NEEA to support a wider regional scope for the Pacific Northwest. This research supports the primary goal of the LC-CO2 Project: Address the needs for design and installation of low-global warming potential (low-GWP) central heat pump water heaters.

[2] U.S. Energy Information Administration 2015
[3] Joint Center for Housing Studies of Harvard University 2022
[4] https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program

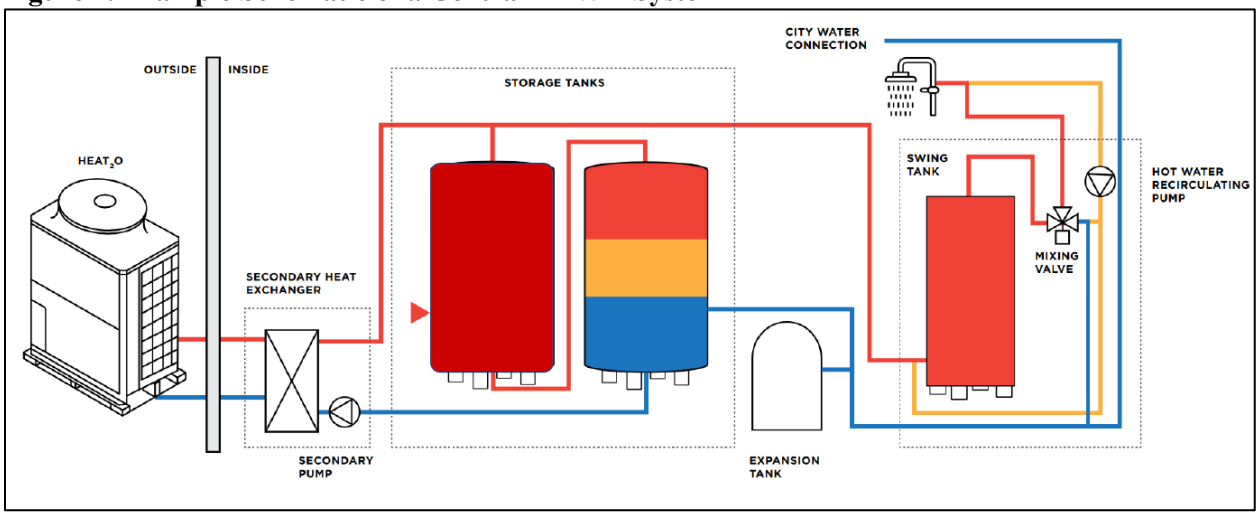
For this research, NBI targeted key market actors who could provide information via surveys and interviews, as described in the following sections. NBI set three primary goals for this research:

- Identify all primary barriers to central HPWH adoption
- Better understand the value propositions (i.e., drivers) for each market actor in the central HPWH supply chain
- Utilize market actor feedback to understand the most effective pathways to increased market adoption of central HPWHs

1.1 Central HPWH Technology Overview

Central HPWH systems are ideally suited to meet the domestic hot water needs of multifamily apartment buildings, hotels, and dormitories. Central HPWH systems heat and store water in a central location and typically use a recirculation loop to distribute the hot water throughout the building. Central HPWH systems have several configuration options, with four main components typical: primary heat pumps, primary hot water storage tanks, a temperature maintenance system (often called a "swing tank"), and a mixing valve.

Figure 1. Example Schematic of a Central HPWH System



Source: LC-CO2 Project Team

At the time of publication for this report, three central HPWH manufacturers currently sell equipment in North America that uses low-GWP CO_2 as the refrigerant: ECO_2 Systems, Lync by Watts and Mitsubishi.

1.1.1 Packaged System Approach

To date, central HPWH systems have typically been designed by combining key components to create a custom system for each project. To ease market adoption, the industry is moving toward a packaged system approach in which manufacturers offer a "plug and play" solution that can be shipped and installed as a complete solution. At a minimum, this includes the primary heat pump(s), the primary storage tank(s), the temperature maintenance system, and a control system. This approach streamlines the design process by housing all key components of the system in

one package, typically mounted on a skid, which can decrease design complexity, simplify the installation and commissioning process, and reduce upfront cost.

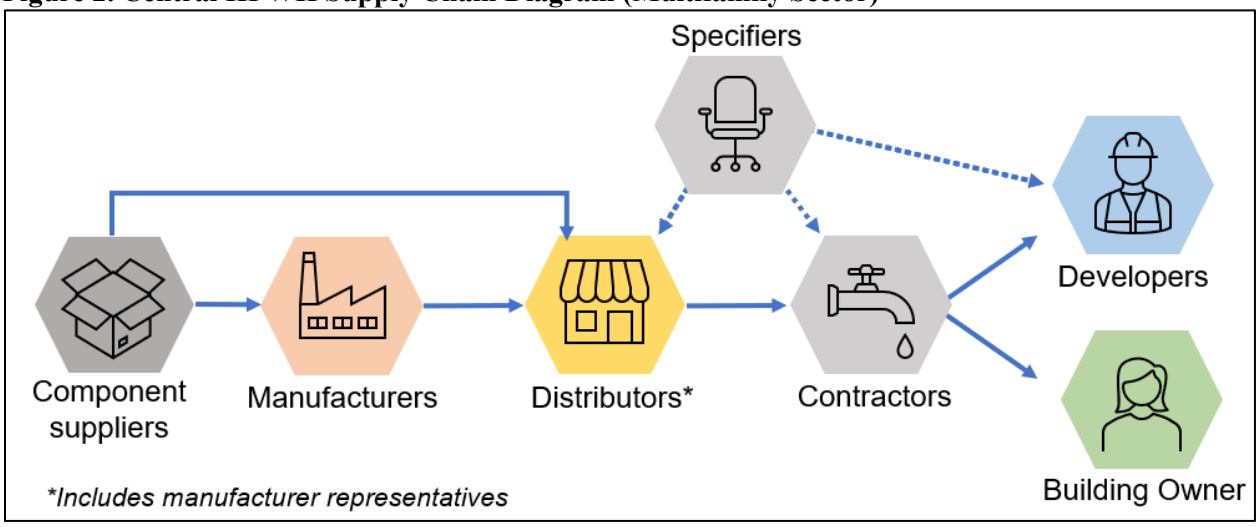
1.1.2 Central HPWH Specification and Qualified Products List

Work is underway to develop a qualified products list (QPL) for commercial/central HPWH systems. NEEA's Advanced Water Heating Specification (AWHS)[5] provides a mechanism for the QPL, which will provide a basis for prescriptive utility program support of central HPWH systems. The Bonneville Power Administration is working with central HPWH manufacturers to get products listed on the forthcoming QPL and is collaborating with NEEA on updates to the Commercial AWHS. The Ecosim tool created by Ecotope (not yet available for widespread distribution)[6] is used to model system performance and to predict an average annual system coefficient of performance (COP). This system COP will be used to qualify products based on the efficiency tiers set in the AWHS.

1.2 Central HPWH Market Actors and Supply Chain

Figure 2 illustrates a simple representation of the supply chain for central HPWH systems for multifamily buildings. Component suppliers provide raw materials to manufacturers, and supply items like plumbing connections and pumps directly to regional distributors. Much like large HVAC equipment, central HPWHs are brought to the market through regional distributors or manufacturer representatives. Distributors typically maintain a limited stock of units. Distributors also work with specifiers to design central HPWH systems, given the many components outside of the heat pump itself. Contractors then purchase equipment and parts from the distributor and pass the cost to the developer or building owner. Throughout this process, specifiers may also work directly with the contractor and/or developer, depending on the project type.

Figure 2. Central HPWH Supply Chain Diagram (Multifamily Sector)



[5] https://neea.org/resources/advanced-water-heating-specification-v8.0
[6] https://www.bpa.gov/-/media/Aep/energy-efficiency/emerging-technologies/20220602-ecosim-user-manual.pdf

Throughout this document, “installers” refers to the individuals installing the equipment. The “contractor” can also act as the installer, although often a general contractor oversees installation logistics and hires subcontractors with the relevant accreditations to complete the install.

In this document, “specifiers” includes architects, designers and mechanical engineering professionals (MEPs). In the central HPWH market, this most directly applies to MEPs working to design the domestic hot water system for a multifamily building. A project may employ a team that includes multiple entities in the specifier role (e.g., a plumbing engineer and an architect).

Methodology

NBI used a three-phase approach to evaluate the multifamily heat pump water heater market:

- Phase 1 (February 2021–November 2021):
  - Literature review
  - Preliminary interviews with key project contacts
  - Collaboration with other organizations conducting similar research
- Phase 2 (November 2021–March 2022):
  - Online survey of specifiers and installers
  - Follow-up interviews with interested survey respondents
- Phase 3 (April 2022– August 2022):
  - Targeted interviews with other supply chain actors

More details about each of these activities are provided below.

2.1 Phase 1: Literature Review and Preliminary Interviews

The goal of the first phase of research was to build foundational knowledge about central HPWH systems and the multifamily market, which would inform the focus areas of the following two phases of research.

NBI interviewed individuals from AEA and Ecotope (LC-CO2 Project Team), as well as two manufacturers, to get a sense of the barriers they have encountered and the questions they wanted to see answered through the research.

In this phase of the research, NBI coordinated with D+R International and Cadeo, two organizations also conducting research related to central HPWH systems, to ensure that the same market actors were not being tapped for similar information in short succession.

Lastly, NBI conducted a literature review. This included reviewing lessons learned and best practices identified for the single-family HPWH market to identify market transformation strategies that could be adapted to multifamily applications.

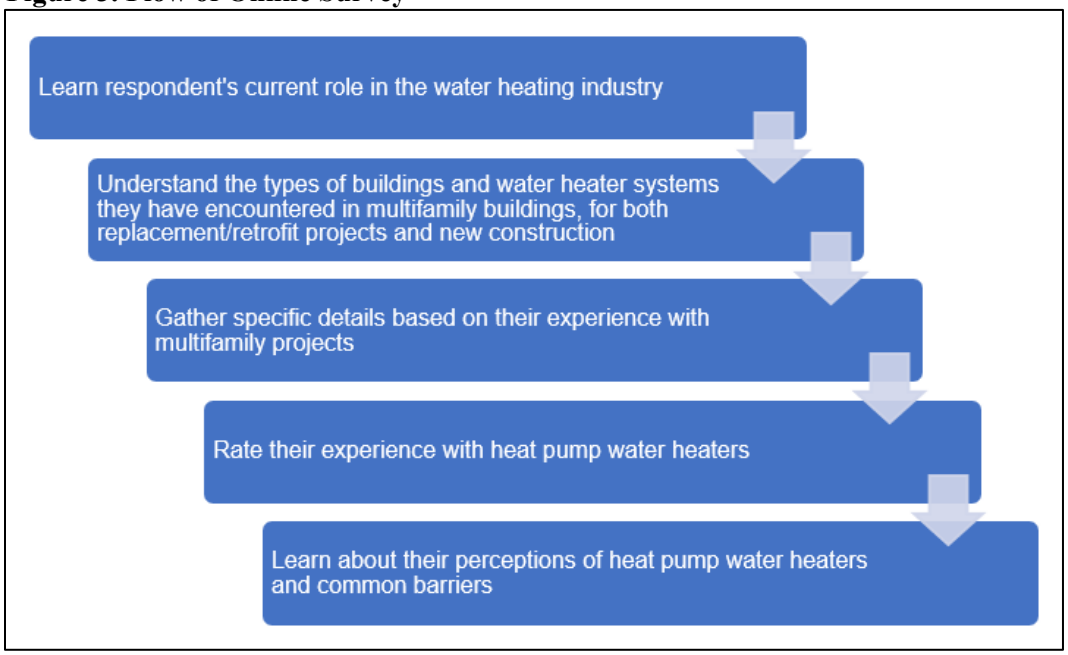
2.2 Phase 2: Online Survey of Specifiers and Installers

To better understand the existing water heater market and perceptions of HPWHs, NBI created a survey tailored for specifiers and installers, with input from the LC-CO2 project team. Specifiers and installers are key market actors in the central HPWH supply chain. Installers are the "boots on the ground" and face barriers in their day-to-day operations. Due to the limited number of skilled installers in the current market, they can have a larger influence on the overall cost of a central HPWH system than other market actor groups and project teams may be required to select an installer charging a premium. Specifiers and installers also interact substantially with other market actors, including developers and building owners.

This market group was identified as a good candidate for an online survey due to the large number and diversity of firms operating in California and the Pacific Northwest. NBI included installers in the survey sample to maximize the potential touchpoints, given they comprise a difficult group to reach.

NBI created a survey consisting of multiple choice, rating scale, drop-down, open-ended, and ranking questions. The survey was designed to take no more than 15 minutes. Figure 3 outlines the flow/structure of the survey.

Figure 3. Flow of Online Survey



NBI created a targeted email list based on its known contacts in the industry and recommendations from AEA and NEEA. The contacts were primarily located on the West Coast and primarily based in the U.S., with some representation from Canada. From that list, NBI contacted 96 individuals via email asking for their participation in the online survey and explaining the purpose of the study. Figure 4 illustrates the market actor breakdown. As described in Section 1.2, specifiers may include architects, engineers, or consultants. In addition to the targeted email list, NBI provided AEA and NEEA with the survey link so they could directly reach out to additional contacts. NBI also posted the survey in the Advanced Water Heating Initiative (AWHI) quarterly newsletter and shared with NBI senior fellows to cast the widest net possible.

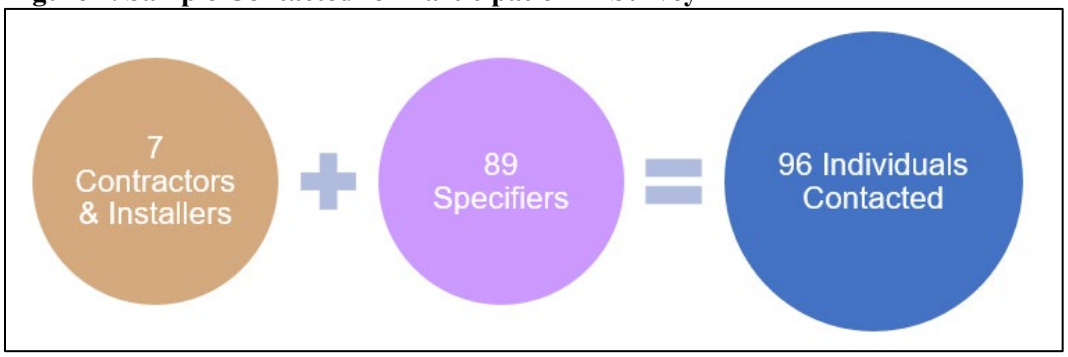
NBI contacted individuals on the original targeted email list a second time if they did not complete the survey within three weeks. The survey was left open for three months, and 40 recruits completed the survey during that time, with 34 complete responses.

The online survey included a question for respondents to indicate if they were interested in participating in a follow-up interview. Eighteen of 34 respondents indicated they were interested in a follow-up conversation. NBI contacted nine of the 18 for follow-up interviews, aiming for a wide range of responses and experience from among those willing to participate in an interview. Of the nine individuals contacted, three agreed to a follow-up interview.

NBI conducted 30-minute video interviews with these three respondents, who identified as engineers (2) and non-engineering consultant (1). In addition to standard questions for each

interview, NBI tailored some questions to gather more information on relevant survey responses. During the interviews, NBI led with the prepared questions, but allowed for open conversation about topic areas most important to the interviewee. As such, not all questions were asked in every interview.

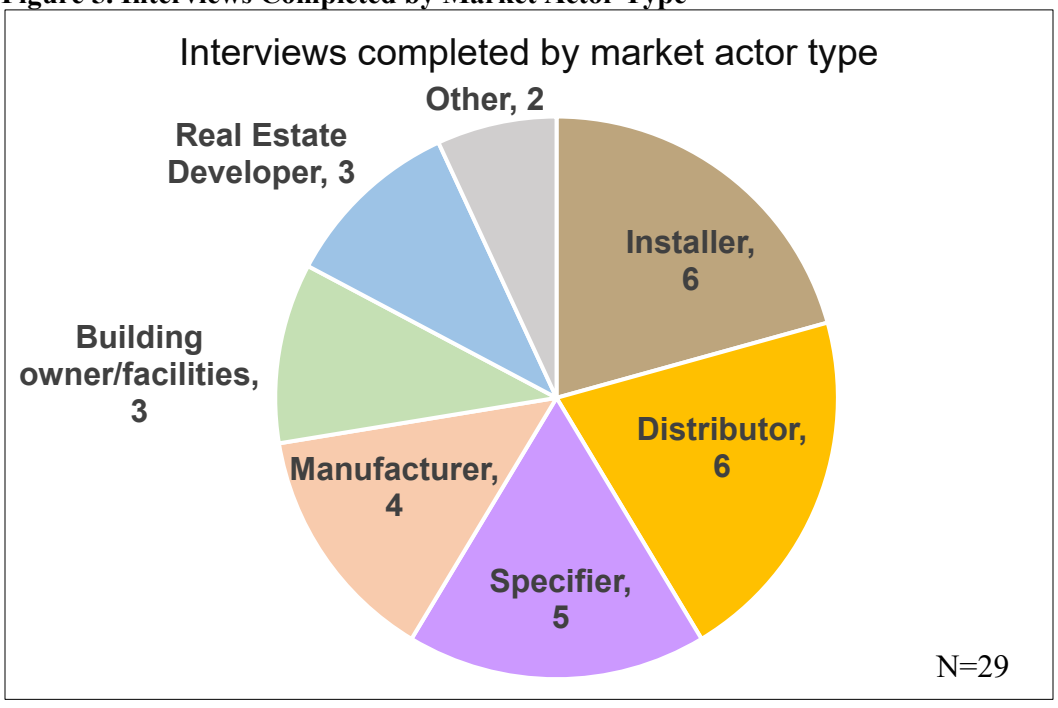
Figure 4. Sample Contacted for Participation in Survey



2.3 Phase 3: Targeted Interviews with the Supply Chain

NBI conducted a total of 29 interviews with members of the supply chain, as summarized in Figure 5. This includes the three follow-up interviews with survey respondents as described above and an additional 26 interviews through direct outreach. Additional details are provided in the sections that follow. Figure 6 summarizes the outreach modalities and ultimate interviews for all market actors.

Figure 5. Interviews Completed by Market Actor Type



Note: "Other" refers to consultants involved in a central HPWH project that did not fit into any of the other categories (e.g., an implementer of a field study).

2.3.1 Installers—The "Boots on the Ground"

The goals of conversations with this market actor group were to:

- Gauge familiarity and confidence with HPWH
- Understand common issues that complicate installation and commissioning
- Identify the best way to reach this market actor group for training and education

Installers proved difficult to reach, for several reasons: 1) They spend a large amount of time in the field; 2) The number of installers familiar with the technology is limited; and 3) Their revenue is directly tied to onsite project work. The absence of incentives for participation in this research created a challenging value proposition to this market group. Due to the low number of installers who completed the survey, NBI conducted additional direct installer outreach via phone and email to a total of 20 installers that were not previously contacted through the survey outreach. Among these, NBI was able to conduct video interviews with six organizations with direct installation experience or representing installer interests.

2.3.2 Specifiers—The Connectors

The goals of conversations with this market actor group were to:

- Gain greater understanding of the key barriers to designing central HPWH systems
- Identify the key drivers to selection of central HPWH
- Get insight on interactions and influences between market actor groups

Specifiers were the easiest group to reach due to the number of firms operating in California and the Pacific Northwest, and the number of existing relationships the LC-CO2 Project Team had with this group. This market actor group also includes more job roles – for example, both architects and mechanical engineering professionals (MEPs) were grouped into this market actor category. NBI's primary outreach to this market actor group was for the online survey, for which 89 individuals were contacted and three follow-up interviews were conducted. Additional targeted outreach was completed to six individuals (who did not complete the survey) resulting in two additional interviews.

2.3.3 Facility Managers, Building Owners and Real Estate Developers—The Demanders

The goals of conversations with this market actor group were to:

- Understand motivations for choosing HPWHs
- Gauge maintenance needs and perceptions of ease of operation
- Understand satisfaction with HPWHs and flag potential areas of dissatisfaction

For these interviews, NBI compiled a list of building owners, facility managers and real estate developers through recommendations from AEA, Ecotope and NEEA. Additional contacts came from recommendations from other partner organizations and from NBI's database. The interviewees consisted of building owners, facility managers and developers that had previously installed a HPWH, considered installing a HPWH, or were interested in HPWHs for future projects. NBI contacted 26 building owners, facility managers, and developers and ultimately conducted six interviews. NBI prepared interview questions in advance and allowed each interview to serve as an open forum and discussion.

2.3.4 Distributors/Wholesalers/Manufacturers' Reps—The Sellers

The research goals for this market actor group were to:

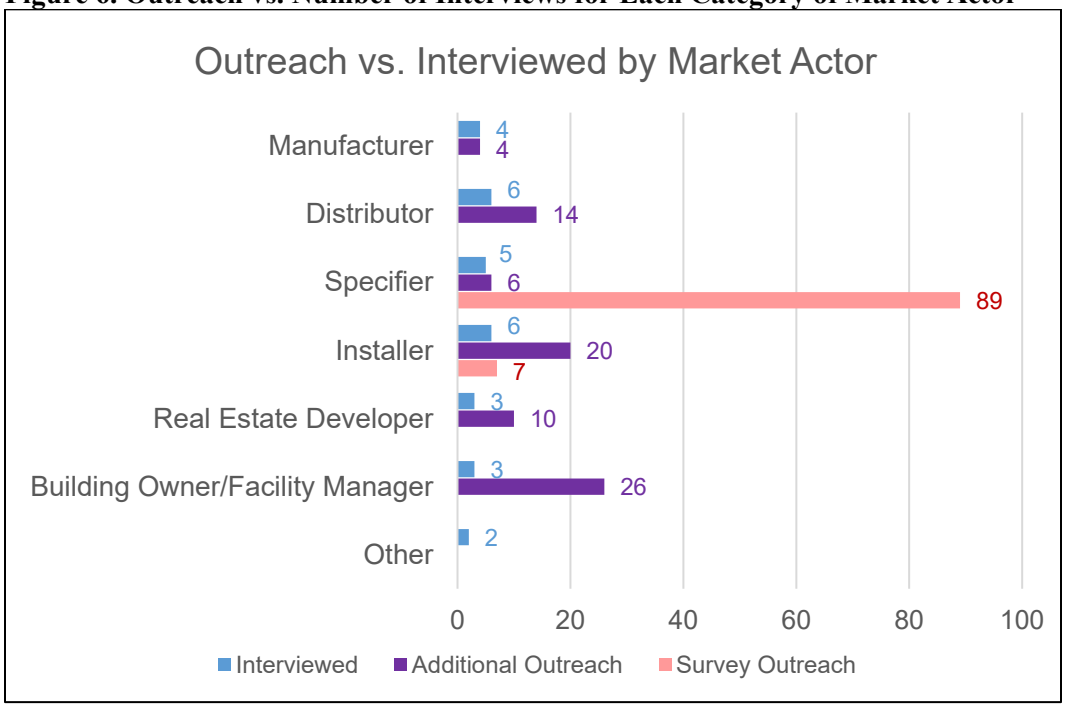
- Understand supply and stocking barriers
- Gain insights into market demand
- Understand pricing agreements with manufacturers
- Identify resources the distributor is providing to the market

For these interviews, NBI used contacts from NEEA, AEA and Ecotope, plus additional contacts from previous relationships within AWHI. NBI contacted 14 distributors and interviewed a total of six. The interviews were the same structure as those described for the previous market actor categories.

2.3.5 Manufacturers—The Suppliers

The goals for manufacturers were similar to those for the distributor interviews. To recruit manufacturers, NBI leveraged contacts from the LC-CO2 project team and relationships NBI built through AWHI. NBI ultimately interviewed representatives from four manufacturers that currently offer commercial HPWHs, with the same structure as the previously described interviews.

Figure 6. Outreach vs. Number of Interviews for Each Category of Market Actor



2.4 Limitations

Due to the large amount of data collected through the phases of this research, NBI faced a few important limitations:

- **Recruitment**—Recruiting participants to take the survey and participate in interviews proved more of a challenge for some categories of market actors than others. Specifically, NBI had difficulty contacting installers due to installers' highly variable schedules and time spent in the field. The team found some outdated building owner and facility manager contacts (i.e., the individual was no longer with the company); in other cases, the contacts NBI could reach were not employed at the time of the central HPWH system installation.
- **Experience Bias**—NBI intended to gather data from market actors with a range of expertise levels, but data may be skewed toward those with higher levels of expertise; participants may have only felt comfortable participating in the research if they had previous experience with HPWHs. Additionally, the pool of individuals NBI contacted is inherently skewed toward individuals with an interest in efficient water heating, as many of the contacts are part of AWHI.
- **Generalizability**—A common limitation of market research is generalizability, the extent to which findings from a study apply to a wider population. The research included a small sample size and focused on a specific region.
- **Current Market Conditions—**This research was conducted as the market was recovering from the COVID-19 pandemic, which heavily impacted the supply chain including equipment and part availability, workforce availability, and changes in channels of communication and interaction. This report does not detail challenges directly related to the pandemic; the goal is to provide information that will be applicable in a more typical market condition.

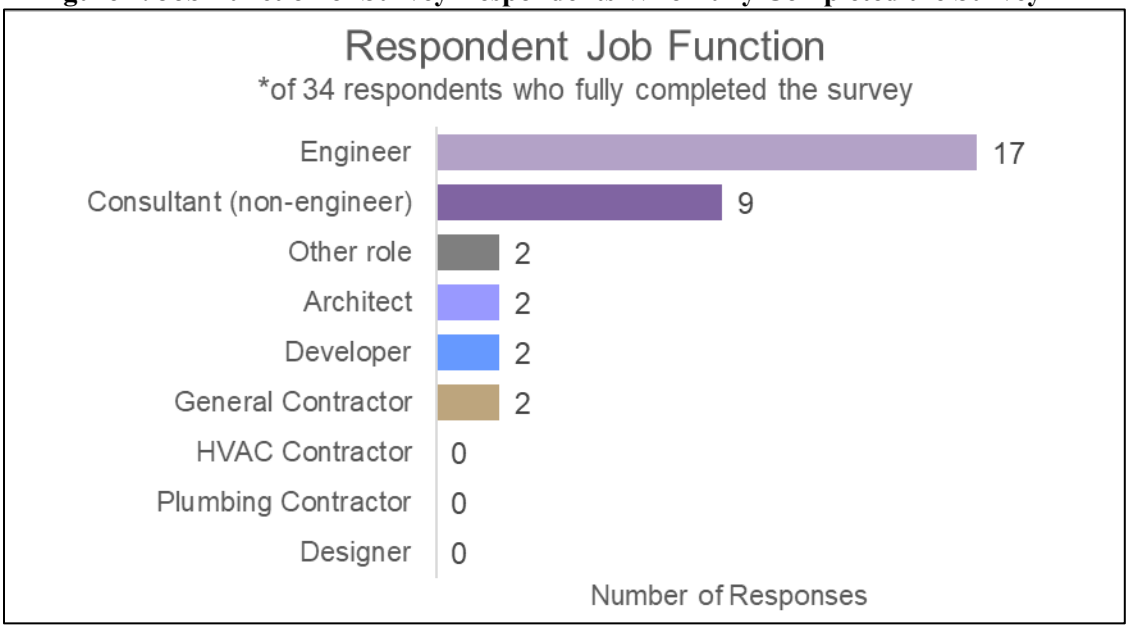
Analytical Results

3.1 Survey Response Demographics

The online survey targeting specifiers and installers resulted in 40 responses, with 34 considered complete enough to include in the analysis. Most respondents (59%) operate in states applicable to NEEA (Oregon, Washington, Montana and/or Idaho), followed by California (27% of respondents). Other locations represented include New York, Canada, the Northeast, Texas, and Oklahoma.

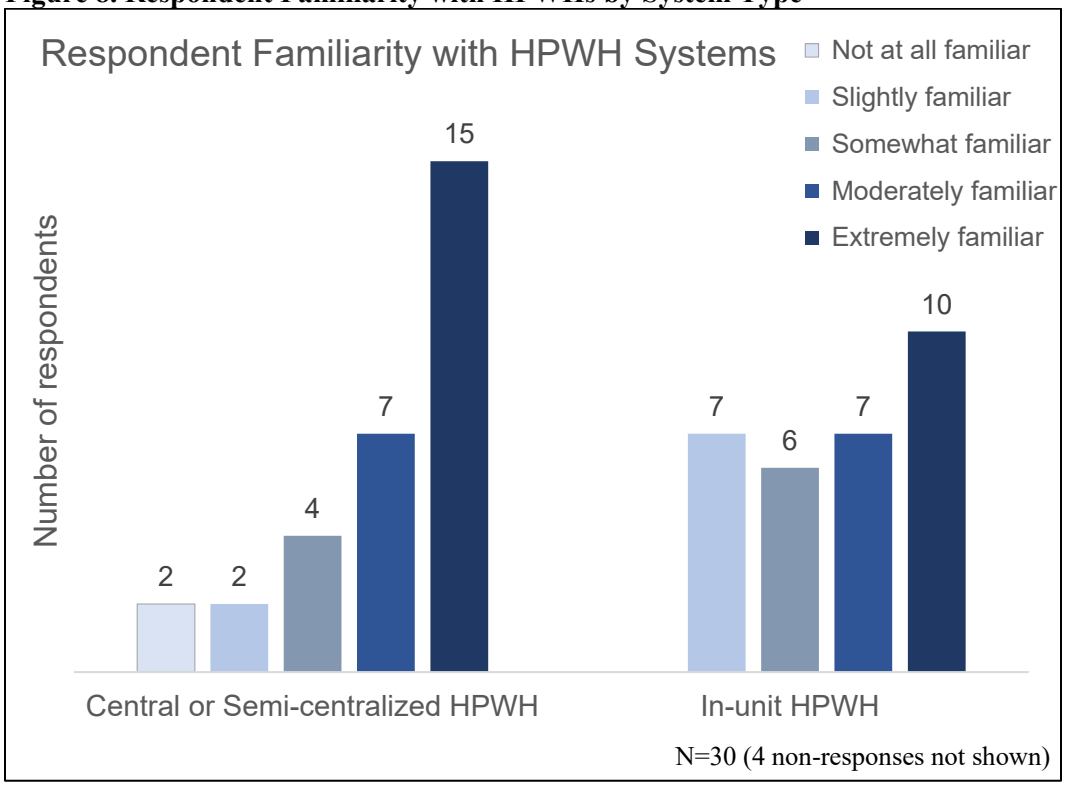
Nearly 90% of survey respondents are mid-senior level or higher in their career. As shown in Figure 7, most respondents self-identified as Engineers or Consultants. No respondents identified as a HVAC or Plumbing Contractor or Designer.

Figure 7. Job Function of Survey Respondents Who Fully Completed the Survey



Nearly all respondents who completed the survey are at least somewhat familiar with central or semi-centralized HPWH systems, with most respondents indicating they were extremely familiar. Respondents were also familiar with in-unit HPWHs in multifamily buildings, but fewer indicated they were extremely familiar.

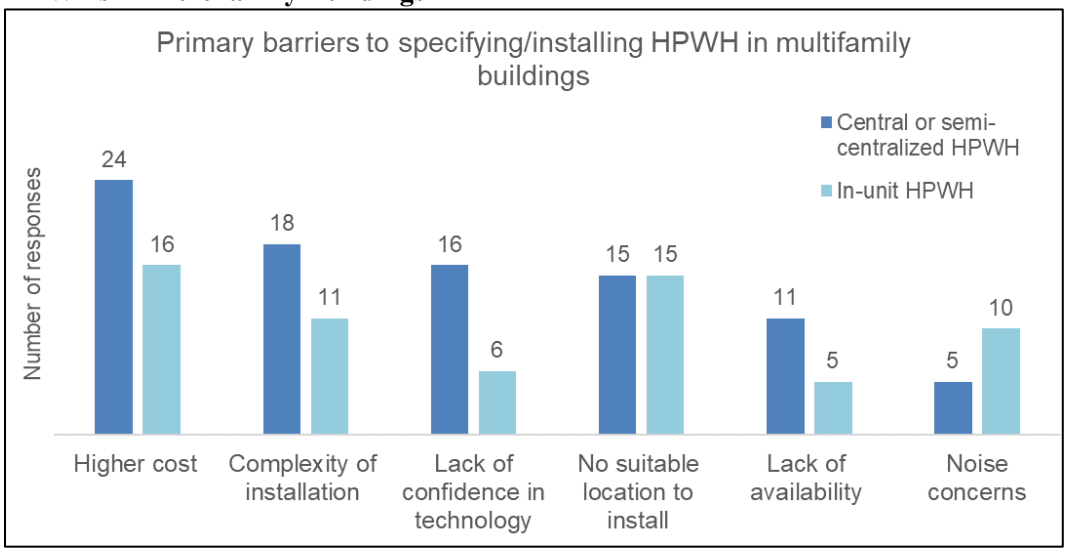
Figure 8. Respondent Familiarity with HPWHs by System Type



3.2 Primary Barriers

NBI used findings from the literature review, preliminary interviews, information from the LC-CO2 project team and knowledge from AWHI to identify a set of primary barriers. Survey respondents were asked to select all primary barriers they had experienced when specifying or installing HPWHs in a multifamily building, for both central and/or semi-central HPWH systems, and for in-unit HPWHs. For central HPWH systems, cost was the most frequently selected barrier, followed by complexity of installation.

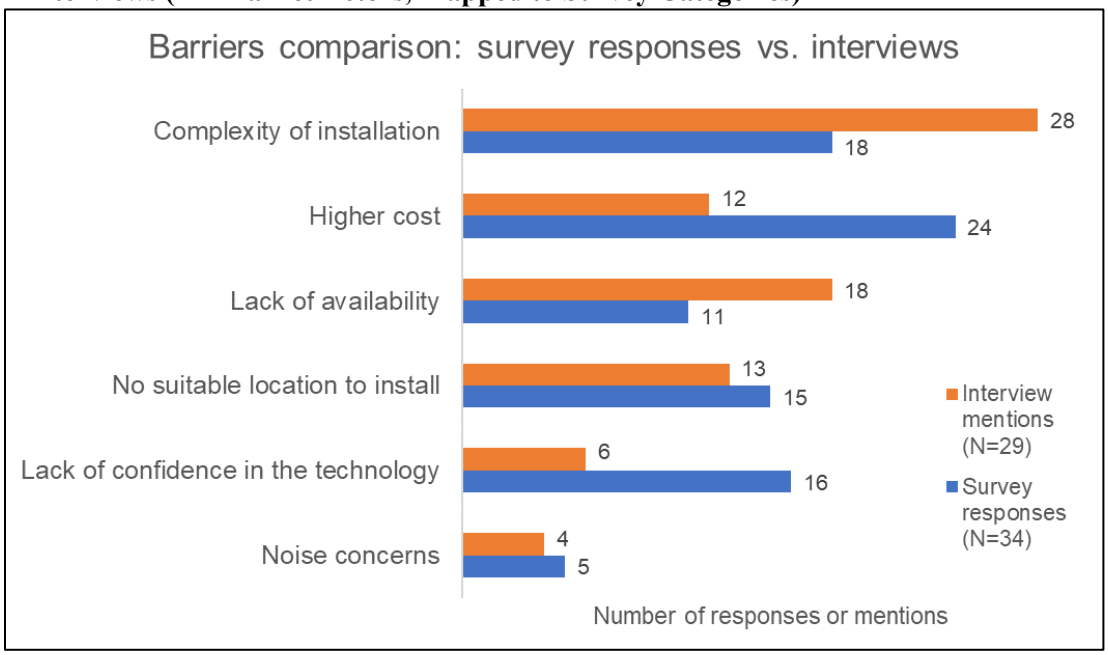
Figure 9. Barriers Experienced by Survey Respondents When Specifying/Installing HPWHs in Multifamily Buildings



Although many survey respondents cited lack of confidence in HPWH technology as a primary barrier (see Figure 9), respondents reported a high level of confidence in HPWH technology: nearly half of the respondents (44%) claimed to be completely confident in the technology to reliably provide hot water when needed, assuming the system is designed and installed correctly. Another 41% were fairly confident, and the remaining 15% were somewhat confident. Interview responses revealed that much of the lack of confidence is related to performance in colder climates.

To allow a degree of comparability between the survey responses and interview findings, barriers mentioned in the interviews were mapped to the barrier categories presented in the survey. Because the interview conversations did not follow a restrictive script, the interview results only indicate the barriers that interviewees felt most compelled to discuss. Figure 10 shows the barriers, mapped to the survey categories, most frequently mentioned in the interviews vs. survey responses.

Figure 10. Barriers Mentioned in Survey Responses (Specifiers and Installers) vs. Interviews (All Market Actors, Mapped to Survey Categories)



Among interview responses, complexity of installation was frequently mentioned across the Supply Chain (manufacturers and distributors), Designer (engineers and consultants) and Installer (general contractors and installers) participants. The End User group (developers, building owners and facility managers) cited lack of suitable installation location as the top barrier. The Installer participants cited higher cost as a barrier more frequently than did other market actor groups.

Table 2. Barriers by Market Actor Group

Barrier	Supply Chain	Designers	Installers	End Users
Complexity of installation				
No suitable location to install				
Lack of availability (equipment and labor)				
Higher cost				
Lack of confidence in the technology				
Noise concerns				

Note: Darker red cells indicate a higher frequency of mentions for the associated barrier. Unshaded cells indicate no mentions of the barrier by the market actor group.

3.3 Drivers and Value Propositions

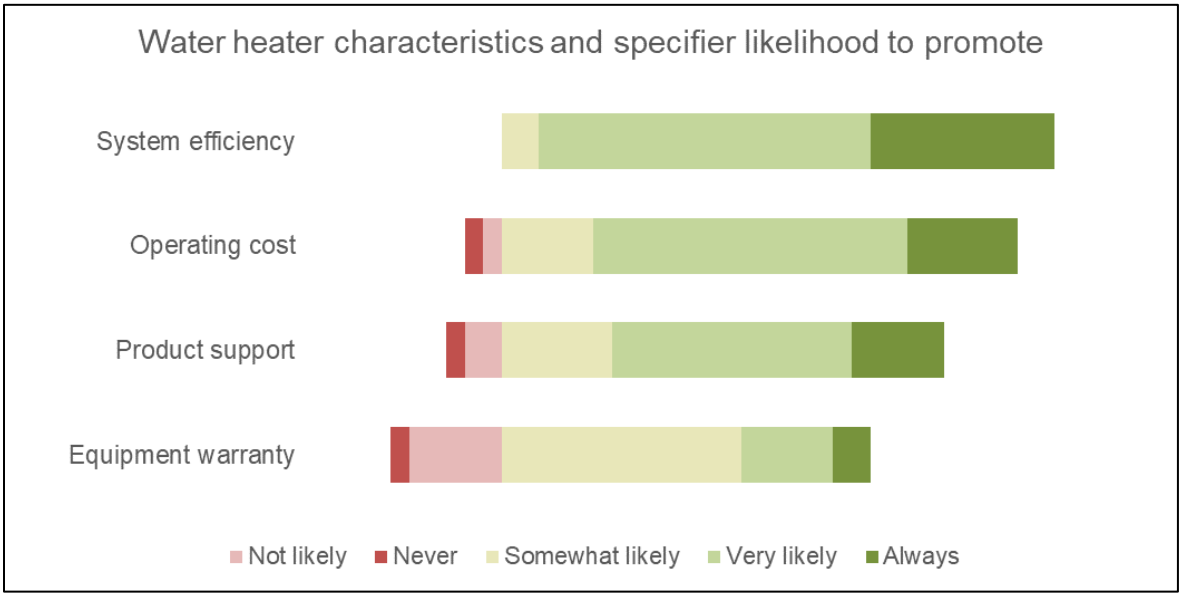
3.3.1 Water Heater Characteristics

NBI sought to identify the equipment characteristics specifiers promote when recommending a water heater for a project (not specific to central HPWHs). Among four water heater

characteristics respondents were asked to rate on likelihood to promote (see Figure 11), all respondents who rated *system efficiency* claimed they typically promote it, with *operating cost* a close second. While respondents cited lower levels of promotion for *product support* and *equipment warranty,* a majority of those who ranked those characteristics still claimed they do promote those categories. One respondent noted that they would not lead with the equipment warranty and product support, but clients will proactively request information about these aspects.

Among open-ended "Other" responses to the question regarding promotion of water heater characteristics, respondents cited promotion of the reliability and capability of the system to deliver hot water, their knowledge and experience with the system, installation cost, future government mandates and incentives, and local availability of parts and service for both the installation and the lifetime of the equipment.

Figure 11. Likelihood of Survey Respondents to Promote Certain Water Heater Characteristics



Note: All respondents did not indicate their likelihood to promote every characteristic, thus some characteristics have slightly more responses than others.

3.3.2 Incentives

Among interview participants, incentives were the most frequently cited driver for considering a central HPWH system. Several participants said that they were not initially considering a central HPWH system, but lucrative incentives attracted them to learn more and ultimately to select central HPWHs for their buildings' domestic hot water needs. For example, the TECH Clean California initiative offers incentives up to $1,800 per apartment served for central HPWH systems.[7] Interview participants also frequently mentioned sustainability goals, which includes

[7] Incentive at the time of writing. More information can be found here: https://energy-solution.com/tech/

developer and building owner interest in reducing carbon emissions, electrifying major mechanical systems, and maximizing energy efficiency.

3.3.3 Codes and Policies

Interview participants see codes and policies as a future driver of central HPWH adoption. Some noted that they are proactively promoting central HPWHs in anticipation of upcoming mandates. Others asserted that code requirements are the only way that central HPWHs will see widespread adoption. Some jurisdictions are beginning to require HPWHs in certain water heating applications. For example, Washington state has adopted requirements for HPWHs in commercial buildings in some applications and is currently considering a similar requirement for single-family homes.

Additionally, jurisdictions are also beginning to adopt demand responsive water heating requirements such as CTA-2045 (e.g., Washington state, the City of Denver and a proposal to the International Energy Conservation Code (IECC)). Given these demand responsive controls are primarily being implemented on HPWHs, their adoption effectively requires use of HPWHs.

3.3.4 Project Team Influence

Several interview participants stated they made the decision to choose a central HPWH system because a member of the project team (e.g., architect, engineer, installer) promoted the technology and had confidence in its ability to meet hot water needs. In one case, the utility representative suggested central HPWHs, which influenced the developer.

3.3.5 Project Focus

The project focus constituted a less frequently cited but still-important driver in choosing central HPWHs. The design approach and project team composition impact the project focus, which can be lowest cost with fastest return on investment, or can be more focused on sustainability. See Section 4.1.1, “Impact of Project Delivery Method,” for more information.

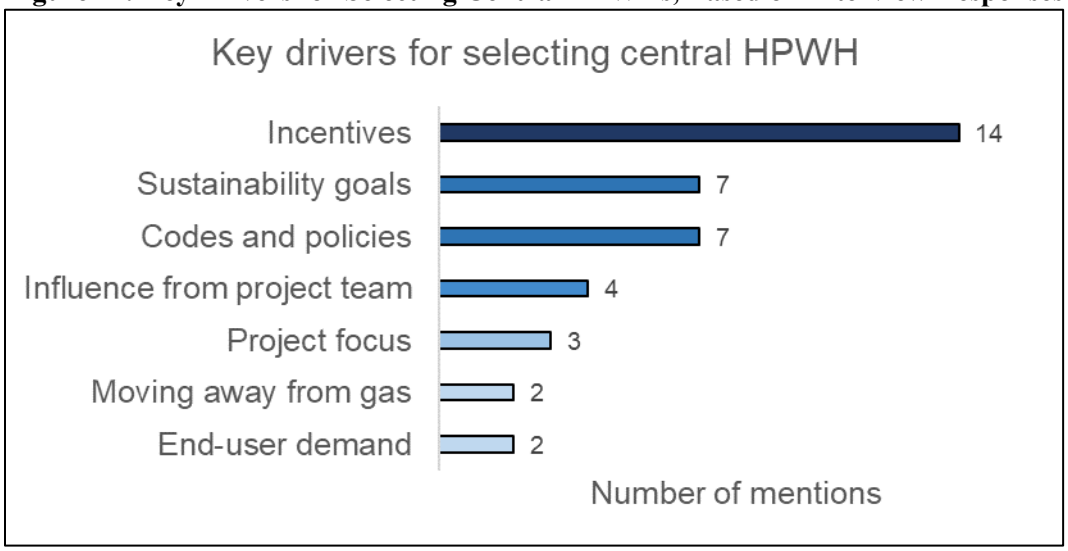
3.3.6 Moving Away from Gas

Two interview participants highlighted the benefit of moving away from natural gas on a property. Downgrading or removing a gas connection in retrofit projects provides a cost benefit and was cited as a human health benefit to tenants. Removing or avoiding the installation of gas infrastructure also provides added convenience to the developer and/or building owner as it eliminates the need to work with both a gas utility and an electric utility.

3.3.7 End User Demand

One manufacturer and one engineer each mentioned that an end user proactively showing interest in or requesting central HPWHs served as a driver. One developer said they have only general knowledge of the technology systems available to them; they look to the project team to recommend equipment. This speaks to the importance of education to midstream and upstream market actors.

Figure 12. Key Drivers for Selecting Central HPWHs, Based on Interview Responses



3.3.8 Drivers Most Commonly Observed by Market Actor Group

Table 3 summarizes the drivers most frequently mentioned by each market actor group. This does not necessarily indicate that they are a driver to that group. Instead, it provides a summary of the drivers seen as most influential in the selection of central HPWHs. For example, though manufacturers and distributors may not receive incentives, they recognize them as a primary driver for the market overall. Similarly, general contractors (part of the installer group) may not be pushing sustainability goals themselves, but they have observed that end user sustainability goals are a driver for the selection of central HPWHs.

Table 3. Heatmap of Drivers Mentioned by Each Market Actor Group

Driver	Supply Chain	Designers	Installers	End Users
Incentives				
Codes and policies				
Sustainability goals				
Influence from project team				
Project goals				
End user demand				
Moving away from gas				

Note: Darker red cells indicate a higher frequency of mentions for the associated barrier. Unshaded cells indicate no mentions of the barrier by the market actor group.

Key Findings

Four key findings emerged from NBI's qualitative and quantitative research activities for this project. The findings provide a snapshot of the market sentiment at the time of the research (Fall 2021 through Summer 2022). Many respondents called out the progress already made related to mitigating jurisdictional hurdles, availability of education and resources related to proper sizing, and the general level of awareness and education about central HPWHs, especially among specifiers.

Respondents also noted that as of the time of interviews in early to mid-2022, the supply chain seems to have mostly recovered from the challenges experienced during the height of the COVID-19 pandemic.

1 Installation complexity and lack of installer education creates barriers across the supply chain

The complexity of the technology, workforce shortages, and lack of interest from installers causes project delays and increased costs that jeopardize central HPWH selection.

2 Space constraints create early roadblocks to adoption

The size, ventilation needs, and other attributes of central HPWH systems limit installation location options inside the building, and outdoor installations bring their own challenges.

3 Proper commissioning and building staff handoff are critical to end—user satisfaction and operational success

Day-to-day operations fall to maintenance staff, who need to feel confident in the system, competent to troubleshoot minor issues, and supported by a service contractor.

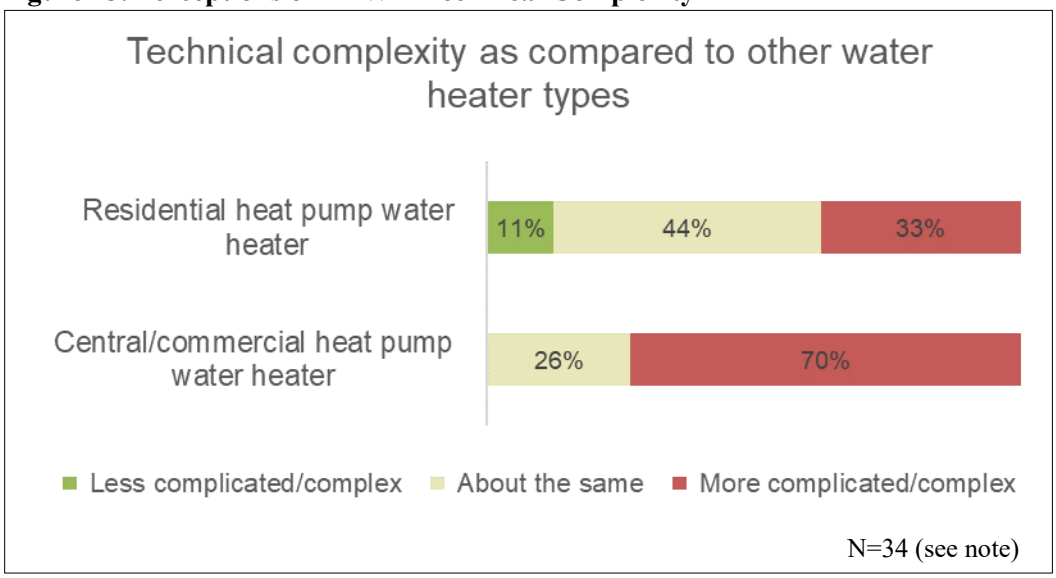
4 Incentive programs are the number one driver for adoption, as upfront cost remains top barrier

Upfront cost is a major barrier to adoption, but downstream and midstream incentives can provide an effective solution.

4.1 Installation Complexity and Lack of Installer Education Creates Barriers across the Supply Chain

Complexity of installation was the most commonly mentioned barrier to central HPWH adoption within the interview group (mentioned by 97% of interviewees) and was cited as a primary barrier by 53% of survey respondents. Survey respondents also consider central/commercial HPWHs more complicated/complex than other water heater types to a greater extent than the same comparison for residential HPWHs vs. other water heater types, as shown in Figure 13

Figure 13. Perceptions of HPWH Technical Complexity



Note: From responses to online survey. Three "not sure/not applicable" responses excluded.

Interview responses contributed details regarding the most challenging facets of installation complexity and highlighted the impact of this barrier across the supply chain. Many facets of this barrier relate to installation contractors. Central HPWH systems are unique in that they require multiple trades for installation: plumbing contractors, mechanical contractors, and refrigeration contractors, which adds complexity to project logistics. Most project teams include a general contractor that acts as the project manager for the installation.

All market actor categories agreed about a lack of installers educated about central HPWH systems, specifically contractors with plumbing certification—an issue that is common for single-family residential HPWH installers as well. Moreover, respondents reported that most plumbing contractors have little/no interest in learning about central HPWHs and charge a premium labor cost for projects that include central HPWHs. Some interviewees posited that contractors will make no effort to become familiar with the technology until it is required by code. Most contractors, according to interviewees, are not interested in learning about central HPWHs because they naturally favor the equipment with which they are already familiar and have spent years learning how to install and maintain the equipment (typically gas appliances). They also lack confidence in HPWHs and/or do not understand the electrical requirements, making it difficult for them to maintain equipment and answer questions. While contractors could take the time to learn the equipment and how to properly install, they simply do not have the bandwidth because their income is project-dependent. Some manufacturers have struggled with contractors trying to cut costs by swapping out necessary components of the system, causing the system to have a lower efficiency or to not work at all.

Despite the hesitance of many installers to accept central HPWHs, some contractors have familiarized themselves with the technology and are qualified to work on central HPWH projects. However, interview participants reported a shortage of knowledgeable contractors of all kinds, and added that knowledgeable contractors are overbooked, causing project delays.

In addition to these installer-related challenges, interviewees cited a profound gap in the market for service contractors, and training is not easily accessible to them. Manufacturers and distributors typically provide training only to their customer—the installation contractor. The installation contractor does not always provide a service contract for ongoing service and maintenance. Thus, contractors who specialize in service only (i.e., not installations) must proactively seek training at their own expense if they wish to learn about a particular central HPWH system. One building owner stated that they had to work directly with the central HPWH manufacturer to develop a service plan and search for a service contractor. Despite this effort, they have been unsatisfied with the service provided by the contractor and are seeking an alternative contractor.

Due in part to the factors described above, onsite commissioning support is provided by either the manufacturer or distributor for all the central HPWH equipment represented in our interviews.

4.1.1 Impact of Project Delivery Method

Both engineers and distributors noted that the project delivery method can impact the likelihood of choosing a central HPWH for a project, and the predominant project delivery method varies by geographical region. Seattle, which boasts a large share of existing central HPWH installations, is predominantly a design-build market. This delivery method has proven successful because the contractor that oversees installation is also involved in the design process. In the plan-spec delivery method, the installation contractor is typically involved later in the project. One distributor explained that they have seen issues with this delivery method when the installation contractor is unfamiliar with central HPWHs and has not been a part of the design process. As a result, the contractor is not invested in the project and does not want to take any responsibility if issues arise. Interviewees also shared that projects with specialized consultants can be more successful. This may include engaging a domestic hot water consultant to work with the mechanical engineer or hiring a commissioning consultant to assist the installation contractor.

4.2 Space Constraints Create Early Roadblocks to Adoption

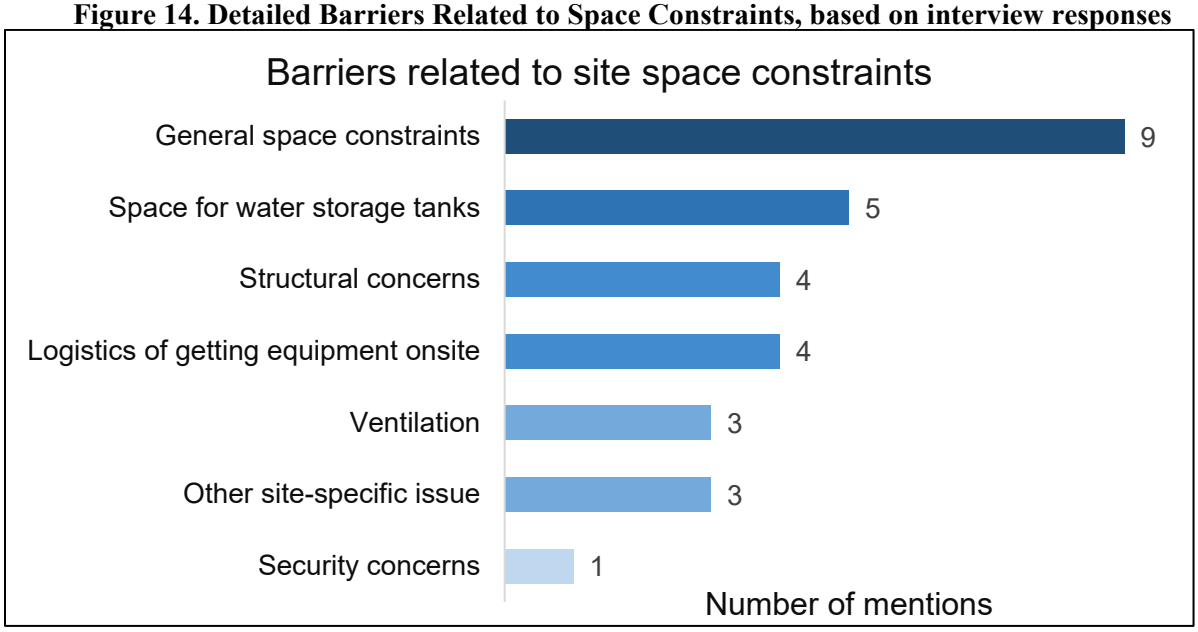
Challenges related to space constraints (e.g. “no suitable location to install”) were cited as a primary barrier to central HPWH adoption by 44% of the respondents of the online survey and was the third-most mentioned barrier among interview participants. Central HPWH systems can require more space than typical gas boiler systems, and retrofit applications can be challenging for project teams to fit the heat pump and the water storage tanks within existing mechanical rooms. Interview participants also noted potential challenges for the heat pump to receive proper ventilation in such spaces.

Alternatively, installing the heat pump outside of the building presents security concerns and may require the addition of fencing and a locked gate to prevent unit tampering. One interviewee cited aesthetic concerns as a factor that prevented a central HPWH system from being installed on the exterior of a building. Installation on the roof provides another alternative, one that requires careful consideration to ensure the added weight creates no structural concerns.

Although representing only a small subset of the existing building stock, one developer with a portfolio of historic buildings noted that they face limitations on where they can install the equipment and the number of changes they can implement in their buildings. Another

consideration, mentioned by four interviewees, pertained to getting the equipment onsite. Narrow streets, vehicles parked on both sides, and one-way streets make it challenging to deliver the equipment via truck. If a crane is required to place equipment, this requires permits and raises logistical challenges that are rarely part of a traditional water heater system replacement project.

Figure 14. Detailed Barriers Related to Space Constraints, based on interview responses



4.2.1 Geographical Considerations

The geographic location of the building can present additional challenges related to space constraints. In warm, sunny climates, including most of California, HPWHs can be installed outdoors without concern about compromising heat pump performance. While there are some challenges related to outdoor installations as described above, an outdoor installation can provide a pathway for central HPWH installation when indoor space is constrained. In cooler climates like the Pacific Northwest, the ambient outdoor conditions must be considered more carefully when designing a central HPWH system.

To combat potential issues, many central HPWH installations in the Seattle region have been installed in underground parking garages. This semi-outdoor solution is a secure option that typically mitigates space and ventilation issues while benefitting from more temperate ambient conditions than a fully outdoor installation. However, one developer noted that other Pacific Northwest cities like Portland do not have underground parking requirements like Seattle does. Without existing underground parking for retrofit projects, or the requirement to include underground parking in new buildings, this installation option will remain unavailable.

4.3 Proper Commissioning and Building Staff Handoff Are Critical to End User Satisfaction and Operational Success

Commissioning is an important part of any multifamily water heater project but is especially critical to ensuring that central HPWH systems work as expected. Getting the system up and

running quickly and optimized right away is important to minimize system downtime. In a multifamily building, downtime can inconvenience tens to hundreds of tenants who may then contact building management or maintenance staff seeking a solution, creating a stressful environment for troubleshooting and service. Building management and facilities staff interviewed for this project indicated that they have experienced subpar performance due to incorrect commissioning, to the point that they would not be comfortable removing the gas-fired backup system they elected to keep operational despite installing a central HPWH system.

Once the central HPWH system is operational, maintenance staff, who may be employed only part-time, are responsible for the day-to-day management. Adequate training on system controls and basic troubleshooting is needed to ensure the system continues to perform optimally. Distributors and contractors asserted that operation and maintenance manuals are provided to building facilities staff at the time of installation along with hands-on review of the system features. However, this handoff can introduce challenges due to language barriers. Additionally, if the building owner is not present for the handoff, and if maintenance staff turnover occurs, the manual alone may not provide a sufficient level of guidance for maintenance staff to feel comfortable. Regardless of the level of education provided to maintenance staff, most building owners will need a service contract with either the installation contractor or an independent service contractor. System maintenance plans that can be used to enter into such a contract are not always provided to building owners or maintenance staff, leaving them to work directly with the manufacturer to develop the contract or to rely on finding a service contractor that is already familiar with how to service a central HPWH.

Because central HPWH systems include more components and more complicated controls than the traditional systems with which maintenance or facilities staff may be familiar, staff are intimidated by the system and lack confidence to troubleshoot issues. One building manager stated that they felt some of the issues they have faced with their central HPWH system are due in large part to improper management of the system by maintenance staff. Another building owner noted that because maintenance staff feel ill-equipped to deal with issues that do arise, their overall satisfaction with the equipment decreases each time an issue arises. This, coupled with the lack of service contractors available to help with larger issues, can contribute to overall dissatisfaction with the system.

4.4 Incentive Programs Are the Number-One Driver for Adoption, as Upfront Cost Remains Top Barrier

Higher cost constituted the most common barrier to central HPWH installation in multifamily buildings, (71% of online survey respondents). Cost-related barriers also merited frequent mention in the interviews, ranking fourth (see Figure 10). In addition to the direct mentions, cost plays a role in other barriers. For example, upgrading electrical service presents both a cost barrier and increases the installation complexity, which is another key barrier. All of these factors contribute to upfront cost serving as a very influential barrier.

In the absence of incentives, central HPWHs have a higher upfront equipment cost than gas boilers, in addition to the higher labor cost often associated with installation. For developers who focus on a rapid return on investment (ROI), this can be a dealbreaker.

In addition to the high upfront cost of central HPWHs, other upfront costs may exist related to the additional electrical load needed to support the central HPWH system. In the interviews, developers frequently cited electrification challenges such as needing an additional transformer

or upgraded electrical service as reasons they elected not to pursue central HPWH systems in more buildings. In one case, the developer wanted to install a central HPWH system, but the local electric utility did not have the infrastructure to support the additional load to the building. However, one developer also noted that the central HPWH system they installed will use about half the electricity that an electric boiler system would have required. In jurisdictions with electrification mandates, this may provide a pathway for central HPWHs to be selected over other electric domestic hot water systems.

Other costs associated with central HPWH systems, including operations and maintenance, were not explicitly included in the installer and specifier survey questions. Operations and maintenance costs were rarely mentioned by interview participants. One facilities manager noted an unexpected cost associated with troubleshooting initial issues in the first three months of the central HPWH system operation. However, once the issue was resolved, the operation cost has not been an issue, and the interviewee noted that fixing a broken gate on the property has cost more than the central HPWH system.

4.4.1 Carrots and Sticks: Incentives vs. Codes for Central HPWHs

Incentives were, by far, the most frequently cited driver for selecting central HPWH systems. Existing incentives, including pilot demonstration grants, have been pivotal in the advancement of this technology. Incentives are currently offered from a limited number of utilities and programs such as California's Low-Income Weatherization Program (LIWP). Existing programs are downstream-focused, paying incentives to the developer or contractor (often the general contractor). While the success of midstream and upstream programs has been demonstrated for residential HPWHs, the interview findings from this project suggest that a downstream delivery method may be most effective for central HPWHs. One distributor interviewee, who actively participates in incentive programs for other product types and considers themselves proactive in promoting high efficiency equipment, stated that incentives for central HPWHs would be most influential if given to the contractor or end user (developer or building owner). Research conducted by Cadeo[8] also supports this sentiment.

Multiple interview respondents emphasized the importance of streamlining incentive programs to ease the administrative burden of participation and to prevent free-ridership. One distributor participating in residential heat pump water heater incentive programs in Oregon voiced frustration with conflicting requirements and incentives as well as a lack of clarity related to the program(s) available based on the project site address. This distributor cited at least one job they lost due to a competitor incorrectly representing the potential incentives available. As a result, their competitor's bid was much lower, although the building owner was not actually eligible for the incentive in the end.

Incentives facilitate adoption of emerging, energy-efficient technologies that are more expensive than traditional offerings. As more units are deployed, the market adapts to create tools and training mechanisms that ensure successful installations and customer satisfaction. Incentive programs can provide a mechanism to track the performance and actual energy savings of installed units, depending on the level of tracking undertaken by the utility. Tracking quantitative

[8] Presented at the 2022 Hot Water Forum. Slides can be found here: https://drive.google.com/file/d/15yqMfLnhXbNt0tet-6qEXikHXqS0kaR6/view

details about deployed units paves the way for the product to be adopted into local and/or state building and energy codes. However, as one interview participant noted, as soon as a product is adopted into code, it often can no longer be incentivized, depending on how the measure is adopted. Because adopting new measures into code can be a lengthy process, incentive programs can be offered in tandem during the building code adoption and implementation process.

Overcoming Barriers and Harnessing Drivers: Recommendations

The following section offers suggested approaches to harness the drivers and value propositions uncovered in this research with the goal of overcoming the primary market barriers and increasing central HPWH adoption. The sections below summarize both tangible resources that could benefit the market as well as further research opportunities. The four primary recommendation areas are:

1. **Sharing best practices**
   The market needs a comprehensive guide or central repository of best practices.
2. **Workforce education, training, and awareness-building**
   Accessible training opportunities and awareness-building activities are a need, especially for installers.
3. **Access to quantitative performance data**
   Quantitative performance data will build confidence in the technology.
4. **Development of packaged systems**
   Packaged systems can simplify the design process. Cost comparison tools and a better understanding of market potential can help this technology.

5.1 Sharing Best Practices

Despite a number of successful central HPWH system installations in California and the Pacific Northwest, the survey respondents and interview participants felt that no efficient way exists to share or learn best practices. For example, a frequently mentioned best practice was to ensure all members of the project team are enthusiastic about all-electric projects or are educated about the choice to install a central HPWH system as early as possible: getting utility and city officials on board early will help ease the permitting process later, and engaging installers during the engineering phase will increase understanding and acceptance of the technology.

Many interviewees also shared tactical lessons learned from installations; they said that this research project was the first opportunity they had to share this information. One building owner said they would find great value in a forum for building owners/operators, installers and engineers to share tips and tricks and first-hand experience.

Resources are already available to streamline the design of a central HPWH system, such as the Ecosizer tool created by Ecotope.[9] Documenting and sharing these resources in a way that reaches the supply chain at large would help to spread the knowledge base.

[9] https://ecosizer.ecotope.com/sizer/

Recommendation: Ensure that lessons learned are well-documented for pilot projects and that technology transfer is included in project budgets. A comprehensive guide to best practices or a central repository of resources containing best practices, segmented by market actor, would be valuable to the market, as would a virtual or in-person forum for knowledge sharing. A research project with the specific focus of gathering best practices could be beneficial.

5.2 Workforce Education, Training, and Awareness-Building

As discussed above, lack of contractor education and negative perceptions are major barriers to interest in installing central HPWHs. Installation contractors were also the most difficult type of market actor to reach for this project. Additional research into installer drivers and value propositions would be valuable, in addition to increasing the training opportunities available to this market group.

The manufacturers, distributors and contractors interviewed for this project provided the following advice for training installers and contractors:

- Manufacturer-specific training is more valuable than universal/generalized training
- Hands-on training is much more valuable than virtual training
- A lunch-and-learn format with food provided tends to attract the most participants
- Providing real-world operational data helps to improve confidence in the technology

Several interviewees also emphasized the importance of converging on standardized terminology related to HPWHs, both within the supply chain and in permitting jurisdictions. For example, one manufacturer noted the use of both "swing tank" and "recirculation tank" to refer to the backup water storage tank included in central HPWH systems. Providing education to planning and permitting departments about the technology would help to simplify the permitting process.

Building facilities/maintenance staff could also benefit from improved resources and training. As described above, substantial benefits would accrue from providing maintenance staff a maintenance plan and basic troubleshooting guide at the time of commissioning. Ideally, a service contractor should be identified and engaged prior to system installation to minimize downtime due to equipment malfunctions or maintenance needs.

All the training materials described above should strive to be mindful of the primary language of the audience and avoid technical jargon to ensure the information is easily understandable.

Recommendation: Seek additional opportunities to understand broader drivers and value propositions for installers. Encourage manufacturers and distributors to offer hands-on, product-specific trainings with real-world operational data for installers, reduce the financial barriers for service contractors to participate in these trainings, and provide a maintenance plan and basic troubleshooting guide tailored to building owners and maintenance staff.

5.3 Increasing Access to Quantitative Data

Across the supply chain, interviewees expressed interest in more quantitative data related to central HPWH costs and performance. One distributor shared that one-page fact sheets are helpful collateral for engaging and educating installers, especially if the fact sheets are regionally specific and provide cost and energy comparisons between central HPWHs and more traditional product offerings.

Cold-climate performance is of interest, especially to market actors operating in the Pacific Northwest. Developers and building owners with a national portfolio asserted that designers need to demonstrate the equipment will perform within the design parameters before they would be comfortable selecting a central HPWH system.

A more robust and centralized tracking mechanism for installed central HPWH systems would be a benefit to the market, especially if cost and performance data are included. Incentive program evaluations are one avenue for collecting this data, but often only include select participants. More holistic tracking of all installations would allow for clearer analysis of performance and dissemination of data through the collateral described above.

Recommendation: The market would benefit from one- or two-page fact sheets, case studies, and other easy-to-digest collateral that include quantitative performance data and cost information. Additional research and education into cold-climate performance is also suggested. Improved tracking on installed central HPWH systems would provide data needed to develop collateral.

5.4 Promoting the Development of Packaged Systems

As described in Section 1.1.1, the central HPWH industry is moving toward a packaged "plug-and-play" approach, with several manufacturers developing offerings. One such system was successfully installed in a single afternoon at Bayview Tower in Seattle in late 2021.[10] These systems decrease system complexity, ease the commissioning process, and reduce the likelihood of issues related to swapping of components.

One of the barriers to this emerging technology, described by a manufacturer developing a packaged system, is the difficulty of providing an "apples-to-apples" cost comparison between the packaged approach and a typical central HPWH system. This is because many of the ancillary costs (e.g., pipes and fittings) in a standard central HPWH installation are typically not included in the upfront cost estimate. This makes the packaged approach appear more expensive upfront when that may not actually be the case. Similarly, terminology and test methods have not been fully standardized for comparing packaged systems and built-up systems (e.g., system COP). NEEA's AWHS provides guidance, but will require wider adoption to become fully effective.

[10] https://newbuildings.org/news/at-bayview-tower-ecotope-and-bonneville-power-administration-mark-a-step-forward-in-decarbonizing-buildings/

Another barrier to this emerging technology is trying to understand the market potential. Because these systems are packaged on a skid, their footprint is well-known, but less adaptable in terms of conforming to the space constraints of a specific building.

Recommendation: Clearer "apples-to-apples" cost and performance comparison tools are needed to compare the cost of a packaged central HPWH system with a non-packaged system and other alternatives. Research on the market potential of packaged systems is also needed. Advancement of a Qualified Products List will enhance the potential of the packaged approach.

Appendix A: Online Survey

Q1. Which of the following options best describes your job function at your current company or organization?

- Entry-level
- Associate
- Mid-Senior Level
- Executive
- Owner

Q2. About how many people are employed by your current company/organization?

- Less than 10 employees
- 10 - 50 employees
- 51- 200 employees
- More than 200 employees

Q3. Which of the following states does your company serve? Select all that apply.

- CA
- OR
- WA
- ID
- MT
- Other (please specify)

Q4. Approximately how long have you been involved in the water heating industry?

- Less than 1 year
- 1 year - 5 years
- 5 years - 10 years
- More than 10 years

Q5. Are the majority of the projects your company or organization completes on existing building retrofits or new construction?

- Mostly Retrofits
- Mostly New Construction
- About the same

Q6. Which of the following best describes your current role in the water heating industry?

- Designer
- Architect
- Engineer
- Consultant (non-engineer)
- Plumbing Contractor
- General Contractor
- HVAC Contractor
- Other (please specify)

Q7. Do you work on projects in the single-family sector, multifamily sector, or both?

- Single-Family

Multifamily
Both

Q8. Please select all of the multifamily building types you have worked on:

Low-rise (1-3 stories)
Mid-rise (4-6 stories)
High-rise (7 stories or more)

Q9. What existing water heater system types have you replaced in multifamily retrofit projects? Please select all that apply.

Central/commercial system (gas-fired)
Central/commercial system (electric)
Semi-central system (gas-fired)
Semi-central system (electric)
In-unit (gas-fired)
In-unit (electric)
Not sure/not applicable
Other (please specify)

Q10. What types of systems have you specified/installed in multifamily retrofit/replacement and multifamily new construction projects? Please check all that apply.

Central/commercial system (gas-fired)
Central/commercial system (electric)
Semi-central system (gas-fired)
Semi-central system (electric)
In-unit (gas-fired)
In-unit (electric)
Other (please describe)

Q11. Of the in-unit water heaters you have encountered in existing buildings or specified/installed in new buildings, where within the dwelling unit have the water heaters been located? Please check all that apply.

Interior of dwelling unit
Exterior of dwelling unit
Not sure/not applicable

Q12. How often do you work with a water heater manufacturer representative, such as a distribution sales associate, when working on projects in multifamily buildings?

Never
Rarely
Most of the time
Always
Not sure/not applicable

Q13. When recommending a water heater to a building owner, what aspects of the equipment do you typically promote?
Respondents were asked to rank each choice using the following options: Never promote, Not likely to promote, Somewhat likely to promote, Very likely to promote, Always promote

Equipment Warranty

System Efficiency
Operating Cost
Product Support
Other (please specify)

Q14. Please reflect on your experience with replacement/retrofit projects to replace or upgrade an existing central/commercial water heating system in a multifamily building. For these projects, how often are upgrades to components other than the water heater itself considered (for example, upgrading the distribution system by adding thermostatic mixing valves)?

Upgrades to additional components are never considered
Upgrades to additional components are sometimes considered
Upgrades to additional components are always considered
Not sure/not applicable

Q15. How would you rank your familiarity with each of the following heat pump water heater technologies in multifamily buildings?
Respondents were asked to rank each choice using the following options: Not at all familiar, Slightly familiar, Somewhat familiar, Moderately familiar, Extremely familiar

Central/commercial heat pump water heater plant serving an entire building
Semi-centralized heat pump water heater "plants" serving multiple dwellings
In-unit heat pump water heaters serving one dwelling

Q16. Have you ever considered specifying or installing any of the following heat pump water heater types for a multifamily project? Please select all that apply.
Respondents were asked to answer for both Replacement/retrofit and New construction.

Central/commercial heat pump water heater
Residential heat pump water heaters
Neither/Not applicable

Q17. For multifamily projects where a heat pump water heater solution was considered, was the heat pump water heater solution actually installed?

Yes in all cases
Yes in some cases
No in all cases
Not applicable/not sure

Q18. In your experience, what are the primary barriers to specifying/installing heat pump water heaters in a multifamily building (both central/commercial and residential)? Please check all that apply.

Higher cost
Lack of availability
Lack of confidence in the technology to deliver hot water
Concerns about noise level
Complexity of installation
No suitable location to install
Not sure
Other (please describe)

Q19. How often have you experienced the following barriers to specifying or installing heat pump water heaters in multifamily buildings?

Lack of product availability
Longer product lead time
Upfront equipment cost

Q20. Would you expect the soft costs (labor costs, for example) for a project that included specification/installation of a heat pump water heater solution to be higher than a project that did not include heat pump water heater solution?

Yes
No
Not sure/not applicable

Q21. How would you rank your confidence in heat pump water heater technology to reliably provide hot water when it is needed, assuming the system is designed and installed correctly?

Not confident at all
Slightly confident
Somewhat confident
Fairly confident
Completely confident
Not sure

Q22. Do you feel that specifying/installing a heat pump water heater is more technically complex or complicated than other water heater types?
Respondents were asked to answer for both Central/commercial heat pump water heater and residential heat pump water heater.

Less complicated/complex
About the same
More complicated/complex
Not sure/not applicable

Q23. In your experience, what is the industry standard lead time for residential heat pump water heaters for a multifamily project?

Stocked and immediately available
1-3 business days
4-7 business days
More than 7 business days
Not sure

Q24. For a multifamily project that includes a central/commercial heat pump water heater, how would you expect the time required to complete each of the project phases listed below to compare to a project with an alternative central/commercial water heater option?
Project Phases:

Design
Equipment procurement
Installation

Choices:

Much longer
Somewhat longer
About the same
Somewhat shorter

Much shorter
Not sure/not applicable

Q25. Have you ever completed a training on central/commercial or residential heat pump water heaters?
Respondents were asked to answer for both Central/commercial heat pump water heaters and residential heat pump water heaters.

Yes
No

Q26. If you wanted to learn more about heat pump water heaters, do you feel that there are adequate resources and trainings available to you?
Respondents were asked to answer for both Central/commercial heat pump water heaters and residential heat pump water heaters.

Yes
No

Q27. Thank you for your valuable feedback! Would you mind sharing the name of the organization/company you currently work for?

(Free response)

Q28. Please complete the information below if you amenable to a follow-up conversation. If you choose to share this information, it will be kept confidential and will only be used for the purposes of better understanding your perspective and responses.

(Free response)

Q29. If you have any additional comments or information you would like to share, please use the space below.

(Free response)

Appendix B: Interview Guides

The following guides were used to facilitate interviews with selected market actor groups. These guides were developed prior to the interviews and were created only to provide a general direction for the interview. The final set of questions asked to each interviewee was tailored to their expertise and/or specific project(s). Due to time constraints not every question was answered by all respondents.

Interview guides were not created for manufacturers due to the small number interviewed; each interview was tailored to the manufacturer with some standard questions. Interview guides were also not created for installers, instead, the specifier and installer online survey questions were used as the basis of the interviews.

Distributors

Preliminary Scoping questions

1. How involved are you with the specification and design process for new buildings, and how are you involved with retrofit projects in existing commercial/multifamily buildings?
    a. For larger equipment like commercial heat pump water heaters, do you typically know what kind of building it will be installed in (restaurant vs. multifamily vs. multi-use)?
2. Do you stock central/commercial water heaters [specifically for MF, if they know]?
    a. If yes, do you stock any commercial heat pump water heaters, or residential HPWH installed in commercial applications?
    b. If no, have you specifically ordered any commercial heat pump water heaters?
        i. If yes, is the customer typically a developer/building owner, engineering firm like Ecotope, or an installer?
3. Of the commercial HPWH you have sold, is it typically just the water heater itself, or do you sell the accessories as part of the package?
    a. Does this package include the tanks? Swing tanks? Recirculation pumps?
    b. What about connectivity and controls?
4. Do you have a sense of the percentage of your water heater sales that go to new buildings vs. existing building retrofits?

Barriers

1. Have you experienced any challenges with promoting products to your customers due to supply chain issues or challenges with manufacturers' ability to deliver units?
    a. Would you say the manufacturer is providing adequate technology support and training?
2. What is the typical timeline between when you order a commercial water heater from the manufacturer and when you receive it?
    a. Is this longer than traditional water heater solutions?
3. What would you say are the top barriers to market adoption of commercial/central HPWH in multifamily applications?
    a. How much of a barrier is the upfront cost for you?

4. How would you rate your confidence in HPWH to reliably provide hot water when it is needed, assuming the system is designed and installed correctly? [1 to 5 scale]
5. Do you work in multiple states? If so, do you face any external influences/challenges? (e.g., regulatory landscape)
    a. Any challenges with code officials?
6. Can you connect us to any installers you think would be willing to talk with us about HPWH?

Stocking

7. What factors contribute to what water heaters you choose to stock (bulk pricing, agreements w/ manufacturers, demand, others)?
8. How does your company learn about new products on the market (like HPWH) and make the decision to stock or sell this equipment?
    a. Expos, from manufacturers whose products you already represent?
9. How often do you recommend a specific water heater brand/model to a customer vs. them coming to you, knowing what they want to order?
    a. How do you think the customer knows in advance about a specific solutions or product?
    b. What do you typically promote when recommending a water heater (warranty, efficiency, support, 1st cost, total cost of ownership, incentives, other)?

Building Owners, Facility Managers, and Developers

Rationale for transitioning to central HPWH

1. Were you initially considering a HPWH for your retrofit project?
    1.1. If yes, what aspects of the HPWH appealed to you? [*Examples include efficiency, operational cost savings, carbon reduction, incentive*]
    1.2. If no, what intervention caused you to end up choosing a central HPWH?
2. Were you involved with any of the tasks leading up to installation of the heat pump water heater?
    2.1. If yes, were there any challenges?
    2.2. Anything that was easier/better than you expected?
3. Were you involved with the actual installation of the heat pump water heater?
    3.1. If yes, any challenges?
    3.2. Anything that was easier/better than you expected?
    3.3. If you were not involved in the installation, who from your property was [*examples may include previous staff or a maintenance person*]?
        3.3.1. If applicable, would that individual be willing to speak with us?

Maintenance/issues

1. At the time of central HPWH installation, was any training regarding maintenance and operation provided?
2. Do you have a dedicated maintenance person or staff that can address plumbing issues, or do you contract with a third-party company to provide maintenance?

3. Can you describe any alarms or notifications you have in place in case of a failure in the water heating system?
4. Do you have a backup system in case of failure of the water heating system?
5. Do you recall if you have had to replace any components of the central water heating system since the HPWH was installed?
    5.1. If yes, who did you work with to complete the replacement? [*installer, mfg rep, bought from wholesaler*]
        5.1.1. Did you have an existing relationship with this firm/individual?
    5.2. If yes, what component(s) were replaced?
        5.2.1. Were other upgrades considered at the time of replacement?
    5.3. If not sure, move to next question
6. Do you have a specific budget set aside for water heater maintenance?
    6.1. If yes, what are some examples of recurring expenses and maintenance activities?
7. Have you had any issues with the heat pump water heater?
    7.1. If yes, please describe
8. Who have you contacted/would you contact with issues related to the heat pump water heater?
    8.1. If they have had an issue and contacted someone: Would you say you were satisfied with the support you received?
    8.2. Do you have direct relationship with the water heater manufacturer or distributor, or do you work with a plumber directly?
9. Do you receive any feedback from tenants regarding the hot water?

Satisfaction with HPWH

The following questions are related to your satisfaction with the heat pump water heater. You can provide a numerical response on a scale of 1 to 5, with 1 being completely dissatisfied and 5 being completely satisfied.

How would you rate your satisfaction with:

1. the ability of the central HPWH to deliver hot water?
2. the level of maintenance required for the HPWH?
3. the operating cost of the HPWH?

Thank you. Just two more questions.

4. How do your energy costs for domestic hot water with the HPWH compare to the costs of your previous system?
5. Do they feel like having a central HPWH affects potential tenants impression of the property in any way?