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Energy Trust of Oregon Wall-Mounted Heat Pump Coordinated Research Project

Phase One Report

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Executive Summary

The initial phase of this coordinated research project was designed to gain insights into an emerging category of packaged residential heat pumps in the market, referred to as “wall-mounted heat pumps” in this report. The research objectives of Phase 1 were focused on learning more about the usability of the equipment, installation constraints, and user acceptance. A total of 15 installations comprised of two different brands/models of wall-mounted heat pump products were planned in this phase. Pending positive results of these initial installations, a second phase would involve a significantly larger sample size where heat pumps are installed and evaluated to determine average energy savings and installation costs with enough confidence and accuracy for use in measure development activities.

One of the models involved in this research project performed considerably better than its counterpart in a variety of categories, including noise during operation, quality of materials, readiness for installation and protection from exterior elements. However, the installation of both units proved to be difficult for the experienced contractors selected for this study and the electrical wiring/panels of existing residential homes were not consistently compatible with the electrical demands of at least one of the models. Additional challenges from a DIY standpoint for both products included identifying an appropriate location in the home with adequate space for a roughly 3’ wide x 2’ high box, ensuring proximity to an outlet on a circuit with adequate load available and the lack of onsite manufacturer support to guide the installer through the wide variety of troubleshooting needed during this phase of the research project.

MEMO

Date: 10/5/2022
To: Energy Trust Board of Directors
From: Dan Rubado, Sr. Project Manager – Planning & Evaluation
Andrew Shepard, Sr. Project Manager – Residential
Subject: Staff Response to the Wall Mounted Heat Pump Research Phase 1

Energy Trust's Residential program conducted a research project to investigate a new category of packaged residential heat pumps that are mounted to the inside of an exterior wall, referred to as "wall-mounted heat pumps." The goal of the study was to identify a heat pump product that could be installed in similar applications to ductless heat pump (DHP) systems (displacing electric resistance heating) at a lower cost, while providing similar energy savings and customer benefits. In recent years, DHP costs have inched up while available tax credits have been reduced, and evaluations have shown lower than expected energy savings. These factors have combined to make DHPs no longer cost-effective as an energy efficiency measure for Energy Trust. However, the Residential program has continued to provide incentives to support DHPs under a cost-effectiveness exception from the Oregon Public Utility Commission. If a less expensive substitute could be identified and proved to be viable, particularly one that allowed customer self-install, it could potentially replace DHPs in some applications and provide more cost-effective energy savings in homes with resistance heating.

The first phase of research, described in this report, was focused on the installation process and requirements, usability of the products, and customer acceptance of two wall-mounted heat pump products. The report describes the products investigated, the research methods, and the findings and recommendations that emerged. Energy Trust staff's takeaways from this research project are summarized below:

- The equipment and installation costs for the selected products were relatively high, not providing significant cost savings over a single head DHP
- The installations were complex, took a long time and a high degree of skill, and were not suited to customer self-install, negating the hypothesized benefits of this technology
- There were numerous technical issues, call backs, and noise complaints resulting in low customer satisfaction
    - However, one product appeared to be of higher quality and operated with fewer problems than the other product tested
- It was challenging to identify homes where the products would work and there was enough wall space with a nearby outlet to accommodate the units, limiting the applicability of these products
- These products do not appear to be a suitable or cost-effective technology for displacing electric resistance heat in homes

Based on the phase 1 research results, Energy Trust will not be moving forward with the planned second phase of research at this time, which was intended to evaluate energy savings and assess installations and market acceptance on a larger scale. Energy Trust does not intend to further develop efficiency measures or offer incentives for this technology. We will monitor the results of similar studies that other utility programs are conducting with this technology and see if any promising results emerge. Unless the installation requirements, installation complexity, or costs change dramatically, we will not be further investigating or promoting this technology but will continue to promote DHPs in these applications.

Background

Phase 1 of the Wall-Mounted Heat Pump research project officially launched with the first installation in October 2021. In total, Phase 1 was expected to include 15 total heat pump installations performed by two vetted contractors in a combination of existing single family and multifamily homes. Customers for this project were primarily recruited from the Portland Metro and Central Oregon regions who were previous participants in other Energy Trust of Oregon incentive offers.

The key research objectives in this phase included:

Product-Market fit:
What is the value proposition to customers? Does this product solve a unique problem or remove a barrier to participation?
What is the market's receptivity to these products? Installers, distributors, CAP agencies, etc.

Proof of usability, installation constraints, and user acceptance:
What are the installation requirements?
How long does installation take?
What are the appropriate site conditions and/or locations for installation?
How is condensate managed?
Is the installation process simple enough to allow for DIY installations?
Are these units suitable for replacing PTACs?

What is the customer experience and acceptance of these products?
What is the customer acceptance of this equipment?
Is the level of noise during operation acceptable?
Do customers like the aesthetics more/less than alternative options?
How do these units impact occupant comfort?

Product Selection and Research

Product Selection

The products used in this study were selected based on the following criteria:

- Packaged unit (no remote outdoor unit)
- No backup electric resistance heat built into the unit
- Potential option for DIY installation in retrofit residential construction
- Plug-in option only. No hardwire connection and/or circuit upgrade required
- No onsite refrigeration work required. HVAC specialty tools and EPA 608 card not required
- Capable of serving as primary heating and cooling option within the immediate space of the home
- Based on this criteria, two manufacturers/models were selected. Both products will remain anonymous in this report, and will be identified as follows:
    - PRODUCT A
    - PRODUCT B

Product	PRODUCT A	PRODUCT B	
Dimensions	35.6" W X 20.5" H X 8.5" D	39.7" W X 21.9" H X 6.5"D	
Retail Price (as tested)	$2,595*	$3,073*	
Intake/Exhaust Venting Size:	8" Diameter	**6" Diameter (tested model)**	**8" Diameter (non-tested model)**
Cooling Capacity (Rated)	8,150 Btu/h	8,100 Btu/h	8,100 Btu/h
Cooling Efficiency Rating	9.9 CEER	11.0 EER / 16 SEER	11.9 EER / 18 SEER

Heating Capacity (47°)	8,150 Btu/h	8,100 Btu/h	8,100 Btu/h
Heating Energy Efficiency (47°)	3.8 COP	3.43 COP/10.3 HSPF	3.54 COP/11.5 HSPF
Heating Capacity (17°)	NA	4,800 Btu/h	5,000 Btu/h
Heating Energy Efficiency (17°)	NA	1.60 COP	1.82 COP
Key Energy Efficiency Components	ECM fan Inverter compressor	ECM fan Inverter compressor DC motor	
Warranty	7-Year Compressor / 2-Year Parts	1-Year Full Onsite / 9-Year Limited	
Installer certification required for warranty?	Yes, web based on-demand training delivered by manufacturer staff	No, follow installation guide and document each step of installation with photos for warranty qualification	

*Pricing as of Sep. 2021

Electrical Code Research

Prior to the launch of this study, research was completed to confirm that the use of these products on shared 15-amp & 20-amp circuits was in alignment with local, state and federal electrical codes. Based on an internal review of the electrical code applied to residential equipment (NEC 2020 NFPA 70 version), as well as a discussion with state code officials, it was determined that these heat pump units should be treated similarly to portable and window AC units and would be appropriate to plug into both shared and dedicated circuits with either 15- or 20-amp breakers. However, it is important to avoid circuits with other devices capable of drawing larger amounts of amps to avoid flipping the breaker. Both products' Maximum Current Ampacity (MCA) are rated below 7.5-amps, which is the maximum allowed by code on a shared circuit with a 15-amp breaker. Devices plugged into circuits on a 20-amp breaker can have a MCA of 10.0 or less.

Moisture Management

Both products selected were screened for summer and winter condensate management strategies, ensuring they were appropriate for the Pacific NW climate as well as the common exterior wall construction design of single-family and small multifamily housing found in the region.

Warranty Eligibility Requirements

Securing warranties for each product requires additional steps prior to and/or during the installation, however, they do not require installation by a licensed contractor.

- PRODUCT A requires the individual(s) installing their product to take a virtual installer training course (approximately 60-90 minutes long), scheduled directly with the manufacturer's internal trainer. Following the installation of the heat pump, the warranty is activated by registering on the manufacturer's website.
- PRODUCT B provides a step-by-step guide for photo documenting key aspects of the installation. Upon completion of the installation, the manufacturer requires the installer to submit the photos by email and wait to receive confirmation from the manufacturer that the installation was compliant with their requirements before the customer uses the unit.

Product Availability/Shipping – Both products are manufactured in Italy and as of the time of purchase for this research project, were not stocked locally in the Portland metro area. PRODUCT A is stocked in the United States and can be shipped within 1-2 weeks. PRODUCT B is built to-order in Italy and required 2-3 months manufacturing + shipping lead time during this research project. While our team preferred to test the version with 8" diameter venting, only the 6" diameter venting option was available for orders under 50 units. Due to the lengthy delays in receiving PRODUCT B, the decision was made to purchase 12 of PRODUCT A and only 3 of PRODUCT B.

Additional Product Observations

Quality: The PRODUCT B units were built with superior parts (metal shell vs. plastic shell used on PRODUCT A)

Preventing freezing in drain pan: PRODUCT B has a built-in drain pan heater, while PRODUCT A requires the separate purchase of a drain pan heater and installation by the customer or hired technician

Protection from exterior elements/critters: PRODUCT A requires louvers on the exterior with large gaps, allowing potential entry of wind-blown rain, debris, and insects. PRODUCT B allows louvers with smaller openings, creating better protection from weather, debris, and insects.

The power cord is located on the left side of PRODUCT B and the right side of PRODUCT A. Additionally, access to the condensate drain is on the left side of PRODUCT B and the right side of PRODUCT A.

Contractor Selection

The number of contractors selected to participate in this research project was intentionally limited to only two companies, one for the Portland Metro area installations and one for the installations in the Bend/Arlington areas. The benefits of limiting the number of installers included maintaining consistency in the installations and benefitting from an evolution of installation methods building off lessons learned.

- **CONTRACTOR A** – Serving Central Oregon – selected for this research project due to their knowledge and experience working in residential construction, as well as the owner demonstrating a sincere interest in learning more about this technology and a willingness to perform installations at a fixed price.
- **CONTRACTOR B** – Serving Western Oregon – selected for this research project due to their experience installing heat pump water heaters in existing residential construction, which involve very similar installation methods to the wall mounted heat pump product. Additionally, CONTRACTOR B was the primary installer for a previous coordinated research project and proved to be a great partner through their understanding of how research projects operate and the flexibility required.

Recruitment Process

Outreach was initially focused on friends and family of program representatives. Upon exhaustion of this outreach pool, program representatives focused on past participants of Energy Trust incentives with electric resistance heat within geographic proximity to the Portland Metro. An effort was made to include a variety of housing types, thus coordination with the Small Multifamily program contributed a small number of those customers to the outreach pool.

Initial recruitment efforts came in the form of an email or phone call to potential participants with a general overview of the offer. Upon response, the first phase of the screening process was performed via a short phone interview with the homeowner to confirm appropriate site conditions and to provide an overview of the participation requirements for the customer. Participants meeting the conditions stated in the phone interview moved to the second and final phase of the screening process. This involved a follow-up virtual site review conducted by program staff to visually confirm key installation requirements, ensure an appropriate location for the unit was available and generate a list of tools and materials required for the installation. Lastly, an install date and time was coordinated between the customer, the installer, and internal staff to document the installation process.

SITE AND CUSTOMER QUALIFICATIONS

Effort was made to verify that sites and customers would be a good fit for participation. Concerns generally included avoiding fuel switching, ease of install, health and safety, and customer enthusiasm. Outlined below is a detailed list of both phases of the screening process:

Initial Screening – Phone Interview:

- Electric resistance as primary heat source (this was later adjusted to include ADUs and Additions)
- Wood exterior siding
- Preferred sheetrock interior wall material
- Absence of asbestos in residence
- Preferred install site on first floor of residence

- Customer comfort with interior and exterior unit aesthetics
- Customer comfort with program representative presence to document installation
- Customer comfort with participation in post-installation survey

Final Screening – Virtual Site Review (video-assisted via smartphone/tablet):

- Electric resistance as primary heat source (this was later adjusted to include ADUs and Additions)
- Sheetrock interior walls
- Wood exterior siding
- Home not in need of substantial repair
- 4’ x 3’ free space on interior and exterior wall with a preference for low mounted units
- 4’ proximity to grounded 3-prong outlet (right-side PRODUCT A/left-side PRODUCT B)
- Install location on first floor
- Generally isolated circuit (no significant appliances or heating elements on circuit)

RESULTS

- **Recruitment:** 151 homeowners were contacted by program staff via phone and/or email with an invitation to participate in this study.
- **Initial Screening (Phone Interview):** 22 homeowners responded to the recruitment emails/phone calls and decided to proceed with the phone interview.
- **Final Screening (Virtual Site Review)**: 14 of the 22 interested participants (63.6%) completed the phone interview and were determined to be eligible for the final screening process.
- **Participant Selection**: 9 of the original 22 interested participants (41%) successfully completed the virtual site review and were selected to participate in the study.

RECRUITMENT AND QUALIFICATION CHALLENGES

Initial Outreach

Soliciting a response from the initial outreach was a significant challenge. Age of contact data, general skepticism of the offering and spam filters could have been contributors to a lack of initial uptake. It should also be noted that there were a significant number of homeowners who responded but did not make it to the initial screening for a variety of reasons. These included HOA restrictions, hesitation about the heat pump product, needing to discuss with other decision makers in the household, etc. Quite often follow-up outreach with these customers did not receive a response.

Site Qualification – Phone Screening

The site challenges encountered during the phone screening were relatively limited. Siding and interior wall type proved to be the largest barriers to entry, preventing four potential customers from participating. Two potential customers did not have electric resistance as the primary form of heat, which was a study requirement. On two occasions, it was established that the homeowner was in the process of selling and could not participate in later installation surveys.

Site Qualification – Virtual Site Review

The site qualification process during the virtual site reviews resulted in the disqualification of five customers. Four customers did not have a minimum of 4’ x 3’ interior and exterior wall space available in the preferred installation locations and one customer did not have an electrical outlet within four feet of the planned installation location on a circuit with adequate capacity.

Installations

OVERVIEW

Installation Date	Product	Location	Housing Type
Oct 2021	PRODUCT A	Arlington, OR	Single Family
Nov 2021	PRODUCT A	Bend, OR	Single Family
Nov 2021	PRODUCT A	Portland, OR	Single Family
Nov 2021	PRODUCT A	Bend, OR	Single Family
Dec 2021	PRODUCT A	Portland, OR	Single Family
Dec 2021	PRODUCT A	Portland, OR	Single Family
Dec 2021	PRODUCT A	Beaverton, OR	Small Multifamily (Townhome)
Jan 2022	PRODUCT A	Oregon City, OR	Single Family
Apr 2022	PRODUCT B	Portland, OR	Single Family
Jun 2022	PRODUCT B	Portland, OR	Single Family

PRODUCT A - INSTALLATIONS #1-8

Preparation

Both installers, as well as the PMC research team, joined a 2-hour virtual training with PRODUCT A (P-A) representatives. This served as the official training required for warranty eligibility as well as an open Q&A session to discuss a variety of product and installation-related topics.

The P-A units were not shipped with a drain pan heater, which is required for heat pump operation in the Pacific Northwest's climate. Installing the drain pan heater was not possible with the instructions from the manufacturer. New instructions were sent from the manufacturer, which made the task possible. Installation of the drain pan heaters required the removal of approximately 16 screws to access the insides of the machine. This task took between 45 to 60 minutes. The install crew soon started accomplishing this task in their shop before installation of the unit.

Day of Installation

The overall installation process of the P-A units was problematic from the start. Issues centered around poor manufacturer-provided instructions, onsite ducting problems, and out of the box product failures. These issues led to install times of six to seven hours per site as compared to the original estimate of four hours per site. This time did not include the one hour of shop labor to install the drain pan heater.

Typical Installation Sequence

Interior wall location: Choosing a location for the unit involved a combination of the following criteria:

- Homeowner acceptance. This was a combination of aesthetics and practicality.
- Nearest electrical outlet (must be within 6 feet of the right side of the unit). The nearest outlet was always a shared circuit. The crew inspected each circuit to ensure that heavier electrical loads such as washing machines and resistance heating devices were not on the same circuit.
- Wall stud location. The hanging bar for the unit was not predrilled for homes with 16 inches on center walls. The two venting holes to outside (intake and exhaust) had to straddle one stud. Units located near windows or corners often had additional studs not conforming to the 16 inch-on-center rule. The crews used various stud finders including magnetic devices and IR cameras to help locate the studs. All units were installed with at least two anchors into studs and multiple sheet rock anchors added for support.

- Plumbing and electrical wiring location. While the stud detectors proved useful for locating wall studs, they did not work well for finding electrical wiring mounted to the outside wall. In two cases, the ducting holes were drilled only to find horizontal wiring runs mounted against the outside wall. This required patching the holes and finding a new location.
- Condensate disposal to non-walkway surfaces. Winter condensate from the unit is estimated to be 2.5 gallons a day. Finding a suitable location away from walkways where the condensate may freeze in colder weather proved challenging at two sites.

Temporarily mounting the template: The unit included a template that was used to locate the position of the hanging bar, the intake and exhaust duct holes and the condensate tubing. In one instance, the wrong template was included with the unit, which resulted in the condensate drain line being drilled in the wrong location.

Drilling the ducting holes and condensate line to outside: Crews encountered several types of exterior cladding ranging from cedar shingles to Hardie Plank. Several tools were used to create the 8-inch intake and exhaust ducting including jigsaws, 8-inch hole saws and multi-tools. The Hardie Plank siding proved to be the most difficult material to cut through when using the hole saw due to the limited blade tip options found with hole saws. Due to the open nature of the intake and exhaust grilles, the crews sloped the holes to the outside in case wind-blown rain entered the ducting. The condensate line was sloped in a similar fashion.

Ducting and installing the intake louvers: The units were shipped with a sheet of plastic that was formed to create the 8-inch ducting that connected the unit itself to the intake and exhaust louvers. The seam of the formed duct was located at the top of the duct in order to prevent any accumulated water from leaking into the wall cavity. The ducting and louvers were designed to be completely installed from the inside of the house. Fortunately, this was not necessary and would have prohibited sealing the grilles in a watertight fashion to the outside of the house. The process of forming the ducting and installing in a manner that allowed water to drain to the outside was time consuming. This process could take as much two hours.

Mounting the hanging bracket: As noted earlier, locating the hanging bracket proved time consuming. Once a suitable location was found, hanging the bracket was relatively simple. The crews quickly learned to anchor the ends of the bar to the sheetrock to avoid the ends twisting when the unit was hung on the wall.

Condensate piping: The unit itself has a rubber hose that drains the condensate collection pan. This hose runs through the hole drilled to the outside. The install crew did not want the condensate line to drip on the siding. As a result, the entire condensate line was placed inside of CPVC piping and the condensate was guided below the siding.

Starting the system and homeowner education: Once the system was mounted, the units were plugged in and turned on. The systems were then programmed to display in Fahrenheit and set to either a high or low wall configuration. Instructions for doing so were incorrect and led the team to call for technical assistance from the manufacturer. In one case the IR receiver on the unit would not respond to signals sent from the remote controller. This unit was replaced.

PRODUCT B - REPRESENTING INSTALLATIONS #9-10

Preparation

Prior to the initial PRODUCT B (P-B) installation, a mock wall was constructed to use for a practice installation. Key insights gained from this process included:

- Developing a simple yet effective connection between the interior and exterior sides of the intake/exhaust ports
- Identifying a potential issue with GFCI outlets. There appeared to be a conflict between the P-B unit and the GFCI outlet initially used to test the unit. The unit display powered on, but the cooling and heating operation would not activate when selected on the control panel.

Day of Installation

The installation process for the P-B units was very similar to that of the P-A units. Notable differences included the following:

- Ducting to outside. The P-B units did not ship with ducting or exterior louvers. Instead, the P-B manufacturer provided a list of approved louvers from third-party vendors. The install team purchased plastic wall caps that included rain guards with built-in protective screens. The wall louvers had a 4-inch throat that slid into the exhaust and intake holes. Six-inch sheet metal airtight takeoffs were used to connect the intake and exhaust ports on the back of the unit into the wall cap's throat.

- The louver design made the intrusion of rain and insects into the ducting far less likely to occur than with the P-A models and resulted in a more secure connection between the unit and the exterior.
- Anti-lift bracket: The P-B unit comes with a bracket to be installed at the rear of the unit, preventing the accidental lifting and dislodging of the unit from the wall.
- Warranty-required photo documentation. In order to qualify the unit for a warranty, the installer is required to take 18 photos as directed by the manufacturer throughout the installation process. These photos add time and can become a distraction to ensure no photos are missed while also trying to follow the installation process.

Post-Installation Observations/Issues

PRODUCT A (P-A)

Noise

Noise was a frequent issue with most of the units. Some units produced noise at a high but tolerable level while others produced extremely loud noise and required repairs. Simply removing and re-hanging the unit would help solve some of the moderate sound issues. The solutions for the more extreme noise levels offered by the manufacturer included providing the customer/installer with instructions to bend refrigerant pipes within the unit and weights to put onto the pipes to reduce vibration. The installers and program staff found it to be unreasonable to assume customers would be capable and/or comfortable making these adjustments, with or without the help from a contractor.

For one site, the noise issue was significant enough to require direct support from the manufacturer. During an investigation, A P-A service tech was available by phone to guide our team through the repair. The casing, front and back panels were removed. It was determined that the reversing valve was pressed against the back panel, causing a vibration throughout the unit. The valve and associated piping were “pushed” away from the back panel and the unit was reassembled. While the crew was present after the correction, no abnormal sounds were detected. Follow-up with the homeowner will be conducted to determine if the correction resulted in a long-term solution.

Electrical

Electrical-related issues occurred at 3 different sites shortly after the P-A units were installed. Each issue was somewhat unique and not necessarily due to a problem within the P-A unit. Instead, there were issues with the home’s wiring or electrical panel that popped up once the P-A unit was added to the circuit. This included an aging breaker that was overdue for replacement, an overloaded circuit that damaged a breaker and an outlet with poor terminal connections between the outlet/wiring.

Condensate

The condensation from the unit became an issue at one site. The connection between the condensation line and the CPVC pipe running to the outside was not properly sealed and moisture was able to flow back into the interior of the home, resulting in minor paint damage. This was more of an installation error than a design flaw.

A minor condensation issue occurred at one other site – the condensate line became disconnected from a P-A unit during a noise troubleshooting service call.

Other

The P-A units developed a few additional issues including:

- One unit’s fan stopped working during the cooling season. This issue was resolved by simply rebooting the system. Similar but more minor issues at other sites were also resolved by rebooting the system.
- One unit was unable to receive the remote's IR signal. It was determined that the unit’s IR receivers were defective. The unit was replaced.
- One unit’s plastic shell required replacement, provided by the manufacturer at no cost. A piece of the plastic shell where a screw fastened the shell to the internal frame broke, likely breaking during the multiple instances when the shell was removed to install the drain pan heater and to investigate noise issues.

Warranty

No warranty claims were submitted as of the time of this report, however, the P-A manufacturer did provide a free replacement shell for one of the units due to a broken plastic piece. This piece was critical to securing the plastic shell to the steel frame inside the unit.

PRODUCT B (P-B)

General – The only issue tied to the P-B units was an inoperable fan. This occurred at the first installation. An alternate unit was installed and, with manufacturer support, the fan in the original unit was repaired by the installer offsite. The issue was determined to be a disconnected wire between the fan and the main control board. Per the manufacturer, this can occur occasionally during shipping.

Table 1 – Summary of Installation Issues/Quantity Site Visits

Product	Total # Installations	Avg. Time of Installation (2-person crew)	Avg. # Post-Installation Site Visits/Callbacks	Noise Issues		Condensation Issues		Pipe Bending and Other Modifications Required		Electrical Issues	
				Total #	% of Installs	Total #	% of Installs	Total #	% of Installs	Total #	% of Installs
PRODUCT A	8	7 hrs.	2	7	87.5%	2	25%	5	62.5%	3	37.5%
PRODUCT B	2	5 hrs.	0	0	0%	0	0%	1	50%	0	0%

Customer Survey Results

Surveys were administered to each of the participants a minimum of 30 days after the installation was completed. The goal of the survey was to gauge satisfaction with the unit with regards to aesthetics, fit within their space, noise levels, controls/operation, comfort and overall general satisfaction. A brief overview of the survey results is included below. General observations include:

- PRODUCT B scored higher than PRODUCT A across the board
- PRODUCT B scored particularly well compared to PRODUCT A in noise
- Despite the low scores and associated comments for the noise issues of PRODUCT A, the overall satisfaction score was modestly positive. The fact that there was no cost to the customer may be skewing this score.

For a full breakdown of the results, please refer to Appendix A in this document.

Table 2 – Summary of Customer Satisfaction via Survey Results

	Customer Satisfaction Results					
	% Customers satisfied with how heat pump looks	% Customers satisfied with amount of space used by heat pump	% Customers satisfied with noise levels of the heat pump	% Customers satisfied with the ease of use of the controls on the heat pump	% Customers satisfied with the heat pump's ability to heat the space it is in	% Customers satisfied overall with the new heat pump
PRODUCT A	71.4%	42.9%	14.3%	57.1%	71.4%	66.7%
PRODUCT B	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Summary*

*Comments found in the summary are general observations of both products unless noted otherwise

Due to the challenges described above, this research project ended before the 15 planned installations were completed. In total, (8) PRODUCT A and (2) PRODUCT B units were installed. Two sites were located in Bend, OR (single family detached), one site in Arlington, OR (single family detached), and seven customers in the Portland Metro area (1 small multifamily / 6 single family detached). The third PRODUCT B unit is being held back to replace one of the installed PRODUCT A units due to unresolved noise issues and customer dissatisfaction.

INSTALLATION REQUIREMENTS OVERVIEW:

What are the installation requirements?

Installer knowledge/experience: Moderate carpentry skills, ability to perform risk assessment with in-wall electrical and plumbing components, general understanding of moisture management and building shell principles. Licensed electrician may be required, depending on existing condition of outlet, circuit, breaker and panel.

# of installers required: While one person could complete an installation, this is more appropriate as a two-person job due to the lifting of the unit onto the wall.

Tools required: Hole saw and/or jig saw, screwdriver, drill, drill bits, level, measuring tape, caulk gun, ladder (if installed higher than 4'-5' above ground level), cutting tool (scissors/box cutter), pliers, hand shears.

Optional tools: Thermal camera or scoping tool to locate obstructions within the wall, stud finder, voltage detector.

How long does an installation take?

PRODUCT A units, on average, required 7-8 hours to install (including the additional time required to install the drain pan heater prior to arriving at the site). PRODUCT B units, on average, required 5 hours to install. For reference, the time required to install a ductless heat pump with one indoor head (not including electrical) averages around 4-6 hours.

What are the appropriate site conditions and/or locations for installation?

Challenges associated with finding suitable install locations limit the potential customer base. When compared to a ductless heat pump, finding a suitable indoor location is considerably more difficult due to the larger size of the unit and the requirement of a nearby 120-volt outlet with adequate capacity available on the circuit. The various electrical issues associated with these products cast doubts on the compatibility with older housing stock.

How is condensate managed?

Condensation drains directly to the outside through a sloped tube running through the exterior wall. Drain pan heaters (additional cost + requires installation for the PRODUCT A unit) prevent condensation from freezing. In retrofit situations, finding a suitable termination location for the condensate can be difficult. Winter condensate was measured at one site, the average daily volume of 2 to 2.5 gallons. In the case of installations above the first floor, special consideration for the disposal of the winter condensate and ice melt from the unit would have to be taken. It is most likely that multifamily buildings in the Northwest will not have existing drain hubs for the disposal of the condensate. Simply letting the condensate free fall from a short condensate pipe could risk building shell damage from the condensate, and ice damage during freezing conditions. Running the condensate line to the ground would also be problematic during freezing conditions as the water could easily freeze in the line.

Is the installation process simple enough to allow for DIY installations?

No. The installation process was challenging for the installers selected to participate in this study, both of whom have significant experience working on residential building shells. The products included in this study require a high level of carpentry skills to install in a professional manner. Installing the units in a manner that meets the aesthetic requirements of the homeowner, the manufacturer's installation requirements, and that does not compromise the integrity of the building shell requires an installer with exceptional skills. The required skill level is in most cases beyond that of the average homeowner and HVAC installer. If these units were to become an incentivized measure, finding carpenters to install these units would be a significant barrier to their widespread adoption.

Additionally, the variety of issues encountered with the PRODUCT A unit would be extremely difficult for a DIY customer to resolve. The manufacturer does not offer any service support from internal technicians and does not cover labor costs to have an external contractor provide support.

Are these units suitable for replacing PTACs?

While this study did not include a wall mounted heat pump replacing a PTAC unit, it is expected that either of the two products could be a reasonable replacement option for PTAC units. This would likely require the installation be performed by a licensed contractor/electrician. Also, for installations above the first floor, the original condensation solution used by the PTAC would need to be compatible with the condensation design of the wall mounted heat pump units. This typically is through an internal wall drainage system. If not compatible, the moisture concerns mentioned above would apply.

CUSTOMER EXPERIENCE/ACCEPTANCE OVERVIEW:

Customer acceptance of the equipment

The PRODUCT A units generally were not received well by customers, primarily due to the noise level during operation. An additional complaint with the PRODUCT A unit was tied to the occasional need to reset the unit and consequently reconfigure the schedule and reset the Fahrenheit/Celsius display mode. On the other hand, the PRODUCT B unit was generally received well by customers.

Noise level during operation acceptable?

As described above, a majority of the installed PRODUCT A units produced unacceptable levels of noise during operation. The PRODUCT B units operated at an acceptable noise level.

Do customers like the aesthetics more/less than alternative options?

- In general, customers seemed to be neutral/positive in regard to the aesthetics of the unit itself. The design of both wall-mounted heat pump models is modern and simple. However, the limited length of the power cord often resulted in less than positive feedback once the unit was installed and the cord stretched across the wall, often at an angle. The alternative heating/cooling options for the customers in this study would likely include ductless heat pumps or a combination of wall/baseboard electric resistance heat and portable AC units, each of which have their own aesthetic drawbacks. Ultimately, the aesthetics of the wall-mounted heat pump product seemed to have a minimal impact on the overall acceptance by the customer.

How do these units impact occupant comfort?

- Since this report only covers operation during winter/early spring, the feedback is limited to heating-based comfort. During colder days, the heat produced by the PRODUCT A unit was unable to maintain the desired temperature of the immediate living space on its own. In these cases, existing adjacent secondary heating sources were relied upon. Otherwise, the units were generally able to maintain a comfortable temperature. The PRODUCT B units were installed in the Spring of 2022 and there is not yet sufficient feedback to characterize the customers' opinion regarding comfort during the heating season.

Recommendations

Due to the complexity of installation for both units included in this study, the limited support from the manufacturers to provide onsite support, the permanence of the installation methods (drilling multiple 6"/8" holes through the exterior wall) and the concerns regarding compatibility with existing shared circuits, this product is not deemed to be a practical solution for retrofit in residential sites or for the DIY audience. Additionally, the costs of these units, coupled with the higher-than-expected installation costs and unknown savings, would likely make these units not cost-effective.

We recommended not proceeding with the pending Phase 2 of this study.

In the future, if similar products emerge with lower capital costs and less intensive installation requirements, these may present a more suitable and cost-effective DIY heating/cooling solution in dwellings where central system or DHPs are not applicable or not economically viable.

Appendices

Appendix A: Survey Instrument & Full Results

1a	*How satisfied are you with the way your new wall-mounted heat pump looks (aesthetics/visual appeal)? On a scale of 1 to 5 with 1 = Not very satisfied and 5 = Very satisfied Rating*
1b	*[If response = 1 or 2] Why did you give that score? Open Ended*
2a	*How satisfied are you with the amount of space used by your wall-mounted heat pump in the room (aesthetics bulkiness/slimness)? On a scale of 1 to 5 with 1 = Not very satisfied and 5 = Very satisfied Rating*
2b	*[If response = 1 or 2] Why did you give that score? Open Ended*
3a	*Is noise an issue with your new wall-mounted heat pump? On a scale of 1 to 5 with 1 = A big issue and 5 = Not an issue at all Rating*
3b	*[If response = 1 or 2] Why did you give that score? Open Ended*
4a	*How would you rate the controls on your wall-mounted heat pump? On a scale of 1 to 5 with 1 = Very difficult to use and 5 = Very easy to use Rating*
4b	*[If response = 1 or 2] Why did you give that score? Open Ended*
5	*Do you primarily use the remote or onboard controls? Two Choices*
6a	*Given that your wall-mounted heat pump is a space heater rather than a whole home heater, how would you rate your wall-mounted heat pump's ability to heat the space that it's in? On a scale of 1 to 5 with 1 = Not very satisfied and 5 = Very satisfied Rating*
6b	*[If response = 1 or 2] Why did you give that score? Open Ended*
7a	*Overall, how satisfied are you with your new wall mounted heat pump? On a scale of 1 to 5 with 1 = Not very satisfied and 5 = Very satisfied Rating*
7b	*[If response = 1 or 2] Why did you give that score? Open Ended*
8	*Were there any issues with the initial installation process? Open Ended*
9a	*Have you encountered any problems with the operation of your new heat pump since the installation? Two Choices*
9b	*[If yes] What issues have come up? Open Ended*
9c	*[If yes] Have they been resolved? Open Ended*
10	*Do you have any additional comments about your new wall-mounted heat pump? Open Ended*

	PRODUCT A (7) total responses					**PRODUCT B (2) total responses**				
Q1a: How satisfied are you with the way your new wall-	1 = Not very satisfied / 5 = Very satisfied					1 = Not very satisfied / 5 = Very satisfied				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**

mounted heat pump looks (aesthetic/visual appeal)?	**0.0%**	**0.0%**	**28.6%**	**56.1%**	**14.3%**	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**0.0%**
Q1b: Why did you give that score? (score given above)	- "Bigger than expected." (3) - "Unit is a bit off center on a wall with a curtain." (3) - "It's a big thing on the wall." (4) - "The unit is pretty large." (4)					- "It is mounted up high on the wall and the bottom is unfinished. A piece of trim on bottom would have helped." (4) - "The unit is a little thick." (4)				
Q2a: How satisfied are you with the amount of space used by your wall-mounted heat pump in the room (aesthetics bulkiness/slimness)?	1 = Not very satisfied / 5 = Very satisfied					1 = Not very satisfied / 5 = Very satisfied				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
	0.0%	**0.0%**	**56.1%**	**14.3%**	**28.6%**	**0.0%**	**0.0%**	**0.0%**	**50.0%**	**50.0%**
Q2b: Why did you give that score? (score given above)	- "Would be better if it was 75% as big." (3) - "Looks pretty massive in our house but it isn't in the way. Compared to window units, this is pretty nice." (4)					- "Don't have an issue with the size at all." (5) - "Could be slimmer" (4)				
Q3a: Is noise an issue with your new wall-mounted heat pump?	1 = A big issue / 5 = Not an issue at all					1 = A big issue / 5 = Not an issue at all				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
	56.1%	**0.0%**	**28.6%**	**0.0%**	**14.3%**	**0.0%**	**0.0%**	**0.0%**	**50.0%**	**50.0%**
Q3b: Why did you give that score? (score given above)	- "Lots of rattle, I have removed case to see if it makes a difference." (1) - "Noisier than cadets!" (1) - "Seems loud when it revs up to keep a constant temperature." (1) - "Noisy at times when it is really cranking, especially when it's cold. But at steady state it is fairly quiet." (3) - "Can barely hear it." (5) - "The noise level is very unpredictable." (1) - "It hisses. It howls. It kicks. It's a combination between annoying and hilarious. On cold days it would kick on and rattle and moan. It is loud but our family likes the heat." (3)					- "I know it is running, but it isn't terribly loud." (4) - "Noise is not an issue at all. The noise it does make is pretty pleasant. Broad frequency range blends into background." (5)				
Q4a: How would you rate the controls on your wall-mounted heat pump?	1 = Very difficult to use / 5 = Very easy to use					1 = Very difficult to use / 5 = Very easy to use				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
	14.3%	**14.3%**	**14.3%**	**14.3%**	**42.8%**	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**0.0%**
Q4b: Why did you give that score? (score given above)	- "Waiting for the beep took a while to learn." (4) - "Unit froze up in single digits, thawed out with hair dryer." (5) - "Can't seem to get setting back to Fahrenheit. Not intuitive – the remote specifically. Could not find anything in the manual to get it back to Fahrenheit." (1) - "I wait for the beep. The timer doesn't always work. I sometimes have to reboot the system." (3)					- "The manual and remote are pretty intuitive." (4) - "It is straightforward. I'm not a fan of symbols. Language/words would be more clear. Onboard controls are a little finicky. Difficult to tell where the buttons are on the display." (4)				
Q5: Do you primarily use the remote or onboard controls?	**Remote Control**		**Onboard Controls**			**Remote Control**		**Onboard Controls**		
	100.0%		**0.0%**			**100.0%**		**0.0%**		

Q6a: Given that your wall mounted heat pump is a space heater rather than a whole home heater, how would you rate your wall mounted heat pump's ability to heat the space that it's in?	1 = Not very satisfied / 5 = Very satisfied					1 = Not very satisfied / 5 = Very satisfied				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
	0.0%	**0.0%**	**28.6%**	**42.8%**	**28.6%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**100.0%**
Q6b: Why did you give that score? (score given above)	- "Expectations were met." (4) - "Didn't work in really cold weather, learned to leave it alone." (3) - "We only turned it on during the coldest weather." (5) - "It has been doing a really great job. The house has really great insulation. It did great during the recent snowstorm. We shut down the baseboard heater circuit entirely in bedrooms. We use this heater in tandem with a fan to circulate heat." (5) - "It is okay until the outdoor temp drops below 40 degrees." (4) - "It is very poor at catching up to the targeted room temperature but it is good maintaining temperature once the set point is reach." (3) - "When it gets cold it can't keep up. Every once in a while the space heaters had to come on." (4)					- "Plenty of heating and cooling capacity for that room. Installers had the heat on to test and it fully filled the room. Used it limited since then but it happened fast when it did." (5)				
Q7a: How satisfied are you overall with your new wall-mounted heat pump?	1 = Not very satisfied / 5 = Very satisfied					1 = Not very satisfied / 5 = Very satisfied				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
	0.0%	**16.7%**	**16.7%**	**49.9%**	**16.7%**	**0.0%**	**0.0%**	**0.0%**	**50.0%**	**50.0%**
Q7b: Why did you give that score? (score given above)	- "Score is based on noise complaints." (3) - "It is noisy and not good in cold weather." (2) - "Noise can be a factor. Manual is a little confusing. Need a writer to put a troubleshooting page in. Manual can be condensed. Maybe a user guide and then a tech manual. Panel to clean filter should be on the side and not the top. Need to climb on ladder and take top piece out to get filter." (4)					- "Only marked it down because outside vents are right by deck where you hear the unit if you're on the deck. The condensate run is not aesthetically ideal." (4) - "It is awesome." (5)				
Q8: Were there any issues with the initial installation process?	- "Yes, I did not like the visual looks from the outside." - "Yes, had to reposition the exterior vents." - "Yes, they had to drill two extra holes. Had to add foam to dampen noise from cabinet." - "Yes, sloppy caulk on the outside. Installer came back twice, diagonal power cord on the inside looked bad aesthetically, circuit board crackling, had to rewire the circuit." - "Yes, there was condensate leakage to the inside." - "Yes, the switch to the fain in the laundry room burned out. We had to move the coffee maker to a different plug." - "Yes, the serial number is blocked due to proximity to side wall. Also was hard to find the studs in the					- "Yes, first unit mounted didn't work… but apart from that, there were no issues. Very careful on inside of the house due to wood paneling. Cord that goes across the wall, aesthetically not pretty." - "Yes, have dedicated outlet for the unit. Worried if they didn't have that if it would have caused electrical issues."				

	wall. Overall, the process was great and the people were great."			
Q9a: Have you encountered any problems with the operation of your new heat pump since the installation?	**Yes**	**No**	**Yes**	**No**
	83.3%	16.7%	0.0%	100.0%
Q9b: If yes, what were they and have they been resolved?	- "The system wasn't running correctly due to the intake and exhaust ducts somehow getting out of alignment. The bracket was moved, and the system is running fine now." - "The system has been freezing. Also the cord is too visible. The noise is an issue but has been reduced with some adjustments. The other issues have not been resolved. I would not do this again. Thinking of removing the system." - "Sometimes the temperature doesn't change when pushing the controls on the remote or unit. Have to reset the system by unplugging. This issue has not been resolved." - "There has been noise issues and the schedule/timer setting doesn't always work. The noise issue has mostly been resolved, but the timer issue has not."			
Q10: Do you have any additional comments about your new wall-mounted heat pump?	- "Interested in seeing how it performs when cooling." - "I am not sure if this is vermin or insect proof due to the large openings on the outside of the house." - "The cord looks strange stretched across the wall, but I knew that going into this project." - "I just switched it over to cooling and there was a disconnect between the remote and the unit."		- "Installation took a little longer than expected but happy the team took the extra time. But if someone had a time constraint it might be an issue. Parking was an issue for the installers. But everyone was very pleasant and nice." - "No comments. I love it."	

Appendix B: Other studies – Ecotope. (April 2022). *Olimpia Splendid Maestro Pro Feasibility Study & Bench Test.* Retrieved from https://www.bpa.gov/-/media/Aep/energy-efficiency/emerging-technologies/olimpia-splendid-maestro-report.pdf