B O N N E V I L L E P O W E R A D M I N I S T R A T I O N

Emerging Technologies

Olimpia Splendid Maestro Pro Feasibility Study & Bench Test

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Ecotope, Inc.

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

Executive Summary

The Olimpia Splendid Maestro Pro is a dual-ducted packaged terminal heat pump (DDPTHP) offering heat pump space heating and air-conditioning to single-family, multifamily, and light commercial buildings. Replacing electric resistance space heating is an energy conservation goal that BPA has long been pursued; this unit is a promising low-cost measure that could be adopted in affordable housing, single family homes, and market rate developments.

Codes and Certifications: State and local energy codes are pushing new construction away from electric resistance and fossil gas towards heat pump space heating. This unit is a promising product to meet this requirement; however thermostatic controls must be programmed to ensure this unit operates as the primary heat source, if paired with external backup heating systems. Energy codes (such as WA State Energy Code) require 7-day programmable controls for the primary heat source. Also, this unit does not yet have a certified AHRI rating which is important to show compliance with equipment efficiency requirements.

Performance: This unit provides heat pump space heating (at a COP greater than 2.5) throughout typical winter temperatures seen in the costal Pacific Northwest. Further testing is needed to understand how defrost operation works and how that impacts heating capacity during the coldest temperatures. No internal backup electric resistance heating means designers must be sure this unit can provide enough heat.

Cost: This unit and other models in the class of DDPTHPs all have promise for rapid uptake in the multifamily market, primarily due to their relative low cost (compared to other available heat pump technology). With no outdoor remote equipment to connect to the indoor heat pump unit, install time is drastically reduced.

Constructability: The Maestro Pro is a single piece of equipment which eliminates the need for refrigerant piping and simplifies the supporting electrical/controls systems. Condensate management from the unit is a major coordination point for this unit, as this unit will produce roughly 1 gallon of water per day over the winter.

Maintenance: This unit requires regular air filter cleaning (washing or vacuuming), a simple task for the owner or maintenance staff. Care should be taken to never allow condensate drains to backup or freeze (if routed outdoors).

This product is also well suited for single family retrofits. In single family homes, the detail of condensate management is much simpler than in a large multifamily building; and the unit's ability to receive power from existing 120VAC electrical outlet eliminates the need for costly electrical work.

This feasibility study is the first step in the Technology Innovation Model (TIM) and aimed to assess the Maestro Pro applicability to the market. This study has approved this unit through feasibility analysis and recommends it to continue to the next step of the TIM.

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Acronyms

AHJ – Authority Having Jurisdiction

BPA – Bonneville Power Association

COP – Coefficient of Performance

DDPTHP – Double-Duct Package Terminal Heat Pump

DHP – Ductless Heat Pump

EEM – Energy Efficiency Measure

ETDP - Emerging Technology Development Process

PTAC - Packaged Terminal Air Conditioners

PTHP – Package Terminal Heat Pump

SEER – Seasonal Energy Efficiency Ratio

VRF – Variable Refrigerant Flow

Background

Market Landscape

As people continue to flock to Pacific Northwest cities, new low- and mid-rise multifamily buildings are being built to meet housing needs. These apartments tend to be smaller and, due to record-breaking heat waves and bad air quality resulting from wildfires, developers are increasingly including cooling technologies in their units. In fact, the 2020 U.S. Census Bureau's American Housing Survey shows home air-conditioning in Seattle has increased by more than 10% in four years. As cooling equipment becomes more prevalent, it will increase the summer energy demand on the regional electrical grid. While heating energy is still a more intensive overall energy end use, it is important for building codes and utilities to encourage efficient cooling measures for new construction and retrofits.

The most common cooling options offered by market-rate developers are ductless heat pumps (DHP) or Variable Refrigerant Flow (VRF) heat pumps. Mid-market buildings typically offer inefficient Packaged Terminal Air Heat Pumps (PTHPs) or portable air conditioners for lease to their tenants. Portable AC units do not offer heating energy savings and low-quality PTHPs switch to electric resistance heat when outside temperatures drop below the mid-40°s F.

This study focuses on double-duct PTHPs (DDPTHP). These products are mounted on the interior side of an insulated exterior wall with two small duct penetrations through the outside wall to bring air to the condenser/evaporator. As opposed to traditional PTHPs, where the entire unit penetrates the insulated envelope of the building, this unit preserves more of the exterior wall insulation and helps maintain targeted air tightness.

Purpose

This feasibility analysis is meant to assess the Maestro Pro's ability to efficiently meet the heating and cooling needs of multifamily, residential, and light commercial buildings in the Pacific Northwest. While this unit has several unique qualities, many of the aspects of this feasibility study could be used to assess other competing DDPTHP products as well.

The feasibility analysis is the first step in the Technology Innovation Model (TIM). The TIM is designed to rapidly take a technology through a series of Stage Gates representing different areas of inquiry to ensure that the product can be applied safely and cost effectively in a manner that will help ensure performance and savings in the marketplace.

Stage Gates for the TIM are:

1. Engineering Feasibility Analysis
2. Applications Testing (Bench Testing)
3. Demonstration or Pilot Installations
4. Monitoring: Measurement and Verification (M&V) and Persistence
5. Design Guidelines

To determine feasibility, the Maestro Pro has been assessed for certifications, performance, cost and constructability, and maintenance. Each of the four assessments inform the appropriateness of moving this product forward to performing a complete bench test over the winter of 2022-2023, which would lead to a demonstration/pilot, further testing, and developing a new efficiency measure for regional utilities.

DDPTHPs are complex units, and with complexity come more potential points of failure. The subsequent steps in this emerging technology study, the bench test, lab test, and pilot projects, will access the product's robustness.

Certifications Assessment

The Certifications Assessment confirms the product will pass requirements of the local Authorities Having Jurisdiction (AHJs). It confirms whether the product meets all codes and has all certifications required for installation in the Pacific Northwest. If the product does not meet certain requirements, this section confirms which are lacking and whether the manufacturer intends to pursue compliance.

Codes

The Energy Code addresses operational efficiencies and controls, the Mechanical Code addresses allowable refrigerant charge, the Plumbing Code addresses condensate management, and the Electrical code addresses design of electrical connections. For the Maestro Pro to be a viable product in the Pacific Northwest it must comply with the following codes[1]:

- Energy Code
  - International Energy Conservation Code (IECC)
  - Washington State Energy Code (WSEC)
  - Oregon Energy Efficiency Specialty Code (OEESC) – Base code is AHSRAE 90.1
- Mechanical Code
  - International Mechanical Code (IMC)
- Plumbing Code
  - Uniform Plumbing Code (UPC)
  - International Plumbing Code (IPC)
- Electrical Code
  - National Electrical Code (NEC)

The product does appear to be able to conform with Mechanical, Electrical, and Plumbing Codes. However, Electrical and Plumbing codes do present some challenges when designing infrastructure to support the unit.

Regional Energy Codes are based on the IECC or ASHRAE 90.1, and equipment efficiencies requirements are set at the federal level. Federal efficiencies rely on the American Heating and Refrigeration Institute (AHRI) to classify systems and provide testing procedures for efficiency. Current federal standards require unitary systems, with less than 65,000 BTU/hr

[1] Some municipalities, such as Seattle WA, have additional regulations that amend the Mechanical, Energy, and other codes.

capacity, to be tested per AHRI 210/240 and perform at or above 14.0 SEER.

This unit has not been officially tested per AHRI standard; therefore, it is difficult to ensure manufacturer's efficiencies meet federal standards. Furthermore, since certain local codes (specifically City of Seattle and possibly Washington State) are limiting the amount of electric resistance heating in multifamily units, further testing and coordination with the manufacturer is needed to ensure this unit's controls can meet standards set forth in current codes. For example, most commercial codes require 7-day programmable thermostats for the primary heating/cooling system. This unit should come standard with onboard controller to integrate with a 3rd party programmable thermostat.

Certifications

The Maestro Pro meets Intertek ETL-listed requirements and UL-listed requirements to meet safety standards in the US.

Performance Assessment

Performance Assessment confirms the equipment will have adequate performance to gain acceptance of designers and users. It is broken down into four sections, Architectural, Engineering, Owner, and User.

Architectural

The Maestro Pro is designed to be sleek, compact, and aesthetically pleasing, making it more attractive than its traditional counterparts. To confirm architectural performance, the Maestro Pro is assessed from an interior and exterior perspective. We also analyzed how it integrates into a building's thermal boundary and waterproofing.

To fit the Maestro Pro into an interior design, designers need to be aware of the dimensions, required clearances, available orientations, acceptable mounting locations, and colors. The largest hurdle in incorporating the Maestro Pro into an interior design is how it will fit in apartments with tall windows or minimal opaque wall area. This unit is 20.5 inches tall, with roughly a 4-inch clearance required above and below the unit. That means the unit needs at least 2-foot 4-inch vertical space to be installed above or below windows. See Figure 1 (next page) for the installation diagram. The unit can be mounted in a low or high position on an exterior wall.

The purpose for installing this on the inside of an exterior wall is that two small duct connections must penetrate to the outdoor air in order to allow the unit to transfer heat in and out of the indoor space. The duct penetrations are 6.5 or 8 inches in diameter, must be installed with a slight slope down towards the exterior (to ensure any condensate buildup within the ducts will flow outside). Two sheets of thick, bendable black plastic are provided with the unit to form into a duct. This allows for simple install by a do-it-yourselfer (DIY), but for a commercial installation in a large multifamily building, it would be assumed that sheet metal would be used instead.

Exterior wall caps are provided with this unit and are sized to fit the ends of these duct penetrations. The primary concern with these louvers is that they are not weatherproof, so there is no guarantee that they would not hold up to wind-driven rain and could cause issues with the building waterproofing. It would be preferred to specify 3rd-party louvers that integrate with the exterior finish and maintain weatherproofing of the building.

Engineering

Engineering performance can be broken into structural, mechanical, electrical, and plumbing performance. Due to heating and condensate removal requirements, mechanical and plumbing present the most challenging designs.

Structural

The Maestro Pro weighs roughly 90 pounds and mounts via two brackets on the backside of the unit. The newest generation includes a continuous mounting bracket that is secured directly to the studs. Aside from ensuring that two 8" ducts do not penetrate a stud, structural detailing is simple.

Mechanical

The main function of the unit is to provide heating and cooling to the indoor space via an electrically powered compressor. Key performance indicators for mechanical engineers are efficiency and capacity at different temperatures (reliability), control sequences, controls integration with other equipment, and defrost capability.

This DDPTHP operates through a vapor-compression cycle with R410A as the working refrigerant. Unlike an electric resistance heater, they do not produce heat, but rather move heat between the interior and exterior of the building. Through the vapor-compression cycles (heat pump cycles), heat can be moved at a much

Figure 1. Installation Diagram

higher efficiency than it can be produced by electric resistance or fossil gas. Additionally, the Maestro Pro features an inverter-driven compressor which takes AC current, converts it to DC, and drives a variable speed compressor. This allows the unit to operate at part load conditions and avoid inefficient cycling.

When heating a home, DDPTHPs take heat from outdoor air and move it inside, even when it is colder outside. But as the temperature drops outside, it becomes more difficult to extract heat from the outdoor air, so the capacity and efficiency decrease, which means DDPTHPs' performance drops in cold climates when the demand of heat is highest. This is also an issue for other heat pump systems, such as the mini-split, and VRF systems.

At 20°F outdoor temperature (coldest expected west of the Cascade Range), performance curves provided by Maestro Pro show it can produce 4 kBTU/hr of heat to the indoor space. Below 17°F (seen east of the Cascades), it will operate at a significantly reduced capacity and would certainly need a backup heating source. Since this unit is ductless, it is intended to serve a single room, or zone, within an apartment or single-family home. Typical room heat loads in a Pacific Northwest apartment are between 1 and 7 kBTU/hr. This means in some cases this unit will not cover the entire heating load of a single room over the winter, and the designer may opt to provide an external backup heating source. Appropriate sizing and understanding of this unit's heat capacity is crucial for designers to understand in order to meet comfort expectations while delivering energy savings to utilities and end users.

Designs combining external electric resistance heaters with the Maestro Pro present a new challenge. Ideally, only the compressor will operate as the primary heat source, when it is unable to meet setpoint, the electric resistance heating element should engage. For milder climate, like the Seattle area, the electric resistance heater should rarely, if ever, engage. This control sequence between the unit's compressor (heat pump) heating and a separate electric resistance heater is a key compliance issue to Seattle and (possibly) Washington State Energy Codes.

The Maestro Pro does not have an outdoor air connection for ventilation purposes; the two air ducts are only used to transfer heat between the inside and outside. As such, mechanical engineers will need to be sure to provide ventilation air through other means, as required by local codes.

The unit comes with a remote-controlled thermostat that measures room air temperature and determines whether heating or cooling is required. For this unit to be adopted for new construction in the region it will need to come standard with onboard controls that can communicate with a 7-day programmable wall thermostat, as required by local energy codes.

Future lab testing is critical for DDPTHPs to understand heating performance in cold climates. Most impactful information includes performance maps indicating how capacity decreases as temperatures decrease and defrost cycle implications when frost builds on the coil. This will help designers understand how to maximize energy savings while meeting heat loads in the living area.

Electrical

The Maestro Pro requires a 120 Volt or 208-230 Volt, 60 Hertz, single phase (120VAC/60HZ/1PH) connection. The 120 Volt model can be powered via a standard wall receptacle with a cord-and-plug assembly or hard-wired directly to a branch circuit via local disconnecting means. A 120 Volt cord-and-plug assembly is preferable for simple retrofits, but new construction installations will likely be direct connections.

As previously noted, a unique feature of this unit is that it does not come with an internal backup electric resistance heater, which makes this a great option for single-family retrofits. Since electric resistance heaters typically require 208-230V/1PH power and a dedicated circuit from the electrical panel, retrofit applications would require an electrician and added permits. However, with only a 120VAC power requirement and a lower amp draw, this unit can be plugged into a standard 120V outlet circuit with no modifications necessary to the existing electrical wiring.

In most designs, a local disconnect will be required in order to easily shut off the unit for maintenance. If a local disconnect is required, it shall be installed in accordance with NEC Article 440, within sight of and readily accessible to the unit. This could be a simple "light switch" type of manual switch located on the wall adjacent to the DDPTHP or the power cord supplied with this unit (if not hardwired).

Overcurrent, short circuit, and/or ground fault protection are not built into the unit and would typically be provided in the local disconnect or as part of the panel serving the device. The best practice is to install overcurrent, short circuit, and/or ground fault protection in the local disconnect, within the line of sight. Manufacturer installation instructions recommend using a 15 Amp time-delay fuse or other equivalent device, which aligns with National Electrical Code (NEC) Article 250 requirements. The time delay fuse allows a large power draw for a short period of time to start the compressor but does not allow sustained power spikes that could harm the equipment.

Plumbing

The Maestro Pro comes with a condensate drain pan. The condensate connection is off the bottom of the unit and must drain by gravity or be pumped to the nearest appropriate drain location. Condensate pumps are not included with this unit and can be noisy and costly. However, plumbing code restrictions add challenges to routing condensate by gravity. In multifamily buildings condensate will be required to be routed to the sanitary sewage system. Plumbing code does not allow any fluid (including condensate) from one apartment to be connected to a drain line in another. When approved by the AHJ, condensate from these units may be routed back out to the exterior and daylight into landscaping.

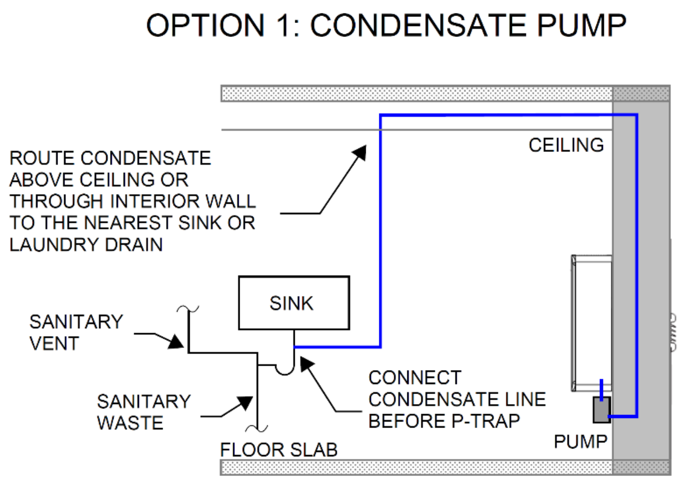


Figure 2. Condensate pump system diagram

To manage condensate routing from these DDPTHPs, four options are available: using condensate pumps to route from the unit to drain into a sewage connection in the apartment (such as the washer box or bathroom sink tailpiece), a condensate riser in the wall with an indirect drain to sewage at the bottom, a condensate riser in the wall routed to exterior landscape or add a drain near the unit within the living space.

A separate condensate pump will add cost, potential noise, and another electrical connection. Pumped condensate will route through the wall over to a sink or laundry drain, as shown in 2.

The second and third options of adding a riser adds cost, displaces insulation at the exterior wall, and adds coordination across trades. If the riser is in the exterior wall architectural features like windows will have to be avoided. The riser could run through an interior wall, in which case the condensate pipe would need to be sloped and routed horizontally.

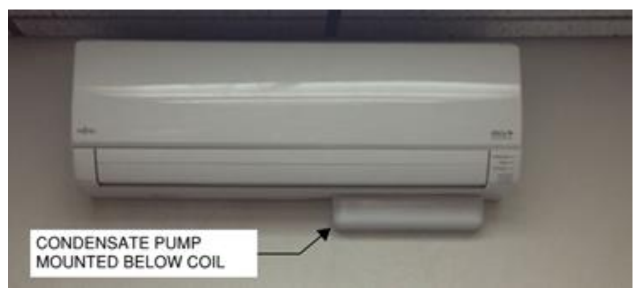


Figure 3. Condensate coil mounted below split system heat pump indoor unit

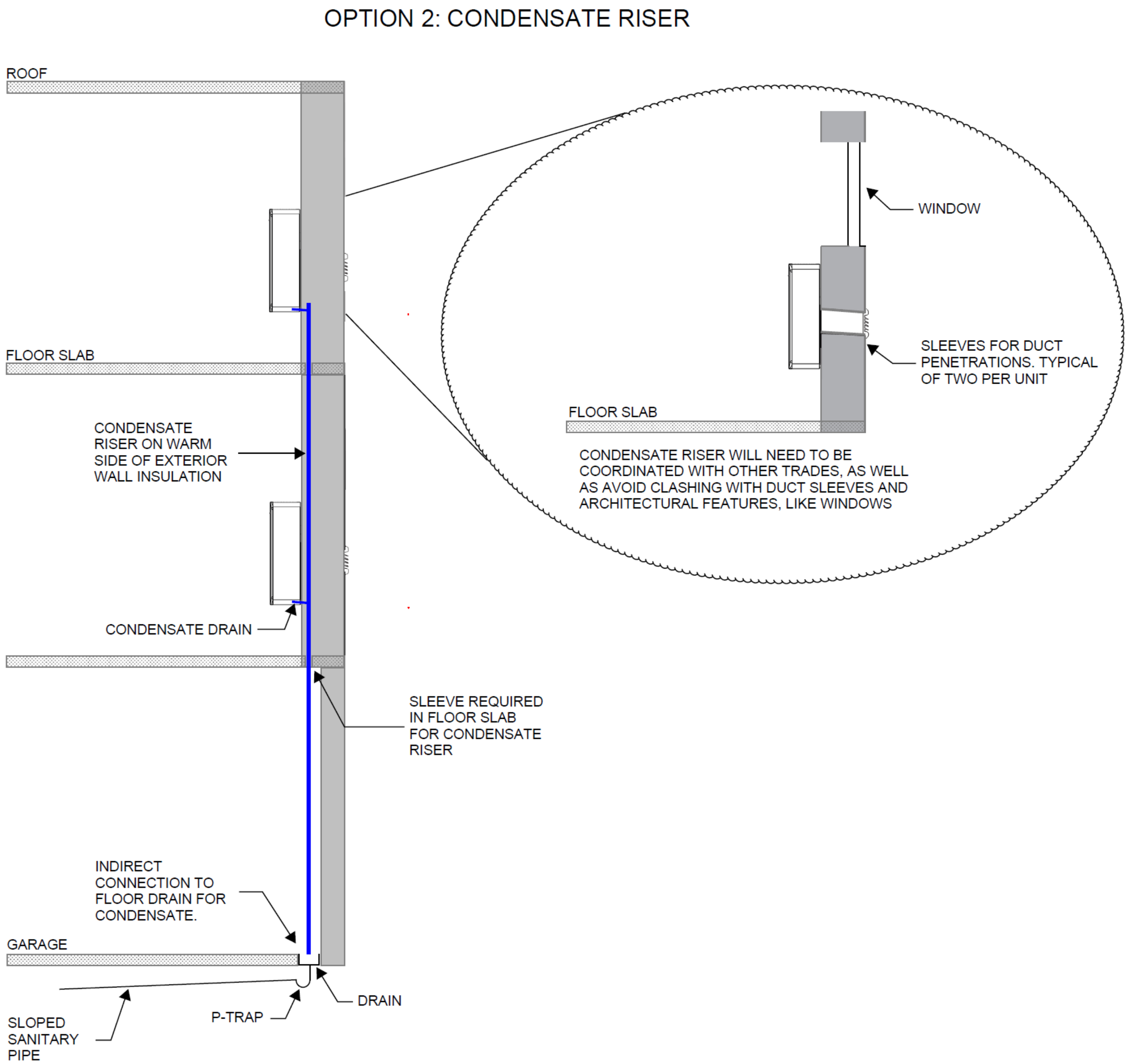


Figure 4. Condensate riser diagram

If the condensate drain or riser (Figure 4) routes outside of the heated envelope, it is recommended to include a condensate pan heater. During cold weather events (even those seen west of the cascades), any ice forming in the condensate drainpipe, as it exits to the outdoors, can force the unit to shut off due to high levels of condensate in the drain pan. Supplying means to melt this ice before blockage occurs is critical to keeping this units running through a severe cold stretch.

The final option may be undesirable from an architectural perspective because it requires there to be a sink near the exterior wall where the Maestro Pro is installed. In this option, it may be desirable to install a cabinet or casing below the unit to hide the indirect drain to p-trap, if allowed by local AHJ.

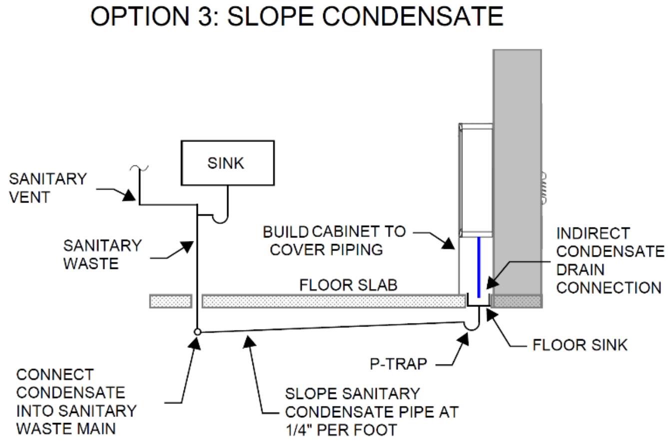


Figure 5. Sloped condensate diagram

Water in the air is condensed on the coil of the Maestro Pro when the unit is in heating or cooling mode and must drain out of the unit. About a gallon per day of condensate will form during winter heating operation. In new construction, designers can address this requirement upfront; but in retrofit scenarios (for multifamily), addressing condensate management is the biggest hurdle for this technology's adoption.

Owner

Owners will be primarily concerned with the durability of the product. Most malfunctions with products like the Maestro Pro occur from water damage related to condensate failures or forgetting to clean the air filter. The exterior of the equipment can be cleaned with a damp rag, but in no circumstance should water be poured on the product. The Maestro Pro is equipped with a dirty filter alarm that will indicate when it is time to clean or wash the air filters. When the filter needs to be removed and cleaned, the occupant or maintenance staff can do it. However, if this maintenance is deferred, the Maestro Pro's performance will suffer; if maintenance is not done, the unit will stop functioning. Luckily, when operation ceases due to a clogged filter, the solution is simply to wipe and/or vacuum the filter.

The unit will also shut down if the condensate is unable to drain out of the pan (condensate collects during the winter and summer months). This issue can arise from dirty and grime blocking the drain, or ice forming during cold streaks.

Users

To investigate performance from a user's perspective, comfort, acoustics, energy efficiency, and ease of operation are addressed below.

The Maestro Pro features an inverter-driven compressor, which allows it to meet different load conditions without cycling on and off. The inverter-driven compressor should increase comfort over similar technologies by allowing the equipment to operate at a part load condition, avoid equipment cycling, and temperature swings above and below setpoint.

The Maestro Pro puts out a minimum and maximum of 32dB and 43dB, respectively, of sound, making it quieter than a typical PTAC (~ 44dB) but noisier than a mini-split system (~ 20dB). Installation will also have an impact on volume. For instance, if more than 40 of these are installed facing a common courtyard, an acoustical engineer should calculate the potential impact of any resonance frequency of sound emitted by these units.

The user interface is a touchscreen that is onboard or can be ordered with a wall-mounted thermostat. The unit comes with a fully digital remote control which also acts as the interface between the unit and the end user.

This unit does not have an outdoor air connection and cannot provide ventilation air to the apartment. This increases occupant comfort by eliminating any cold drafts of outdoor air that would otherwise be able to drift into the living space. This is a detail that relates back to this unit's ability to maintain the building's thermal and air barrier better than competitors.

(Preliminary) Applications Testing

Purpose

Applications testing for the Maestro Pro was performed in a single-family test site located in Seattle, WA. The unit was installed in an insulated basement. Testing periods were focused on the coldest winter conditions since the capacity under those conditions is most relevant to occupant comfort. The timing of system setup precluded a full assessment of cold weather performance, but the upcoming winter should offer that opportunity. This section describes the instrumentation and methodology devised to calculate real-time capacity (heating/cooling output) and efficiency (coefficient of performance, or COP), as well as findings from the testing periods.

Testing Instrumentation & Monitoring

To calculate capacity and performance, measurements of temperatures, air flows, and electrical usage are needed. The necessary inputs were gathered through a combination of one-time and continuously recorded measurements, with some being more straightforward to collect (temperature and power) and others requiring more effort.

Metering was composed of several temperature sensors, a current transducer, a power meter, a pressure sensor, and a datalogger. The temperature sensors measure outdoor air temperature, temperature of the air coming off the outdoor coil, and the temperature of air entering and leaving the indoor coil. The last two measurements, combined with an indication of system airflow (see below), allow direct calculation of heating or sensible cooling output. The watt transducer measures real-time voltage to the heat pump, current, and corrects for power factor, outputting true RMS power and energy (which is what the utility meter also measures). On-site instruments were wired to an Obvius AcquiSuite datalogger that collected and transmitted the one-minute interval data to Ecotope servers via an internet connection.

Measurement of system airflow is the most complicated part of the metering assembly. There are two parts to the measurement. One is a set of one-time measurements of flow that are matched with simultaneous measurements of face velocity (feet per minute) of air going into the heat pump from the room. A flow box is used for this - it is a large assembly placed around the unit and therefore acts as a sort of plenum that can be depressurized by a calibrated fan as the system operates in different heating and cooling modes. For these one-time measurements, a rigid enclosure was built around the discharge to capture all air flow. This was connected to a Duct Blaster, available from The Energy Conservatory. Duct Blaster Fan speed is adjusted for a pressure in the enclosure of 0 ±2.5 Pa to ensure that the flow through the flow sensor on the Duct Blaster is the same as through the heat pump. The Duct Blaster has a nominal flow accuracy of ±3%. See Figure 6 for an example set-up similar to that used in this study.

Flow and velocity measurements were made over as wide a range of flows as possible, exercising the system across various modes (heating/cooling) and low to high fan speeds. As the system is exercised in these modes, the face velocity of the return air changes and so a 'map' of velocity vs measured flow is drawn. The measured flows were correlated with a leave-behind sensor, a reliable pressure gauge that can measure either velocity or static pressure of the supply air flow. For normal system operation, the flow box is removed and only the pressure sensor remains, which can then be used to calculate air flow from the unit based on the relationship captured in one-time flow/velocity testing.

NREL/PIX 18321
Credit: Xia Fang

Figure 6. Example setup using a temporary rigid plenum for air flow testing of a non-ducted mini-split indoor unit

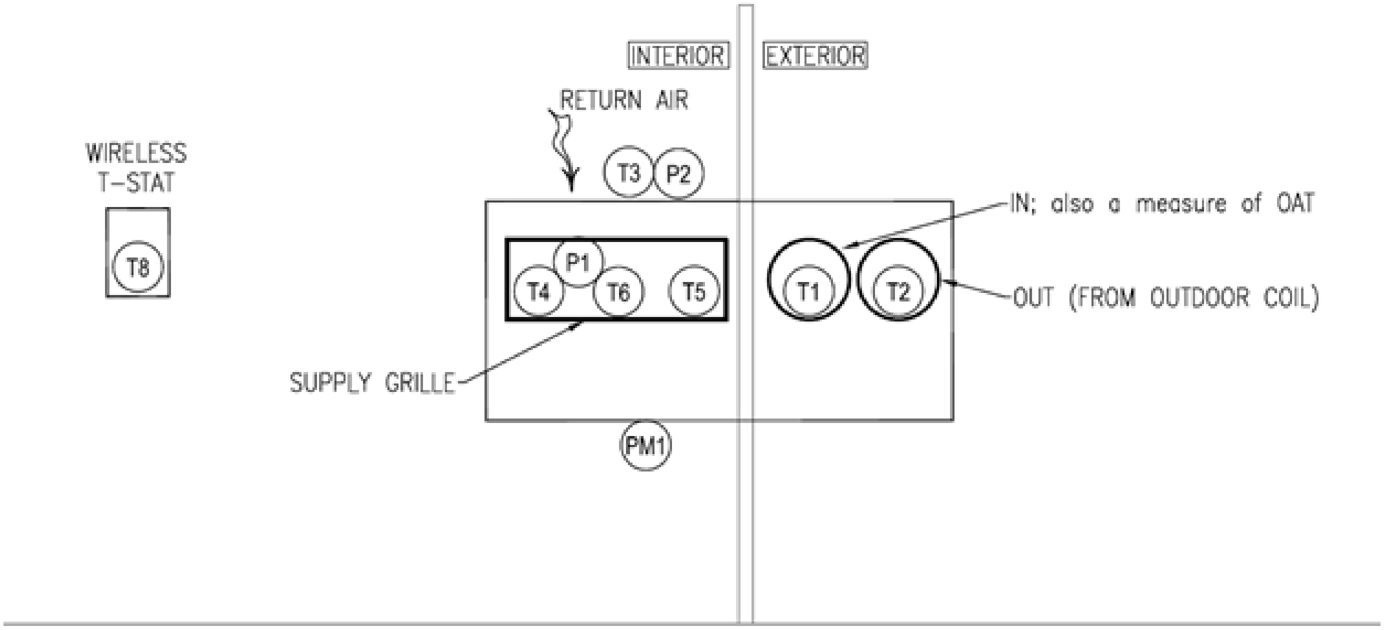


Figure 7. Schematic showing location of measured points

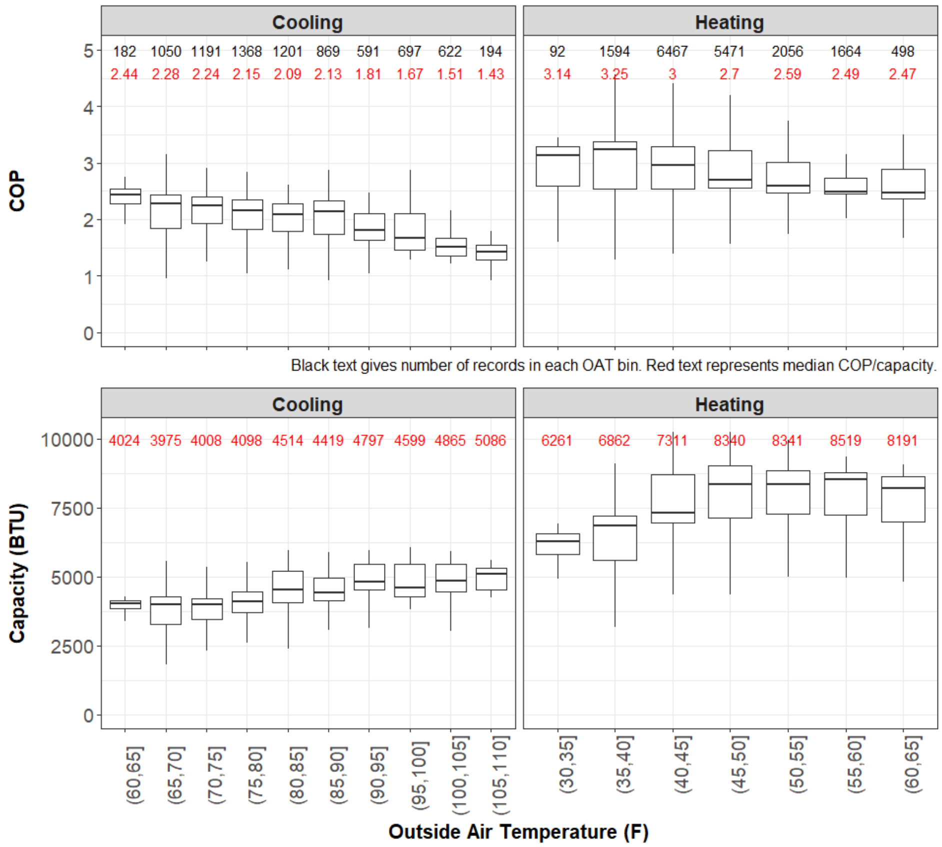
Figure 7 outlines the installed and one-time sensors used for applications testing and data retrieval.

Data Summary and Analysis

Data were collected over two windows: March 18-21 and March 27 – April 4, 2021, representing the heating season, and June 25 – July 4, 2021, representing cooling. The June/July period coincided with an extreme heat event in the Pacific Northwest (outside air temperatures as high as 107°F at the testing site). Heating season data collection covered outside air temperatures down to the mid-30°s F.

Error! Reference source not found.Error! Reference source not found. provides a summary of the observed capacity and coefficient of performance (COP) during field-based applications testing. The average COP was 2.9 during heating and 2.0 for cooling across the metered outdoor temperatures. This is lower than what is reported by the manufacturer, but the reported COP is produced at a single (likely warmer) outdoor temperature rating.

At least 30-minutes of cumulative operation within a given ambient temperature bin were required.



season	OATbinned	SAT	RAT	OAT
Cooling	(60,65]	48.49	67.77	64.22
Cooling	(65,70]	49.19	68.32	67.42
Cooling	(70,75]	49.40	68.81	72.73
Cooling	(75,80]	49.45	70.39	77.51
Cooling	(80,85]	47.56	71.69	82.39
Cooling	(85,90]	48.38	72.58	87.18
Cooling	(90,95]	48.13	74.12	92.14
Cooling	(95,100]	49.14	74.48	97.61
Cooling	(100,105]	49.03	75.27	101.65
Cooling	(105,110]	49.35	76.14	106.19
Heating	(30,35]	91.15	63.45	34.72
Heating	(35,40]	92.70	63.29	37.60
Heating	(40,45]	104.82	67.11	43.42
Heating	(45,50]	110.65	69.02	47.23
Heating	(50,55]	114.32	70.49	52.74
Heating	(55,60]	115.87	71.86	57.02
Heating	(60,65]	115.57	72.83	62.23

Figure 8. Summary of coefficient of performance (COP), and capacity (BTU) calculated during applications testing. Table summarizes average supply air temperature (SAT), return air temperature (RAT), and outside air temperatures (OAT) for each season

With outside air temperatures below 35°F, supply air temperatures measured at the supply air grille were approximately 90°F. With more moderate outdoor temperatures (40-50°F), 105-110°F air was supplied to the interior space. In the cooling season, with outside air temperatures above 100°F, the unit provided supply temperatures of 50°F or lower.

Measured capacity was higher in the heating season (average capacity = 7,409 BTUH) and closer to product literature rated capacity values (8,150 BTUH heating/cooling) than during cooling (4,237 BTUH). Sensible cooling capacities were much lower than anticipated, suggesting this heat pump may have difficulty cooling a space with direct sunlight (e.g., apartments with substantial south- or west-facing glass areas).

During the heating season, as outside air temperatures were more moderate (45-60°F), capacity appeared to plateau, and performance drop slightly. Especially notable was the drop off in capacity as the outdoor temperature dropped below 35° F. Lower outdoor temperatures also coincided with a drop in input power, so COP was maintained. Power draw by outside air temperature for the testing periods is shown in **Error! Reference source not found.**.

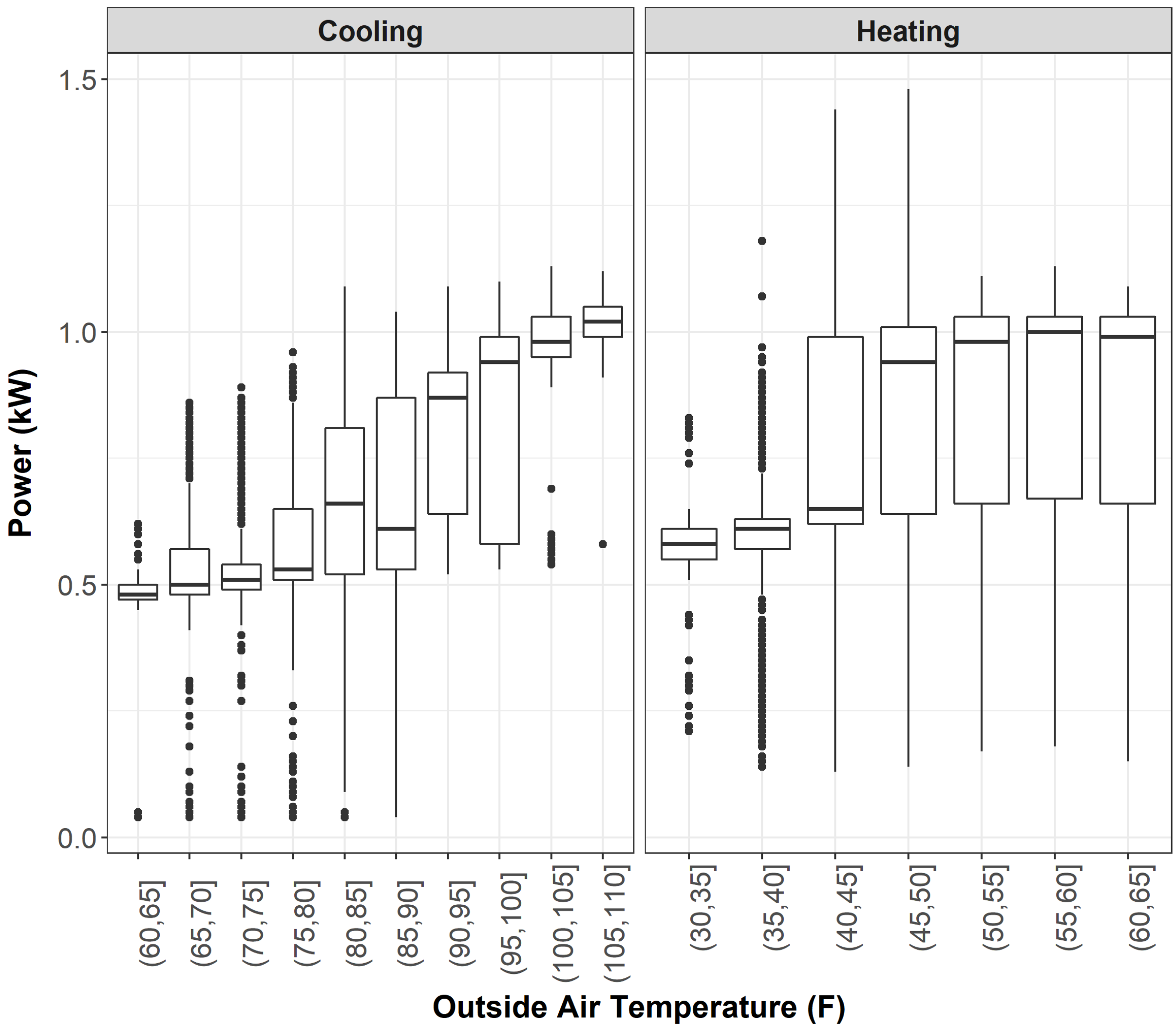


Figure 9. Power readings by outside air temperature in cooling and heating seasons

As anticipated, the measured power draw coincided with published values of rated power consumption in cooling (830W) and heating (850W) - with maximum values being somewhat higher than expressed in the literature: 1,480W for heating and 1,130W for cooling.

Although this equipment offers energy efficiency opportunities, further testing is needed to ensure the system can satisfy typical seasonal extremes in the Pacific Northwest.

Cost and Constructability Assessment

The Cost and Construction Assessment confirms additional costs associated with acquiring and installing the product. It assesses cost associated with initial market entry, and potential for cost reduction as the product becomes more widely available.

Availability

This section discusses the capacity of the manufacturer to provide products for the growing Pacific Northwest market and lead times associated with the product in a fast-paced construction market.

Olimpia Splendid builds the Maestro Pro units in their manufacturing plant in Brescia, Italy. Warehouses in New Jersey and Oregon handle the US market and sell approximately 2,400 units per year. Olimpia Splendid is well-established and familiar with mass production of quality products so we expect they will be able to increase production to meet a growing market need.

Olimpia Splendid keeps approximately 300 units of Maestro Pro in their Medford, Oregon warehouse at all times.

In addition to providing ETDP analysis for the Maestro Pro, facilitating competition to enter the market would be beneficial for DDPTHP adoption by reducing cost, increasing supply and demand, and making multiple options available.

Construction Schedule

Unlike split systems, which require refrigerant to be routed through the building to a remote outdoor unit, DDPTHPs are relatively compact. As this is a new technology, the general contractors will need to review their typical construction sequencing to install this unit, but we do not anticipate any significant challenges. It is likely that all infrastructure support (condensate piping, electrical) will be installed at rough-in phase. After insulation and sheetrock, the holes will be cored through the exterior wall, sleeves/ducts added, and the units hung. Weatherproofing of the exterior louvers must be addressed ahead of the whole-building air tightness testing, as required by local energy codes. The construction schedule impacts will be further assessed during bench testing.

Cost Impacts

The Maestro Pro will appeal to developers if it can be installed for less than competing products, such as ductless heat pumps (DHP). It is expected that the final installed cost for the unit is between $3,500 to $4,500, which is about $2,500 less than a DHP.

Equipment cost for the Maestro Pro will likely between $2,000 and $2,500, however the real cost savings for this product come from a reduction in materials, install time, and coordination efforts. DDPTHPs eliminate the need for refrigerant piping and require fewer electrical support systems compared to split system heat pumps (DHP or VRF). An additional cost component to these DDPTHPs systems is the condensate riser and is expected to cost roughly $500 per unit.

Retrofit Feasibility

The Maestro Pro is designed to be easily retrofit into small single-story buildings where condensate can be drained directly through the exterior wall (be sure to address potential ice dams forming in the condensate lines if routed directly outside). However, in multifamily buildings, or other buildings where it is unacceptable to drain condensate through the exterior wall, retrofits will be more challenging.

The unit will require all the supporting infrastructure noted above. The exterior wall must be constructed of a suitable material for drilling two 6-8-inch holes. A 120V power connection must be available within 3 feet of the unit (or provided). The most challenging of these requirements in many cases will be the condensate management system. If a system does not already exist, this could mean drilling through the structure, adding a condensate pump, anti-siphoning device, and connecting to the sewer. Note that split system heat pumps have similar condensate management issues.

Maintenance Assessment

Maintenance assessment is broken into two sections: customer service and maintenance. Customer service assesses the ability of the manufacturer to aid customers in the Pacific Northwest. Maintenance addresses maintenance requirements performed by the owner to insure product longevity.

Customer Service

Olimpia Splendid is a global company providing customer service to the United States from multiple locations across the country. There are equipment warehouses in New Jersey and Oregon, as well as a parts warehouse and its USA corporate headquarters in Dallas, which is where the technical support team is based. The technical support team handles all technical support calls, emails, and job site visits when needed. Olimpia Splendid is in the process of setting up a service center network throughout all of Olimpia Splendid's major markets, including the Northwest, to handle local service calls and unit repairs on behalf of Olimpia Splendid USA. According to Olimpia Splendid's sales team, they have rarely sent a unit back to their manufacturing facility in Brescia, Italy, for unit analysis. This reliability is why the company offers a 7-year factory warranty for the compressor, a 2-year warranty on all other parts, and a "No Hassle" 1-year unit replacement warranty. This "No Hassle" warranty provides a new unit, no questions asked, if the compressor fails in the first 12 months.

Maintenance

The only maintenance requirement of the Maestro Pro is external cleaning and filter cleaning. The Installation, Operations, and Maintenance Manual (IOM) provides instructions for external cleaning mostly so customers do not dump water or cleaning product on the unit, which can damage it. Filter cleaning is required for proper operation and the instructions are clearly documented in the IOM. Like most window AC units, the filter can be washed or vacuumed and does not need to be thrown out or replaced.

Conclusions and Recommendations

Conclusions

The goal of this study was to analyze the Maestro Pro for its ability to provide efficient heating and cooling in new construction and retrofit projects in the Pacific Northwest market. The Maestro Pro has been assessed for certifications, performance, cost and constructability, and maintenance.

After limited application testing, the Maestro Pro showed similar heating performance as stated by the manufacturer. Metering data showed heat pump heating down to cold winter temperatures, which is important for this unit since it does not have any backup heating within the unit. While this shows energy savings can be obtained from this technology alone, the unit's controls should be able to integrate with external backup heaters, if required by designers. Later in the TIM, this equipment will be thoroughly tested for energy performance, controls, and ease of use.

To further the understanding of this unit's (and other DDPTHPs) suitability for a potential rapid uptake in the PNW multifamily market, a few other considerations and impacts should be studied, including:

- Noise levels – how does sound from this unit effect neighbor and property lines. What happens when dozens of these units face a common courtyard.
- Controls – confirm detailed control sequences match local codes and how it can be integrated with backup electric resistance in cold climates.
- Construction sequencing – coordinate with a general contractor what their preferred installation sequencing and detailing would be.
- Defrost operation controls – how does this unit manage defrost and what happens to capacity during this operation.

Recommendations

Manufacturer Recommendations

Ecotope has identified the following potential improvements that would make the Maestro Pro a more effective product for the PNW market:

Recommendation: Explore interaction with the Maestro Pro and an electric resistance heating element. Lack of backup heating is not ideal for heating driven climates like the Pacific Northwest.

Recommendation: Improve controls to include 7-day programmable thermostat that can integrate with an independent electric resistance heater. This addition would make designing the product in large multifamily buildings more appealing and satisfy Energy code requirements for the primary heating system

Recommendation: Redesign so condensate from defrost drains or is pumped into the same drain pan as condensate from cooling operation. This drain pan is in the interior portion of the unit, and in heating mode will have hot air blown across it. The defrost condensate can then be re-evaporated into the room and no condensate piping is needed. This has the added benefit of increasing %RH during winter months when spaces can get uncomfortably dry. This could be a difficult redesign to accomplish but it will make the product much more marketable in the US. Condensate pipe routing is the major challenge and cost addition to installing the Maestro Pro for heating and cooling and could prevent it from being used on some projects.

Recommendation: Work with manufacturer to revise the unit's controls to output more compressor power to increase heating output at temperatures below 35°F, even at the risk of the unit's efficiency.

Utility Recommendations

Overall, the Maestro Pro DDPTHP is a promising product that has potential to save energy and reduce cost in the Pacific Northwest construction market. We recommend that it pass the feasibility study stage-gate in the Technology Innovation Model.

The limited bench testing, completed during the tail end of the 2021 winter, showed promising results. However, Ecotope recommends the bench test be performed over the entire winter of 2022-2023. This will lead to more detailed data the unit's heating capacity at low winter temperatures, as well as a closer inspection of the unit controls to ensure it complies with Seattle Energy Code.

Thorough evaluation through each stage gate ensures that the product enters the marketplace as a robust technology with proven capability to succeed, provide heating, cooling, and quantifiable energy savings over current technologies.