comed℠
AN EXELON COMPANY | Customer Innovation

Variable Speed Heat Pumps as Air Conditioner Replacement

Release Date
January 31, 2024

Prepared For
Commonwealth Edison Company

Prepared By
Center for Energy and Environment

EXECUTIVE SUMMARY

Background

Cold climate air source heat pumps (ASHPs) offer an opportunity to significantly electrify residential heating loads in virtually any location when paired with supplemental heat sources. However, to improve efficiency and capacity range, high-performing ASHPs use variable-speed equipment, typically for both the heat pump compressor and the paired air handler. Centrally ducted variable speed heat pumps (VSHPs) are only traditionally available in the U.S. when installed with brand-matched air handlers or furnaces. As a result, VSHPs require a complete replacement of existing air conditioners (ACs) and furnaces, but a full system replacement can be too expensive for many single-family homeowners. To bridge this gap, a new VSHP product class has come to the market, and it can reduce the installation costs of upgrading to VSHPs at the time of AC replacement.

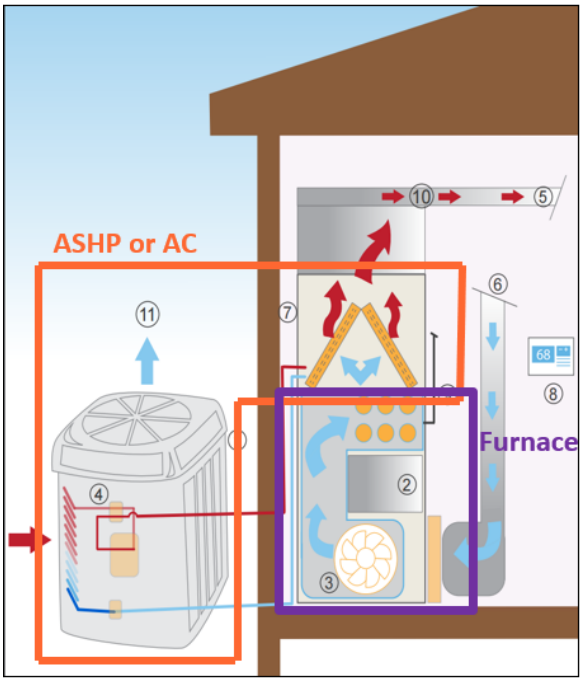

Figure 1: Illustration of a centrally ducted, coil-only VSHP or AC paired with a furnace.

These "AC replacement," "non-communicating," or "coil-only" VSHPs pair a variable speed outdoor unit with an indoor A-coil that can be installed on existing furnaces of any brand whether the air handler is variable speed or not. Their applications in single-family residential applications are the topic of this study. Coil-only VSHPs may succeed as lower-cost ASHPs that deliver good heating performance in cold climates without

requiring a full system replacement. In addition to cold climate-ready VSHPs, entry-level single-stage heat pumps (SSHPs) might also be considered for AC replacement applications. As SSHPs are available from every major ducted HVAC manufacturer and usually efficiency-rated across many furnace product lines, finding an SSHP option for AC replacements is usually also possible. SSHPs were not the focus of this project, but three SSHPs installations were included in this field study for comparison.

Approach

To better understand VSHPs as AC replacements, this study describes a field evaluation of thirty VSHP systems comprised of six different models installed as retrofits in single-family homes throughout northern Illinois. Three single stage heat pumps SSHPs were also monitored for comparison. Field monitoring included instrumentation sufficient to continuously evaluate system coefficient of performance (COP) on intervals as short as a second. Monitoring occurred between fall 2022 and summer 2023 and the ASHPs were installed on a variety of existing furnaces, including low- and high-efficiency models using propane or natural gas fuels. Besides AC replacement, many installations underwent thermostat replacement, but other weatherization or system upgrades were not required. In addition to the field evaluation, the research team engaged manufacturers, distributors and installers in interviews to gather market insights that could accelerate the adoption of VSHPs as AC replacements. Participating homeowners also provided feedback through online surveys about their experience with their heat pumps as AC replacements.

Major Findings

Market Insights

Product Selection

The selection of Air-conditioning, Heating, and Refrigeration Institute (AHRI)-rated coil-only VSHP products was limited during the recruitment phase of this project for reasons ranging from supply chain delays to changing AHRI rating methods. However, feedback from a few manufacturers indicated that more VSHPs suitable for AC replacements will be available with efficiency ratings soon. The project found that coil-only VSHPs can be installed much like other AC replacements. Only three significant differences were identified between retrofitting a VSHP compared to an AC: VSHPs have specific thermostat requirements to enable dual fuel operation, site conditions of the outdoor VSHP unit should mitigate the chance of ice and snow build-up, and the best practices for sizing VSHPs should be segmented based on the economics of the supplemental heat source.

Contractor Perspective

Despite the similar labor and expertise required to install VSHPs as ACs, HVAC contractors do not often recommend heat pumps as a replacement option for ACs in Illinois. Contractors do frequently suggest full system replacements, but not usually with a heat pump included for customers using natural gas heat. Instead, VSHPs are more commonly installed in ductless residential applications in Illinois. Still, positive experiences with coil-only VSHPs proved influential with contractors. All three contractors who provided feedback after completing installations for the project said they now always offer ASHPs for AC replacements. High incremental costs were cited by contractors as the usual reason a homeowner would choose an AC over an ASHP. For the systems installed in this project, the average incremental cost for a 3-ton VSHP over an AC replacement was $3,353, and a 3-ton VSHP cost $8,778 on average. These prices may have been influenced by the participation incentives offered to homeowners by the project. In comparison, the SSHPs installed for the project had an average incremental cost of only $512 over an AC replacement.

Homeowner Perspective

Homeowners who participated in this project provided positive feedback overall. Ninety-six percent of participants said they would recommend an ASHP to others, and more than half reported being "very satisfied" with their heat pump while none reported being "dissatisfied" overall. The most common reasons cited by homeowners for recommending an ASHP to others, in descending order of frequency, included cost savings, improved comfort, energy efficiency, and decreased noise. Comfort improvements reported by participants were related to both improved cooling season performance and more consistent or even temperatures throughout the year.

Field Performance

Savings

All sites that used their VSHPs for some portion of the heating season achieved net site energy savings during the study period, with a weather-normalized average site energy savings of 22 percent. A few sites exceeded 40 percent site energy savings. Energy savings depended on how much heating load was displaced by the VSHP. Indeed, substantial reductions in natural gas use were achieved, averaging 51 percent gas savings per site. As expected, gas displacement and energy savings were influenced by the typical thermostat switchover temperature (wherein the VSHP is no longer used for heating). See Figure 2.

Cost savings varied significantly more. They depend on the same system characteristics that impact energy savings but are also sensitive to supplemental heating fuel source type and ever-changing utility rates. Cost savings increase when supplemental fuel

rates are high compared to electric rates. Customers with propane furnaces have the largest cost savings opportunity, but customers with natural gas furnaces can realize cost savings too, depending on system details. The focus of this project was on validating field performance and not bill impacts, however, a simple utility billing analysis was completed that normalized costs by weather and made rate assumptions reflective of 2023 electric and natural gas rates. This analysis estimated that natural gas customers might expect customer bill impacts ranging from 21 percent savings to 36 percent cost increases, with 40 percent of the study participants realizing reduced costs. The average cost change estimated was a net increase of eight percent by this modeling method, however this is highly dependent on system-by-system switchover temperatures. Importantly, actual cost savings will vary by season and over time, especially as utility rates change or control settings are adjusted. The thermostat switchover settings for participants in this study were strongly biased to lower temperatures than is usually recommended for economic operation so that more cold weather performance data could be collected. Under other circumstances, average bill impacts are expected to be significantly favored toward cost savings or remain cost-neutral.

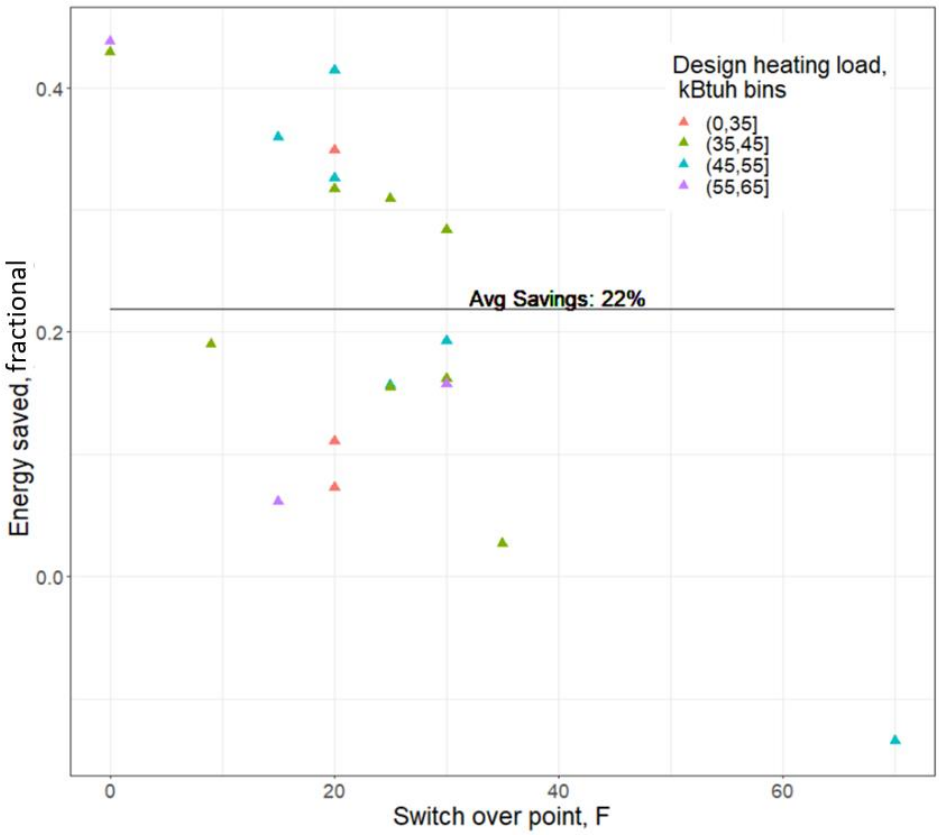

Figure 2: Normalized heating and cooling savings in relation to heat pump and auxiliary switchover point

Heating Capacity

Detailed sizing calculations were not required from installers for this project. Instead, installers generally matched the new VSHP size to that of the pre-existing AC, as is common industry practice. Oversizing is also common in the industry, and the existing furnaces included in the study were found to be oversized by about 3.3 times design heating loads on average. No systems were undersized. For retrofits on oversized systems, VSHPs sized for cooling via existing AC sizes will have more heating capacity than expected for right-sized cooling systems. Figure 3 illustrates the impact oversizing has on the capacity switchover point, which is the temperature at which the home heating load is equal to the VSHP capacity. All systems studied here had the ability to meet their home's average heating loads at least to freezing temperatures, with most having capacity switchovers well below that and some as low as below 0°F. Given recent utility rates, economics will continue to drive optimal thermostat switchover settings for most natural gas customers rather than capacity limitations, even in AC replacement applications. Existing best practices for selecting thermostat switchover settings should be applied to VSHPs as ACs and existing HVAC equipment must not be assumed to be right-sized when making equipment replacements. Unfortunately, right-sizing a VSHP and pairing it with an existing oversized furnace may generally be challenging as the airflow rates available from oversized furnace air handlers may be difficult to match to the airflow requirements of a smaller, right-sized VSHP A-coil. Right-sizing the entire HVAC system is a major opportunity for full system replacements and installers should not overlook this selling point when bidding AC replacement options.

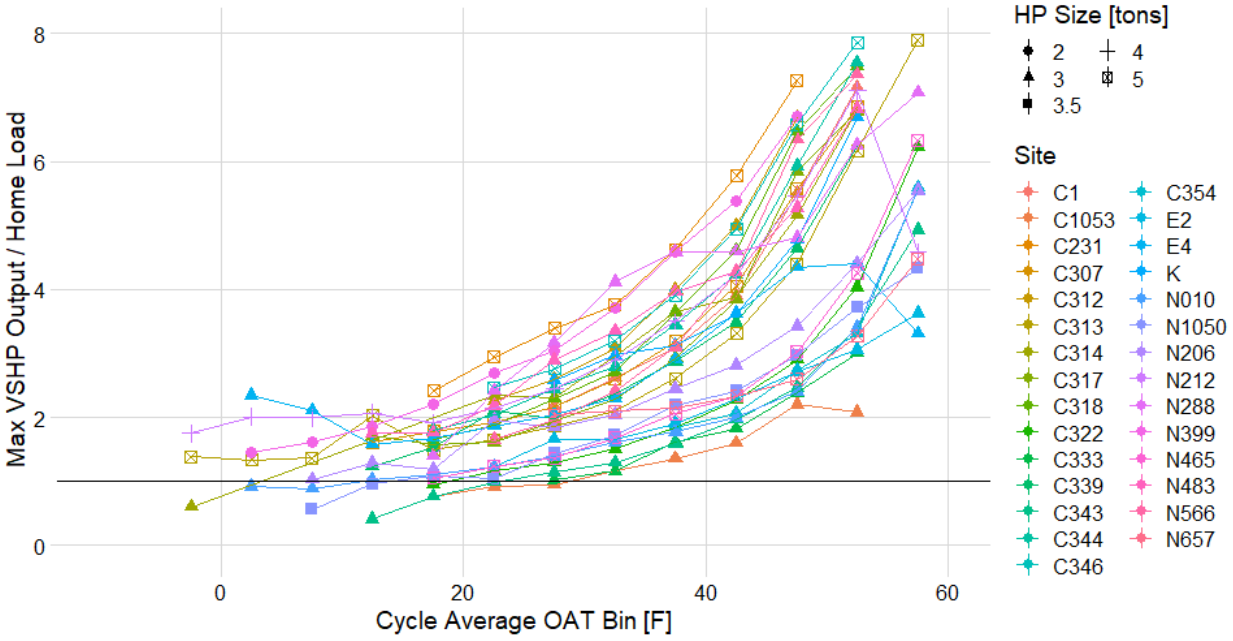

Figure 3: Ratio of maximum observed heating capacity from coil-only VSHPs compared to the measured heating load of the home as a function of outdoor air temperature during the heating cycle for each study site

Efficiency

The importance of equipment sizing became even clearer when evaluating which factors influenced field-realized COPs, as summarized in Figure 4. A wide range of COPs were measured from the studied VSHPs as AC replacements, but the rated heating seasonal performance factor (HSPF) could not predict field-realized performance trends. Instead, the ratio of equipment capacity to design heating load and average cycle runtime are the strongest predictors of coil-only VSHP efficiencies, with right-sized systems having expected COPs increase on the order of 50 percent or more compared to the most oversized systems in the study pool. Figure 5 provides more data. No standardly available equipment specification provided a statistically significant correlation to the COP of the studied coil-only VSHPs. That is, coil-only VSHPs installed with higher HSPF ratings, higher efficiency furnaces, newer furnaces, or furnaces with efficient fan types were not predictably more efficient for heating with statistical significance, given the small sample size of 30 VSHPs here. These results do not prove that these specifications do not have an impact, only that their influence is not stronger than equipment oversizing for a population of 30 coil-only, dual fuel VSHPs.

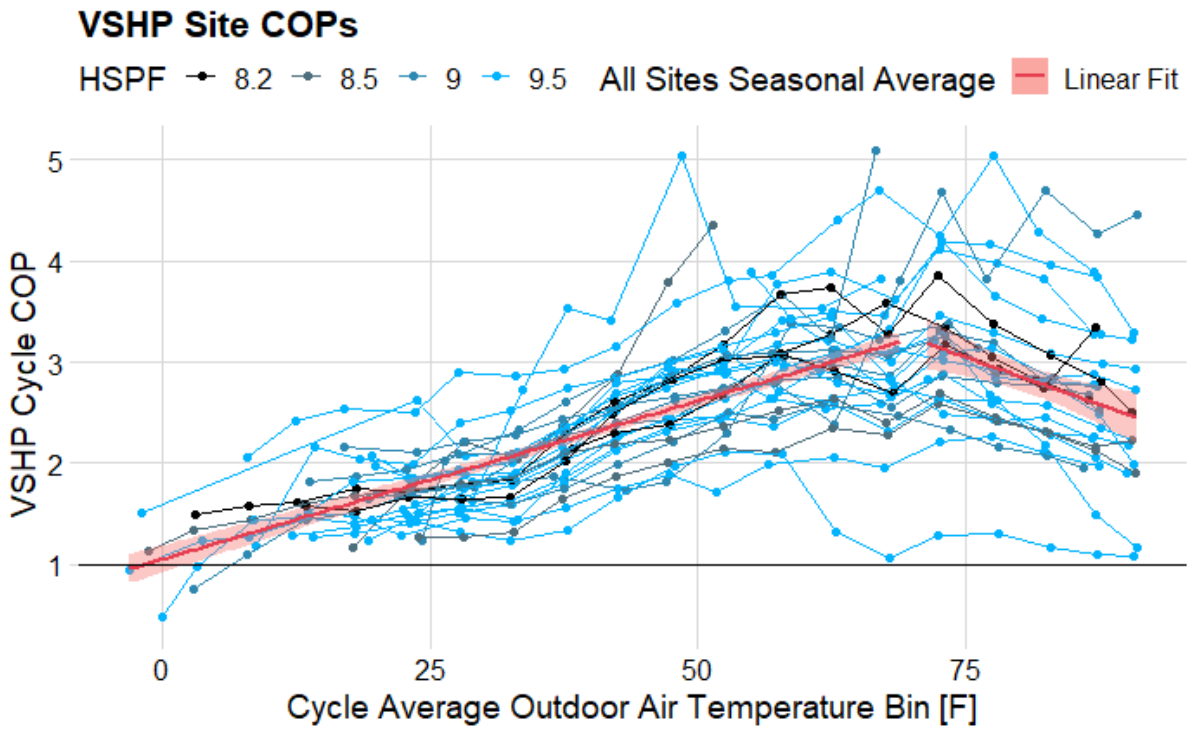

Figure 4: Time-weighted cycle average VSHP COPs as a function of outdoor air temperature for all study sites.

Conclusions

Thermostat and Install Quality is Critical, Not AHRI Ratings Yet

Beyond appropriate sizing, thermostat selection and configuration proved critical for optimizing customer savings. Installation of a thermostat without dual fuel controls or poor configuration of a dual fuel thermostat can result in zero heating season savings from the VSHP. The most impactful thermostat settings are related to how the system switches between VSHP heat and supplemental heat. These include aux and compressor lockout (switchover) settings but also emergency heat mode and staged heat control settings. Emergency heat mode is a switch that can immediately lock out the VSHP from running. While it is intended for troubleshooting or equipment repairs only, some participants used this setting without a clear understanding of its impacts, inadvertently locking their VSHP out for long periods of time. Staged heat controls allow the supplemental heat to take over if the ASHP does not easily meet the heat load. This reduces the importance of checking the set switchover against the capacity switchover point and may improve comfort. However, these controls can easily sacrifice efficiency for a fast system response. For best results, they should be based on

setpoint drops of at least two to three °F and timer-based staging controls should be avoided altogether to maximize VSHP cycle runtimes.

Appropriate selection and configuration of thermostats was a challenge for installers and customers alike. It had more impact on coil-only VSHP savings than HSPF ratings, which had no correlation with field performance. Based on the results of this project, programs in support of VSHP as AC replacements are recommended to focus on strategies to ensure and maintain quality installations rather than strict efficiency rating cutoffs to designate eligibility. Until right-sizing and correct thermostat configuration become standard, these factors are more likely to influence savings than efficiency rating tiers for AC replacement applications. Given the current reliance of TRM measures on AHRI specifications for estimating savings, this strategy should not necessarily apply to all VSHP programs, but approaching ratings with flexibility will be critical to accelerate ASHP adoption at the time of AC replacement via coil-only products.

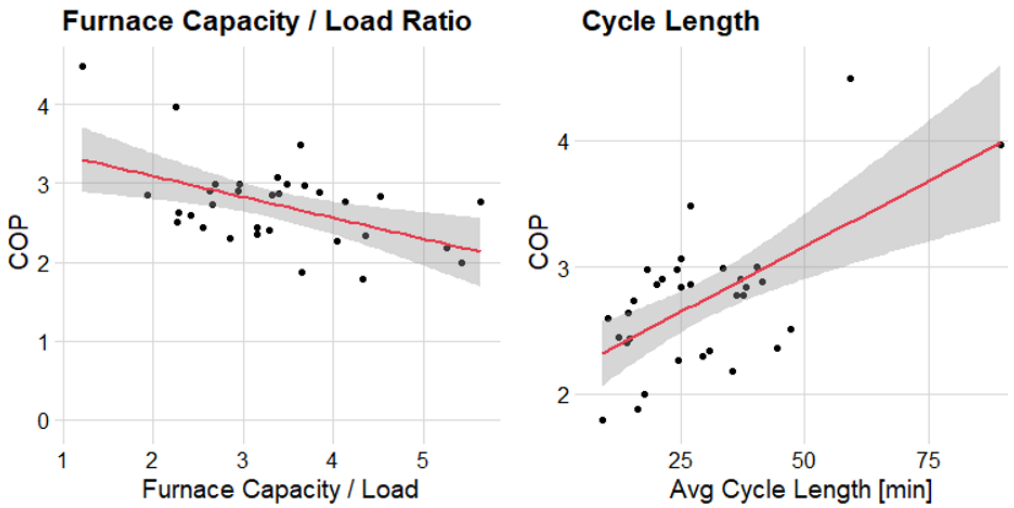

Figure 5: Factors that best predict COPs at 47°F of coil-only VSHPs

ASHPs as AC Replacement Programs Should Segment by Customer Priorities and Heating Fuel Type

Three SSHPs installed as AC replacements were included in this study. Surprisingly, the field data could not show with statistical significance that coil-only VSHPs had higher temperature-dependent COPs than the sample of SSHPs. See Figure 6 for data. Instead, the clearest difference between VSHPs and SSHPs was their temperature-dependent capacity. The SSHP heating capacities fell linearly with decreasing temperatures while similarly sized VSHPs were able to maintain heating capacity to at least 0°F. Since economic switchovers for natural gas customers remain high (usually above 30°F) and

the incremental costs of SSHPs are low (~$500), programs to support SSHP as AC replacements for natural gas customers should be developed, especially for low-income customers. While SSHPs will not yield the impressive comfort improvements or the flexibility for future utility rate changes that VSHPs offer, when installed correctly for the right customer, SSHPs could cost-effectively deliver some energy savings today while accelerating ASHPs in becoming the default AC replacement technology in Illinois. Simultaneously, customers with propane furnaces or an interest in improved comfort, reduced noise, increased efficiency, or resiliency against utility rate changes can turn to coil-only VSHPs for their AC replacement needs and immediately unlock greater energy savings opportunities compared to installing an AC or SSHP. For best results, efficiency programs will recognize the opportunity for segmentation within the ASHP as AC replacement market based on supplemental fuel type and customer priorities.

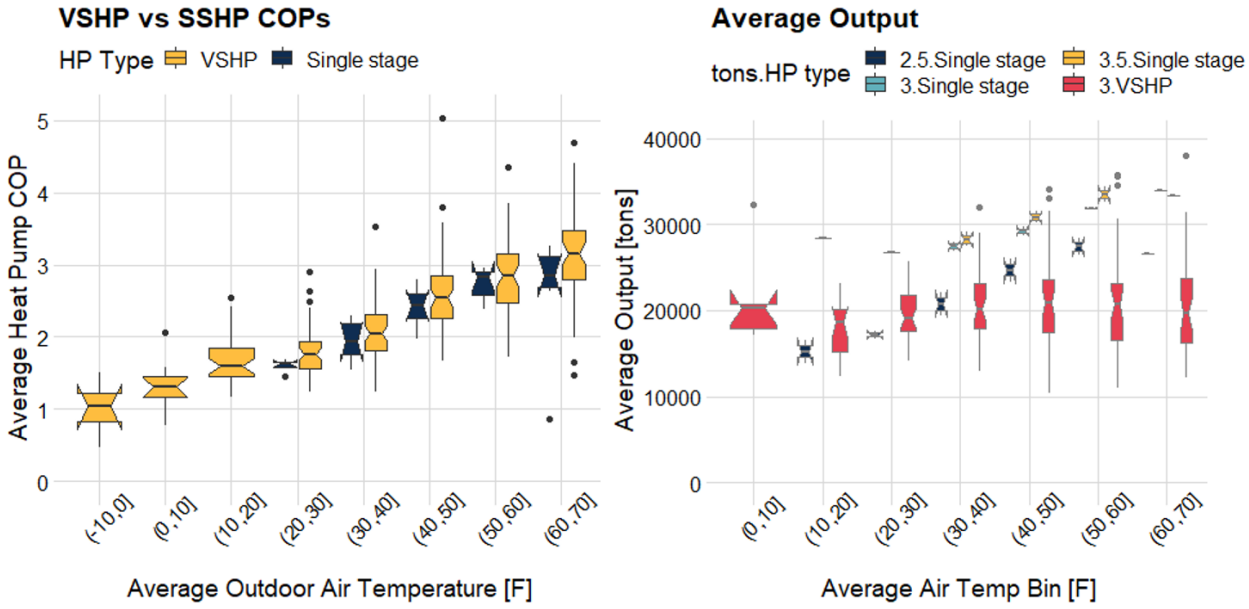

Figure 6: Performance of variable speed heat pumps (VSHPs) to single stage heat pumps (SSHPs) installed as AC replacements as a function of heating season outdoor air temperature (OAT)