

Why We Should Never Install Another Air Conditioner!

Authors: Ben Schoenbauer (Center for Energy and Environment), Josh Quinnell (Center for Energy and Environment), Emily McPherson (Center for Energy and Environment), Isaac Smith (Center for Energy and Environment), Alex Haynor (Center for Energy and Environment).

ABSTRACT

Air source heat pumps (ASHPs) are not currently cost competitive as a full replacement of natural gas heating in most cold climate applications. ASHP systems often require replacing the existing furnace and result in higher initial costs than a typical air conditioner (AC) replacement. However, ASHP technology advances allow ASHPs to integrate with existing furnaces and/or air handling equipment, regardless of make and manufacturer, which reduces initial cost and removes adoption barriers. ASHPs also provide more energy savings than AC units in the cooling season. These dual fuel applications can optimize for emissions reductions, operating costs, or efficiency, which provides significant benefit in the heating season but can also add complexity to system design and decision making.

ASHP systems that integrate with existing furnaces and/or air handlers have been developed for a range of performance and price points, including variable speed systems designed to heat at very cold temperatures. This report will share results on the best applications, energy savings, cost considerations, and performance of ASHP systems deployed as direct AC replacements. The findings are synthesized from several ASHP projects conducted by Center for Energy and Environment (CEE) focused on market research, modeled performance, and installation and field validation efforts. These findings will reveal that regardless of installation type, single speed, or variable speed, all electric heat pumps offer enough customer and environmental benefits over air conditioners that rebates and programs should be designed to prioritize heat pumps over central air conditioners as we continue to transition to an energy efficient, low carbon future.

INTRODUCTION

Heat pumps (HPs) have significant benefits over ACs in all cold climate applications. Currently, incremental costs to consumers are such that HPs may not deliver short-term paybacks based simply on energy cost savings, but the overall benefits and future flexibility are significant enough that they should be installed in all cases. To drive down costs to consumers and harness economies of scale, market demand for heat pumps needs to significantly increase. The raw equipment cost or componentry for single-speed entry level HPs is not significantly higher than that of basic ACs, the major variance causing a higher price differential is simply market scale. This necessary increase in demand needed to transform the market can be accomplished through consumer awareness campaigns, supply chain support, midstream and upstream incentives and downstream customer incentives – increasing HP rebates and discontinuing AC rebates, which will help accelerate the adoption of HPs.

Recent advances in variable speed heat pump (VSHP) technology have helped lower the cost for an AC replacement application. This was accomplished by adapting controls so these systems

can be installed without replacing the existing air handler or furnace unit. These installations are now comparable to an AC replacement, but the existing outdoor unit is replaced with a new variable speed heat pump. Additionally, the indoor cased coil is replaced with a coil designed for this VSHP application and the system controls are designed to work with the existing air handler and supply fan. These systems should be considered in cases where electrification/decarbonization and cost (rates) benefits are significant enough. In most cases, a single speed HP should be installed instead of a 13 SEER AC. To pursue this strategy, there are technical (design and install) and market barriers, however these barriers have readily deployable solutions.

This paper will discuss HP product categories for AC replacement applications, as well as the technical barriers related to installation, sizing, and ductwork. Energy performance, operational costs, and emissions savings are also examined as these are key to market acceptance, as well as policy and incentive options. Lastly, key market actors including manufacturers, distributors, contractors, and customers were interviewed and surveyed to develop an understating of the current AC replacement market, as well as opportunities and barriers of HP adoption.

PRODUCT DEFINITION

Air source heat pump technology is very flexible and a good fit for many applications. Flexibility and adaptability are a significant benefit for heat pumps, allowing for multiple configurations and access to a larger range of installations. However, this adaptability can cause some confusion over terminology and aligning stakeholder interests.

For the air conditioner replacement market, heat pumps can be utilized in three main product categories: dual fuel - single speed or entry level heat pumps (SSHPs), dual fuel - variable speed heat pumps (VSHPs), and all-electric - variable speed heat pump (EHP) systems.

Using heat pumps in a single speed application is a more traditional approach to the technology; these systems have been available in the market for decades and most installers are familiar with this approach. These entry level heat pumps are not able to modulate performance and deliver the necessary heating capacity at cold temperatures and are typically lower efficiency. However, these systems are often less expensive to install than VSHPs and have comparable performance at moderate or shoulder season temperatures.

Using VSHPs as an AC replacement is an emerging application. VSHPs deliver higher efficiencies and larger capacities at colder temperatures than the SSHP alternatives. These systems come with a higher upfront cost but meet a greater portion of the home heating load. Figure 1 compares the capacity of a VSHP to an SSHP. When outdoor temperatures are at and below freezing, the VSHP system has greater capacity and therefore can meet more of the heating load than the SSHP system.

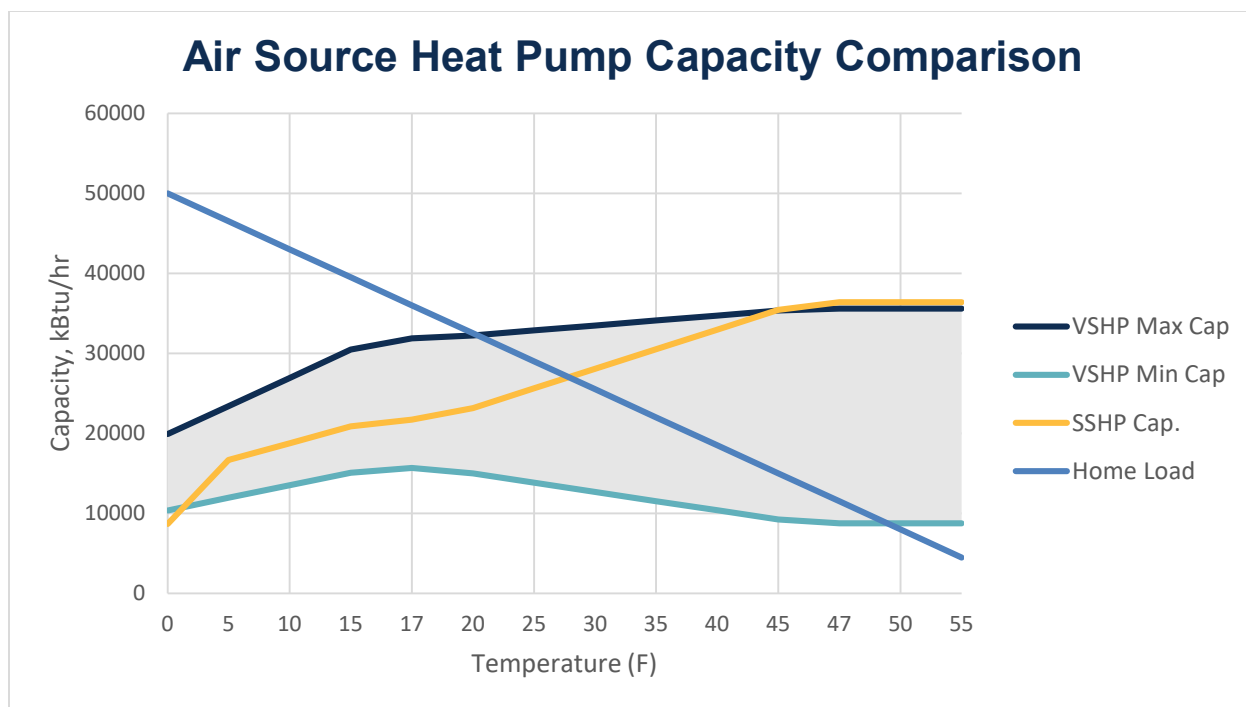


Figure 1. Comparison of heating capacity for a three-ton single stage heat pump and a three-ton variable speed heat pump.¹

All electric systems pair a variable speed HP with an electric resistance auxiliary heater to fully electrify the heating load in an AC replacement scenario. Cold climate applications require HPs designed specifically for cold climate use (Northeast Energy Efficiency Partnerships 2021). These systems, cold climate heat pumps or ccASHP, allow for the highest fraction of the heating load to be met by the heat pump, minimizing backup heating use.

Single Speed or Entry Level Heat Pumps for AC Replacement

Single speed or entry level HPs are non-inverter heat pumps. This type of HP is offered by every major manufacturer of unitary (ducted) HVAC equipment. These HPs are very similar to ACs, except they include a ~\$25 reversing valve that allows for heating in addition to cooling. This technology has been around for a long time, but it has shown recent efficiency improvements with better performance at moderate temperatures. This technology still has limited capacity output and performance at colder temperatures (below 30°F).

Entry level HPs are a very similar install to air-conditioners, and like ACs they typically require a matched pairing between the indoor and outdoor unit, meaning the same brand or manufacturer. However, these systems have AHRI ratings across a wide variety of existing furnaces and are offered by every major manufacturer, which limits this application barrier.

These systems also come in at a lower price point than VSHPs, making them a low initial cost option for customers considering an AC replacement. However, these systems tend to be more expensive than comparable ACs, even though they have very similar components. This is likely due to the supply and demand for this product. If demand were to increase for these products,

¹ These capacity values were interpolated from data in the NEEP ccASHP product list as well as manufacturer product tables.

they would be supplied in larger quantities by distributors and manufacturers, which would likely lower the price. Increasing the demand will be key to shift the market from ACs to heat pumps. This can be done through a variety of tactics including upstream incentives to distributors and manufacturers, as well as consumer awareness campaigns and downstream incentives. Some jurisdictions may even consider banning AC installs altogether.

Variable Speed Heat Pumps for AC Replacement

This application pairs a variable speed outdoor unit with an indoor cased coil that can be installed on any existing furnace or air-handler. This product category offers many benefits; it is an easy and familiar install for contractors, has the potential to significantly reduce cost compared to a full system replacement, and delivers the savings and performance benefits of a VSHP.

Prior to this product development, VSHPs had to be a matched pairing between the indoor unit and the outdoor unit. Meaning, the furnace or air-handler (indoor unit) had to be the same manufacturer as the outdoor unit. A matched pair allows for better communication between these units, but past research results indicate that this isn't utilized very often. Plus, the need for a new indoor unit adds significant cost to the install and overlooks a customer segment that may only be interested in replacing the AC.

A potential shortcoming of this product category lies in the AHRI rating. Since this system can be installed on any existing furnace, AHRI assumes a worst-case permanent split capacitor (PSC) fan motor to calculate the SEER and HSPF ratings, which has significantly deterred manufacturers from developing this type of product. This is an issue due to the high energy use from a PSC motor, which lowers the ratings to a level that reflects the lowest possible performance. Based on current AHRI ratings of this product category and conversations with manufacturers, a SEER rating that is two to three points higher would better represent the actual performance. This issue needs to be carefully considered as it relates to utility program design and savings calculations.

Available Products

Product Category Rapidly Expanding

The heat pump market is rapidly expanding, and new heat pumps and product lines are emerging seemingly every day. This product category is no exception, and many manufacturers plan to launch a product in this category within the next year. This demonstrates how the AC market is shifting to HPs, with manufacturers launching new products for colder climates and dual fuel applications. The currently available products in this category are discussed below.

Bosch

Bosch was the first to market and has been offering products in this category for more than three years. Bosch has two product lines, the IDS 1.0 and 2.0, that were recently rebranded as IDS Plus and IDS Premium, respectively. Bosch has had success with this product in cold-climate territories with distributors that actively sell and train contractors on the benefits. Bosch was the first manufacturer with an AHRI rating between the outdoor unit and A-coil.

Carrier/Bryant

Carrier plans to launch a product in this category in 2022. Currently, Carrier and Bryant offer an outdoor unit and A-coil system that can be paired with most of their furnace and air-handler offerings. They plan to complete an AHRI rating for the A-coil only pairing this year.

GREE

GREE has been offering variable capacity heat pumps in this product category since 2020. However, the pairing between the outdoor unit and A-coil is not yet rated through AHRI. GREE's equipment is offered by three different brands: GREE, Kinghome, and MRCOOL. The Universal product line under MRCOOL fits this product category and currently has the largest distribution. However, GREE is launching the Kinghome brand and establishing more distribution channels in North America. GREE expects to have these systems AHRI rated in 2022.

Lennox/Ducane/Concord

Lennox subsidiaries Ducane and Concord launched products in this category in 2021. Lennox plans to follow suit with a product launch in 2022. Lennox is the first manufacturer to enter this market that also has strong brand recognition and market penetration in the gas furnace market.

Mitsubishi

Mitsubishi plans to launch this product in 2022, with distributor and contractor engagement already underway. The intelli-HEAT system is Mitsubishi's first product designed to work with a gas heating system. This creates the opportunity for a ducted dual fuel system with a Mitsubishi HP.

Table 1. Manufacturer VSHP A-Coil Products

Manufacturer	Brand	Product Name	Model #	A-coil Model #	Product website
Bosch	Bosch Inverter Ducted Split	IDS 2.0	BOVA20-**	BMAC	Product website
Bosch	Bosch Inverter Ducted Split	IDS 1.0	BOVB18-**	BMAC	Product website
Carrier	Bryant	Preferred	38MARB	CNPVP	Product website
Carrier	Carrier	Performance	38MARB	CNPVP	Product website
GREE	KingHome	Ultranixx	KU**UHO	Not available	Product website
GREE	GREE	Flexx	FLEXX**HP	FLEXX**C	Product website
GREE	MRCOOL	Universal	MDUC0180**	MDUCC150**	Product website
Lennox	Lennox	Elite Series	EL18 XPV	Not available	Product website
Lennox	Ducane	Lynx	4HP18V	EAC4X	Product website
Mitsubishi	Mitsubishi	intelli-Heat	Not available	Not available	not available

All-Electric Heat Pumps

There are many ducted all-electric HP applications, including as a replacement for an existing AC and furnace. These systems pair a variable speed outdoor unit with an indoor air-handler. In cold climates, these systems include an electric resistance auxiliary heater that provides supplemental heat when the capacity of the heat pump can't meet the heating load (discussed further in the installation considerations section).

All-electric HPs are offered by every manufacturer with VSHP products, which includes all of the manufactures discussed above. This product category requires a full system replacement (new outdoor and indoor unit), which results in a higher upfront cost. It is a great option for those looking to remove gas entirely, which lowers monthly fees and emissions.

INSTALLATION CONSIDERATIONS

HPs as AC replacement products rely on installing a new HP outdoor unit and indoor cased coil. These new components are installed with an existing furnace or air handler system and potentially an existing thermostat. In some cases, a new thermostat may be required. The HP as AC replacement category shares many installation requirements with other residential HP installs, such as sizing, switchover temperature control, and integration with backup heating sources (NEEP 2020; Schoenbauer et al. 2017).

Heat Pump Sizing

HPs are sized differently than traditional HVAC systems. HP heating capacities vary with outdoor air temperature. Figure 2 shows the capacity of 3 different sizes of VSHPs (Schoenbauer 2017). Typical VSHP as AC installations will utilize the existing furnace as a backup heating source. A larger HP system can meet the heating load of the home at colder outdoor air temperatures than a smaller system. The correctly sized HP needs to balance desire for the HP to meet the heating load at colder temperatures and any risk of oversizing. A correctly sized HP should ensure that the minimum firing rates are low enough to maintain space temperature and humidity control in the shoulder heating season as well as the cooling season. Most VSHPs have a wide range of modulation and even when increasing the size by 1 to 2 tons over the existing AC systems, the modulation rate will still enable a lower cooling capacity than the existing system.

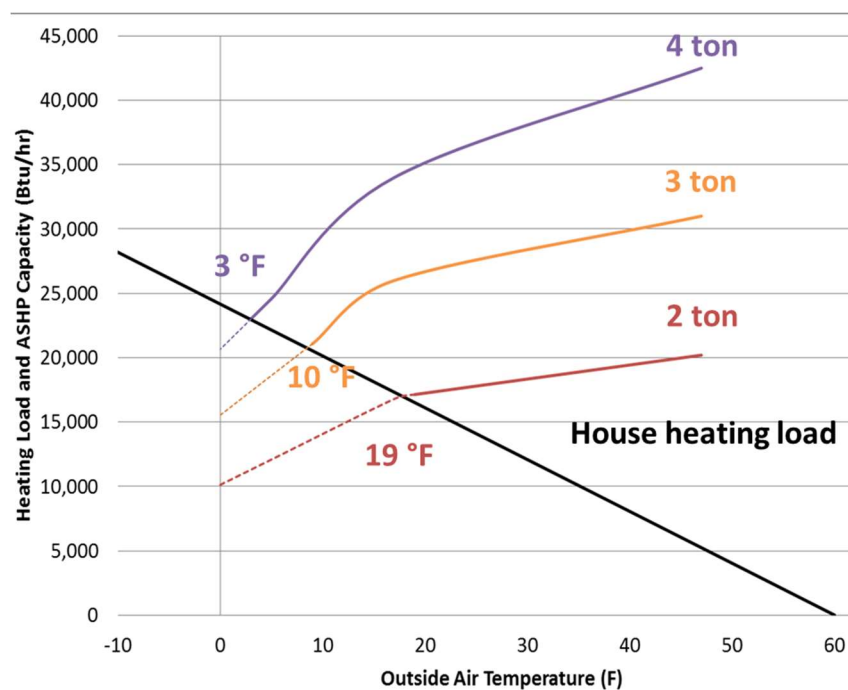


Figure 2. An example sizing chart for a variable speed heat pump installation

Backup Heat and Switchover Temperatures

HPs that are matched with furnaces for backup heating are typically controlled via a switchover point. This is an outdoor air temperature selected and programmed during the installation, at which point the system will switch from HP operation to furnace operation. The switchover point can be selected based on emissions or costs, where the cost or emissions per delivered energy are calculated for each heating component (HP and furnace). The increased efficiency of HPs at warmer air temperatures allows them to run at lower costs and emissions than furnaces. As outdoor temperatures get colder, HP efficiency decreases, and the system becomes more expensive and has higher emissions. Figure 3 shows the cost comparison at some common electricity and natural gas rates.

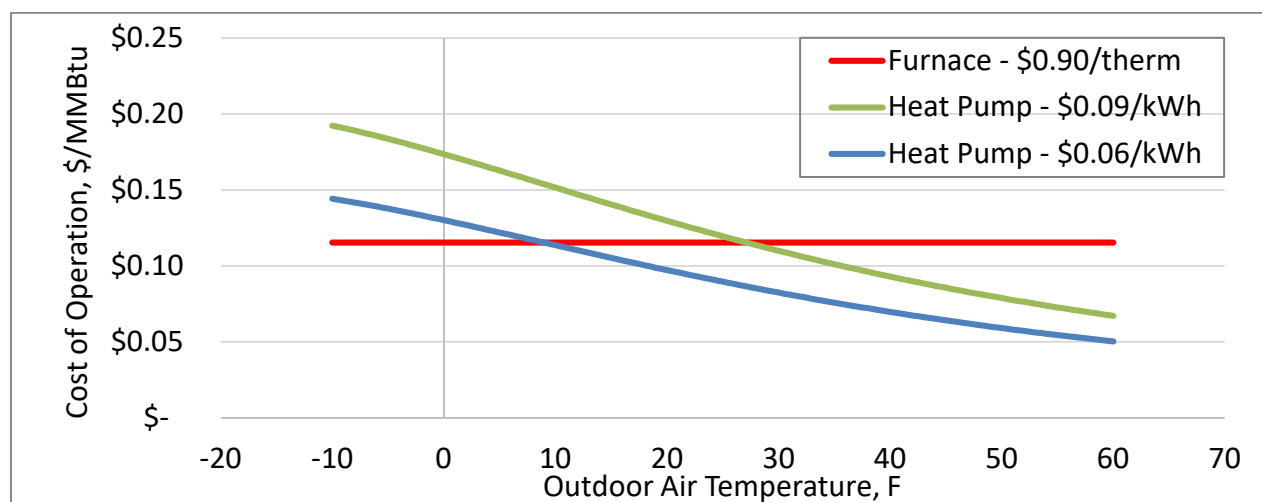


Figure 3. Operating cost by outdoor air temperature for VSHP and gas furnace systems

The second type of switchover point is capacity based. In this scenario, the HP is preferred whenever the system has enough capacity to meet the load of the home. This type of control is preferable in applications where the emissions benefits of electrification are particularly high, and the homeowner is motivated to prioritize electrifying heating loads. This type of control may lead to cases where the VSHP is more expensive to operate than the system it is replacing, especially if electric rates are high. Additionally, all-electric heat pump systems can utilize the HP and supplemental or back-up heat simultaneously.

Ductwork Considerations

In general, HP systems deliver heating capacities at lower supply air temperatures and lower air flow than gas furnace alternatives. In well designed and maintained ductwork systems the combination of lower air temperature and lower flow rates balance to meet occupants' comfort expectations. Adding an HP system to a home with existing ductwork design issues could lead to comfort complaints (Matt Christie 2022). Typically, forced air furnaces are significantly oversized and heating capacity is often delivered at temperatures, rates, and airflows that exceed the space's actual needs. Those oversizing characteristics may overcome some duct leakage or duct restriction issues within a system. Prior to ASHP installations, a ductwork assessment is recommended, including total external static pressure measurements, ductwork inspection, and an assessment of airflow and temperature per zone.

Single Speed or Entry Level Heat Pumps

Preferred applications

Single speed HPs were not designed to meet the increased heating loads of homes at colder temperatures (below approximately 30°F). These systems should only be installed in applications where a supplemental heating system is designed to meet the heating load at temperatures below 30°F.

Installation

Due to the reliance on the existing heating system to meet the home's heating load at cold temperatures, it is important to assess the current heating system to ensure it is capable of meeting the load efficiently. If the system is inefficient, undersized, or near its end of life, replacement should be considered.

SSHPs should be sized for the cooling load of the home in most instances. An HP sized for cooling will have sufficient heating capacities in the shoulder season to meet the home's loads at those moderate temperatures (30°F–50°F). Additionally, without modulation, the SSHP is more susceptible to oversizing in cooling and losing humidity control in the occupied space. An economic switch point control is preferred for SSHP as AC replacement installations.

Variable Speed Heat Pumps

Preferred applications

These products are ideally suited for a retrofit application with a failed or older air conditioning system and an air handler or furnace with remaining useful life. Applications targeting heating electrification, reduced emissions, and/or cooling savings will see further benefit from VSHP as AC replacement.

Installation

VSHP as AC replacement systems also have unique considerations that differ from other HP applications, which include existing air-handler considerations and thermostat selection.

System design and the installation needs to take the existing equipment (air-handler, ductwork, and thermostat) into consideration. Existing AHU age, fan type, and fan performance should all be considered. An AHU near its end of life may not be worth keeping when an AC replacement system is being selected. If the AHU is very old, a full replacement of the furnace and air-handler should be considered, which includes VSHPs with a paired AHU allowing for full system communications and controls. Similarly, an AHU with an inefficient fan motor may add considerable power consumption to HP system. These fan motors (or their AHUs) should be considered for replacement as well. The air-handler and central circulation fan must also be capable of delivering the required airflow needed by the VSHP system. These requirements will differ between system manufacturers and control methodologies.

VSHP as AC replacement systems do not have full communications with all components of the system. Originally, VSHP systems required the installation of a new air-handling unit or furnace

with the HP components. In these scenarios, there is direct communication between the indoor unit and outdoor unit, allowing for optimization at more points of operation, such as delivered airflow rates. Depending on the type of VSHP as AC replacement system, the method for relaying the signals and controlling the modulation of the indoor and outdoor units can differ and are often impacted by the thermostat and its functions. It is important to understand the options a given thermostat has for airflow, outdoor temperature lockout, and use of backup heat.

All-Electric Heat Pumps

Preferred applications

All-electric HP installations should be seen as an extension of the VSHP as AC replacement category for homes seeking to fully electrify heating loads or that do not have access to natural gas. While all-electric HPs can be designed to meet the full heating load on most homes, it is best suited for homes with lower heating loads that have been properly weatherized with insulation and air-sealing upgrades. Minimizing the heating loads of homes will minimize the use of inefficient (and costly) electric heat and allow for smaller HP systems.

Installation

In these applications, the existing furnace burner can be disconnected and replaced with an air-handler and an electric resistance (ER) booster heater.

ER auxiliary booster heaters allow for different controls in all-electric HP systems compared to dual fuel applications. In dual fuel applications, the furnace burner is upstream of the HP indoor coil. When supplemental heat is required, the furnace does the initial heating and prohibits the HP's operation. In an all-electric application, the supplemental heat is downstream of the HP coil, allowing the HP to do the initial heating and the supplemental heat to boost its capacity when it is needed to maintain indoor temperature setpoints. Therefore, all-electric systems do not utilize a switchover temperature, instead the HP runs at all outdoor conditions with the booster heater providing supplemental heat when needed. The controls for the booster heater can have a significant impact on this system's energy performance. In an ideal condition, the booster will modulate to meet between HP capacity and the home's heating load. This avoids excess use of electric heat, which reduces energy use and costs.

ENERGY PERFORMANCE BY APPLICATION TYPE

A key benefit of ASHP technology, and variable speed systems particularly, is the flexibility of the technology. It can be applied to a wide range of applications and operated over a large range of set points. This flexibility makes it difficult to estimate the system performance of many installations across an entire market.

ASHPs can be installed and operated to optimize their performance based on a utility program's and/or occupant's desires. The two ends of the spectrum are 1) an environmental or electrification motivated operator compared to 2) a cost or economic operator. The former is likely to maximize the HP runtime to meet the majority of the heating load, while the latter will select the heating fuel type based on the lower operating cost.

Table 2 outlines an example of the total modeled energy costs and emissions for the three product categories that have been discussed, as well as a baseline AC scenario. This illustrates the cost and emissions impacts of different system choices as well as different switchover temperatures.

Table 2. Energy Costs and Emissions²

HP or AC System	Total Heating and AC Energy Costs	Cost Savings Over Baseline	Carbon emissions (tons)	Carbon savings over baseline (tons)
Baseline - ~13 SEER AC (80% furnace for all)	\$1,020		6.6	
VSHP 35°F switchover	\$1,020	\$ -	5.9	0.7
VSHP 25°F switchover	\$1,070	\$ (50)	5.3	1.3
VSHP 5°F switchover	\$1,190	\$ (170)	4.7	1.9
Entry level HP 45°F switchover	\$1,010	\$ 10	6.3	0.3
Entry level HP 35°F switchover	\$1,030	\$ (10)	5.9	0.7
All-electric VSHP w/ E backup	\$1,320	\$ (300)	4.6	2.0

MARKET RESEARCH OVERVIEW

CEE received funding from the Minnesota Department of Commerce, Division of Energy Resources through their Conservation Applied Research and Development fund (CARD) to study the AC replacement opportunity. This research project began in 2021 and is underway with an estimated completion date of August 2022. The project includes market research to understand opportunities and barriers from manufacturer, distributor, contractor, and customer perspectives. This section will describe key takeaways and highlights from this market research.

Manufacturer Findings Summary

CEE performed five in-depth interviews with manufacturers to understand product offerings, manufacturer perceptions on the product category, barriers, and opportunities. Based on these interviews, the following are key takeaways and trends.

- All manufacturers acknowledged the market is transitioning away from fossil fuels.
- While they had differing opinions on the pace of this transition, they generally agreed that HP AC replacement products will be a helpful transition technology on the way to all-electric systems.

² This table assumes Minneapolis, MN weather as well as \$0.11/kWh and \$0.80/therm energy costs. EPA emissions values were used for natural gas as well as EPA's average emissions for electricity for the state of Minnesota. These values are 765 lbs. per MWh and 116.65 lbs. per mmBtu. This table illustrates first-year costs and emissions.

- Four of the five manufacturers interviewed either already have an HP AC replacement product in the market or were planning to launch one soon (within the next year), indicating they see opportunities for the product to meet existing market needs.

Distributor Findings

CEE performed three distributor interviews to understand perceptions, barriers, and opportunities. Early results from distributor interviews reveal:

- Vast majority of current sales are in the mini-split category.
- Demand for centrally ducted HPs replacing AC comes from the utility and efficiency industry but not from customers.
- Contractors are receptive but not yet actively pushing.
- ~10% of customers always pick the highest end or most expensive and benefit-rich option presented; this would apply if HPs were offered over AC.

Contractor Findings

Contractor interviews were completed with 30 companies to understand perceptions, barriers, and opportunities from installation contractors. Key takeaways include:

- Customer demand for ASHPs as an AC replacement is generally low. Education is needed to make the sale.
- There is a strong sense that ASHP business will increase in the future.
- Rebates that make ASHP's cost-competitive with traditional ACs are a key driver of installs.
- Many contractors consider the heating economics and viability of ASHPs when weighing them as AC replacements.

Customer Findings

The project's customer survey portion was collaboratively designed between CEE and Leede Research. Leede Research performed the survey work and developed the analysis. Surveys were intended to uncover drivers for replacing AC, establishing what homeowners value during replacement, replacement trends such as when homeowners consider replacement, and current understanding or awareness of the technology. The survey completed 438 interviews with qualified homeowners in Minnesota, generating a maximum error of +4.6% at 95% confidence. A mix of homes were reached as part of the overall study data. Time lived in the home was tracked to determine impact on HVAC equipment and related decisions. Size of home was also tracked to determine different needs. Homes were required to have central AC through forced air ducts to be included because of the nature of the ASHP technology being studied. The existing systems showed a mean age of just over 11 years.

Key findings and conclusions from customer research are as follows.

- The vast majority of homeowners are happy with their existing systems, but showed a strong interest in:
 - Upgrading to new and better technology
 - Lowering operational costs

- Reducing environmental impact
- There is a small segment of customers (early adopters) interested in making choices based on environmental drivers.
- Most customers replace on failure; they want to shop carefully but may not have time to evaluate multiple options.
- 63% of customers who recently purchased central AC replaced the furnace and AC at the same time while 37% of customers replaced the AC unit only. When asked if customers would have preferred to replace their AC only, the vast majority responded that they preferred to replace both systems at the same time. This indicates that most customers prefer to replace AC and furnace together, but about a third of customers prefer the lower cost option of replacing their AC only.
- Cooling performance, upfront cost, and operating cost are the most important purchasing decision factors.
- On average, recent purchasers of ACs paid roughly \$4,500 for their system and customers intending to purchase AC in the next three years expect to pay on average roughly \$3,400. This presents a barrier because the initial cost for HPs will be significantly higher than customer expectation.
- However, 55% of customers were willing to pay more for a system that offered lower operating costs on an ongoing basis. The mean incremental cost customers were willing to pay was 14.5% more and the mean payback expectation was 6 years.
- Rebates and financing are important tools for customers; contractors should be prepared to offer these financial tools.
- Awareness of this technology is low to moderate; utilities and customer word-of-mouth can play a powerful role in increasing awareness.
- Customers in colder climates need education to build confidence that the technology will produce heat and operate well in a colder climate. They also need applications that will make economic sense when considering operational costs.

CONCLUSION

ASHPs offer significant benefits over traditional AC systems. ASHP systems are available with a range of cooling features and efficiencies that match or exceed standard ACs. Additionally, ASHPs offer flexibility and heating benefits such as higher efficiency ratings, reduced operational cost, and environmental savings.

Installing ASHPs at the time of AC replacement is a valuable opportunity to utilize the benefits of the technology in a way that meets the needs of the market. Customers are interested in reducing their environmental impact, installing new technology with improved performance, but are still sensitive to operating costs, and installations at the time of failure.

The flexibility of HP systems offers a good opportunity to meet these customer needs across a range of desires, application types, and cost sensitivities. Field research and modeling on equipment performance and system design has shown that these systems can be operated in a

cost-effective manner while delivering electrification and environmental benefits that will only increase over the lifetime of these systems as the electrical grid gets cleaner. Regardless of installation type, HPs offer enough customer and environmental benefits over ACs that rebates and programs should be designed to prioritize HPs over ACs as we move forward.

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