Field Assessment of Cold Climate Air Source Heat Pumps

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ABSTRACT

Over 40% of Midwest homes use delivered fossil fuels or electricity as their primary space heating fuel (EPA, 2009). During periods of high demand, fuel cost and availability can force homeowners to either use other heating sources or drastically reduce the temperature in their home. Cold-climate air source heat pumps (ccASHPs) are a high-efficiency technology that is an ideal candidate for homes relying on delivered fuels or electricity for space heating. Recent changes to the design allow heat to be transferred into homes from exterior temperatures below 0°F while maintaining acceptable capacity and efficiency. These designs have improved the capacity and effectiveness of ASHPs for a greater portion of the cold-climate heating season, thus reducing electricity use and limiting the need for backup heating.

Three ccASHPs were installed in Minnesota homes, along with detailed monitoring equipment, to collect data for the 2015-2016 heating season. Data analysis was performed to determine energy savings, heat pump heating capacity, installed efficiency, and the ability to reduce reliance on the traditional or backup heating system. Space heating energy savings of 39% to 65% and cost savings of 14%-29% were found. The field performance data was also used as a base for analysis of ccASHP policy implications regarding delivered fuels in Minnesota. Analysis shows that it is feasible for a utility energy efficiency program to receive credit for the energy savings achieved from ccASHPs through the reduction in delivered fuels.

Introduction

This paper reports on Center for Energy and Environment's (CEE) on going cold climate air source heat pump field assessment that is supported by a grant from the Minnesota Department of Commerce, Division of Energy Resources through the Conservation Applied Research and Development (CARD) program.[1] Findings presented are from three sites monitored during the 2015-2016 heating season; three additional sites will also be monitored during the 2016-2017 heating season. Air source heat pumps (ASHPs) use a compression cycle refrigeration system to transfer heat from one location to another, allowing the system to heat a home during the winter and cool it during the summer. ASHP systems consist of an outdoor unit that contains a fan, outdoor coil, compressor, and expansion value, and an indoor unit that contains an indoor coil and a fan. In heating mode the outdoor unit uses a fan to draw outside air across a heat exchanger and absorb heat from the outdoor air. The compressor warms the refrigerant further by increasing the pressure of the refrigerant in the system. The warm refrigerant runs through the heat exchanger in the indoor unit, where cooler air from the house absorbs the heat from the refrigerant before the indoor fan delivers the heated air throughout the house. In cooling mode, the system runs in the opposite direction removing heat from the indoor air and transferring it outside, like a traditional air conditioning system. ASHPs transfer heat

[1] This project is also supported by the Electric Power Research Institute and Great River Energy.

from one location to another and do not generate heat directly. This heat transfer process makes ASHPs a highly efficient form of space heating and cooling, outputting more heat energy than the electrical energy required to run the system. ASHP systems are widely used for space heating in climates with mild heating seasons, and with recent upgrades, can now meet the majority of a home's heat load in colder climates. These systems have the greatest potential for adoption in cold-climate regions where natural gas is not available for space heating. ASHPs can offset the use of more expensive delivered fuels, and for homes with electric resistance heat, can result in a significant reduction in electrical use. Additionally, as more federal and state policies require electric generation to become less carbon intensive, ASHPs will increasingly benefit carbon emissions reduction.

Background

ASHP technology has improved by the addition of an inverter driven compressor and updates to the refrigerant, making the systems better suited for cold-climate heating. The inverter driven compressor allows the compressor speed to modulate and increase capacity during periods of colder outdoor air temperatures. Manufacturers claim that these new, cold-climate systems are able to transfer heat into homes at outdoor air temperatures at and below 0°F. The Northeast Energy Efficiency Partnerships (NEEP) has created a set of specifications to identify cold-climate ASHPs (ccASHPs). These specifications include: variable capacity compressor, coefficient of performance (COP) at 5°F ≥ 1.75 at maximum capacity, a heat system performance factor (HSPF) ≥ 10 for ducted systems and ductless single-zone systems, and a HSPF≥ 9 for ductless multi-zone systems (NEEP, 2014). Figure 1 shows the heating capacity and COP values provided by Trane for the XV20i model of ccASHP which has a reported HSPF = 10 (NEEP, 2014). This system can deliver 63% of the design condition capacity at 5°F. A traditional ASHP, without a variable capacity compressor, cannot reach this COP and heating capacity at similar outdoor air temperatures.

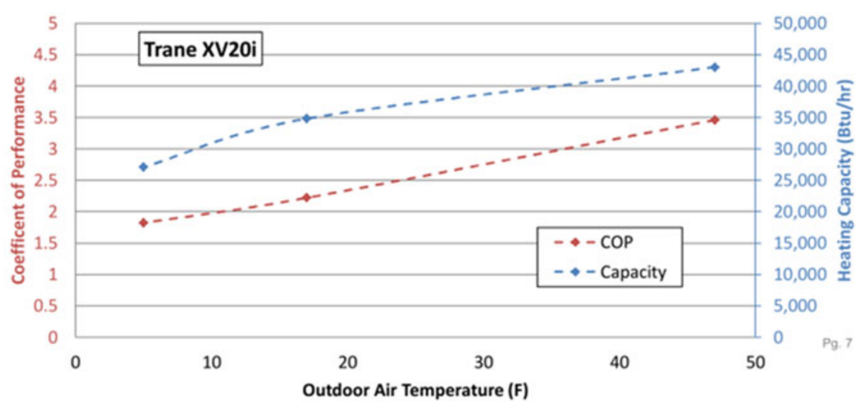

Figure 1. Trane XV20i COP and Heat Capacity. Created from data provided by the manufacturer.

In Minnesota, 16% of homes are heated with either propane or heating oil (US Census 2000). Price increases and shortages in delivered fuels create a desire to reduce reliance on delivered fuel for space heating. During the 2013-2014 heating season, propane prices spiked from $1.67 to $4.61 per gallon in Minnesota (EIA 2016) due to a shortage that was attributed to cold weather, a large damp corn crop that required more propane than in other years for drying, and fuel transportation constraints (Levenson-Faulk 2015). When prices increase and shortages occur, an alternative to delivered fuels are portable electric heaters. In extreme cases, a large increase in the number of homes using electric resistance space heaters can cause increases in electric use and peak demand. The high efficiency of ccASHPs can help reduce reliance on delivered fuels for space heating in cold winter states such as Minnesota. During periods of very cold temperatures when ccASHPS do not have adequate capacity to meet heating load, a furnace or electric resistant heat can be used as backup.

Carbon dioxide emissions attributed to ASHPs vary geographically based on a location's electric generation mix. As electric generation becomes less carbon intensive, the emissions associated with ASHP's will decrease, while emissions from propane and heating oil will not. A study prepared for the Propane Education and Research Council compared the performance of residential heating systems, including annual CO_2 emissions, and found that a traditional ASHP (HSPF 8.5) paired with a high-efficiency (95%) propane furnace produced fewer annual emissions than a propane furnace alone (Newport Partners LLC 2013). Annual emissions would be even less with a more efficient ccASHP.

Increasing the use of ccASHPs in Minnesota would contribute to broad state policies of reducing fossil fuel use and greenhouse gas emissions, while providing economic benefits to the state. Data from the U.S. EIA show that Minnesota imports 100% of the heating oil and propane consumed in the state, and in recent years Minnesota households have spent over $600 million on heating oil and propane. ASHPs could reduce this dollar drain, keeping more money circulating in the Minnesota economy.

Minnesota's Conservation Improvement Program (CIP) benefits Minnesotans by working to decrease emissions and reduce energy costs. Minnesota CIP was incorporated into the Next Generation Energy Act of 2007, which established electricity and natural gas savings goals for utilities across the state. ASHPs also provide electricity savings from air conditioning in instances when they are replacing less efficient systems. Several utilities across the state offer rebates through CIP for ASHPs based entirely on their seasonal energy efficiency ratio (SEER) rating. However, the rebates do not reflect the full benefit of the heating capabilities of the new ccASHPs. Much of the savings from ccASHPs comes from replacing other space heating fuels that are less efficient and goes unrecognized under state policy that does not consider fuel switching.

Under current Minnesota regulations, with the exception of certain low-income customers, there is no way to credit savings in deliverable fuels towards utility CIP goals. Furthermore, historically, CIP programs have not encouraged customers to switch fuel sources in order to achieve increased efficiency. While CIP provides an excellent policy structure for achieving electric and natural gas savings, Minnesota has no comparable structure or funding in place for achieving heating oil and propane savings.

Methodology

Field Characterization

ASHP systems were installed in three Minnesota homes. The ASHPs selected were designed for cold climate operation with a traditional heating system as backup (for example, a propane furnace). The system was installed so that the ccASHP could be deactivated and bypassed allowing the system to be run as either (1) a ccASHP with the existing heating system as backup or (2) an existing traditional system (just the baseline system, without the ASHP). These two modes of operation were alternated through a full heating season to allow for a direct comparison of the two systems over the full range of outdoor conditions. This alternating mode method of test has been used successfully by the Center for Energy and Environment (CEE) and many others for residential HVAC field characterization studies.

Each home was fully instrumented with a residential HVAC data acquisition system that was developed by CEE and successfully used on other field test projects. The system utilizes a Campbell Scientific acquisition system customized to collect HVAC data. The data collection interval was adjusted for high resolution (one second) data when systems are active and lower resolution data when systems are inactive. This logging interval strategy allows for efficient use of short term storage on the data logger with daily transmission by cellular modem or internet connection each night. Table 1 details the data collection system used at each site.

Table 1. ASHP data collection system

Measurement	**Location**	**Monitoring Equipment**
Data logger		
Power consumption and runtime	ASHP outdoor unit ASHP indoor unit ASHP defrost	Watt Transducer Watt Transducer On/Off via a current-sensing rely
Energy consumption and runtime	Backup/auxiliary heating components fuel and electric consumption	Diaphragm gas meter/Watt Transducer
Temperature	Ambient mechanical room Conditioned space Outdoor air Supply duct air Return duct air	Thermocouple Thermocouple Thermocouple/NOAA data Thermocouple Array Thermocouple Array
Airflow	System duct work	Fan Amps calibrated to short term airflow measurements

After the data was transmitted to CEE servers it was processed and validated. This involved three steps: 1) integration with external weather data, 2) filtering for repeated or omitted data, and 3) range checking. In addition to the outdoor air temperature data collected at the field site, CEE integrated weather station data from the nearest available source in the analysis. The data timestamps were checked to ensure that data had not been repeated and/or omitted. Automated range checking was performed, and a warning was output when values outside of a specified range were detected. The timestamp and range checking were used to indicate data acquisition system errors. Although errors were rare, they were important to identify and correct quickly to avoid data loss.

With the exception of airflow, all measurements were made directly by the data collection system. The system airflow was determined through measurements of the supply fan current draw. Short term airflow measurements were made using a TrueFlow for each mode of system operation. The continuously monitored current measurements were then correlated to short-term air flow measurements, which allowed the fan measurements to be used as a stand in for air flow throughout the monitoring period.

The short term measurements of the airflow were made at the start and conclusion of the heating season. In additional to creating the fan power and airflow correlation, short term measurements were used to verify measurement accuracy. A series of temperature traverses were used to ensure an accurate, mixed, supply and return temperature was measured in all modes of operation and the steady-state energy output and energy input measurements for both then ASHP and the propane furnace were compared to expected values for each system.

The data collected in each home was analyzed in two ways. The first method, Analysis A, used the field monitoring data to determine the total annual energy and cost savings of the ccASHP and the reduction of delivered fuel use. A statistical analysis of both the ccASHP operating *with* the traditional backup and the traditional system *without* ccASHP was performed in order to determine the annual energy performance of each system. For each site a model was created for the space conditioning energy use with outside temperature from a regression or binned analysis of the heating system daily use versus outside temperature. For the *traditional system* the linear heating use and outside air temperature model was used with the local typical meteorological year (TMY) data set to compute the annual energy use. For the *ASHP with backup* the process required a binned temperature analysis to capture the non-linear effects as the system efficiency changed with decreasing outdoor air temperature as the backup heating system operated to meet the homes heating load. Figure 2 shows the energy use versus outdoor air temperature correlations for one of the sites in this study. The figure shows the energy consumption for the system with only the baseline furnace system operating (black), as well as the energy used by the ccASHP (orange) and the furnace as a backup (purple).

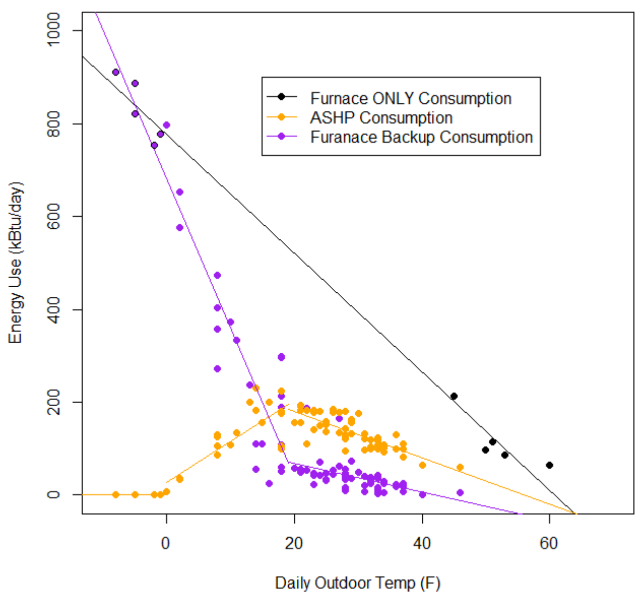

Figure 2. Example of the energy use versus outdoor air temperature method from ASHP site 2

The second analysis, Analysis B, used field data to compute the daily efficiency or coefficient of performance (COP) of the space conditioning systems. Measurements of supply and return air temperatures and the delivered air flow rate were used to compute the energy output. Fuel and electricity consumption data was used to calculate the energy input to the system. The efficiency of the backup system and COP of the ccASHP was computed from the ratio of output to input energy. The installed efficiency of the *ccASHP w/ back-up* were calculated from the site energy consumption and energy delivered from each system. These efficacies can be compared both to each other and to the rated efficiencies of other system types.

The level of monitored detail necessary for this analysis allowed for additional assessment of the systems. The COP and capacity of the ccASHP system was calculated from measured field data over the range of outdoor temperatures typically experienced in the field. The measured COP and capacity were compared to the manufacturer's specifications, the federal rating test point, and any additional manufacturer data. The analysis also determined how well the controls utilize the backup system to minimize the fuel costs while meeting the indoor set temperatures. ccASHP systems that provide space heating at low ambient temperatures periodically required a defrost cycle. Frost can form on the outdoor coil surface at low temperatures, and the amount of frost may be large enough to restrict air passage through the coil and limit heat transfer. Defrost cycles prevent this frost accumulation, but can reduce ccASHP capacity or prevent heat transfer to the space, requiring increased backup heating. Collected data was used to measure the impact of defrost cycles.

Results

System Design

For this study, ccASHPs were sized for the home's heating load, rather than the cooling load, which typically led to an increase in capacity ('tonnage') of the system by one size. This meant that where a home sized for cooling would install a 2 Ton heat pump, the same home sized for ccASHP heating would install a 3 Ton system. In cold climates like Minnesota, sizing the heat pump for a home's heating load is important in order to take full advantage of the system's variable capacity minimizing the use of backup heating. Figure 4 shows the equipment output for a 2Ton, 3 Ton, and 4 Ton ccASHP, all of which have a furnace for backup, charted against the outdoor air temperature. The outdoor air temperature at which the system would switch to backup is at 3°F for the 4 Ton, 14°F for the 3 Ton and 27°F for the 2 Ton unit. If the 2 Ton heat pump were to have been chosen for this home, the furnace would have to take over heating the home at 27°F, significantly limiting the fraction of the heating load met by the ccASHP. The 3 Ton and 4 Ton switchover points are much lower, allowing the system to take advantage of the variable capacity to provide heat to the home at low temperatures. Sizing the system for the heating load does mean that it will be oversized for the cooling load. However, this is not a concern because the variable capacity of the system will allow the heat pump to match the cooling load required.

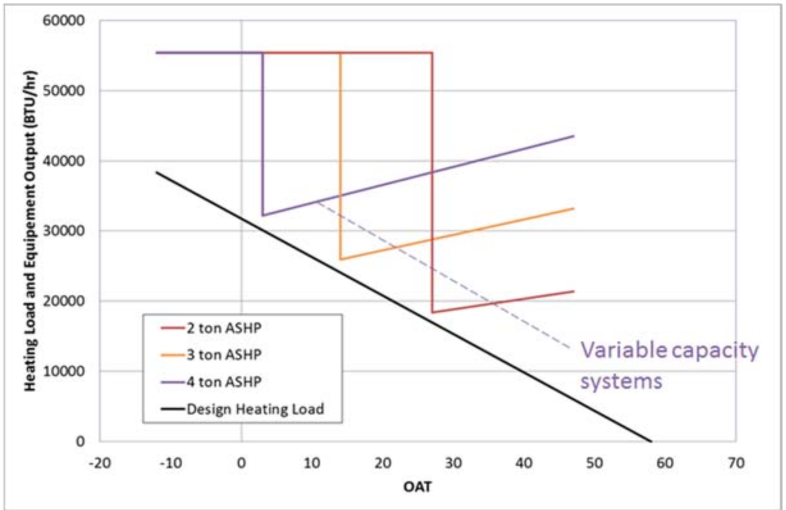

Figure 3. ccASHP sizing implications

Controls allow the installer to program a switchover set point that locks out the ccASHP. For this study, the set point was selected to be 10ºF. Based on how the systems were sized for each home, 10ºF is the outdoor air temperature at which the heat pump cannot meet the full heating load of the home. In Minnesota, it is common practice for installers to set this point around 25 to 35ºF for ASHPs not designed for cold-climate heating. This is done to prevent the ASHP from operating at cold outdoor temperatures where the capacity, efficiency, and delivered air temperatures are unfavorable. In addition to being the coldest point where the ASHP could meet the full load, 10ºF set point was a conservative midpoint between the coldest theoretical operating temperature of the system and a point the installers' were comfortable with. Setting the switchover point to a higher value would have locked out the heat pump at a point where it still had the capability to meet the heating load of the house, preventing the homeowner from taking full advantage of the system benefits.

Integrating ccASHPs with the Backup Furnace

The original intent of this project was to integrate ccASHPs with the existing heat source as backup. However, there are issues that make integrating a ducted ccASHP with the existing furnace complicated. The two primary issues are 1) the furnace and heat pump require communicating capabilities and 2) a multi-stage fan is necessary to achieve the full benefit of the ccASHP. To deal with these issues, manufacturers and installers specify that the furnace and ccASHP are of the same brand. This ensures that the controls for the ccASHP and the furnace can communicate. Integrated controls are required for the switchover set point and the furnace fan speed. With the variable capacity capabilities of ccASHPs, manufacturers require that the fan in the air handler unit also be variable speed for ideal performance of the system. Unfortunately, most 80% AFUE and older condensing furnaces have single stage fans. While it is expected that a wider range of options will become available, at the present time only recently installed and higher end furnaces would have the controls and fan characteristics desired for integration.

Solutions to the integration issues include 1) install a new communicating condensing furnace; 2) install a new 80% AFUE communicating furnace with a multi-stage fan; 3) retrofit the existing fan and furnace controls; or 4) install a plenum electric resistance heater. Option 3 was eliminated as it is complicated and not practical for integration into an energy efficiency program. Option 4 was also eliminated since eliminating the need for a furnace would require a plenum heater that could meet the full heating load of the home. In large homes this would require a very large plenum heater and an air handler to be installed to eliminate the furnace. Options 1 and 2 were both selected as viable solutions that could be easily implemented by installers and used in a utility rebate program. While HVAC installers preferred option 1, it is much more expensive. In the Minneapolis/St, Paul metro area, a homeowner would pay about $4,250 for a condensing furnace and only $1,875 for the same size non-condensing furnace. With a properly sized ccASHP, it is expected that the furnace would have to meet less than 30% of the heating load, and this percentage can be reduced further for homes with lower heating loads. Given that the furnace would only be running for a small portion of the heating season, it is likely to be more cost effective to install an 80% AFUE furnace. An 80% AFUE unit was installed at site 3 where the proper vent was available for an 80% AFUE.

System Performance

The system performance of each ccASHP was analyzed using the methodology previously described. The following section summarizes the energy savings, reduction of reliance on delivered fuels, system COPs, and ability of the ccASHP to meet the homes' load. The annual energy consumption for both the baseline (furnace only) and the ccASHP with backup systems was determined with a binned analysis of the heating system energy consumption versus outdoor air temperature. Table 2 shows the comparison between the ccASHP and the baseline system in each home. There was a 52% to 89% reduction in the propane required to heat each home when the ccASHP was used as the primary heating source. There was an average cost savings of 23% with the largest reduction coming from Site 2 with over $600 saved per year.

Table 2. Annual energy consumption for a propane furnace only compared to a ccASHP with furnace backup

	Baseline System		ccASHP w/ Furnace Back-up				
	Propane Use (Gal/yr)	$/year	Propane Use (Gal/yr)	$/year	Electric Use (kWhr/yr)	$/year	Total Cost
Site 1	1022	$1,320	372	$480	5920	$711	$1,191
Site 2	928	$1,199	102	$131	3701	$445	$576
Site 3	1123	$1,450	539	$696	5401	$649	$1,345

The analysis identified an apparent difference in heating output between the baseline systems and the ccASHPs in each home. The heating load of a home, the rate at which the heating system must deliver heat to keep the home at the desired temperature, should be the same with any type of heating system. Figure 4 shows the heating load (calculated from the measured air flow and delta T at Site 1 at times when the ccASHP and the baseline (furnace-only) systems were in operation. The figure shows that the ccASHP delivered more energy to the home at a specific outdoor air temperature than the furnace-only system. There are several reasons this may have occurred. One is that the occupant may have modified the set point in the home, possible turning the system on and off on shoulder days. The second explanation is a difference in system controls that resulted in one system delivering more energy per day at a specific temperature.

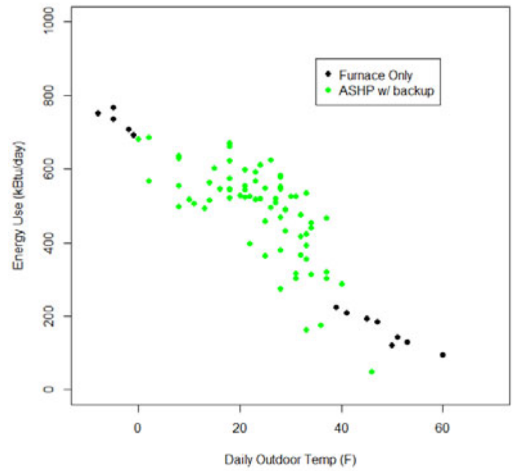

Figure 4. The heating load of the site 1 home for the ccASHP and baseline systems

Table 2 shows the measured energy use of each system calculated based on the delivered heat output per day for each system. The data was also analyzed assuming a single delivered heat output for each site. The energy consumption necessary for both the ccASHP and the backup only system to meet that daily output was calculated. This calculation eliminated the differences in delivered energy and compared the two systems under a condition where the same system output would be required to heat the home from both systems. Table 3 shows the annual energy consumption for the two systems in each home with these adjustments. Table 4 summarizes the savings from this analysis. In these three homes the propane consumption was reduced by 52%, 64%, and 89%, with a cost savings between $191 and $350 per year.

Table 3. Corrected energy consumption for a baseline and ccASHP system (including air handler)

	Baseline System		ccASHP w/ Furnace Back-up				
	Propane Use (Gal/yr)	$/year	Propane Use (Gal/yr)	$/year	Electric Use (kWhr/yr)	$/year	Total Cost
Site 1	1022	$1,320	372	$480	5406	$649	$1,129
Site 2	928	$1,199	102	$131	5978	$718	$849
Site 3	1123	$1,450	539	$696	4051	$487	$1,183

Table 4. Annual savings from the measured energy consumption of each ccASHP system over the baseline system in each home.

	Savings per Year				
	$/year	% Cost	Energy (KBtu)	Energy %	Propane
Site 1	$191	14%	41,130	44%	64%
Site 2	$350	29%	55,338	65%	89%
Site 3	$267	18%	39,606	39%	52%

On average the ccASHP systems saved 50% of the sites' heating energy consumption. These energy reductions were possible because of the significant increase in COP with the ccASHP systems. The baseline furnaces had annual efficiencies between 70% and 85%. Figure 6 shows the installed COPs for the ccASHPs at each site. These COPs were from each individual heating cycles and include no backup energy use. The weather normalized annual ccASHP-only COPs were 2.75, 2.78, and 2.51 for Sites 1 through 3 respectively. These system (site energy) efficiencies are significantly higher than the rated baseline efficiencies, 1.0 for electric resistance and 0.8 to 0.96 for propane furnaces.

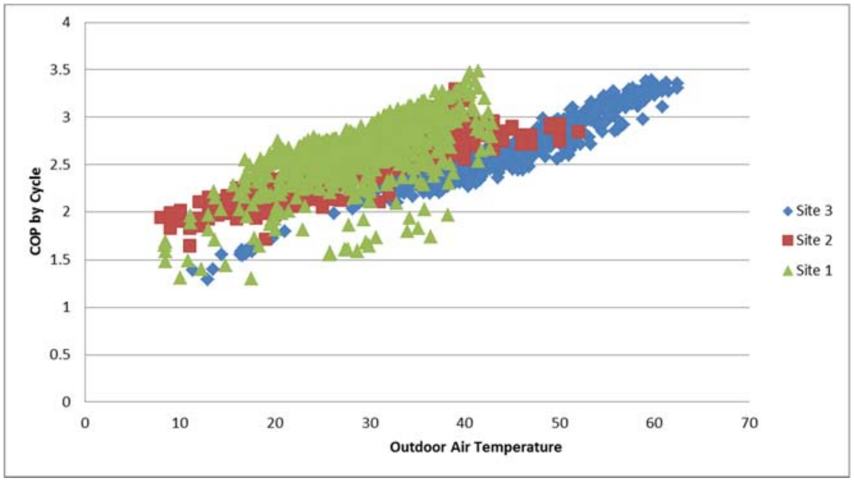

Figure 5. Coefficient of performance (COP) for ASHP heating events

The capacity of each ccASHP was compared to the heating load of the home. In general, the ccASHP ran at low capacity for long periods. Figure 6 shows the capacity of each ccASHP heating event compared to the daily heat load requirements of each site. Above 15ºF the ccASHPs typically operated at capacities greater that the heating load. Below 15ºF outdoor air temperatures the backup systems were used to meet more of the heating load. Figure 7 shows ccASHP runtime as a percentage of the total heating system run time. There were two reasons for the backup system to operate instead of the ccASHP. The first was if the temperature dropped below the change-over point of 10ºF. The second was if for some reason the controls of the heating system preferred the backup over the ccASHP due to limited capacity, defrost, or some other reason. The system controls at all three sites utilized the backup heating more than the higher capacities of the ccASHP. During the instrumentation verification the maximum capacities of the ccASHP were analyzed for each ccASHP. At each site the maximum capacity (determined by forcing high fire) was much greater that the highest capacities shown in typical operation (Figure 6). The 4 Ton systems at Sites 1 and 2 fired at 55,000/hr Btu and 49,000 Btu/hr. The 3 Ton system at Site 3 delivered 38,000 Btu/hr during testing. Improved controls to prioritize ccASHP high capacity operation over backup heating would further increase the savings and reduction of delivered fuels. Additionally, lowering the switchover temperature for locking out the ccASHP could increase ccASHP usage.

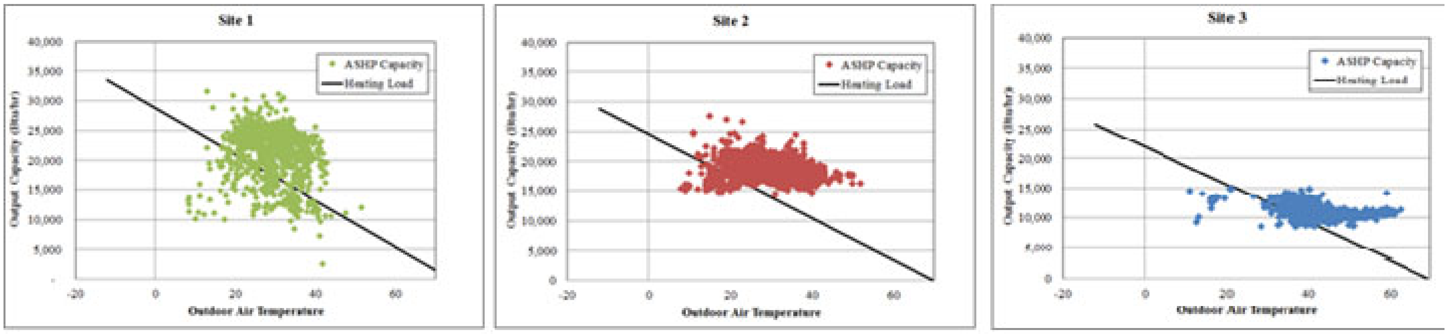

Figure 6. Heating capacity for each ASHP event compared the daily heating load of the home

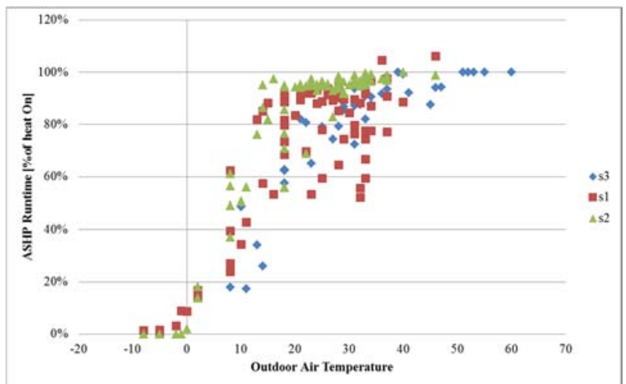

Figure 7. The fraction of heating system runtime met with the ASHP

Policy Analysis

Although there is currently no structure in place for achieving delivered fuel savings from ccASHPs for electric and natural gas utilities under CIP, Minnesota's policy commitment for energy efficiency goes well beyond CIP policy. There are several other Minnesota state policies that could help promote ccASHPs as a way for households using delivered fuels to save energy. For example, the Next Generation Energy Act of 2007 (Helty and Solon 2007), in addition to creating utility savings goals under CIP, set goals to reduce the use of fossil fuels per capita in Minnesota and outlined the state's interest in "increased efficiency in energy consumption" (Sec. 216c.05, subdiv. 1 and subdiv. 2) (Revisor of Statutes 2015). More recently, legislation enacted in 2015 commonly called the "Propane Bill" (HF 550) explicitly opened the door to displacing the use of fuels such as propane with a utility fuel source (natural gas). The "Propane Bill" defined an "energy improvement" as "the installation of infrastructure, machinery, and appliances that will allow natural gas to be used as a heating fuel on the premises of a building that was previously not connected to a source of natural gas" (Sec. 6, Subd. 5, (4)). This establishment of a public policy to allow expansion of a utility fuel source (natural gas) to displace propane and heating oil is analogous to allowing expansion of utility electric energy (via ccASHP equipment) to reduce reliance on the use of propane and heating oil. However, while there are several established state policies in Minnesota that support the concept of reducing the use of fossil fuels, such as propane and heating oil, there is still no established infrastructure or funding source for achieving savings. For ccASHPs, there is currently no way to recognize savings in the application of utility CIP savings goals.

There are areas in the CIP policy framework that could be amenable to recognizing delivered fuel savings from ccASHPs, even though there is not specific structure currently in place. The CIP statute defines “energy conservation” as “demand-side management of energy supplies resulting in a net reduction in energy use” [216B.241, subdivision 1(d)]. This does not restrict energy conservation to only electricity and natural gas. It goes on to define “energy conservation improvement” as “a project that results in energy efficiency ***or energy conservation***” [subdivision 1 (e), emphasis added]. Notably, the subsequent language in the statute setting minimum CIP spending requirements and energy savings goals all use the terminology “energy conservation improvement.” This could open the door to some flexibility beyond direct electricity and natural gas savings. Additional components of the statue that would be supportive of fossil fuel savings include the requirement for inclusion of participant and “societal” benefits in determining cost-effectiveness [subdiv. 1c(f)], as well as the requirement for the Department of Commerce Commissioner to report “estimated carbon dioxide reductions” achieved by CIP programs [Subdiv. 1c(g)]. The Minnesota Division of Energy Resources (DER) has already allowed for a limited inclusion of savings from deliverable fossil fuels for electric utilities under CIP, in the case of low-income customers. In that policy guidance, DER included two particular rationales for allowing CIP to incorporate deliverable fuel savings: 1) an equity concern for ratepayers paying for CIP programs with little opportunity to benefit, and 2) benefits to customers and society from the “reduced consumption of fossil fuels (DER 2012).” These rationales would also apply to a ccASHP program under CIP.

CIP does allow for substantial authority for the Department of Commerce Commissioner to modify a utility’s CIP energy savings goals. The pertinent language reads as follows: “In its energy conservation improvement plan filing, a utility or association may request the commissioner to adjust its annual energy-savings percentage goal based on its historical conservation investment experience, customer class makeup, load growth, a conservation potential study, *or other factors the commissioner determines warrants an adjustment*.” [subdiv. 1c(d) emphasis added]. The statute does specify that a CIP plan must include savings of at least 1% of a utility’s gross annual sales, and that these flexible elements would only apply above that 1% savings level. The statute goes on to list electric utility infrastructure projects and waste heat recovery as examples of types of additional projects that could be included under this flexibility. In summary, the existing CIP statute contains numerous elements that suggest it might be possible, and consistent with overall state policy objectives, to include delivered fuel savings from ccASHPs in a CIP program. Indeed, DER has already opened the door to that incorporation of delivered fuel savings in certain low-income programs.

As in many states, the potential for utilities promoting fuel-switching within an energy efficiency program has been a concern in Minnesota. The historical concerns focus on the possibility that a utility might use its energy efficiency programs as a means to lure customers away from a utility providing a different energy type, which could adversely affect the interests of the customers of the other utility (to whom regulators have some responsibility). These concerns are focused on the issue of fuel switching between electric and natural gas utilities (Docket No. G008/CIP-00-864.07), entities for which the state has specific regulatory responsibilities. An additional concern has been in regard to including cost-benefit analysis to ensure a net decrease in fuel consumption. Neither of these concerns should be an issue with a ccASHP program, as there is no second utility (i.e. on providing natural gas) involved and a new program would incorporate a net-Btu analysis. No specific rulings were found regarding programs that do not involve fuel switching between electric and natural gas utilities. Moreover, there is considerable support for the concept of using a multi-fuel net Btu savings basis for judging whether a project is desirable and cost-effective. Finally, as previously mentioned, Minnesota statute gives considerable discretion to the Department of Commerce Commissioner to approve alternative approaches in a utility CIP plan. The history of these issues in Minnesota suggests that it should be possible to avoid having the 'fuel switching' concern be a roadblock to the use of ccASHPs in the type of CIP program this study suggests.

Using the authority for flexibility provided in the CIP statute, a potential pilot program to promote ccASHPs may be feasible. The proposed programs should contain the following elements:

1. The program should target existing homes that use electricity, propane, or heating oil as their space heating fuel (not utility natural gas).
2. To help ensure that the program is genuinely focused on energy conservation, the program should include incentives and assistance to facilitate building shell conservation improvements (i.e., insulation and air sealing) in the homes that install ccASHPs.
3. Cost-effectiveness should be based on the total energy savings (electricity and heating fuel) of the package of measures installed in the home (ccASHPs plus any building shell conservation measures), net of any increase in electricity use from the ccASHP.
4. Any net electricity savings from the package should be directly credited toward the co-op's energy savings goal under CIP.

Conclusions

Cold climate air source heat pumps have been identified for their potential to provide significant energy and cost savings to homeowners without access to natural gas space heating. Additionally, ccASHP can reduce the reliance these homeowners have on delivered fuels, which can be costly in terms of price, emissions, and limited availability.

The project has concluded that the measured performance of ccASHP installed in real homes confirms the potential to provide significant energy savings (39% to 65% of space heating energy use) and cost savings (14% to 29% of space heating costs). Results also showed that ccASHP reduce reliance on delivered fuels in 52% to 89% of homes. The reduced usage of propane could lead to even greater savings at times when limited availability makes propane unavailable or cost prohibitive.

While the performance of ccASHP had a significant benefit to the homeowners, further improvement of the controls and integration with the backup systems could result in increased utilization of the ccASHP. These improvements would provide even greater savings and further reductions of delivered fuel consumption.

Fuel switching considerations could have an impact on policies around ccASHP programs and market transformation. However, several precedents in affordable housing and emission reductions make programs feasible.

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