Turning Up the Heat on Cold Climate Heat Pumps: *A Statewide Approach*

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ABSTRACT

A 2018 Minnesota statewide energy-efficiency potential study found that over the next decade, cold climate air-source heat pumps (ccASHPs) are the largest source of savings in the residential sector, partially offsetting the reduction in lighting savings – which reduces from 70% of the current residential sector savings, to under 5% in 2029 (Nelson, 2018). Additionally, field research funded or conducted by the authors' organization shows that current ccASHP technology performs well and delivers 55% savings in Minnesota's climate and can operate as low as -20°F (Schoenbauer, 2017). But (based on market research and the author's observations and experiences) the savings can be difficult to achieve due to lack of contractor understanding of application types, product selection, sizing and controls integration with existing heating systems.

The Center for Energy and Environment along with Minnesota Power, Great River Energy, Ottertail Power, Southern Minnesota Municipal Power Agency, and Missouri River Energy Services formed a statewide collaborative designed to pool resources and tackle market barriers, accelerate adoption of cold climate air source heat pumps, and influence installation quality to maximize homeowner savings, comfort, and utility benefit. This effort is launching in 2020 and is funded jointly by utilities and utility aggregators covering the entire state. By reaching across utility territories and representing mutual interests, we will efficiently and effectively remove barriers needed to grow the market. Our program includes market intervention activities including manufacturer, distributor, and installer engagement and support, technical support and strategic marketing assistance. This paper and presentation will cover the research journey that lead to this program and early stage activities and early results of our market intervention program.

Introduction

Recent technology advancements in air-source heat pump technology have significantly increased their efficiency, and importantly, their low outdoor air-temperature effectiveness. In the last five to seven years, it has become practical to use ccASHPs for space heating needs in areas with more extreme winter temperatures. Since 2013 commercially available ccASHP models have been available that can operate down to -10°F or lower (Schoenbauer, 2017). Minnesota is one of the coldest climates in the continental U.S., with a large market for both climate zone six and seven.

Over the past seven years, our organization has performed field research to validate performance of ccASHPs in Minnesota's climate zones. In 2017, we published a state-funded study that included field monitoring of six ccASHP systems. This study along with two other smaller studies, confirmed that customers with existing electric heat could save 55% on their

energy cost and propane customers could save 40% on their energy costs (Schoenbauer, 2017). CEE currently has two additional research projects underway to test ccASHP optimization strategies in single family and multifamily applications. These studies began in 2020 and results will be published in 2022.

With the research findings that validate high savings potential and significant volume of beneficial applications in the state of Minnesota, CEE has convened a group of key utility and aggregators that represent most of the geography in the state to pool resources and tackle market barriers. The end goal of our state's collaborative effort is to maximize the potential for ccASHP technology over the next decade; making ccASHPs the first choice for installers and customers who are replacing electric or propane heat sources. In this paper, we will describe the size of the market opportunity, the field research that illuminates technical guidance, and our program development which is designed to accelerate adoption of ccASHP technology. Our efforts are informed by the Northwest Energy Efficiency Alliance, Northeast Efficiency Partnership and other cold climate utility programs.

Quantifying and Targeting the Large Savings Opportunity

Air source heat pumps—especially cold-climate air source heat pumps (ccASHPs)—present a huge opportunity for Minnesota to save energy. 17% of Minnesota households heat with electricity and 16% heat with delivered fuels with the remainder being mostly heated with natural gas and biomass heat sources. (Nelson, 2018). When installed correctly, ccASHPs can save customers 55% on their energy bill if they currently have electric resistance heat and 40% if they heat with delivered fuels. Over a half-million homes in Minnesota use electric heat and are good candidates for the technology, and homes using delivered fuels spend $630 million annually. (Nelson, 2018)

Figures 2 and 3 show that lighting will decline from representing over 60% of energy-efficiency savings currently, to only 6% of the residential lighting sector in 2029; while air-source heat pumps in 2029 will represent the largest savings measure in the residential sector.

Figure 2: Space heating (from electric resistance-heated homes) is projected the largest-saving end-use for energy efficiency savings in the residential sector in Minnesota in 2029. SOURCE: Minnesota Statewide Energy Efficiency Potential Study, CEE (2018)

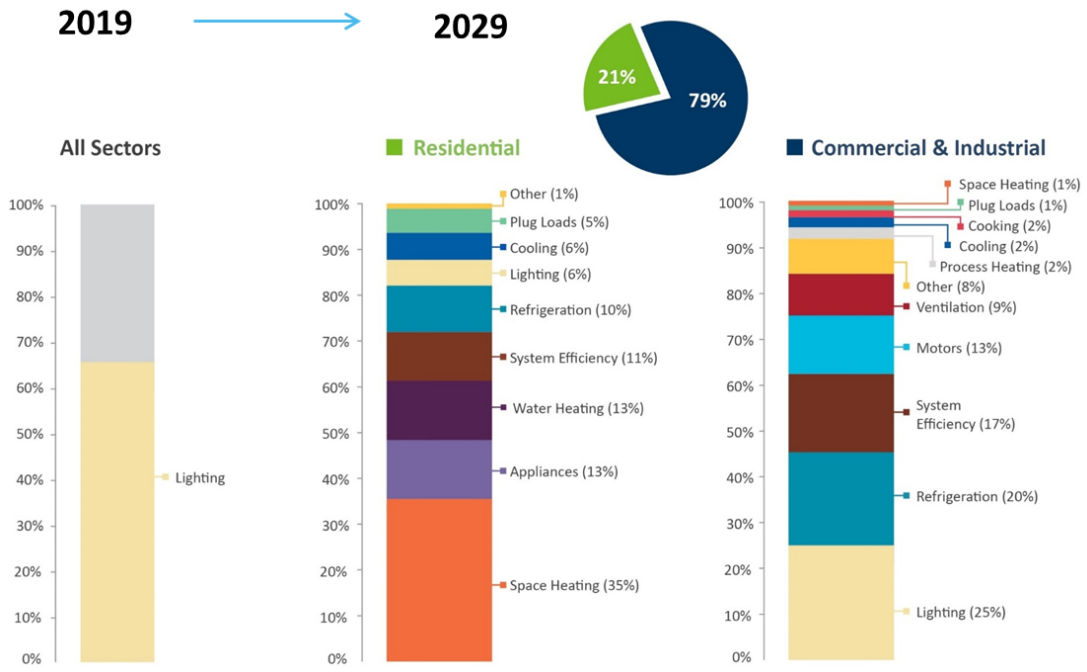
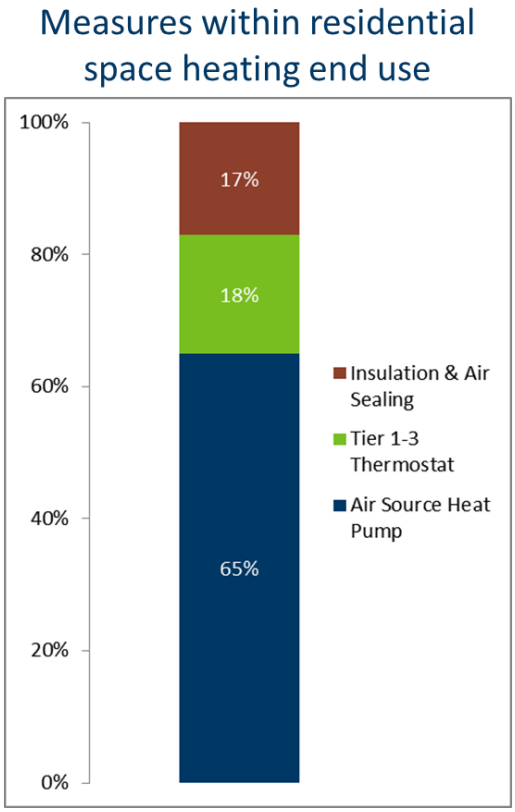


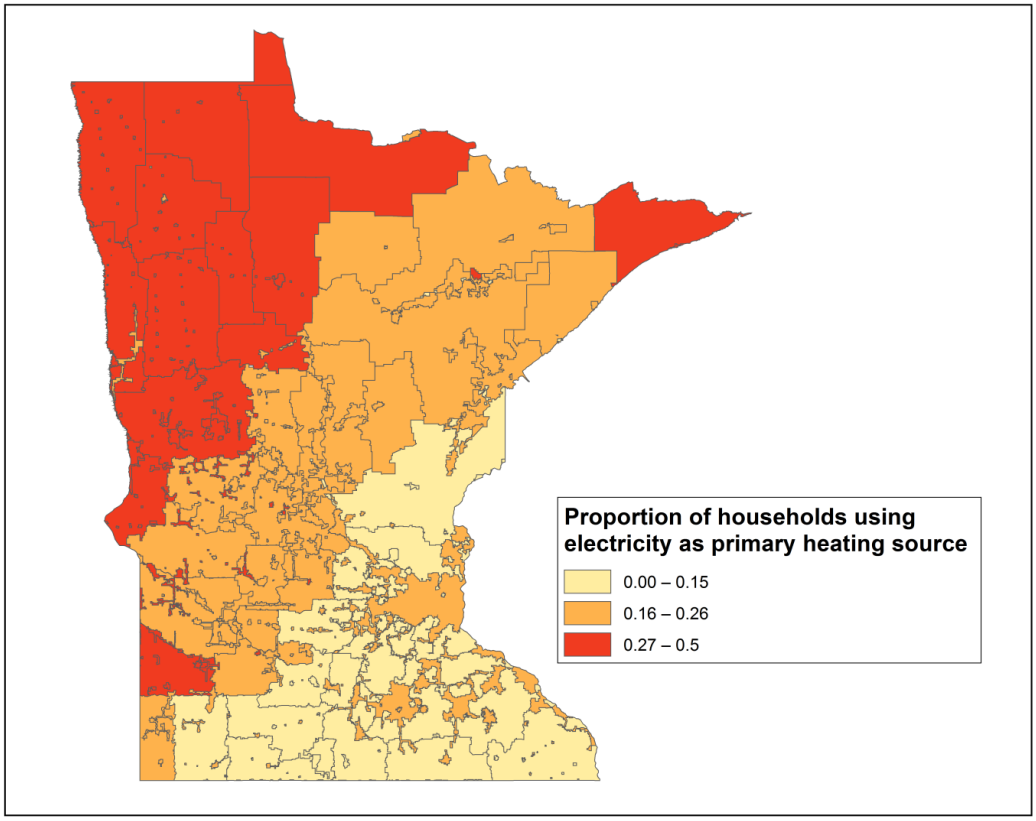
Figure 3: Air-source heat pumps are projected to be the largest source of savings within the space heating end-use in Minnesota, and the single-largest measure overall in the residential portfolio in 2029. SOURCE: ibid.



Note that the study that concluded these findings did not include any savings from fuel switching (as this is not allowed under current Minnesota rules). Future ability to fund fuel-switching programs[1] could increase this potential significantly, particularly from customers on propane that could continue to use propane as a backup fuel, cutting their overall energy costs in half. In Minnesota there are an estimated 278,000 single-family households using propone (Nelson, 2018). When replacing propane with ccASHPs, initial findings show that existing propane customers could cost effectively install ccASHPs while maintaining propane furnaces as back-up heat and save the equivalent of 2,600 GWh per year in heating fuel. This represents 3.6% of all projected retail electricity sales in 2020. This would result in reduced emissions and customer heating costs as well as reduced energy consumption (Nelson, 2018).

While there is large potential for air-source heat pumps in all parts of the state (although in metro areas this is concentrated in multifamily, and not single-family homes), the largest potential for ASHPs exists in the rural parts of the state (Figure 3).

Figure 4: Rural areas of Minnesota, particularly in the north and northwest, have the greatest proportion of electrically heated homes, and thus the largest potential for ASHP savings. SOURCE: Minnesota Statewide Energy Efficiency Potential Study CEE (2018)



[1] Note that pending legislation in Minnesota (S.F. 4409 Rarick/H.F. 4502 Stephenson) is proposing to specifically allow fuel-switching that is deemed to meet certain "beneficial" criteria, e.g., lower emissions, lower cost, and lower overall energy usage. Should this legislation pass, it could greatly expand the potential savings from air-source heat pumps.

Lessons from Field Research

In 2017, CEE completed a Conservation Applied Research and Development (CARD) project on Cold Climate Air-source Heat Pumps funded by Minnesota Department of Commerce, Division of Energy Resources (Schoenbauer, 2017).

In this project, ASHPs were installed in six occupied Minnesota homes where natural gas was unavailable. Propane furnaces were used for back-up at four sites and the existing electric resistance baseboards were used for back-up in two homes. Staff alternated between furnace or electric resistance baseline and ASHP operation throughout the heating season to compare energy use of the two systems during milder conditions. Monitoring of equipment helped characterize the energy use and determine if the system could effectively meet the space heating load. The annual energy use and contractor installation cost was used to determine cost effectiveness. Occupant comfort and acceptance was evaluated from monitored space temperatures and occupant surveys. The results from the field study determined ASHP savings potential and helped facilitate the design of Minnesota utility rebate programs across the state.

Table 1 below shows a summary of site locations, application times and savings outcomes.

Table 1: Summary of savings in Minnesota homes

Air Source Heat Pump	Baseline	Location	Site Energy Reduction	Cost Reduction	Propane Reduction
Ducted	Condensing LP Furnace	Metro	41%	30%	63%
Ducted	82% LP Furnace	Metro	49%	40%	67%
Ductless	Elect. Resistance	Metro	56%	56%	N/A
Ducted	Condensing LP Furnace	Northern MN	36%	26%	55%
Ducted	82% LP Furnace	Northern MN	44%	36%	61%
Ductless	Elect. Resistance	Northern MN	53%	53%	N/A

Main conclusions from this research are that inverter-driven cold-climate ASHPs are capable of operating at very cold temperatures. The monitored performance of the heat pump systems verify that their installed performance is in line with the manufacturer performance specifications.

Additionally, when heat pump equipment is installed and operated with an appropriate back-up system, they provide a cost effective and energy-efficient space conditioning option for homes without access to natural gas.

In instances where ccASHPs are determined to be beneficial; switching off delivered fuels and

replacing less efficient electric resistance heat can be accomplished. Based on the research findings, the following program guidance was developed to optimize utility program design:

- The heat pump should have an inverter drive, have an HSPF ≥ 8, and be sized to meet 100% of the homes' heating load at outdoor temperatures ≤ 10°F.
- If installation requires a back-up heating system to meet the homes' load below 10°F down to the design conditions (-11°F in metro area), the heat pump operation should be prioritized so that backup is only used when needed.
- Programs could also take a tiered approach where the expected savings and performance are based on a calculator or look-up table. Depending on the rated ccASHP performance, installation and capacity of the ccASHP, a tiered savings could be determined. The base level savings could be assumed for any heat pump installation. A larger second tier savings would be given if the equipment meets a minimum rated performance (i.e. HSPF ≥ 7) and the heat pump was installed so that it would meet the full load down to heating moderate temperature (i.e. OAT change point ≤ 25 °F). The largest savings tier would require the highest system performance (i.e. HSPF ≥ 9 and OAT change point ≤ 5 °F). These tiers and the performance metrics could be determined through the use of a calculator.

Upon completion of this initial research, it was understood that more research was needed to uncover techniques to optimize the efficiency of single family and multifamily installations. As a result, CEE is performing two additional research projects currently underway to understand design and installation practices to optimize energy savings. This research will uncover the most cost effective and efficient controls strategies and other installation best practices.

Barriers to Technology Adoption

Research has documented some of the challenges to achieving the full potential for ccASHPs, including the following market barriers:

- ***Most ASHPs installed in Minnesota at present are not the most efficient versions*** — they are frequently not the cold-climate version that can capture the largest heating fraction down to low temperatures.
- ***Contractors are frequently not properly installing, sizing, designing, or pricing systems*** — typically resulting in savings left on the table and/or dissuaded customers.
- ***There is a knowledge gap in integrating heat pumps with existing systems*** — this often results in a missed opportunity for savings, wasted backup fuel, and less electric sales.
- ***Contractors are not presenting the ASHPs as options for a wide enough variety of applications*** — there are also many cost-effective use cases for ccASHPs in renovation/retrofit situations that are typically not presented to customers.

Absent proactive efforts, these barriers will slow down the technology penetration and result in less savings and less beneficial impact from a load perspective (e.g. ineffective controls for demand-response). As HVAC systems typically last for 20 years or more, this will result in stranded assets by homeowners and lost opportunity for utilities.

Minnesota currently has over 150 rebate programs available to overcome cost barriers with ccASHP installations. These programs will not reach their full savings potential if there is not significant work done in the market to overcome barriers at the installer and distributor levels. Upstream work is needed to align the market so that utilities can achieve the maximum impact with their rebates available to customers.

Other Related Efforts

Northwest Energy Efficiency Alliance

The Northwest Energy Efficiency Alliance (NEEA) initiated a market transformation initiative for ductless heat pumps in 2008, which focused on displacing zonal electric heat in single family homes with single zone ductless heat pumps. They were successful in convincing manufacturers to bring new products developed for Asian and European markets and introduce them to North America, coordinating utility rebates, engaging with distributors and installers to adopt the technology. The program remains in place today and has been successful in greatly impacting their target market.

New England

The colder climates in the northwest part of the country, particularly Maine (Efficiency Maine) and Massachusetts (Mass Saves) have had particularly aggressive and effective ASHP initiatives that have gotten significant penetrations, much through the brute force of high rebates. NYSERDA recently announced $120 million of additional funding for ASHPs in New York. Some research has shown that expected savings from early installations was not being achieved in field conditions, in large part due to insufficient controls strategy, or sizing issues. Many programs – particularly Mass Saves – have responded by increased attention to controls specifications and program requirements. This has helped to increase manufacturer interest in producing more options and features and increasing compatibility of ASHP OEM offerings. Additionally, the Northeast Efficiency Partnership (NEEP) has a ccASHP initiative that includes a ccASHP product specification, qualified products list, contractor and customer resources as well as research initiatives related to the advancement of the technology.

The Minnesota ASHP Collaborative Approach

In discussions about how to best address the barriers identified above, and learning from the approaches listed above, the authors realized that coordination across utility boarders would be most impactful on the market. Thus, the following organizations came together to form Minnesota ASHP collaborative:

- Center for Energy and Environment (implementer)
- Great River Energy
- Otter Tail Power
- Minnesota Power
- Missouri River Energy Services
- Southern Minnesota Municipal Power Association

In total, this represents a majority of the utilities in rural Minnesota.

Much of the collaborative's market strategy was influenced by market transformation market interventions as pioneered by NEEA. The initiative's goal is to reach the HVAC market in a high-impact and lasting way through statewide collaboration. By pooling resources and working together on a common vision, this initiative will develop deeper relationships with manufacturers, distributors, and contractors to more broadly and quickly spur market growth. The collaborative will also facilitate a unified approach to technology applications and installation best practices in the state so that customers and utilities actualize the maximum potential energy and cost savings. Below the five main elements of the program design.

Technical Guidance and Installation Best Practices

Currently, ASHP technology is present in the MN market. However, installed systems are not optimized for heating, therefore are not achieving savings potential, and the most efficient products are not widely installed. Additionally, product selection is price- and availability-driven and often focused on cooling applications. The MN ASHP collaborative, has developed recommended product specifications by application type and is also developing installation best practices.

- **Installation application prioritization:** The collaborative has created an application matrix that maps out existing product types and ideal replacement scenarios with corresponding benefits and barriers. Through this process, three primary targets have been identified: ductless mini-splits replacing or displacing zonal electric heat, dual-fuel centrally ducted ccASHPs replacing propane furnaces, and centrally ducted ccASHPs replacing less efficient cooling systems and heating on the shoulder seasons. Additional application types are identified and will be prioritized later in the initiative development.
- **Product specification by application:** Based on the three highest priority application types, high-level product specifications were developed that serve as a recommendation to utility programs and installers when selecting product for installation.
- **Installation best practices guidance:** Based on CEE's research and other national resources, the collaborative is generating installation best practices and system design guides for priority application types. These guides will include key information on product selection, sizing, controls strategies and installation best practices for achievement of optimal energy savings, equipment performance and homeowner satisfaction. These published guides will be available in mid- 2020 and will be circulated to utilities, distributors and installers to promote high efficiency installations.
- **Site inspections:** The collaborative will perform inspections on installations that have been rebated through utility programs to learn what is occurring in the field and communicate findings and results back to utilities, installers, distributors and manufacturers.

Manufacturer and Distributor Engagement

In order to understand the Minnesota market holistically, a directory of all HVAC distributors and manufacturers in the state of Minnesota has been compiled to better understand the supply channel and where product is available. Market intelligence will be continually collected throughout the life of the initiative to inform strategy and track impacts. Data to be collected includes:

- Distributor information
    - Directory of all HVAC distributors throughout the state with branch locations grouped by company with the following data:
        - Site address of each branch location
        - Relevant corporate contacts
        - Branch manager contacts
        - ccASHP brands carried at each distributor
        - what ccASHP product is in stock and what is special order
        - Price information if available
- Manufacturer information
    - Directory of all ccASHP manufacturer contacts that are most prevalent in MN including
        - Key program contact – likely regional sales manager or business development manager
        - Manufacturer rep. contacts
        - Market share information as available
        - Planned tactics and strategies for the ASHP product category in MN

Based on the supply chain information gathered, manufacturer and distributor outreach will be prioritized and initiative throughout the initial three years of the collaborative effort. Quarterly meetings with manufacturers will be held to share activities and align where possible. Meetings with distributor corporate and branch contacts will be held on an ongoing basis to share information and identify areas for collaboration.

In addition to general engagement with distributors, sales data will be requested to gain an understanding of the state of current sales and key installers purchasing ASHPs. Lastly, statewide training efforts will be coordinated with manufacturers and distributors.

Installer Training and Engagement

Installer adoption of ASHP technology and particularly ccASHP technology is currently the biggest barrier for this technology but also the biggest opportunity to develop resources and activities to increase adoption.

In 2020, the collaborative will roll out installer training curriculum that will be delivered both classroom style and in a direct-to-company format. As a result of COVID-19 restrictions, training will be delivered online in the form of on- demand content modules for the time being. Once in-person engagement is possible, classroom style events and direct-to-company training will commence.

This curriculum will be available to utility representatives and distributors to leverage in additional training opportunities. The training curriculum will cover intro to ccASHP technology, performance in MN climate, installation applications, utility rebates, product selection, sizing, controls strategies, installation best practices, as well as sales and marketing.

- **Online training modules** – content modules will be developed for on demand viewing and will cover all topics in the curriculum outline below.
- **Classroom style trainings -** Classroom style training will aim to recruit as many HVAC installation companies as possible to increase general exposure of ASHP technology in the trade network. The target audience from HVAC companies will include owners, technicians and sales staff. As many staff as possible will be encouraged to attend events so that in the event of turnover, there will be numerous trained staff per company.
- **Direct-to-company trainings –** this approach involves working deeply with a small group of high potential installers. High potential, meaning installers that have an interest and likelihood to adopt this technology and have a footprint large enough to serve a high volume of customers. This training approach has five steps:
    - Select target installers based on geographic distribution; utility, distributor and manufacturer recommendation; and responsiveness to program collaboration.
    - Meet with the owners of select companies to understand more about their business and opportunities to promote ASHP technology. With the owner, design a strategy to engage the company in training efforts.
    - Training will take place with sales, technician and administrative staff to provide knowledge and resources necessary for each individual role. Market partners and utility reps. will be included in engagement.
    - Gather feedback from staff and ownership to gain input on training effectiveness and continuously improve installer support.
    - Follow up after time has passed to find out how their ASHP business is developing and if they need any additional tools and resources to be successful.

These training tactics will be developed and delivered through the ASHP collaborative throughout 2020. Based on learnings and results from trainings, installer engagement will continue through 2023 at a minimum to help reach the vision of a transformed MN market.

Utility Program Coordination

Through the ASHP collaborative, utilities in the state of MN will be in frequent contact regarding ASHP programming. The funding utilities will provide input on activity development as well as share specific activities and findings from their territories. By opening channels of communication, utility programs can move towards alignment which will ultimately remove market barriers making it easier for installers and distributors to navigate program requirements. The utility coordination through the collaborative involves:

- Quarterly rebate data transfer to program administrator for trend analysis

    - This data will be used to understand the market, measure statewide growth overtime, and to select sites for quality control inspections.
- Quarterly progress reports and meetings will be held to frequently communicate program updates and updates from each participating utility and aggregator.
- Annual reporting to evaluate progress and make recommendations for future activities
- Collaborative landing page to host utility, installer and distributor materials developed through the collaborative

Strategic Marketing Support

The collaborative is scanning programs in North America to identify strategic marketing best practices. By pooling together best practices our member utilities will be provided information on the most effective and cutting-edge marketing strategies currently available. The collaborative will not execute any direct-to-customer marketing but will rather provide guidance and resources for member utilities to deploy independently. The strategic marketing guidance planned through the collaborative includes:

- **Collect current marketing tactics** – This initiative will track utility marketing activities and maintain within a marketing tracker to increase knowledge sharing and coordination.
- **Case studies and testimonials -** Based on QC inspections and installer engagement, the collaborative will develop case studies and testimonials from ideal installations and pleased homeowners. Utilities partners will be encouraged to leverage case studies and/or testimonials in marketing campaigns.
- **Coordinate community blitzes to raise awareness** – the collaborative will explore the idea of developing community blitzes in specific communities chosen by utility partners to drive consumer awareness of ASHP technology and rebates.

Conclusions

While implementation efforts of the collaborative are too early to share definitive impacts and results, a summary of some of the research and findings and conclusions that have guided the organization of the collaborative are summarized below.

There is a strong energy savings, economic and environmental case for expanded deployment of ccASHPs for heating in cold climates like Minnesota.

In particular, there are a couple of existing use cases that show the most promise: 1) baseboard electric; and 2) propane customers. The use case for existing natural gas customers is more complex (generally the economics are not always favorable for the customer, and emissions benefits are not always favorable, depending on the existing fuel sources for electricity generation), although the potential market is larger for gas.

Financial incentives alone are not sufficient to overcome barriers to accelerating adoption of ccASHPs.

Our research has shown that there are additional barriers to contractors correctly installing ASHPs to capture their full benefit (which will ultimately limit customer adoption), as

well as to embracing ASHPs as a business model. In Minnesota, where most of the near-term potential for ASHP is in rural areas, this issue is particularly important, as less contractor options generally exist for a given customer.

Supply-chain engagement can help to overcome additional barriers to ASHP adoption. In particular, working with contractors to help them understand the technology and its application, providing training on proper installation techniques, and supporting business and sales efforts are tactics the collaborative has adopted. In addition, it was found that supply houses and manufacturers are very motivated to help with this effort, including training, and coordination among these stakeholders can help to provide strong leverage for accelerating ccASHP adoption.

Cooperation and coordination across utility boundaries is essential to achieving maximum impact on the market. Contractors, and particularly supply houses and manufacturers are not contained within utility boundaries, and differences in utility approaches can serve to confuse the market and limit success. By providing clear information on all utility programs and also working to align rebate programs, the market can more readily leverage utility rebates as a valuable resource in selling ccASHP technology.

As resource development and activities continue and engagement work in the market deepens, the Minnesota ASHP Collaborative will continue to share findings, results and impacts where possible. As market feedback and early results are identified, activities and tactics will be adapted over the next three years to maximize impact and transform foundational research into a program that has a lasting positive impact on the residential HVAC market.

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