CARD Webinar Audience Questions & Answers

Air-to-Water Heat Pumps: A Cold Climate Solution for High-Efficiency Cooling, Space Heating, and Water Heating

Webinar Date: December 19, 2023

I'm particularly interested in Air-to-water heat pumps for application in heating swimming pool water. Can you could provide info you have as to the efficacy of that technology?
Center for Energy and Environment (CEE) did not study air-to-water heat pumps (AWHPs) for swimming pool applications in this project. Conceptually, AWHPs may be a great fit for the application but CEE doesn't have further analysis to share.

Do AWHPs have any more or less potential than ASHPs for spaces other than single family homes?
AWHPs do have potential for commercial and multi-family building types, but CEE did not study those applications for this project. Multi-family applications are particularly interesting due to the relatively higher number of these buildings with hydronic heat. Major conclusions from this study likely will apply to those applications as well, but more research may be needed.

I'm very curious how effective the cooling of AWHP is. We're all familiar with radiant in-floor heating, but I don't think I've ever seen a cooling system. I'm particularly interested in effectiveness and efficiency vs forced AC.
CEE didn't investigate radiant cooling applications in this study. Such a retrofit was beyond the scope. Radiant cooling is typically supplied through chilled beam or radiant ceilings and those types of emitters lean very strongly into the advantages of AWHP so we expect better cooling performance and comfort, especially compared to what we observed using the hydronic coils.

Are Arctic, Chiltrix, and SpacePak (inverter drive) manufactured by Phnix or other international manufacturer?
Unfortunately, CEE does not have detailed knowledge of manufacturer relationships for all of these different AWHP models to answer your question.

Were any of the examples conducted in an older home with radiators only? I'm assuming the homes are a bit newer as they have in floor radiant heat.
CEE was only able to find a few homes that had conventional (cast iron / baseboard) radiators and electric boilers. CEE calculated at our expected supply temperatures we could meet less than 40% of the heating load due to lack of emitter capacity. The project scope didn't permit radiator replacement, so CEE focused on radiant floors.

What is COP again please?
COP = coefficient of performance = energy output / energy input. It is a measure of efficiency.

COP?
Seasonal average space heating COPs were 1.35 for the NorAire and 1.8 - 2.01 for the Enertech.

Can you clarify the difference between the composition of the refrigerant and the hydronic fluid?
The refrigerants in these AWHP systems are engineered fluids with excellent thermophysical properties that allow them to evaporate or condense at particular pressures, which is useful for moving heat from one place to another. The refrigerants used in other ASHPs are used in AWHPs. Refrigerants are relatively expensive and specialized compared to hydronic fluids. The hydronic fluid is water plus antifreeze and it is used primarily to deliver heat throughout the home.

For a 1.35 COP, what does the payback period look like versus a replacement resistance electric boiler? What were the installed costs for these systems?
The installation costs observed for this project ranged from $14,000 to $33,000 with installation labor costs ranging from $2,800 to $7,900. The payback period based on energy consumption and utility rates specific to the study sites ranged from 20 to 29 years, but this will vary for other homeowners. Notably, the study sites had electric heat rates, lowering their heating costs per kWh (and increasing payback accordingly). The costs encountered here are likely a ceiling estimate rather than a floor since technologies tend to decrease in cost as the scale of adoption increases.

Can these systems be set up just for DHW application w/o any heating load?
There is a different technology called Heat Pump Hot Water Heaters that are specially designed for DHW heating only. That technology puts the entire heat pump indoors.

What is the expected life of the equipment?
Equipment lifetimes were not studied here, but nothing suggested that they would not last as long as other heat pump technologies. Most expect heat pumps to last 10 to 20 years, depending on use and maintenance.

Will Inflation Reduction Act rebates apply to these systems?
The federal IRA Home Energy Rebate programs will provide rebates for heat pump technologies. Minnesota is currently designing these programs and identifying which upgrades will be eligible. Households will not be able to receive rebates from both programs for the same heat pump upgrade.

- *IRA Section 50121, the Home Efficiency Rebate Program (also known as HOMES) will provide rebates for whole-home energy saving improvements. This program is intended to make homes more energy efficient and provide improvements such as insulation and air sealing and efficient heating and cooling equipment. The rebate amount will vary based on the amount of energy savings achieved and a household's income.*
- *IRA Section 50122, the Home Electrification and Appliance Rebate Program (HEAR), will provide rebates to replace non-electric appliances with more efficient electric appliances, and to upgrade a home's electrical service to be ready for increased electric demand. This program can provide rebates for things such as first-time purchase of heat pump technologies (for air cooling/heating, water heating, and clothes drying), electric cooking appliances (stove, cooktop, range, or oven), and upgrades to a home's electrical panel and wiring. Rebates will be available to households with total annual income less than 150 percent of the area median income of the area in which they reside. The rebate amount will depend on the upgrades and technologies purchased and a household's income.*

In addition, the 2023 Minnesota Legislature appropriated state funding for use by the State Energy Office to implement a state-funded Heat Pump Rebate program, for use in conjunction with the federal Home Energy Rebate Program; households must receive a federal Home Energy Rebate Program to be eligible for the state heat pump rebate. Income-qualifications will apply to these programs; households with incomes over 150% of the area median will not be eligible for a rebate and should instead familiarize themselves with available tax credits.

Further, the Minnesota Department of Commerce tracks and publicizes energy-related funding opportunities. Stay current by watching Commerce's Energy Related Funding Opportunities webpage (https://mn.gov/commerce/energy/industry-government/federal-funding-opportunities/). Send questions related to federal funding opportunities via email to fedquestions.commerce@state.mn.us .

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Why were the Monobloc total install costs significantly higher (2x) than the split systems?
These were higher end systems with higher capital costs. Installation costs were higher due to integration with forced air systems, zoning controls, and DHW.

Can you please send presentation after?
The presentation was recorded and will be made available on the Department's Conservation Applied Research and Development website (https://mn.gov/commerce/energy/conserving-energy/applied-research-development/). Typically, webinar recordings are available within approximately a month of the final broadcast, but the Department's website went through a major transition and is currently under construction which has delayed 2023 webinar postings.

Webinar slides with webinar transcript are planned to be shared with all webinar broadcast registrants within a couple weeks of the broadcast webinar.

The final report is planned to be posted to the Department's Conservation Applied Research and Development website (https://mn.gov/commerce/energy/conserving-energy/applied-research-development/ early 2024.

In the kWh savings slide, were the baselines used for comparison: electric resistance, or the alternative the customer had onsite? I believe Garfield and Fairbault would have natural gas. Curious how the A to W operating cost would compare against nat gas?
Our participants mainly used electric boilers and they served as our baseline. None had access to natural gas. A few used propane for fireplaces and furnaces as backup or aux heat.

For homes or MF buildings heated by boilers/radiators, would AWHP be the recommended path to electrification, or at this time would the recommendation be to retrofit the building to ASHP?
This study did not include MF buildings or SF homes heated primarily by radiators. However, CEE does note that old-fashioned radiators are typically designed for much higher supply temperatures (~160°F)

compared to the temperatures AWHPs deliver (~100 – 130°F). Thus, a careful assessment of the heating load and the capacity of the existing radiators at AWHP supply temperatures would be recommended before implementing an AWHP. If significant weatherization measures have or can be implemented before the AWHP would be installed, the AWHP may be a more cost-effective approach compared to retrofitting a centrally ducted air-to-air HP or deploying many mini-splits.

What were the flow temps for Heating, Cooling and DHW for each site?
Cooling supply temps were about 40 - 50°F, space heating supply temps were 90 - 120°F usually, and DHW supply temps were usually 120 - 130°F

What was the DHW Tank set-point and how long did it take the AWHP to heat the tank to temp and then recover after draws for showers etc?
This AWHP served to preheat water for the existing water heater. The existing water heater would be used for quick recovery, while the AWHP improves overall system efficiency. Note that CEE saw very good results even with an enormous domestic hot water load.

Are AWHPs eligible for IRA tax credits for heat pumps?
*IRS allows tax credits on **federal** tax returns of 30%, up to $2000 per year, for qualifying home improvements using heat pumps. Review the IRS Energy Efficient Home Improvement Credit (https://www.irs.gov/credits-deductions/energy-efficient-home-improvement-credit) and Publication 5886-A (https://www.irs.gov/pub/irs-pdf/p5886a.pdf) or contact the IRS for qualification information on specific heat pumps or how to claim the credit.*

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Any suggestions on where I could look for information on AWHP use in the swimming pool heating application? Apparently they are used in that application, especially for outdoor pools in warmer (than MN) climates.
CEE recommends reaching out to local HVAC engineering, installation, or design firms with your swimming pool inquiry. While swimming pools were not in scope for this work, CEE believes that AWHPs may perform excellently in that application if sized appropriately.

Just to make sure I'm understanding correctly - all costs were for the heat pump install only, no distribution retrofits occurred, right?
Correct.

Any answer about rebates?

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Is the cooling function always done via an air handler and a coil?

The sites studied here all used a hydronic coil on an air handler for cooling but this is not the only option. Modern hydronic fan cassettes are available that work very similarly to air-to-air HP mini split heads. These are promising approaches for providing cooling and controlling humidity with one system. If humidity were controlled in a separate way (e.g. stand alone dehumidifiers), other emitters could also work with cooling, but this is not a proven approach for MN's climate.

If current in-slab hydronic system is working well being supplied by high-effic propane DHW heater and flat-plate exchanger, could DHW HP replacing propane HW heater possibly work, or is a split type system likely needed?

A typical HPWH has a single indoor unit and will not work for a heating application unless it is located in an unconditioned space, which would lead to very poor efficiency (and likely inoperable under ~<40-F ambient temperature). The SANCO2 is technically a split HPWH unit (rare among HPWH systems). It has indoor and outdoor components. Conceptually it is very similar to the NorAire split, but it uses CO2 to make higher temperatures suitable for hot water (at higher efficiency / COP too). Each of your options are plausible and it would likely come down to detailed design work as well as your appetite for risk.

Many older folks have seen HP tech before and think it's not possible for MN. Are you also addressing the marketing of Air to Water with storage?

CEE were unable to investigate storage in this field study but do hope to examine this technology soon.

Would love to know more about application to hydronic systems with panel radiators and prospect for applicability to systems with cast-iron radiators?

This research did not extend to buildings with panel or cast iron radiators. However, CEE does note that old-fashioned radiators are typically designed for much higher supply temperatures (~160°F) compared to the temperatures AWHPs deliver (~100 – 130°F). Thus, a careful assessment of the heating load and the capacity of the existing radiators at AWHP supply temperatures would be recommended before implementing an AWHP. If significant weatherization measures have or can be implemented before the AWHP would be installed, the AWHP may be a more cost-effective approach compared to retrofitting a centrally ducted air-to-air HP or deploying many mini-splits.

Curious what the payback period is for ASHPS as compared to AWHPs?

The payback period of air-to-air HPs is likely much quicker than AWHPs for retrofitting buildings without preexisting hydronic heating while CEE expects AWHPs to be more cost-effective for buildings with existing hydronic distribution that is suitable for low (<130°F) supply temperatures.

Is the ROI based on a comparison to NG and if so what does that look like compared to LP and also a DF electric rate?

This research did not consider any natural gas system baselines to calculate ROIs or payback periods, instead using electric resistance baseline assumptions. However, the payback period for investing in an AWHP generally shrinks the larger the baseline operational costs are, making LP and electric resistance systems good opportunities for AWHP retrofits. With current rates, we expect natural gas customers to be looking for additional benefits from the AWHP than space heating alone to make the upgrade more cost-effective. These additional benefits may include domestic hot water heating or air conditioning.

Would glycol corrosion of indoor in-slab loops be a concern? Is water without any glycol better for indoor part of loops?

Glycol is an important addition to remove the risk of burst pipes in a freeze event but it does require more maintenance than a system without it. If a system with glycol is not regularly checked for its pH level and adjusted to maintain neutral pH, the system can suffer from corrosion due to the acidic byproducts formed by naturally occurring glycol degradation over time. Corrosion can also be an issue for water-only systems but is generally less prevalent than those with glycol.

Can *any* ODU ASHP be paired with an IDU in a split-system configuration?

No. The ODU paired with a third-party split AWHP IDU must be capable of operating in a "non-communicating" system. Generally, if the ASHP can be installed in a third-party configuration for air-to-air applications, it could work with a third-party AWHP. All single stage ASHP ODUs are functionally capable of this and some variable speed HP ODUs are, too. High performance VSHPs which require specific, brand-matched air handler and/or thermostat pairings to work in air-to-air systems may not be suitable.

How/where can a homeowner get help with evaluating sizing and other factors of contractor bids for AWHP in-slab hydronic system?

Homeowners can ask bidding contractors to provide heat load estimates, also known as "Manual J calculations" and provide information on how they determined the size of the equipment they offered. There are also residential HVAC engineering design & consulting firms that may provide more detailed guidance.

Could you explain a bit more about the battle between DHW heating and cooling with an in-slab hydronic system in summer months?

The systems studied here provided DHW as a second priority load; that is, if a space cooling or heating call was ongoing, DHW loads were ignored until the space conditioning needs were met. In the summer, switching from cooling air to heating DHW requires the system to reverse its refrigerant loop. That is, it has to stop ejecting heat to outside and instead absorb heat from outside to send to the DHW. There is an energy penalty involved in heating the refrigerant loop which was just cooled for space conditioning and vice versa.

There are forthcoming AWHP systems that will deliver flow temps up to 165F and that will remedy the compatibility with baseboard and some older HT radiators. This category is called a high temp AWHP

system and operates in ultra-cold climates. Do you consider future study with this new category and also the capability of the thermal storage at that point?
Yes, new technologies are always of interest, and CEE will continue to track the evolution of available AWHP products in Minnesota. A plan is not firmly in place to evaluate this category at this time, however.

What is the IRA statute?
The text of the Inflation Reduction Act is published as Public Law No. 117-169; 08/16/2022 (https://www.congress.gov/117/plaws/publ169/PLAW-117publ169.pdf).

Are there any plans in the future to look at emissions reductions if installing to replace a gas boiler, more specifically with Eco and fuel switching?
Planning for new research related to ECO and fuel switching are ongoing and AWHPs may be considered in this context as those plans develop. A plan is not firmly in place to evaluate this category at this time, however.

Would Solar Thermal being used for floor heating be a better investment instead of using a AWHP due to use of refrigerant?
Solar thermal may be a good technology for some applications, particularly those with relatively small heating loads. The global warming potential of modern refrigerants does remain high, so they can be difficult to justify if emissions reduction is the only goal of an investment. However, for the average homeowner, costs are also important aspect and AWHPs may be more cost effective for the average home, given that typical DHW and space heating loads are difficult to cover with solar thermal systems alone in MN.

Are there any studies of how AWHPs do with cooling?
This study did evaluate two homes with AWHPs providing cooling. The systems proved capable of covering typical single family home cooling loads but was not able to clearly evaluate the savings opportunity, if any, provided by the AWHP compared to conventional cooling technologies. The research team is not aware of other work looking specifically at this aspect, either.

Along those lines -- any resources and/or consulting available for residential changeovers?
Existing ASHP resources regarding changeover points can be leveraged for AWHPs. Consult, for example, the MN ASHP Collaborative at https://www.mnashp.org/

Would Ground Source to Water HP be more efficient?
Ground source heat pumps are generally capable of being more energy efficient than any AHSP (AWHP or air-to-air HPs included) because they interface with ground temperatures that are more consistent compared to outdoor air temperatures.

I have cast iron radiators. I'm interested in this technology to heat my home and take advantage of the IRA rebates. Can I do that?
Old-fashioned radiators are typically designed for much higher supply temperatures (~160°F) compared to the temperatures AWHPs deliver (~100 – 130°F). Thus, a careful assessment of the heating load and

the capacity of the existing radiators at AWHP supply temperatures would be recommended before implementing an AWHP. If significant weatherization measures have or can be implemented before the AWHP would be installed, an AWHP may be an excellent option.

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You discussed future AWHP applications and research in homes with panel radiators which are commonly found in MN homes built in the early 20th century. Can you expand on what questions or research needs should be explored specifically to determine if AWHPs could be a viable heating solution for homes with panel radiators? It seems as though this technology could be a game changing solution for that type of home.

Some important research questions to answer in relation to AWHPs applied to early 20th century hydronic homes include: what is the most cost-effective way (weatherization, addition of radiators, high

temperature AWHPs, supplemental heat use, etc.) to ensure that existing radiators have sufficient heating capacity at available AWHP supply temperatures? What minimum level of weatherization allows existing radiators to sufficiently meet heating loads at AWHP supply temperatures? What maximum heating load is typically achievable at AWHP supply temperatures for typical radiator layouts? What fraction of existing housing stock is already weatherized sufficiently to allow an AWHP to meet a majority of the heating load without radiator upgrades? Do any low-cost strategies such as the addition of fans to radiators enable drop-in AWHP retrofits with radiators?

You discussed air-to-air ASHPs and AWHPs – when would a homeowner or contractor consider one retrofit application over the other? What about a residential new construction application?
In retrofit applications, AWHPs should be considered where the operational economics of energy savings from an ASHP make sense but existing hydronic distribution presents an installation cost barrier. These generally include homes with propane or electric resistance boilers. In new construction, AWHPs should be considered for all homes which include hydronic heating systems and for energy efficient homes with design loads low enough where integrated space heating, cooling, and domestic hot water could be covered by a single AWHP system.

Can you expand on the difference in the performance between the monobloc and split systems? Was that performance difference expected? If the sample size were larger, do you think that performance difference would be as distinct?
The performance differences observed between the monobloc and third-party split systems evaluated in this research were related to differences in the specifications rather than their different configuration types, monobloc vs split. Both configurations are expected to be capable of a wide range of performance. Theoretically, split systems may be able to be slightly more efficient than monobloc systems since they don't necessarily require antifreeze in their hydronic loops. Given that antifreeze is an easy solution for what could be a catastrophic failure, however, antifreeze may be used in many split system installations, narrowing the expected maximum performance difference between the two configuration types. Notably, monobloc systems are promising for use with more advanced refrigerants not currently available for split system use and may be installed more quickly than split systems in some applications. These factors may be important, depending on the definition of system performance.