Welcome

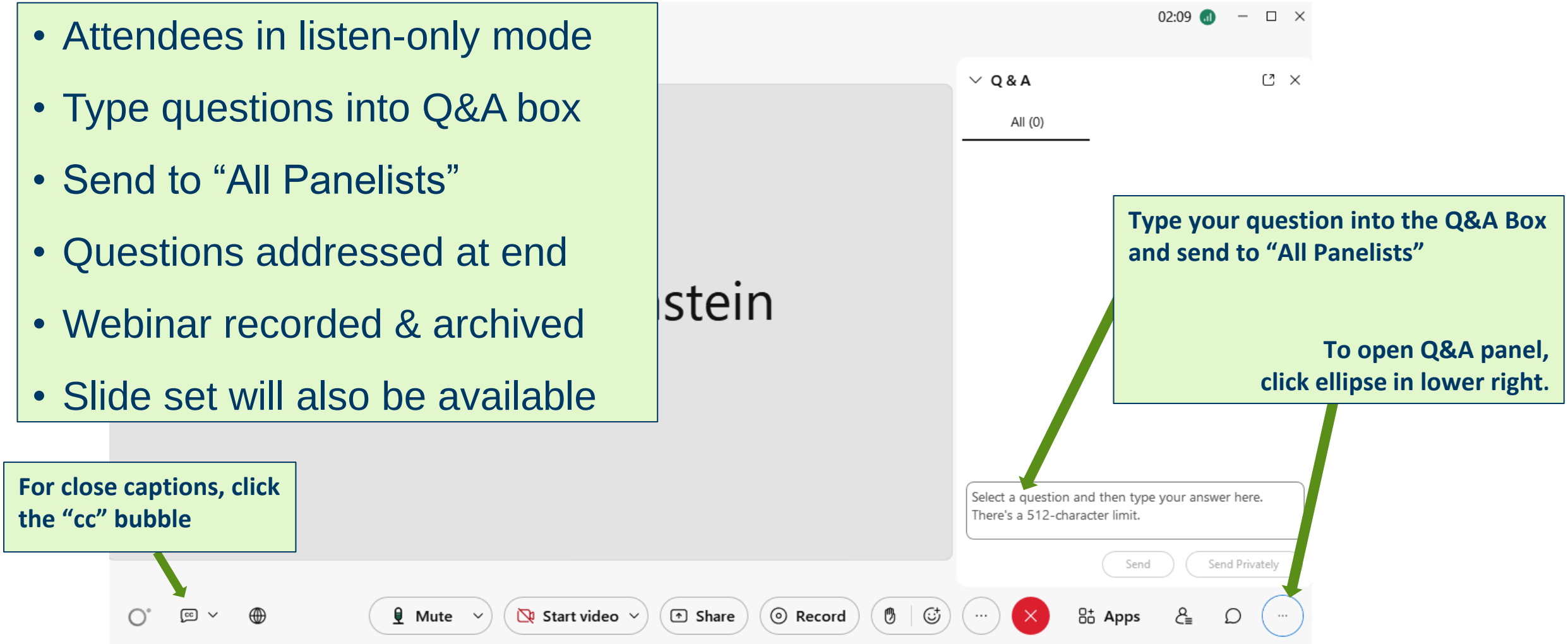
Conservation Applied Research & Development (CARD) Webinar

December 19, 2023

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

Webinar Basics

- Attendees in listen-only mode
- Type questions into Q&A box
- Send to “All Panelists”
- Questions addressed at end
- Webinar recorded & archived
- Slide set will also be available



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

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

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Minnesota Applied Research & Development Fund

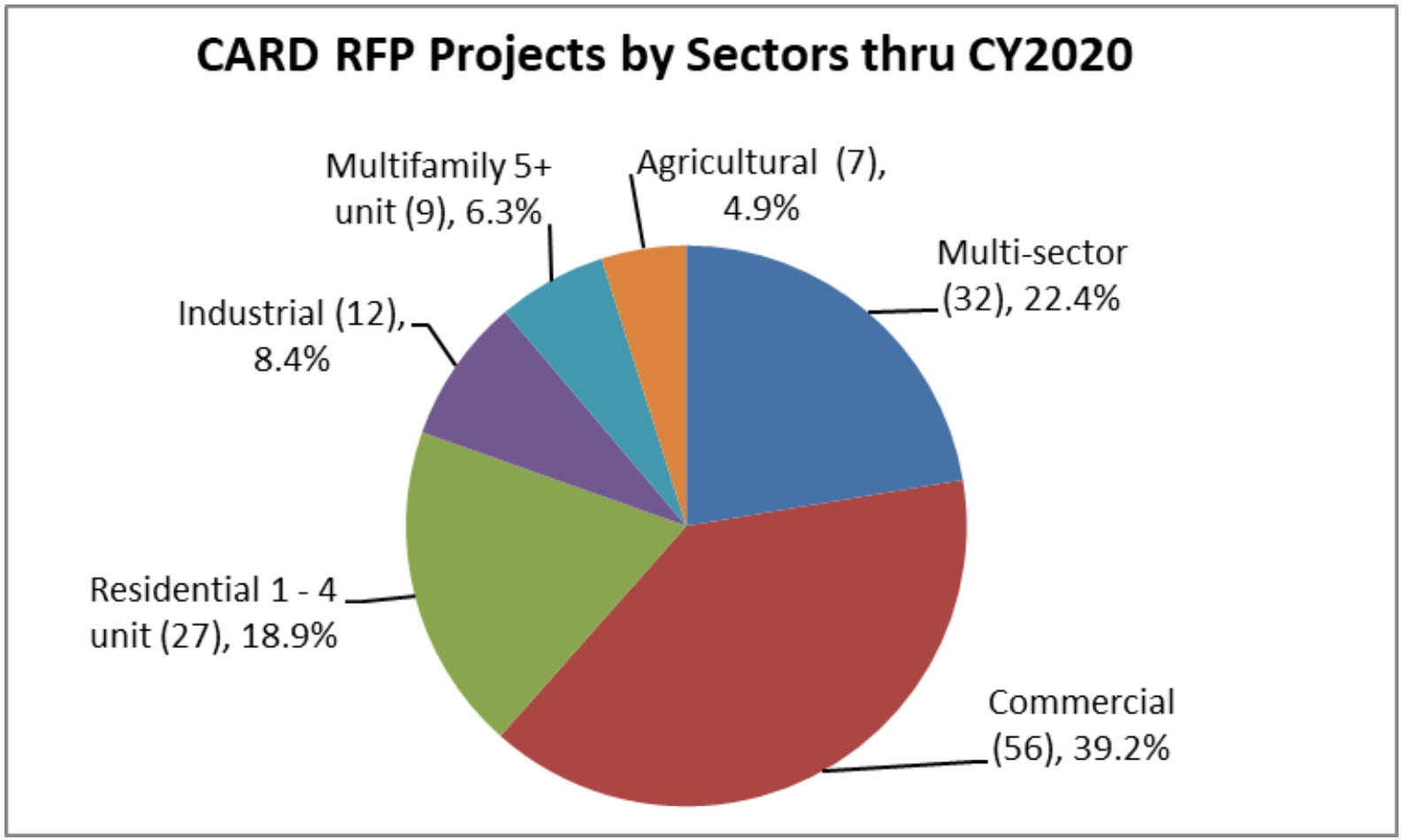
- **Purpose to help Minnesota utilities achieve energy savings goal by:**
  - ***Identifying new technologies or strategies to maximize energy savings;***
  - ***Improving effectiveness of energy conservation programs;***
  - ***Documenting CO_2 reductions from energy conservation programs.***

Minnesota Statutes §216B.241, Subd. 1e

- **Utility may reach its energy savings goal**
  - **Directly through its Energy Conservation and Optimization (ECO) program**
  - **Indirectly through energy codes, appliance standards, behavior, and other market transformation programs**

State Capitol Image: Courtesy Minnesota Department of Administration

CARD RFP Spending by Sector thru FY2020



RFP Summary

- 12 Funding Cycles
- 513 proposals
- 143 projects funded
- $31.2 million in research

December 19th, 2023

AIR-TO-WATER HEAT PUMPS

The cold climate solution for high-efficiency cooling, space heating, and water heating

Samantha Hill, PhD, Ranal Tudawe, Josh Quinnell, PhD

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Agenda

- What is an Air-to-Water Heat Pump?
- Types of AWHPs
- Field Study Background
- Performance Results
- Energy Savings, Costs, and Payback
- Conclusions, Barriers, and Opportunities

What is an Air-to-Water Heat Pump?

What is an Air-to-Water Heat Pump? cont. 1

AWHPs are air source heat pumps with hydronic distribution.

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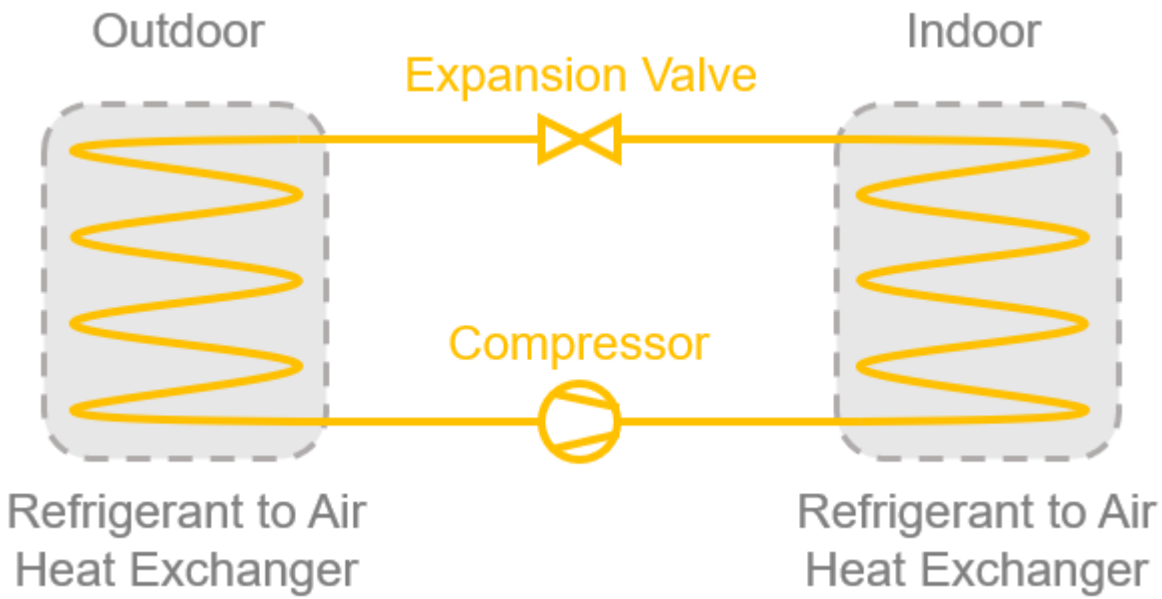
What is an Air-to-Water Heat Pump? cont. 2

A Typical ASHP



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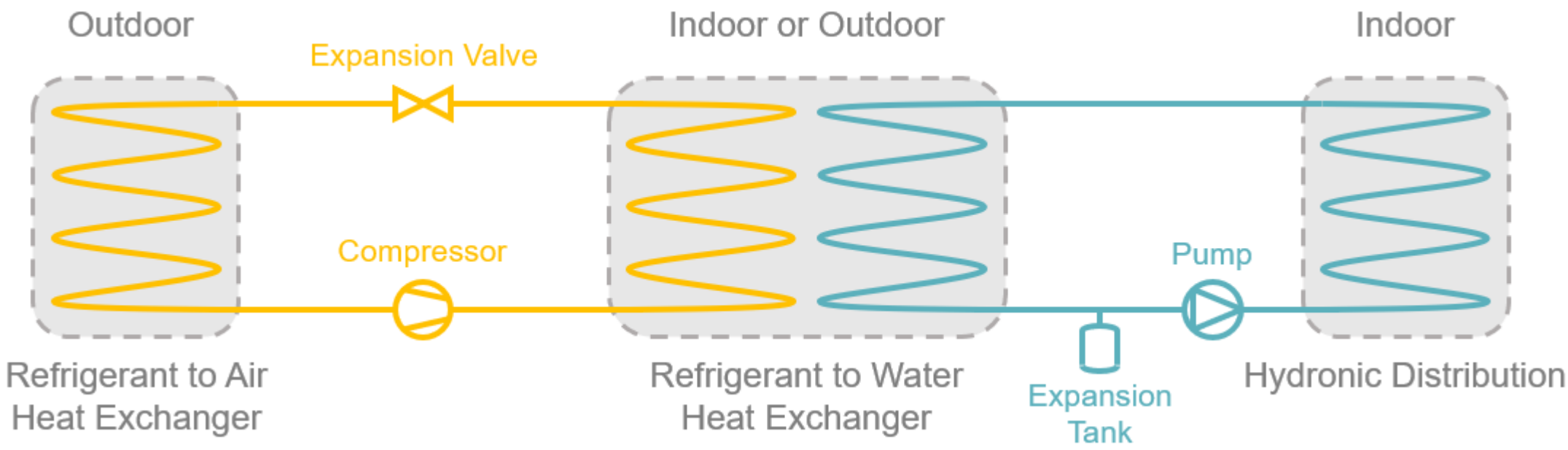
What is an Air-to-Water Heat Pump? cont. 3

A Typical AWHP



Hydronic Distribution: Pros and Cons

- Potential benefits vs forced-air:
  - Higher distribution efficiency
  - Lower supply temperatures possible for certain emitters
  - Diverse emitter configurations
  - Zone control
  - DHW load integration
  - Thermal storage integration
- Potential disadvantages:
  - Additional heat exchanger(s)
  - Cold climates require antifreeze
    - Antifreeze reduces heat transfer efficiency
  - Retrofit challenges may vary

Types of AWHPs

Types of AWHPs cont.

- Dozens of models and configurations are available for virtually any Minnesota residential application.
- Just like ASHPs, AWHPs primarily function as space heating systems, and many also provide cooling.
- When not in heating or cooling, some AWHPs can also provide domestic hot water (DHW) service.

AWHP Configurations

Monobloc

Source: ArcticHeat

Split

Source: SpacePak

Third-Party Split

Source: Electro Industries

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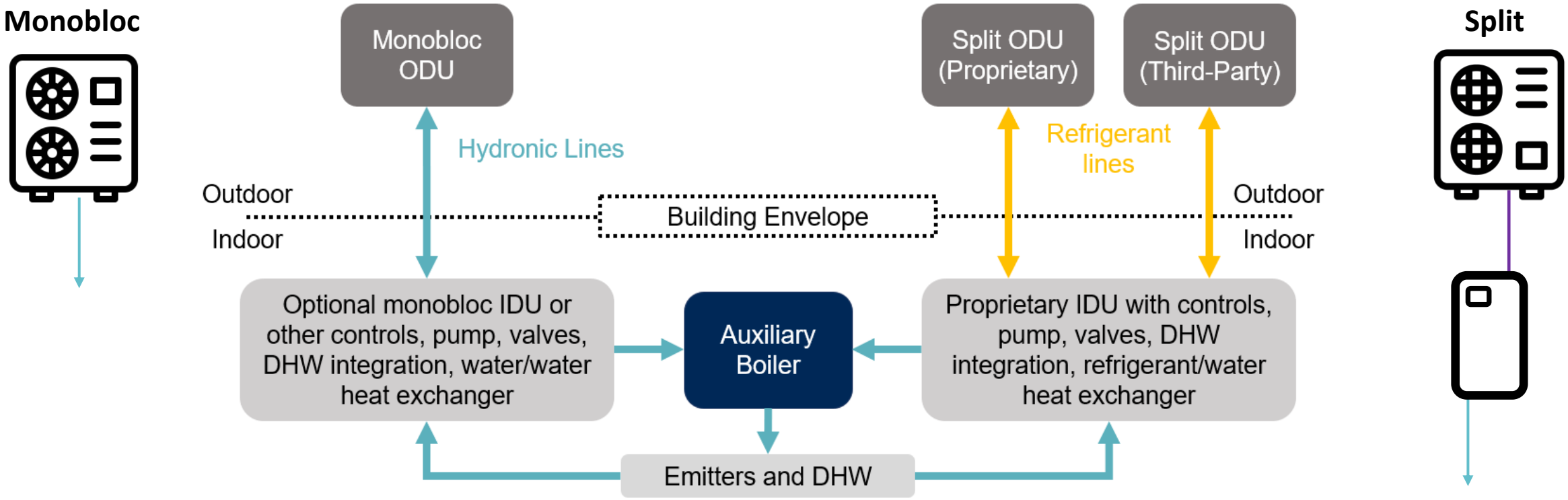
AWHP Configurations cont.



Field Study Background

AWHP in MN: A Brand-New Technology?

- Air source heat pumps are growing in MN
  - Previous research demonstrates cold climate, variable speed ASHPs work in MN's climate (IECC zones 6 & 7) but may need auxiliary heat
  - Natural gas remains the dominant heating fuel
- AWHPs currently have almost no market share in MN
- Hydronic heating is mostly found in two types of single-family MN homes:
  - SF homes built around 1900-1920s with panel radiators
  - SF homes built since 2000 with in-floor heat

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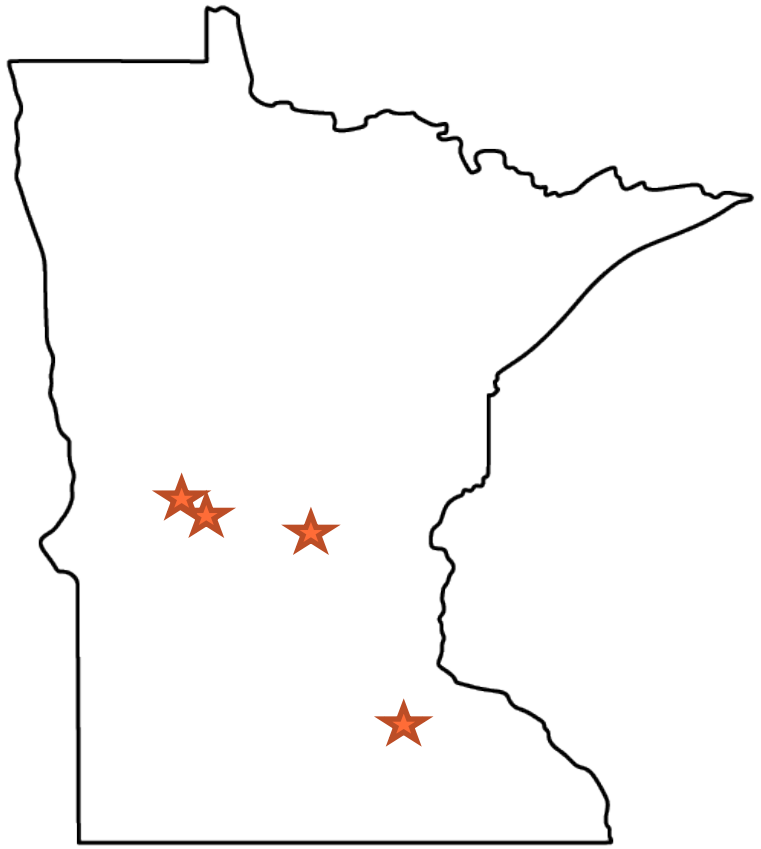
Case Study Scope: AWHPs in MN



- **Goal:** Characterize available AWHP systems and identify best AWHP configurations to serve cold climate MN homes
- **Scope:** Field monitor four single-family homes **retrofit** with AWHPs to evaluate energy savings, costs, and performance
- **Timeline:** Installations occurred late 2021 to early 2022 and monitoring lasted through summer 2023.

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Field Study Site Summary

- **Sites 1 & 2: Third Party Split** with in-floor heat
- **Site 4: Monobloc** with in-floor heat and hydronic coil on air handler
- **Site 3: Monobloc** with in-floor heat, hydronic coil, and domestic hot water (DHW) preheating tank

- Retrofit installations displacing pre-existing electric boilers
- Installed systems include electric resistance auxiliary boilers
  - Aux boiler is downstream of HP: they can operate simultaneously
- Pre-existing thermostats initially left in place
- Primary emitter is pre-existing in-slab concrete floor heat
  - This emitter can deliver majority of heating load at supply temperatures < 110°F
  - Older MN homes' panel radiators are undersized for a drop-in AWHP supply temps

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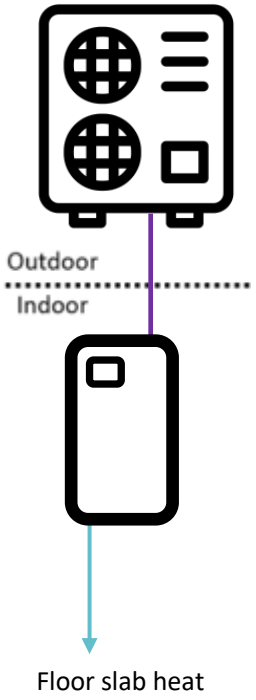
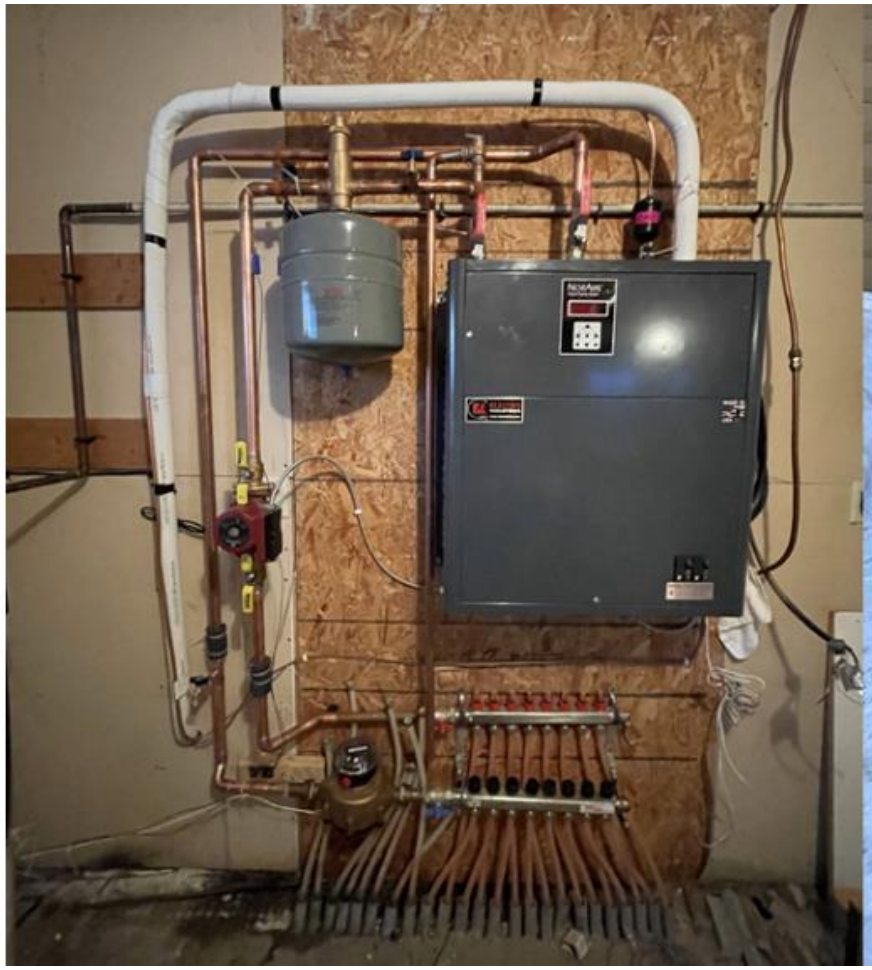
Field Site System Information

Site	City	Home Area (sq. ft.)	Stories	AWHP Model(s)	Emitters	Auxiliary Heat
1	Foley	3,200	1	NorAire EBH-5-020 and 5-ton Bosch BOVA ODU	In-floor heat	Electric resistance auxiliary boiler, woodstove
2	Garfield	2,600	1	NorAire EBH-5-020 and 5-ton Bosch BOVA ODU	In-floor heat	Electric resistance auxiliary boiler, propane fireplace
3	Faribault	2,600	1 + walkout	Enertech Advantage EAV060 with IDU and Turbomax indirect water heater	Lower level: In-floor heat Upper level: central forced AH with hydronic coil DHW: AWHP fed preheater	Electric resistance auxiliary boiler, propane furnace
4	Garfield	4,000	1 + finished basement	Enertech Advantage EAV060 with IDU	Lower level: In-floor heat Upper level: central forced air with hydronic coil	Electric resistance auxiliary boiler, propane furnace, two propane fireplaces

Third Party Split AWHP

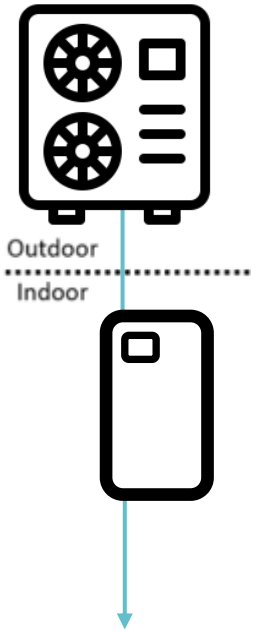


Indoor Unit



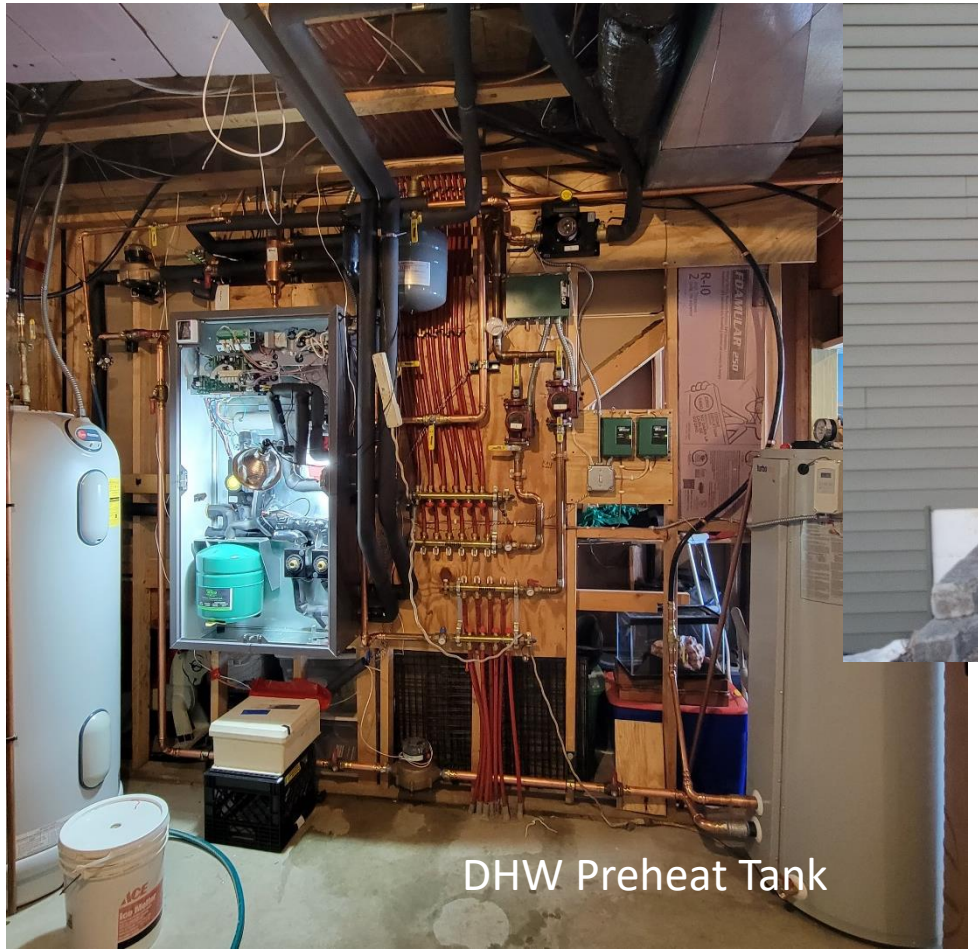
Outdoor Unit

Monobloc AWHP



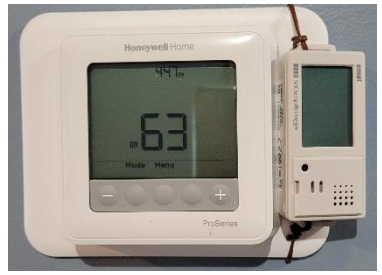
Floor slab heat
Hydronic coil + AHU
DHW preheat tank

Indoor Unit



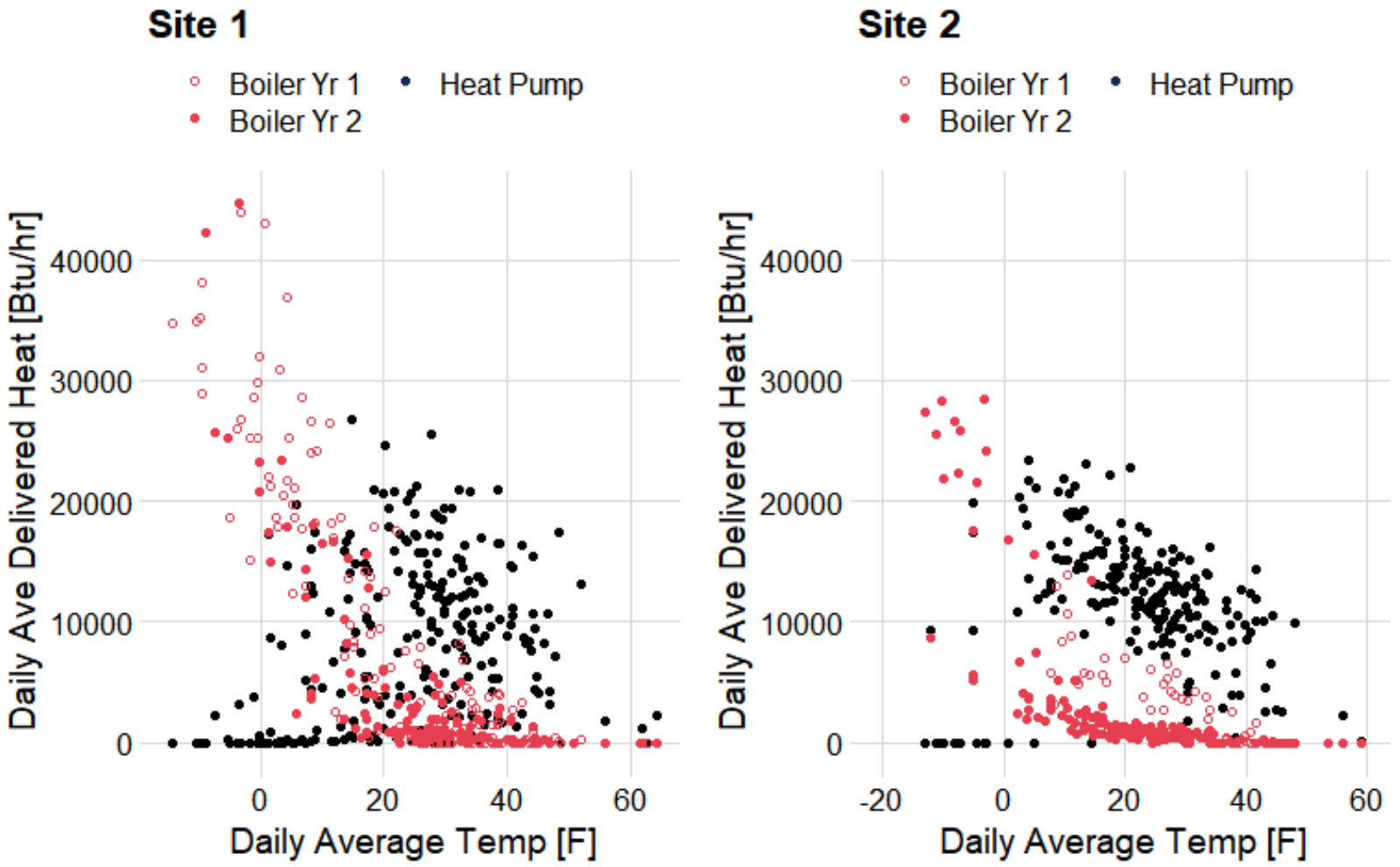
Outdoor Unit

Thermostats



Performance Results

Heat Load – Split Systems, Daily



Hollow circles correspond to winter 1 with no controls adjustments.

Solid circles correspond to winter 2, where controls were adjusted to reduce aux heat usage.

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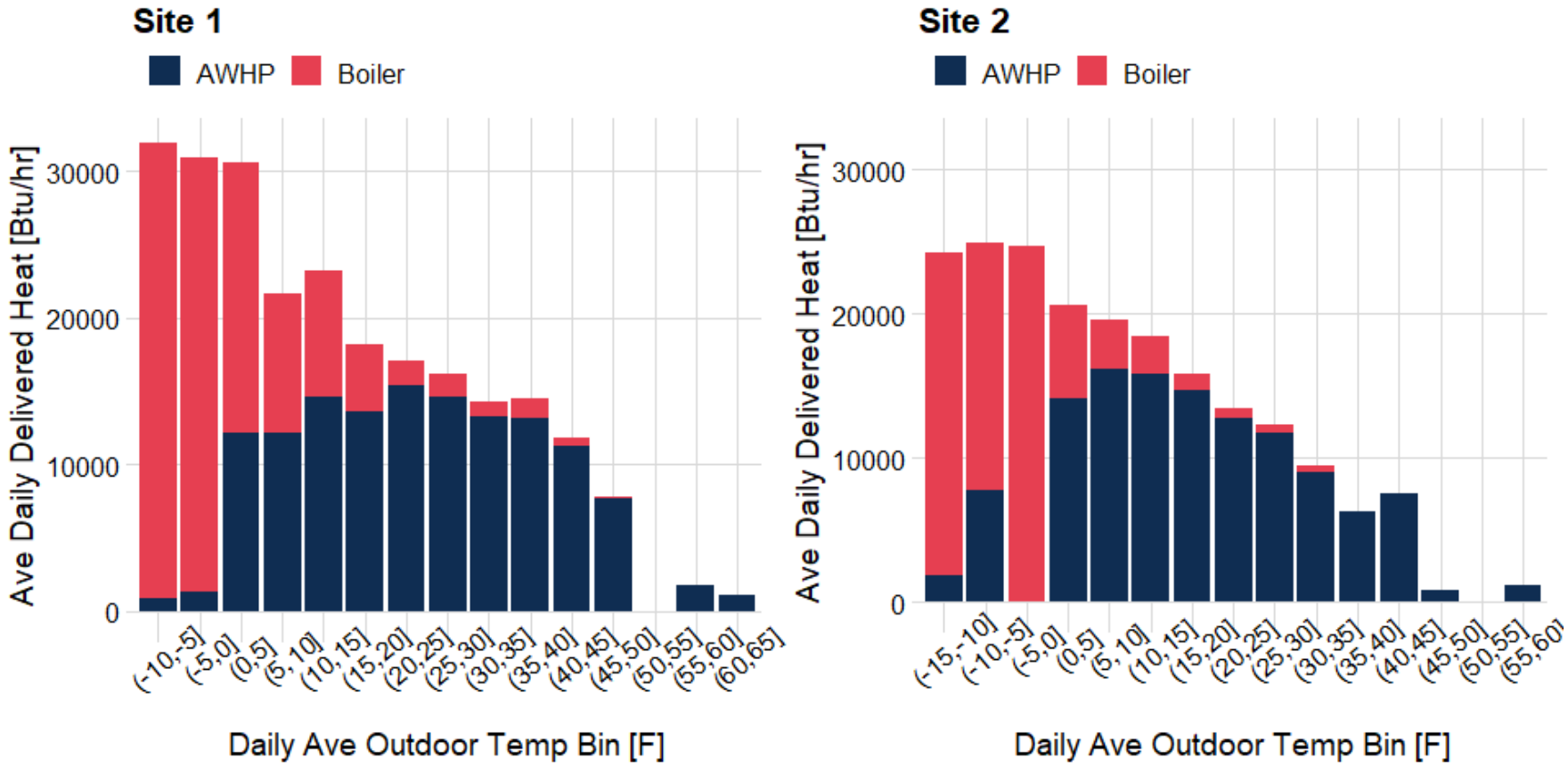
Heat Load – Split Systems, Binned



Binned data shown only for the second winter, after controls adjustments

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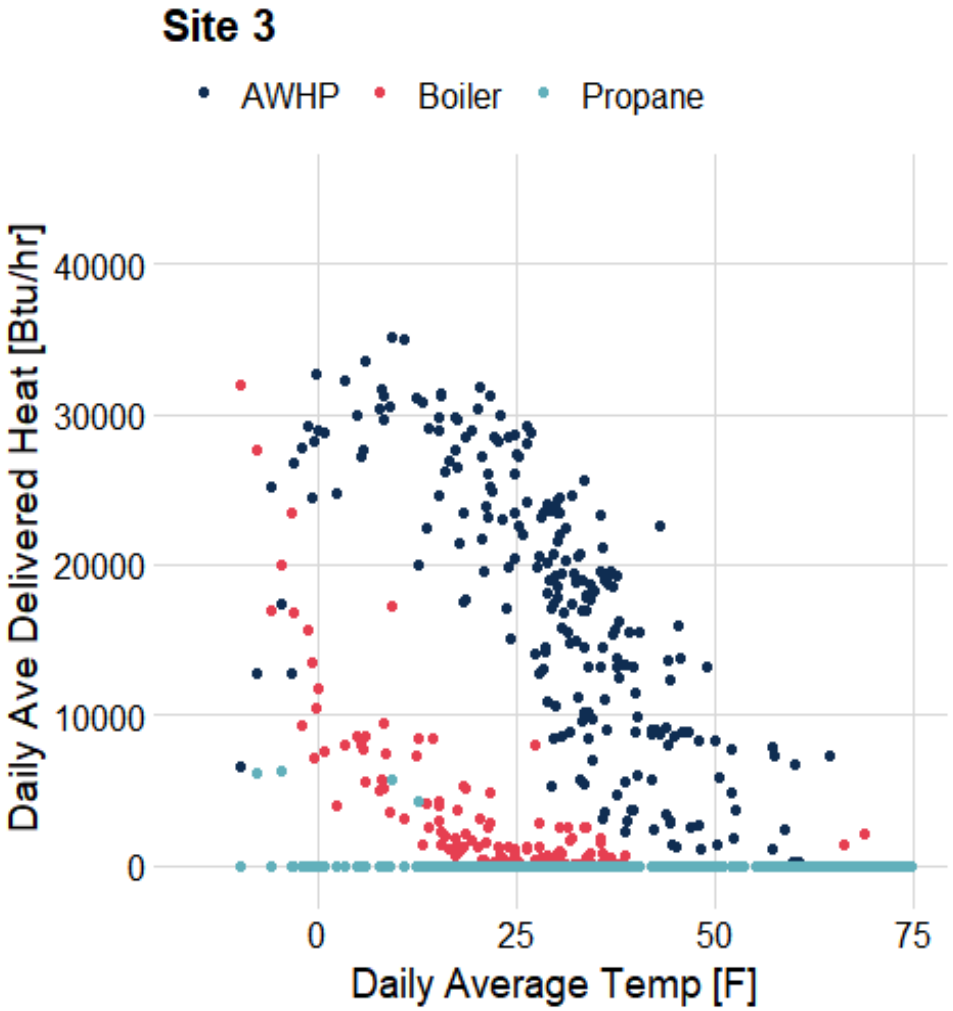
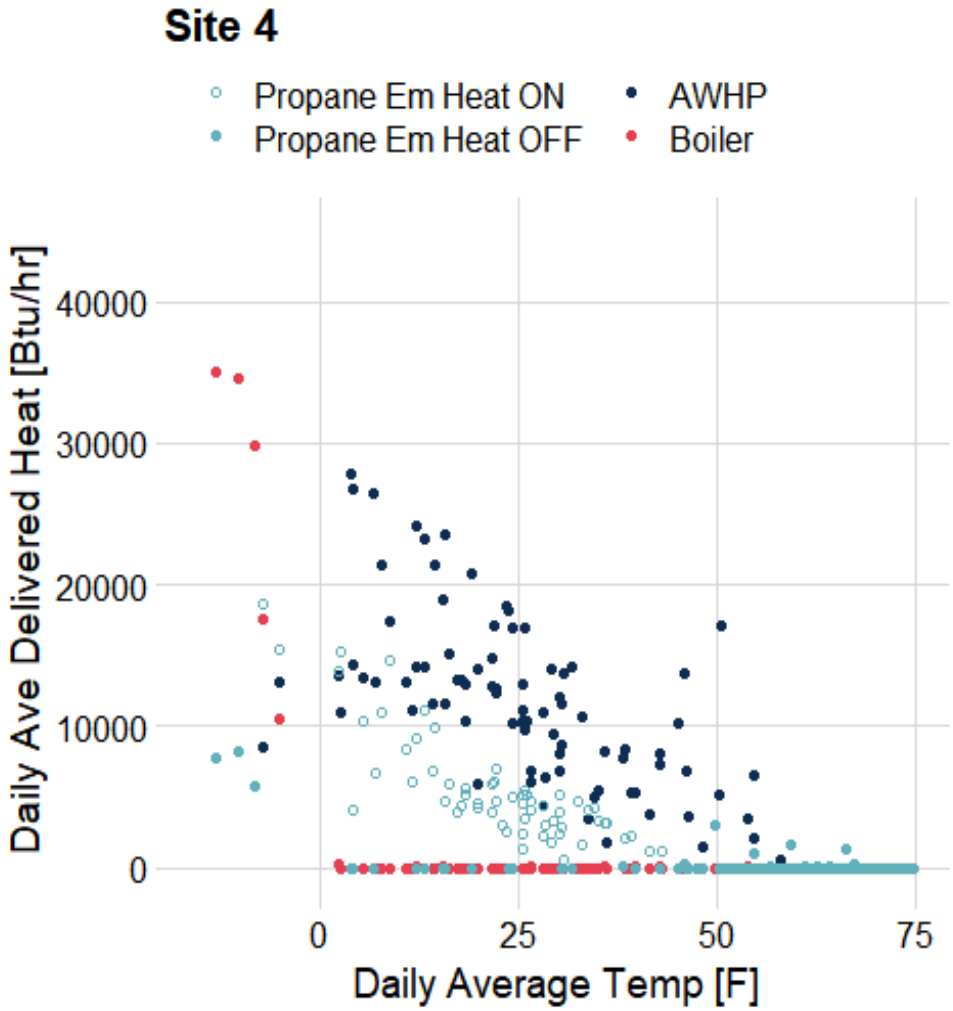
Heat Load – Monobloc Systems, Daily





Hollow circles correspond to thermostat in emergency heat mode.

Solid circles correspond to normal operation.

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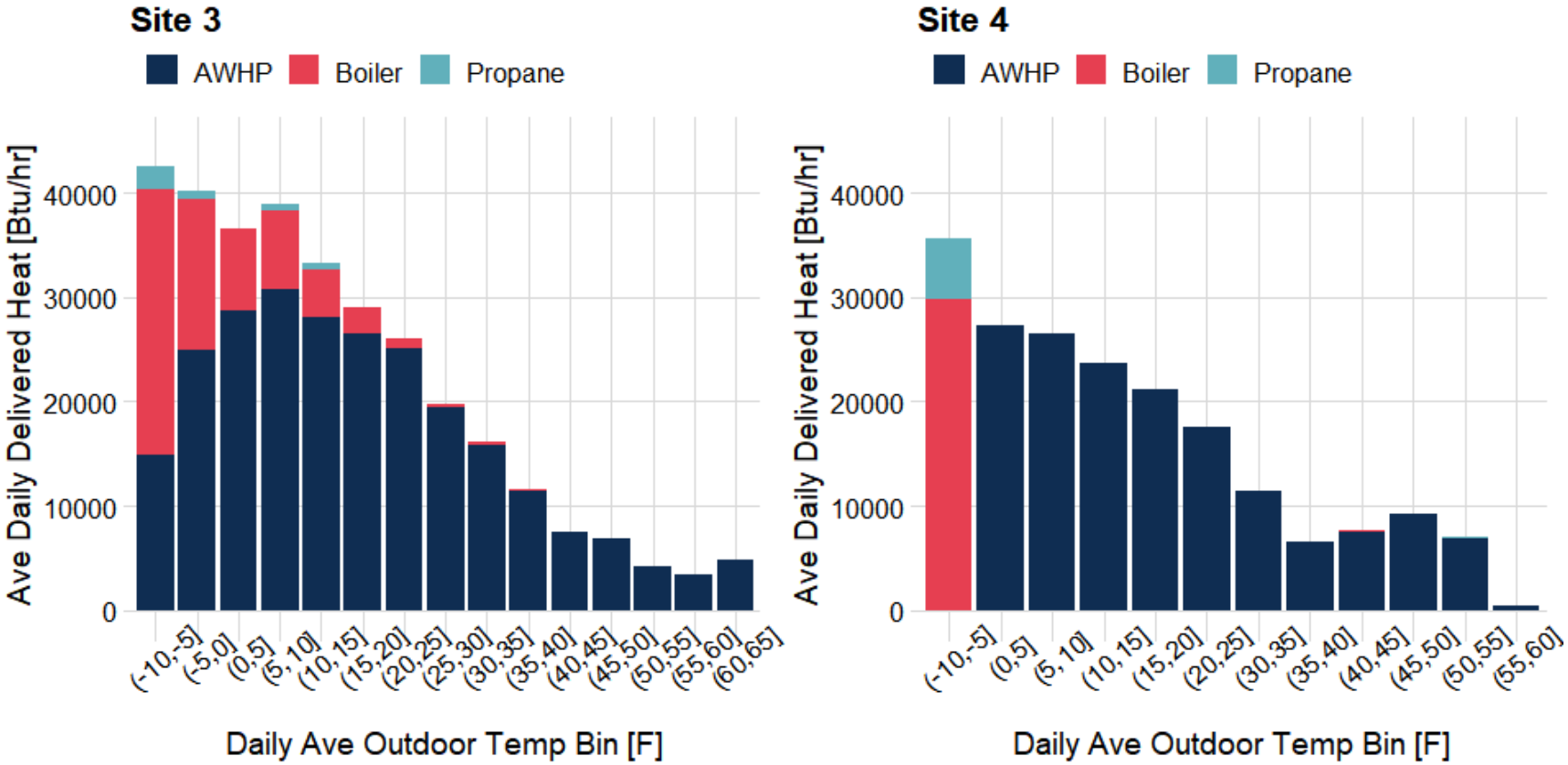
Heat Load – Monobloc Systems, Binned



Binned data shown only for days where the AWHP was fully operational

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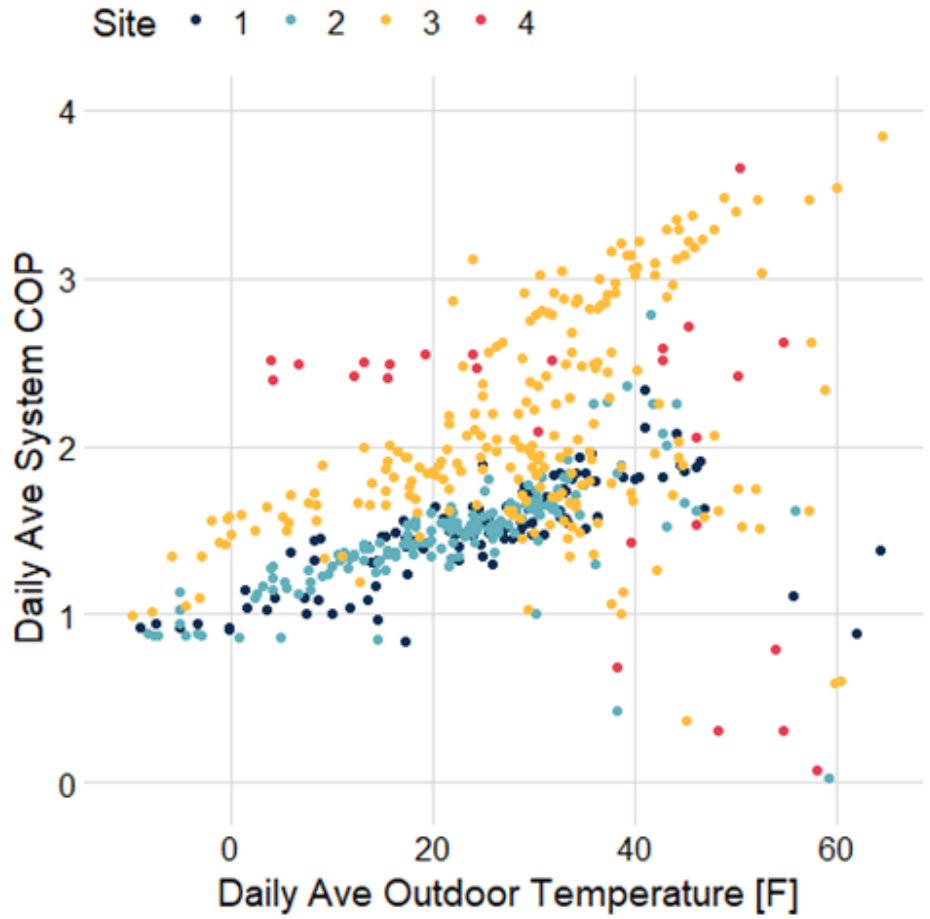
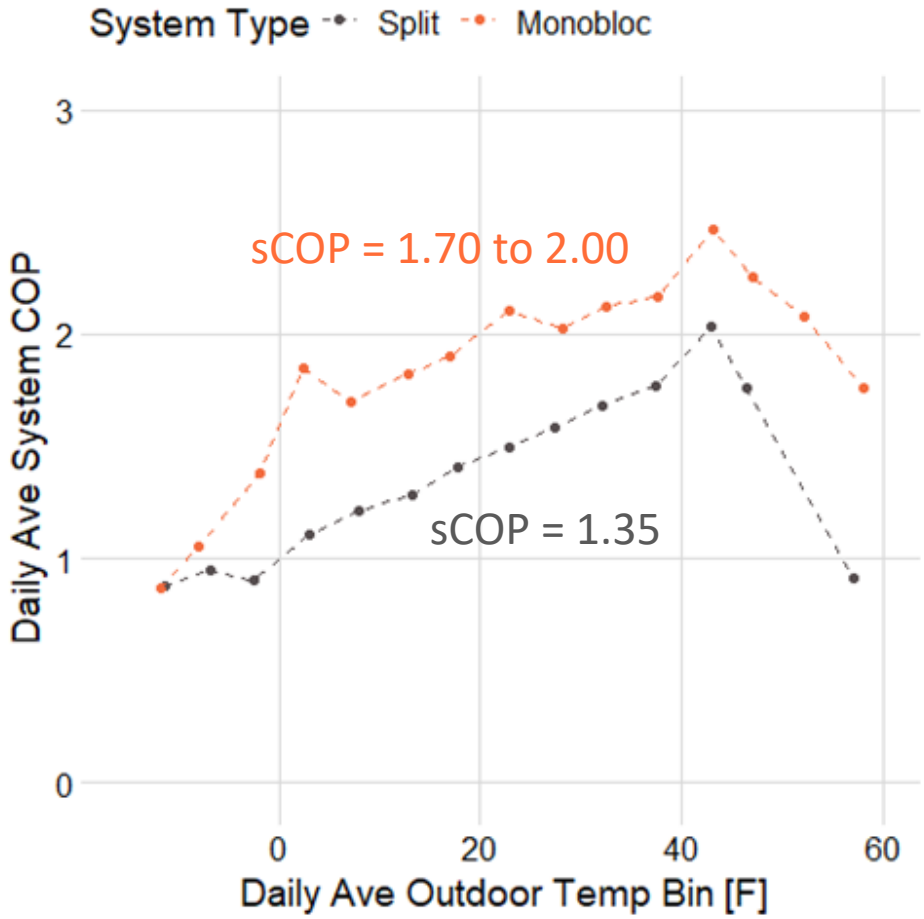
AWHPs Increase System Heating Efficiency





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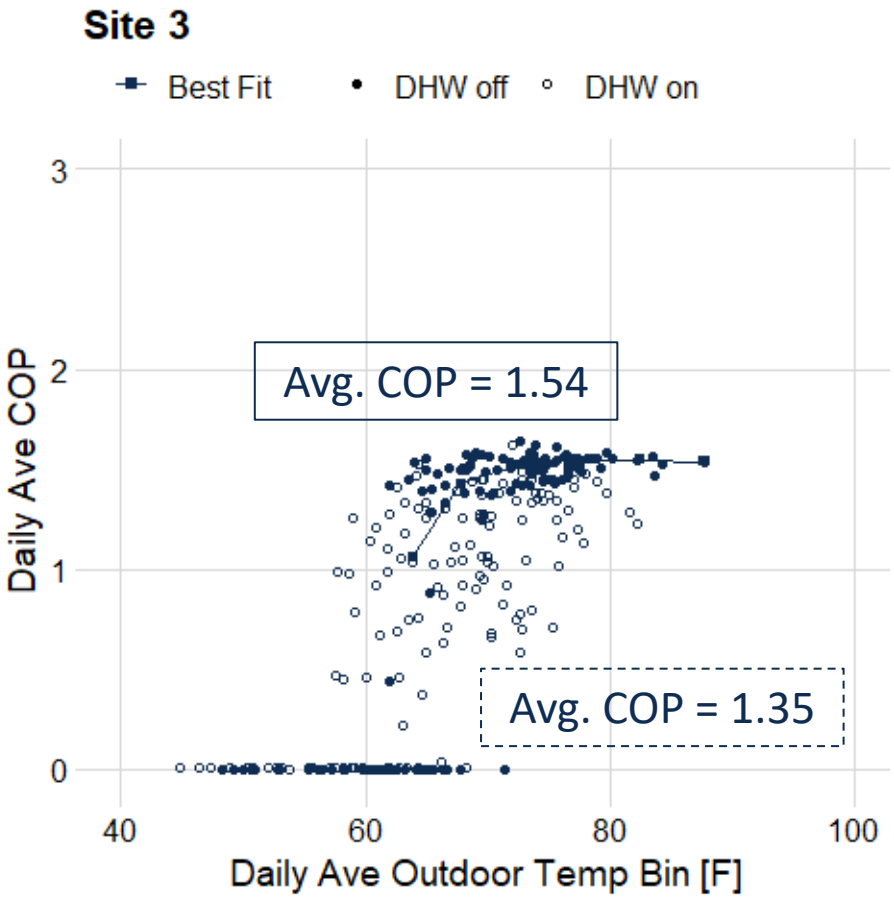
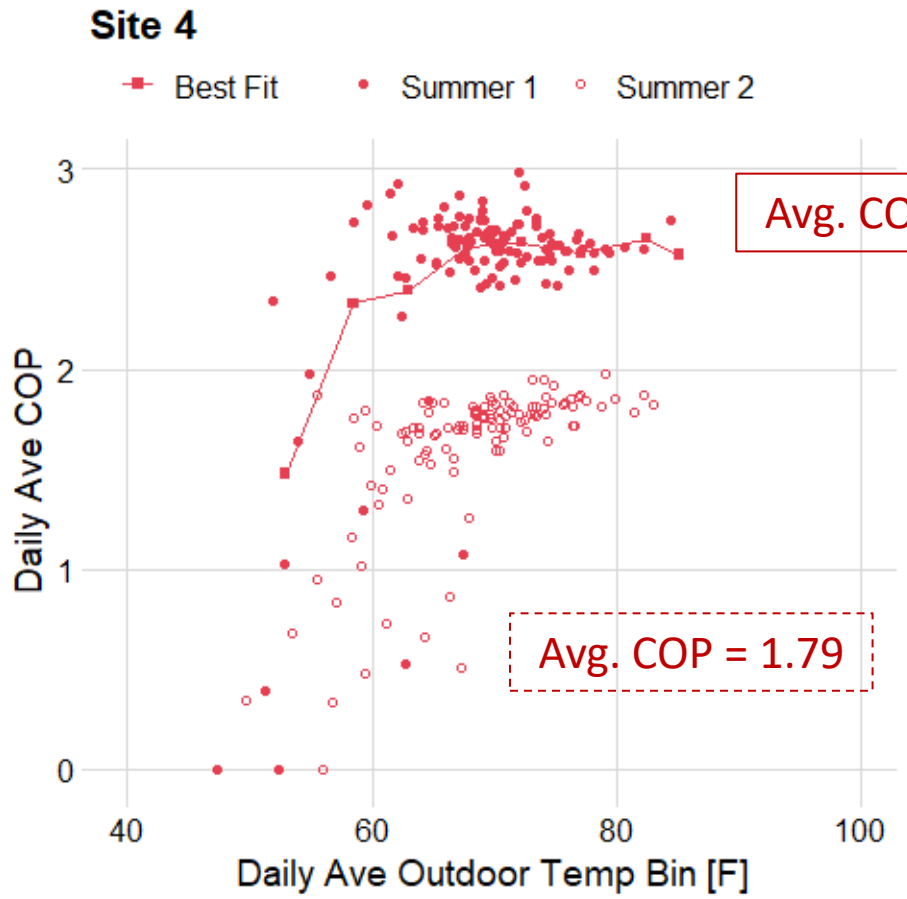
AWHPs May Increase System Cooling Efficiency





COP does not include latent loads (dehumidification)

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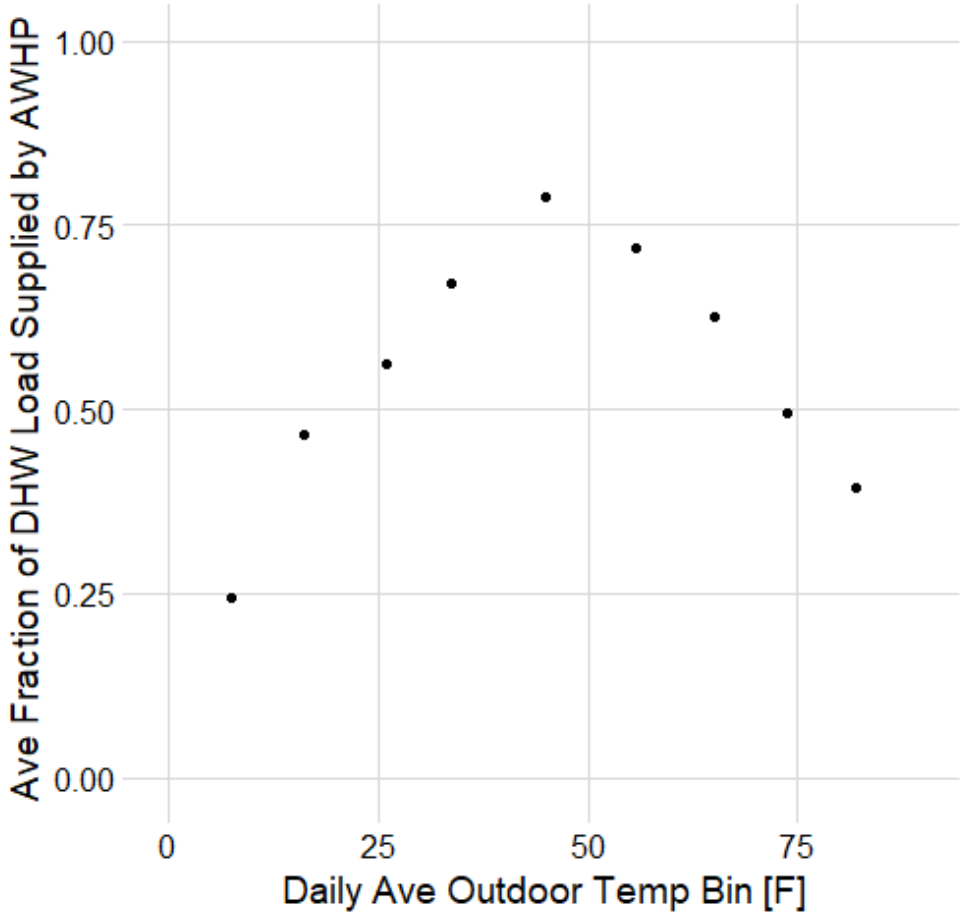
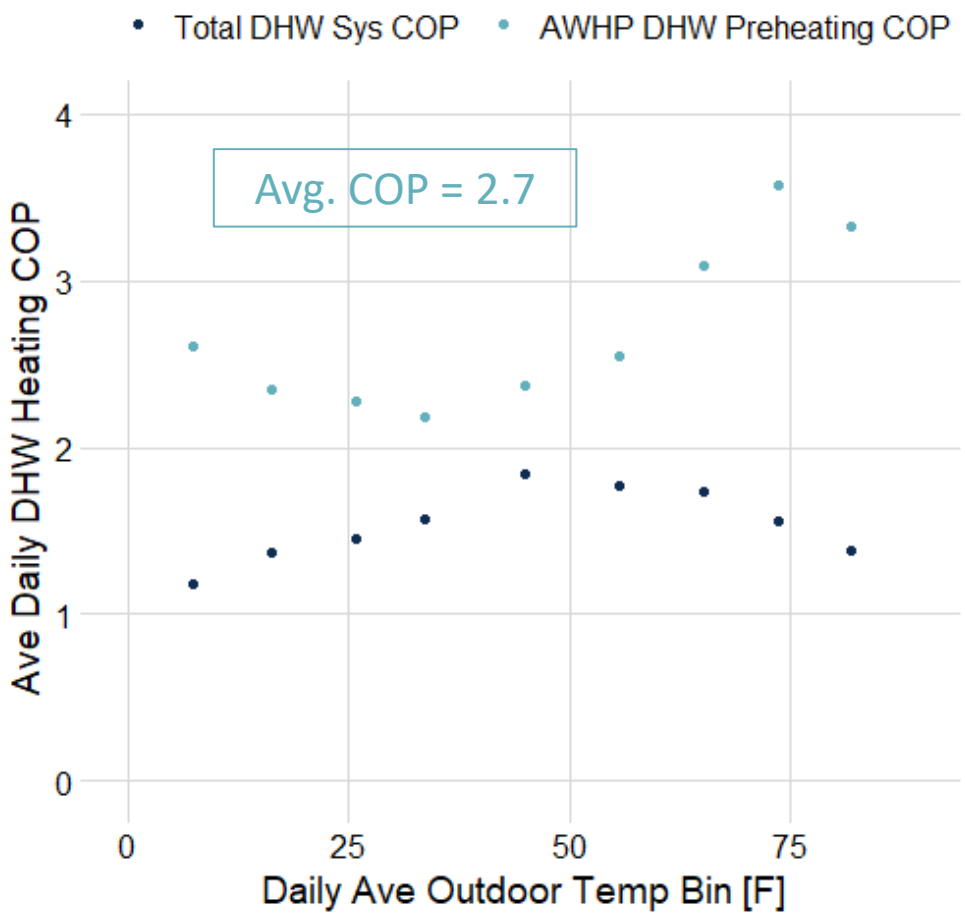
AWHPs Can Integrate Domestic Hot Water





DHW load displacement is a function of AWHP's seasonal excess capacity

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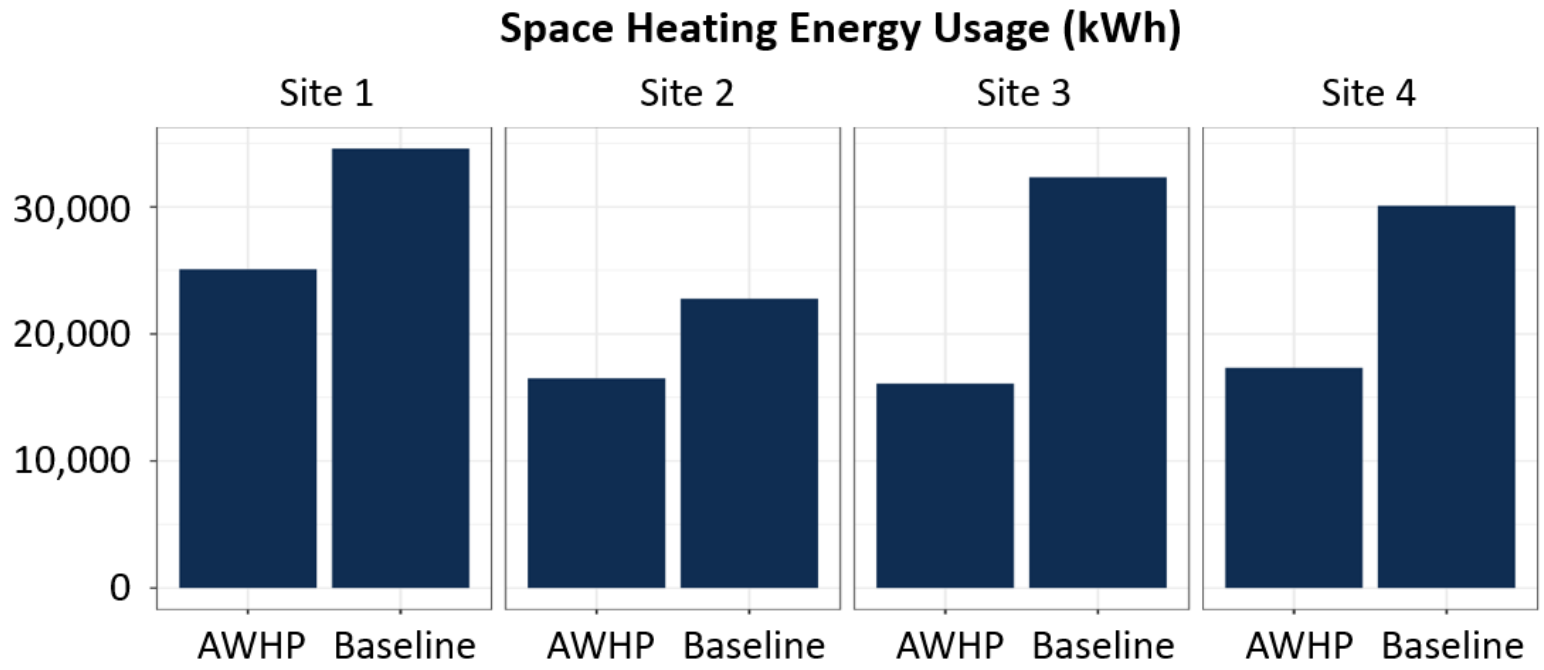
Energy Savings, Costs, and Payback

Energy Savings - Heating



- Energy used for space heating decreases by 27 to 50% and ranged between 16,100 and 25,100 kWh/yr
- The higher specification Enertech AWHP at sites 3 and 4 led to considerably more energy savings than the NorAire unit at sites 1 and 2

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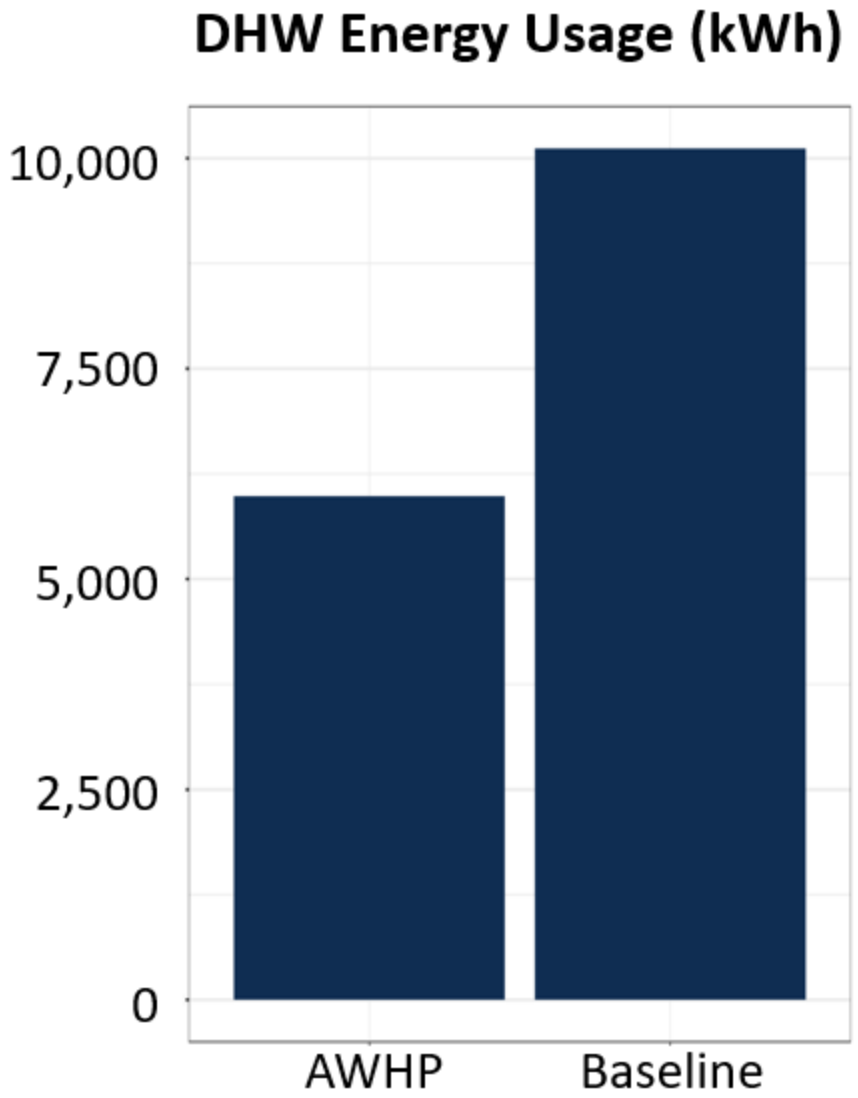
Energy Savings – DHW

- The monobloc AWHP at site 3 functioned as a DHW pre-heater when not supplying space heating or cooling.
- The AWHP displaced just under 30% of the domestic hot water load of 9,500 kWh to yield an annual savings of 4,100 kWh or 40%.
- This site has very large DHW loads, double that of the typical home.



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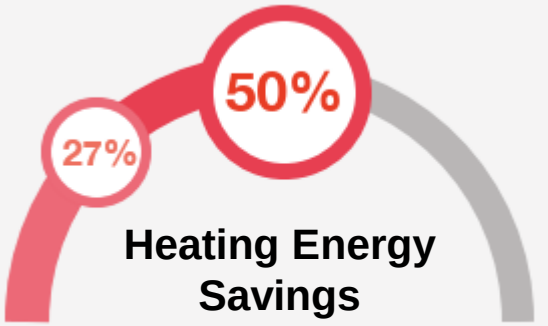
Costs and Payback

Site	AWHP System	Total Install Costs	Incremental Cost ($)	Cost Savings ($/yr)	Payback Period (yr)
1	NorAire 5-Ton Third-Party Split w/ Bosch BOVA ODU	$18,784	$12,784	$571	**22**
2	NorAire 5-Ton Third-Party Split w/ Bosch BOVA ODU	$14,945	$8,945	$453	**20**
3	Enertech 5-Ton Monobloc	$41,160	$28,760	$1,450	**20**
4	Enertech 5-Ton Monobloc	$39,985	$28,585	$995	**29**

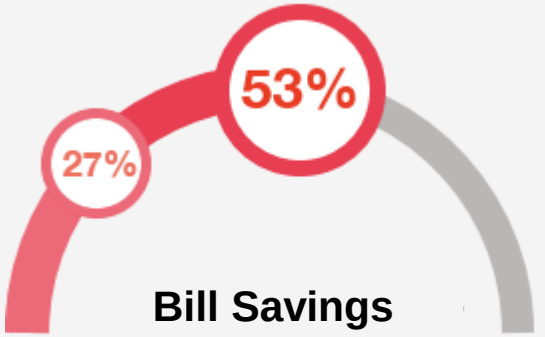
Conclusions, Barriers, and Opportunities

Key Takeaways

- Air-to-water heat pumps are air source heat pumps.
- They are available now and can yield significant energy and bill savings supplying space heating and domestic hot water heating.
- Incremental costs are expected to decrease as the product class matures.
- Similarly, systems will continue to be improved and optimized over time.



Compared to electric resistance unit



Compared to electric resistance or propane unit

Barriers & Opportunities

- High-temperature emitters like cast iron radiators and older baseboard units may struggle to supply sufficient heating capacity.
- Like with any new technology, there exist significant market barriers.
- The flexibility of AWHP systems can add complexity compared to traditional ASHP installations.
- The largest opportunity is in retrofits and new homes featuring low-temperature emitters.

Recommendations

- AWHPs should be treated like other ASHPs and similar program design strategies for overcoming barriers should be replicated for AWHPs.
- Stakeholders should advocate for standardized ratings
- Existing qualified product lists can be used for existing ASHP programs
- AWHPs should be promoted where cold climate ASHPs are beneficial but impractical due to hydronic distribution.

Future Work

- Workforce development, program development, and standardization
- Performance evaluation with other emitters
- Controls optimization
- Improving cooling performance
- Simplifying system design
- Thermal energy storage
- Retrofits with high-temperature hydronic systems

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Questions?

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Send us your questions using the Q&A panel

CARD Project Result Dissemination

- Reports, webinars, fact Sheets, guidelines & tools available online under “Resources”
- Website is currently under construction
- Final webinar recording and report typically available within a month

https://mn.gov/commerce/energy/industry-government/cip/applied-research-development/

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- **Feb 20, 2024: LHB - Field Study of Phase Change Material (PCM) Use For Passive Thermal Regulation**

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