Welcome

Conservation Applied Research & Development (CARD) Webinar

October 5, 2017

Cold Climate Air Source Heat Pump Field Study

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Webinar Basics

Image: Nick Youngson http://www.picserver.org/w/webinar.html

- Attendees in listen-only mode
- Type your questions into Question Box
- Questions addressed at end
- Webinar recorded & archived online
- Handout: webinar slide deck

Minnesota Applied Research & Development Fund

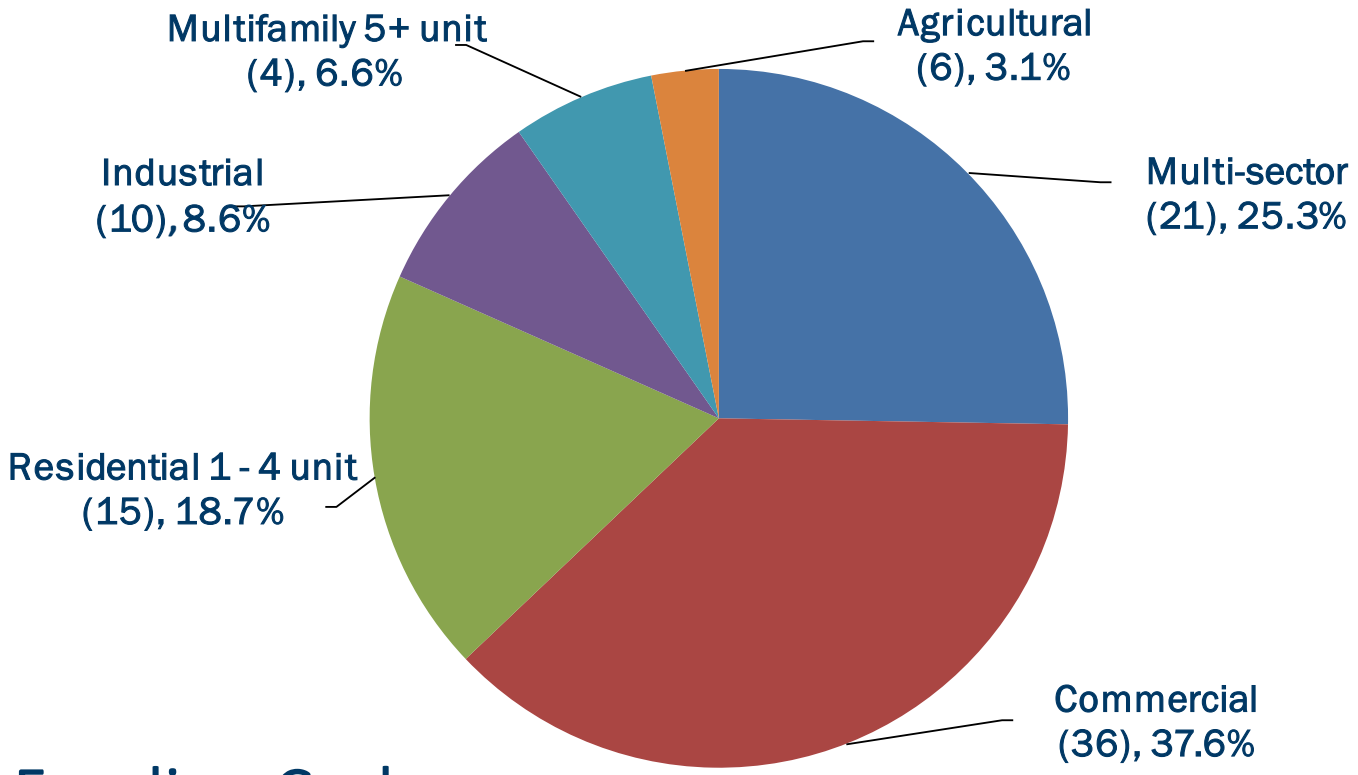
- **Purpose to help Minnesota utilities achieve 1.5% energy savings goal by:**
  - ***Identifying new technologies or strategies to maximize energy savings;***
  - ***Improving effectiveness of energy conservation programs;***
  - ***Documenting CO_2 reductions from energy conservation programs.***

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

- **Utility may reach its energy savings goal**
  - **Directly through its Conservation Improvement Program (CIP)**
  - **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 mid-FY2017



- 8 Funding Cycles
- Nearly 380 proposals
- 92 projects funded

Field Assessment of Cold-Climate Air-Source Heat Pumps

October 2017

Ben Schoenbauer, Senior Research Engineer

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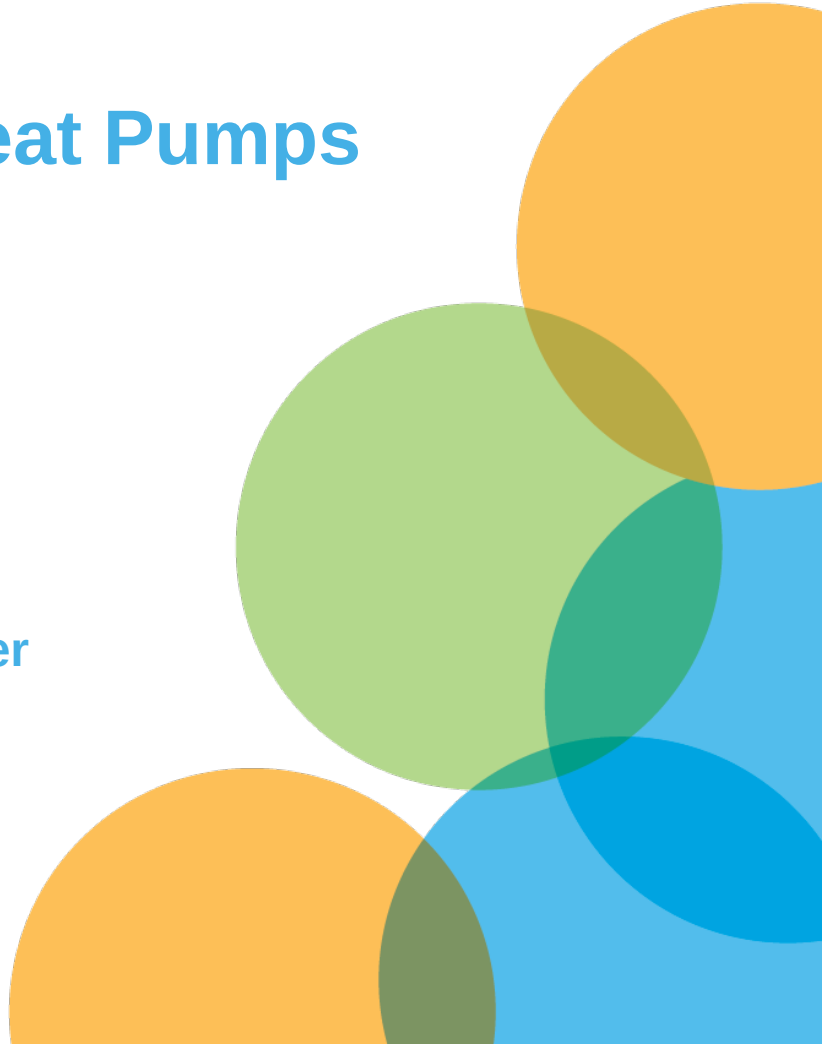

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Discover + Deploy

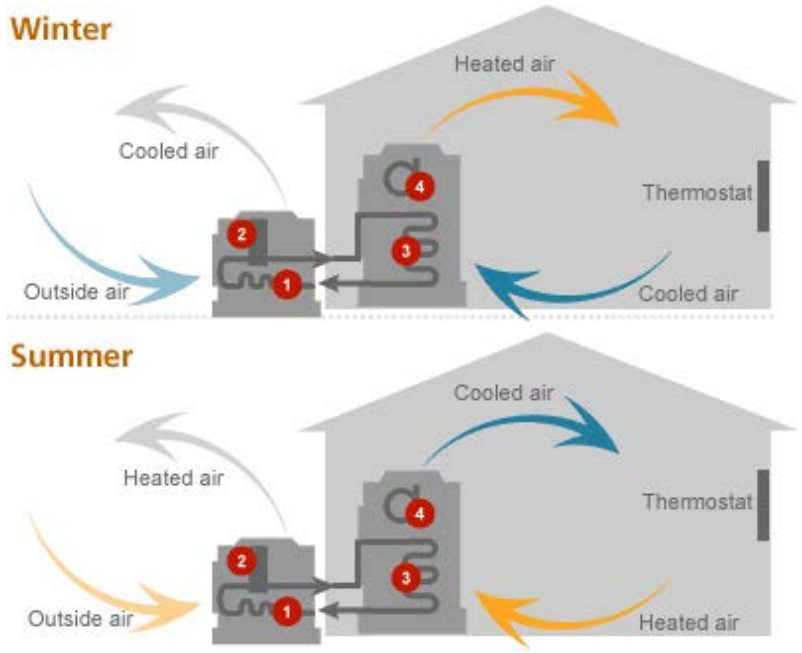
the most effective solutions for a healthy, low-carbon economy

Agenda

- Cold Climate Air Source Heat Pump
  - Technology Advancement
  - Opportunity
  - Installation and operation
  - Results
  - Conclusions

Cold Climate Air-Source Heat Pump?

- An ASHP uses a refrigerant system involving a compressor, condenser, and evaporator to absorb heat at one place and release it at another.
- Delivery of both heating and cooling via forced air distribution
- New generation systems can operate as low as -13 °F
- ASHPs have the potential to deliver energy and peak saving as well as reduce reliance on delivered fuels.



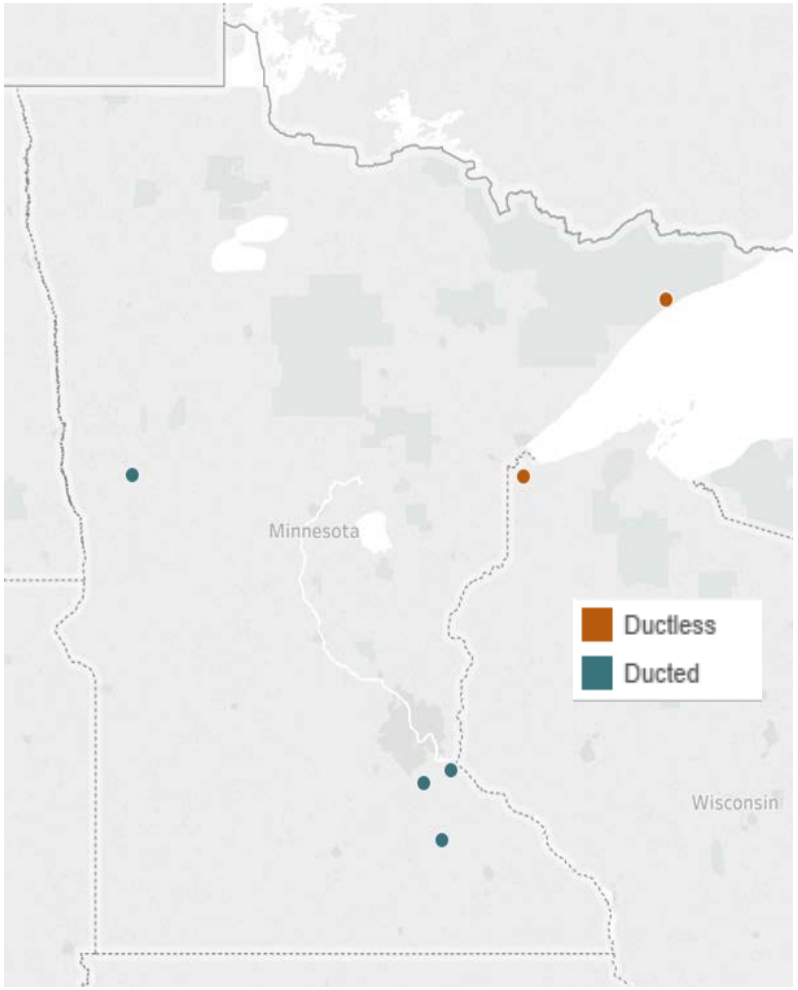
Opportunity

- Winter of 2013/2014 saw delivered fuel shortages in MN
  - Delivered fuel expensive or unavailable
  - Compensation with electric resistance space heaters

- Market:
  - Delivered fuel are the primary space heating fuel for more than 40% of homes in MN, IA, SD, ND (RECS, 2009)
  - Over 25% of Midwest homes rely on fuels other than natural gas for space heating (RECS, 2009)
  - Over 47% of homes in the US rely on fuels other than natural gas for space heating (RECS, 2009)

Study Overview

- Field Study
  - 6 ccASHP in a variety of MN residences
    - 4 ducted whole house system
    - 2 ductless mini-split systems
  - Monitor installed field performance of ASHP & backup
- Incorporate into Conservation Improvement Program (CIP)
- Climate zones 6 & 7



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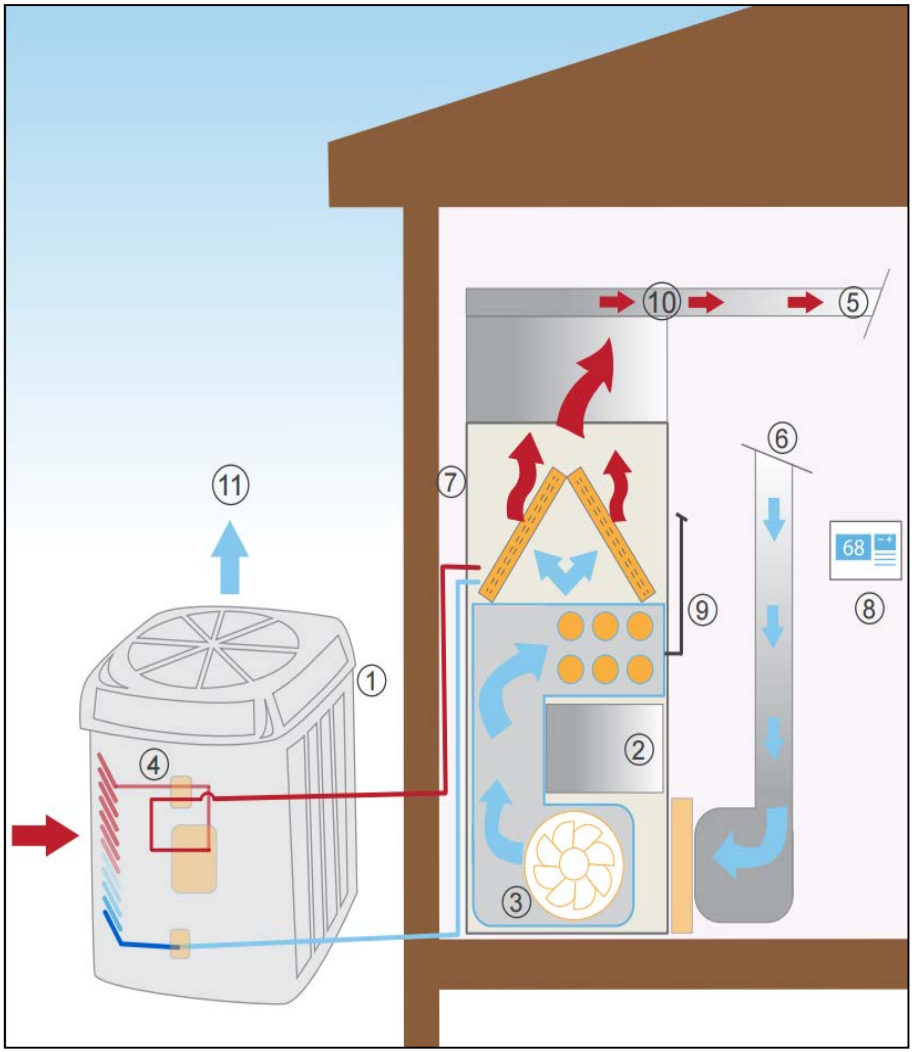
Instrumentation

Power Measurements:
1) Outdoor unit
2) Indoor unit
3) Indoor fan
4) Reversing valve

Temperatures:
5) Supply Air
6) Return Air
7) Mechanical area ambient
8) Conditioned space

Additional:
9) Back up fuel consumption
10) Delivered air flow
11) NOAA data



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Installation

- Important Issues:
  - Equipment
  - Sizing
  - Operation
  - Integration with back-up systems

Ducted Whole House Installation

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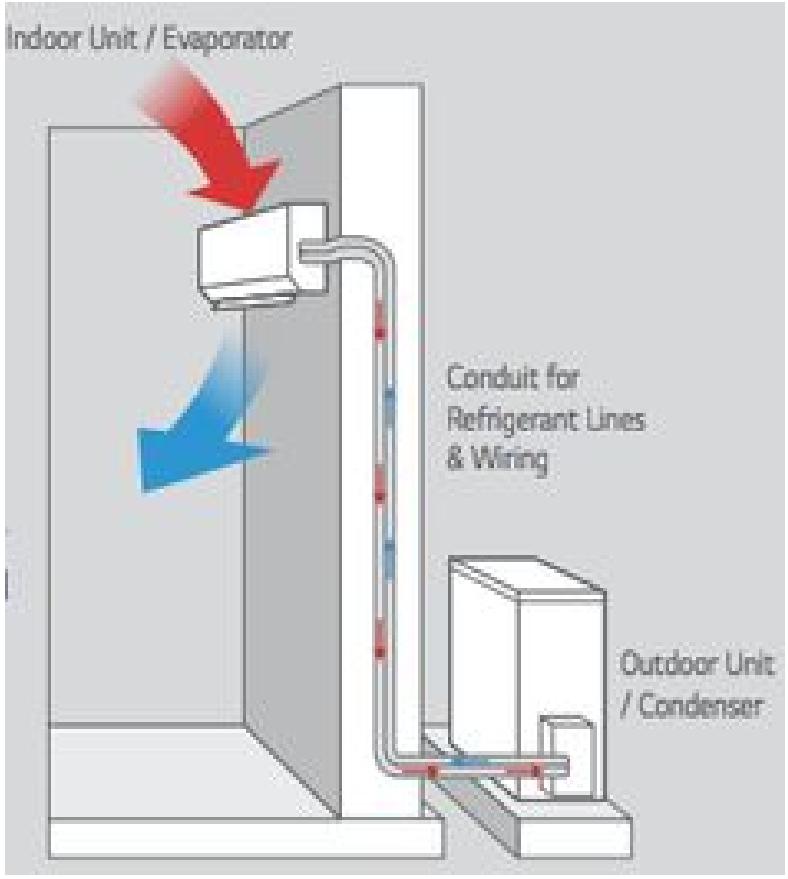
Ductless Heat Pump Installation

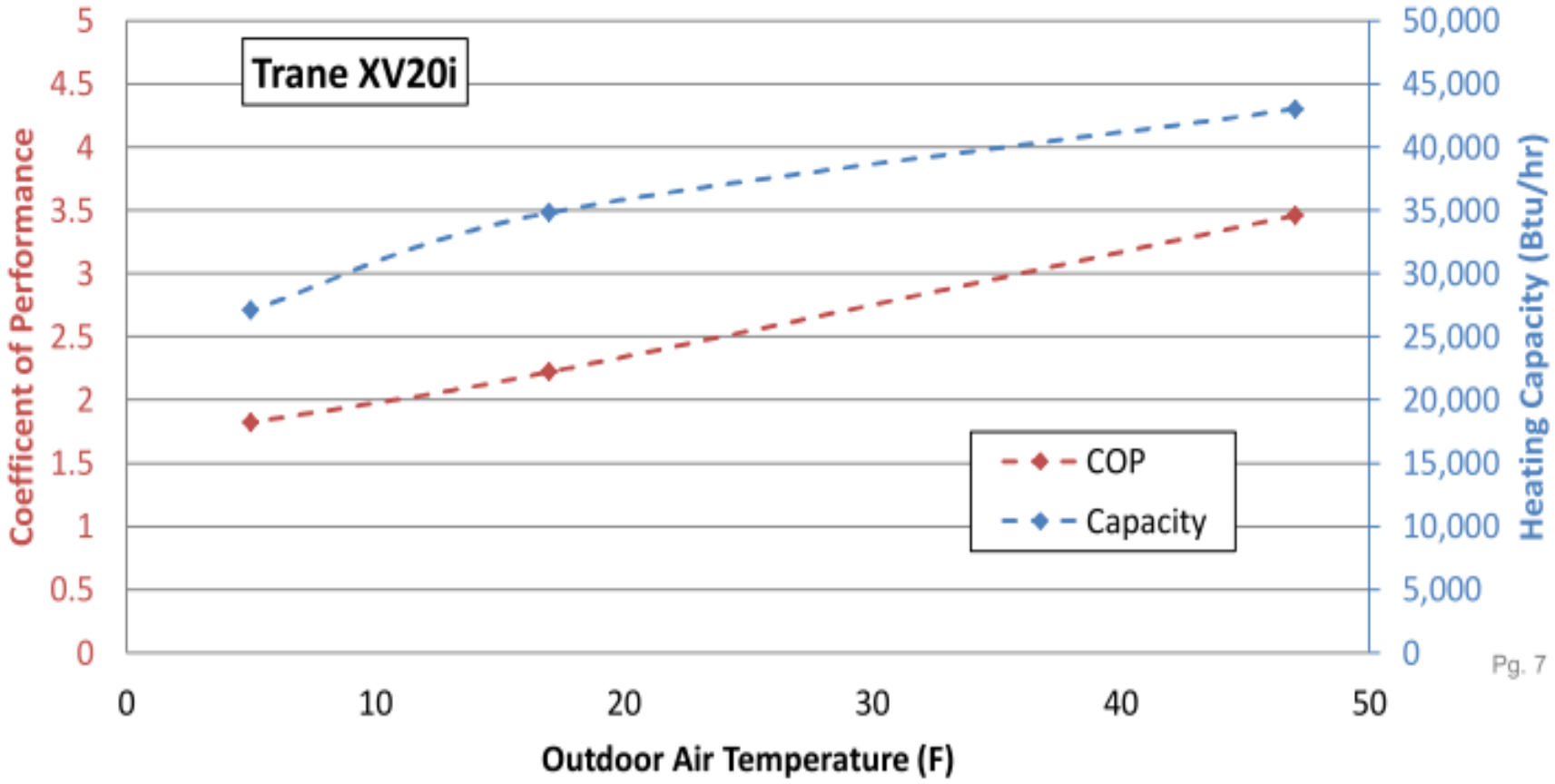


Site Equipment

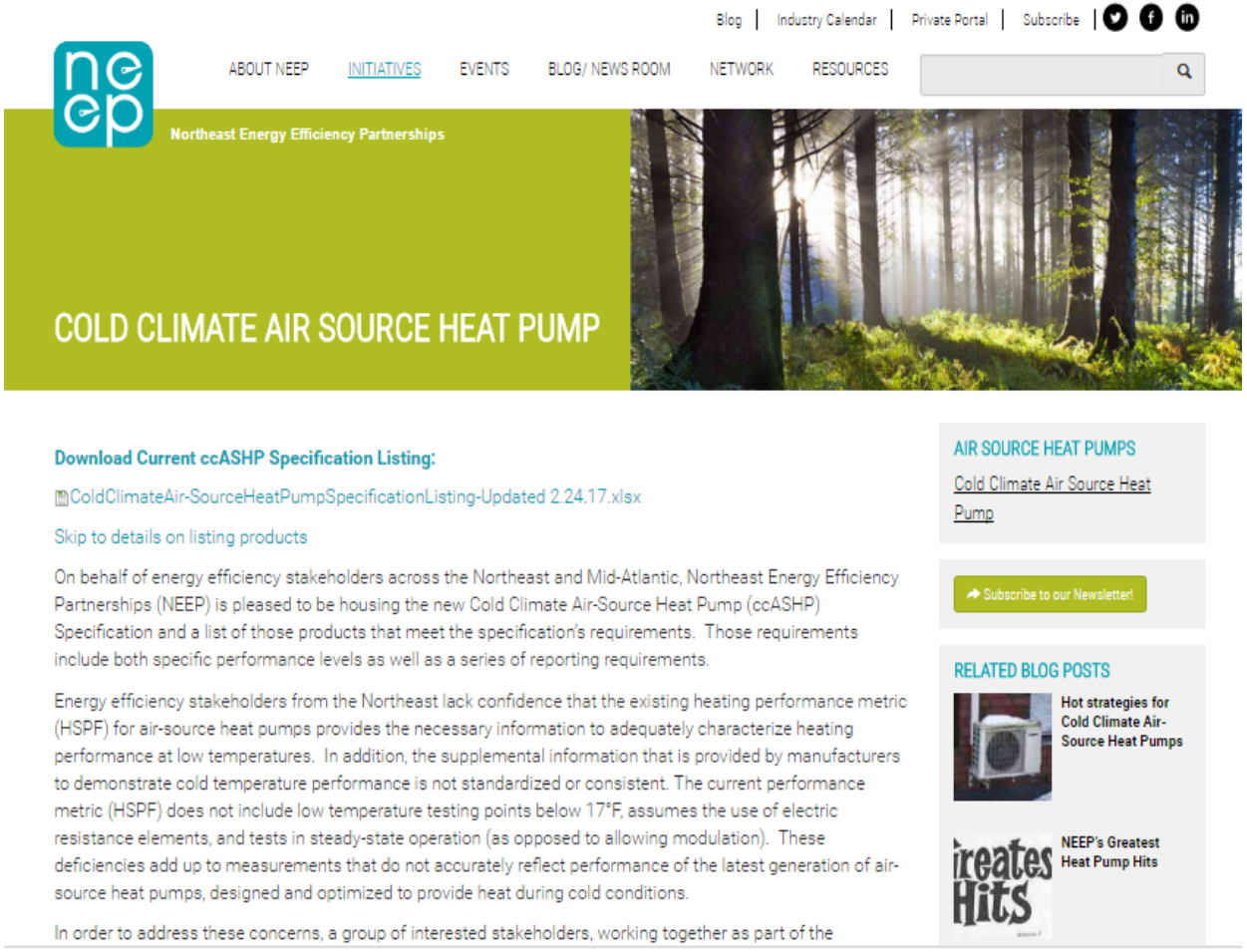
Site Number	ASHP System	ASHP Size	ASHP Type	Backup
1	Carrier Infinity with Greenspeed [25VNA048A003]	4 ton	Ducted	LP Cond. Furnace
2	Bryant Extreme Heat Pump [280ANV048]	4 ton	Ducted	LP Cond. Furnace
3	Carrier Infinity with Greenspeed [25VNA036A003]	3 ton	Ducted	LP 80% Furnace
4	Trane XV20i [4TWV0036A]	3 ton	Ducted	LP Cond. Furnace
5	Mitsibishi Ductless Hyper Heat [MUZ-FH18NAH]	1.5 ton	Ductless	Electric Resistance
6	Mitsibishi Ductless Hyper Heat [MSZ-FH12NA]	1 ton (2 units)	Ductless	Electric Resistance

Whole house ducted systems

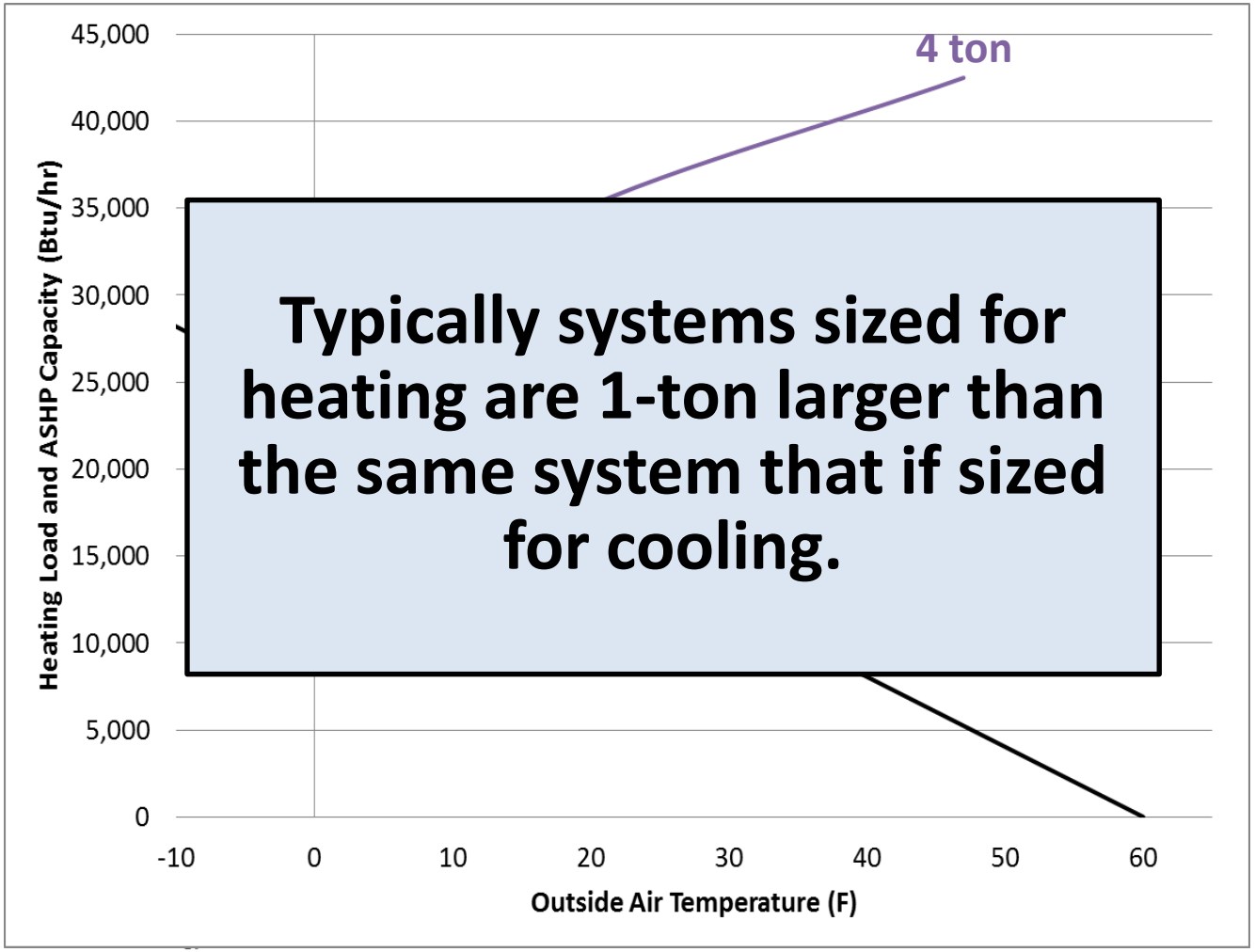
Manufacturer Specified Performance



Cold Climate Specification and Product List



System Design: Sizing for Ducted Systems



The OAT for the systems to switch to back up:

4 ton ~3 F

3 ton ~10 F

2 ton ~19F

Percentage of heating load meet by ASHP:

4 ton ~ 86%,

3 ton ~ 77%

2 ton ~ 60%

*Targeted a maximum change-over temp of 10 F

Operation

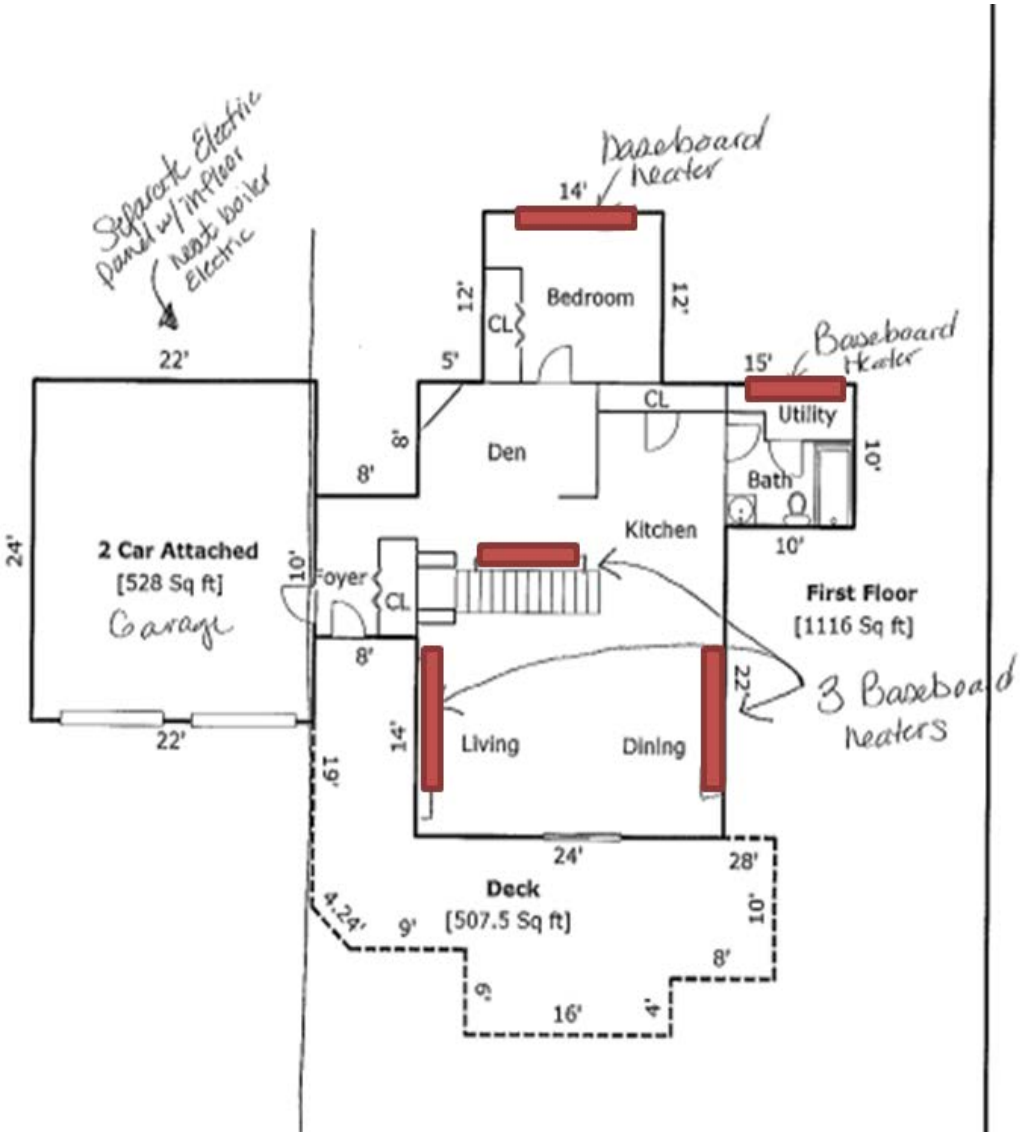
- Switchover set point:
  - Ducted Systems: 10 degrees F
  - Ductless Systems: -13 degrees F
- Controls:
  - Ducted Systems: automated controls to bring up backup
  - Ductless Systems: manual action by homeowner
- Interaction with back-up systems
  - Ducted Systems: Integrated installs with shared controls
  - Ductless Systems: Separate systems

Furnace Integration – Keep or Replace?

- Issues:
  - Air handler requires a multi-stage fan to achieve the full capability of the ccASHPs
  - Furnace and heat pump require integrated controls
- Proposed Solutions:
  - New condensing furnace with control integration
  - New 80% AFUE with multi-stage fan with control integration
  - Retrofit existing system (future?)
  - Plenum electric resistance heater
- Several manufacturers are working on solutions to pair new ASHPs with existing furnaces

Ductless Heat Pumps

Ductless: Install Location



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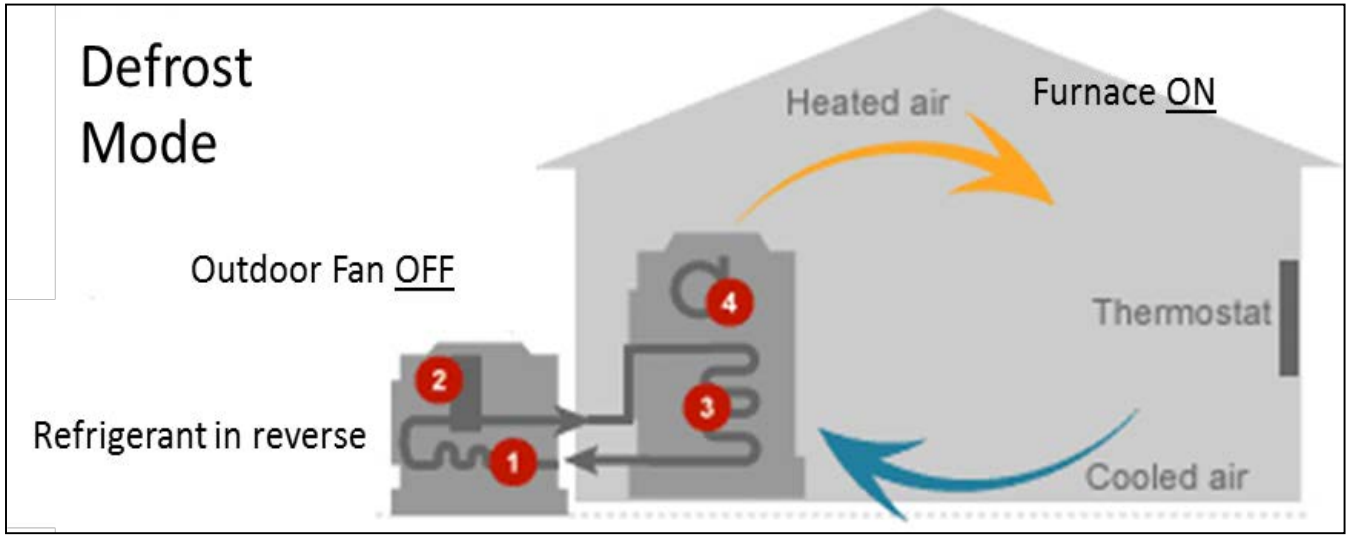
Installation Scenarios

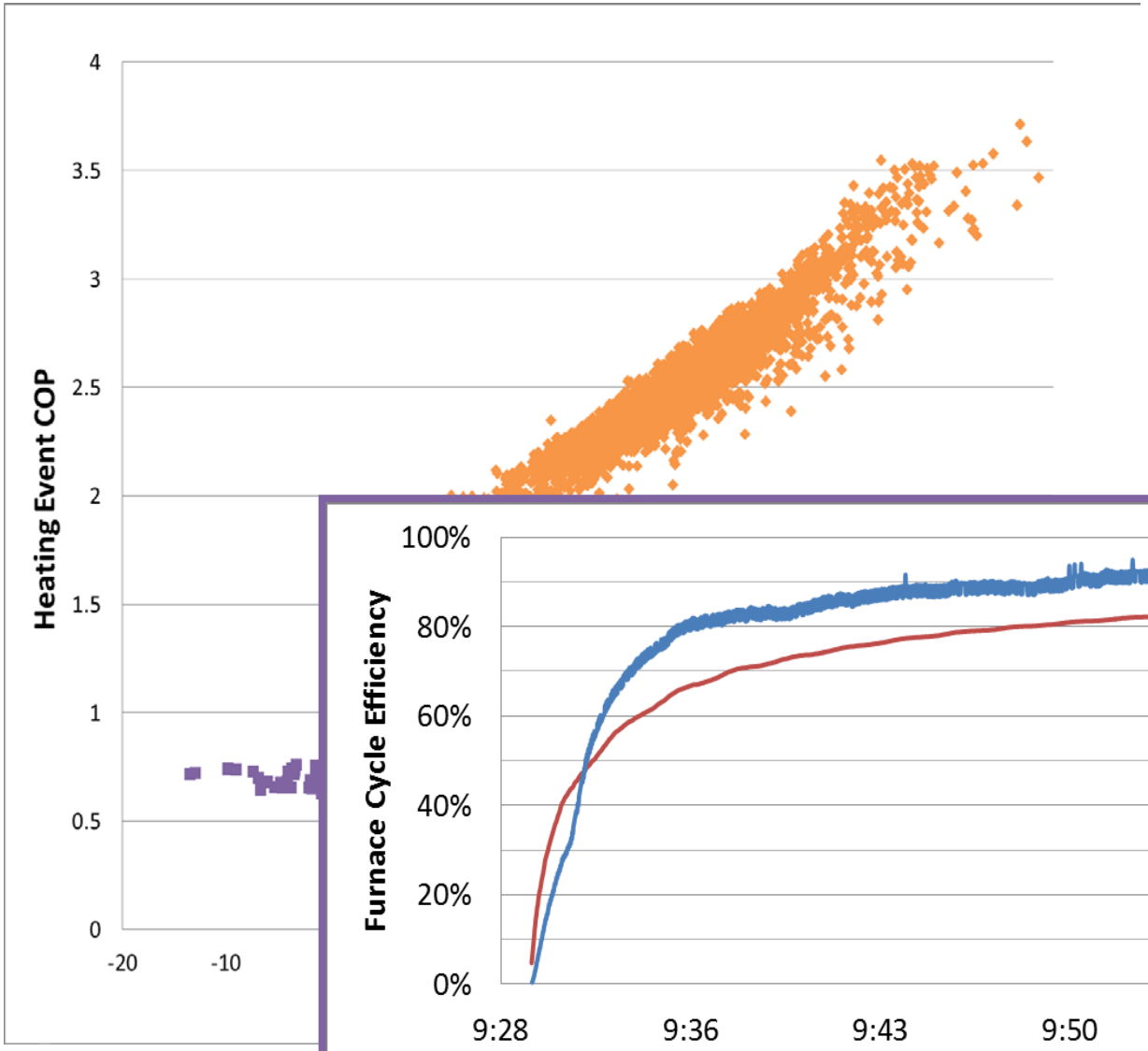
- Home has forced air systems → Ducted Whole House System
  - Does the home have or need air conditioning?
  - Do either furnace or A/C need replacement
- Homes with hydronic → Ductless Mini Split System
  - Does the home have or need air conditioning?
- Homes with electric resistance → Ductless Mini Split System
  - Does the home have or need air conditioning?

Modes of System Operation

- Heating system has 3 modes of operation
  - ASHP heating
  - Back up heating
  - Defrost



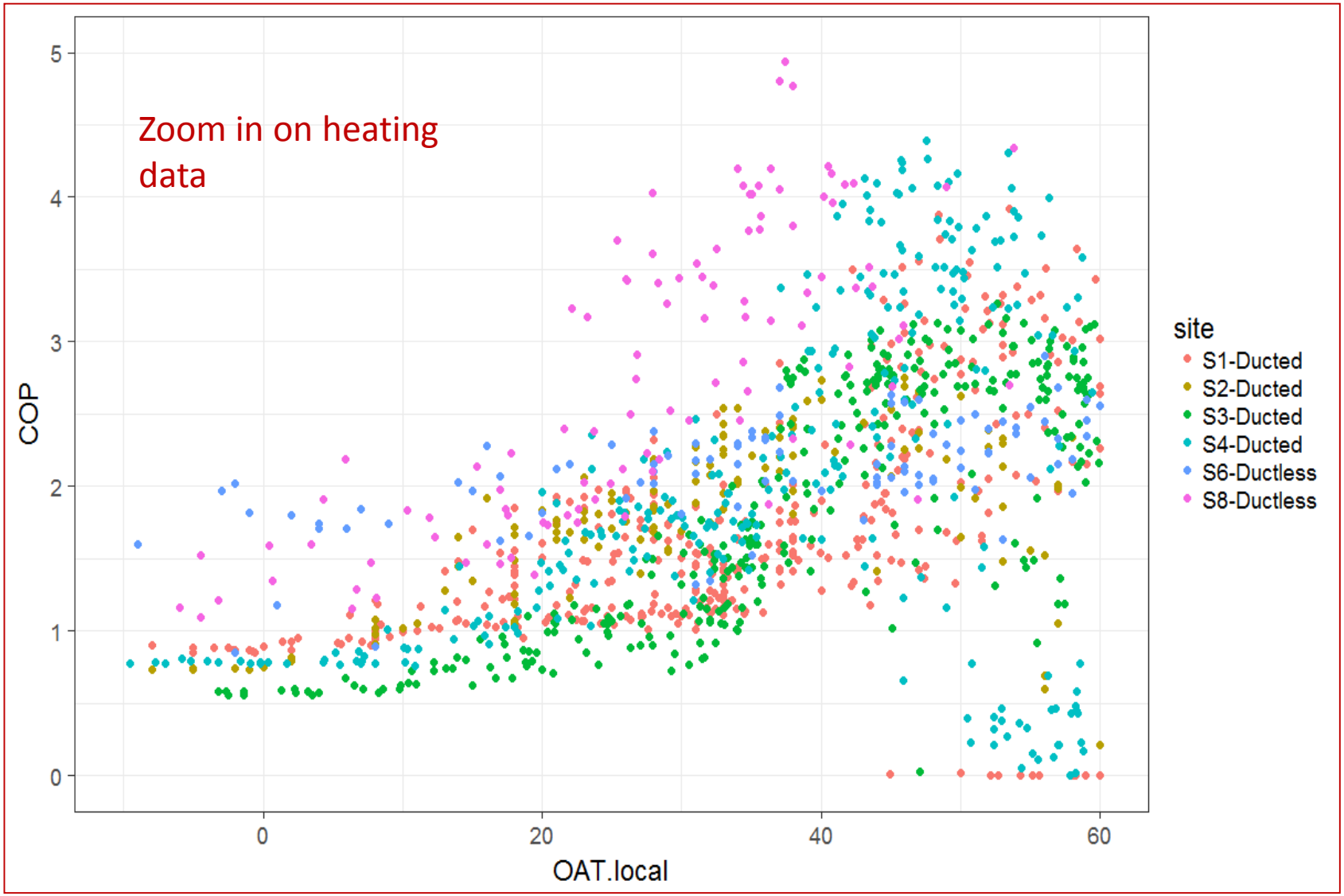
ASHP and Furnace Cycle Efficiency, Site 2



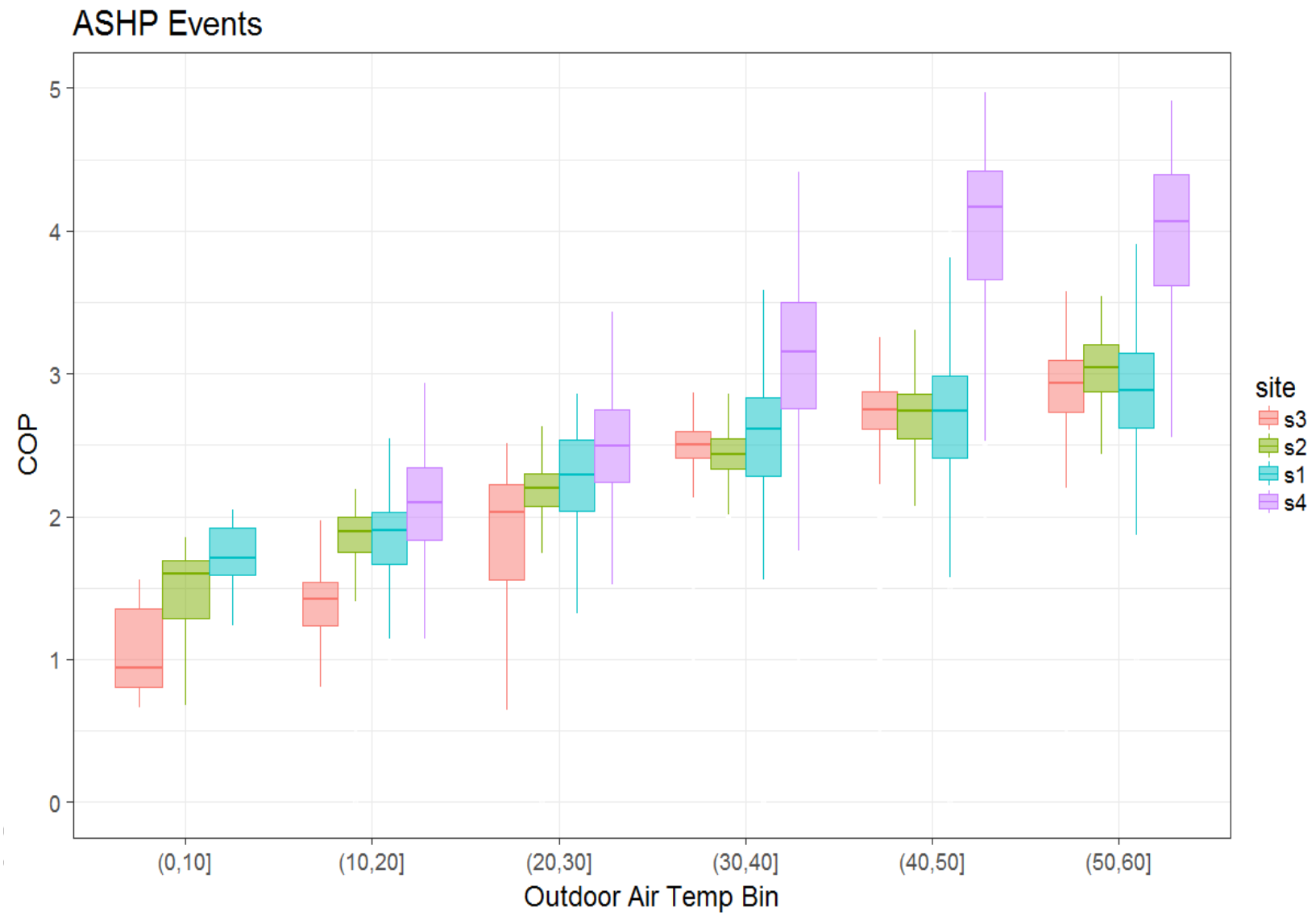
- Without propane:
  - COPs 1.5 to 3.5
- Furnace SS Efficiency
  - 90% +

t 10

System COP vs OAT



ASHP Performance



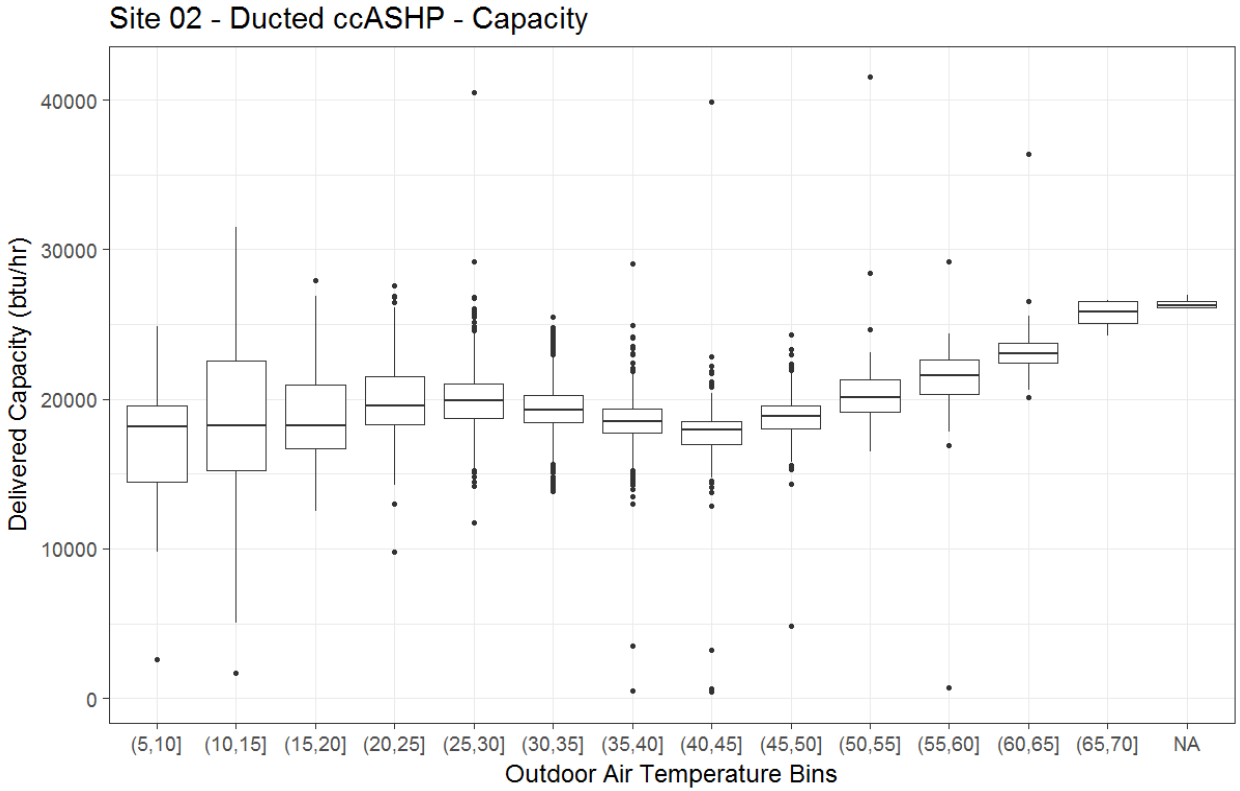
Example: Capacity on a 17 ºF day

At 18:45
OAT = 15 F
House load = 15,300 Btu/hr
ASHP Output = 16,700 Btu/hr
ASHP Sup Temp = 89 F
Airflow = 734 CFM

mode	Active time (seconds)	% of Day
Heating	72248	83.6%
Heating: ASHP only	65991	66.0%
Heating: LP Only	6549	7.6%
Defrost:	8708	10.1%

Cold Temperature Performance of ASHPs

- Ducted ASHPs were capable of delivering heat at outdoor temps from 5 to 10 F
- Ductless systems operated below -13 F.
  - Homeowner in WI has removed several ER baseboards



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Ducted v Ductless

- Heat pump only events have comparable COPs

- Ducted systems
  - have larger capacities than single head ductless
  - have larger airflows

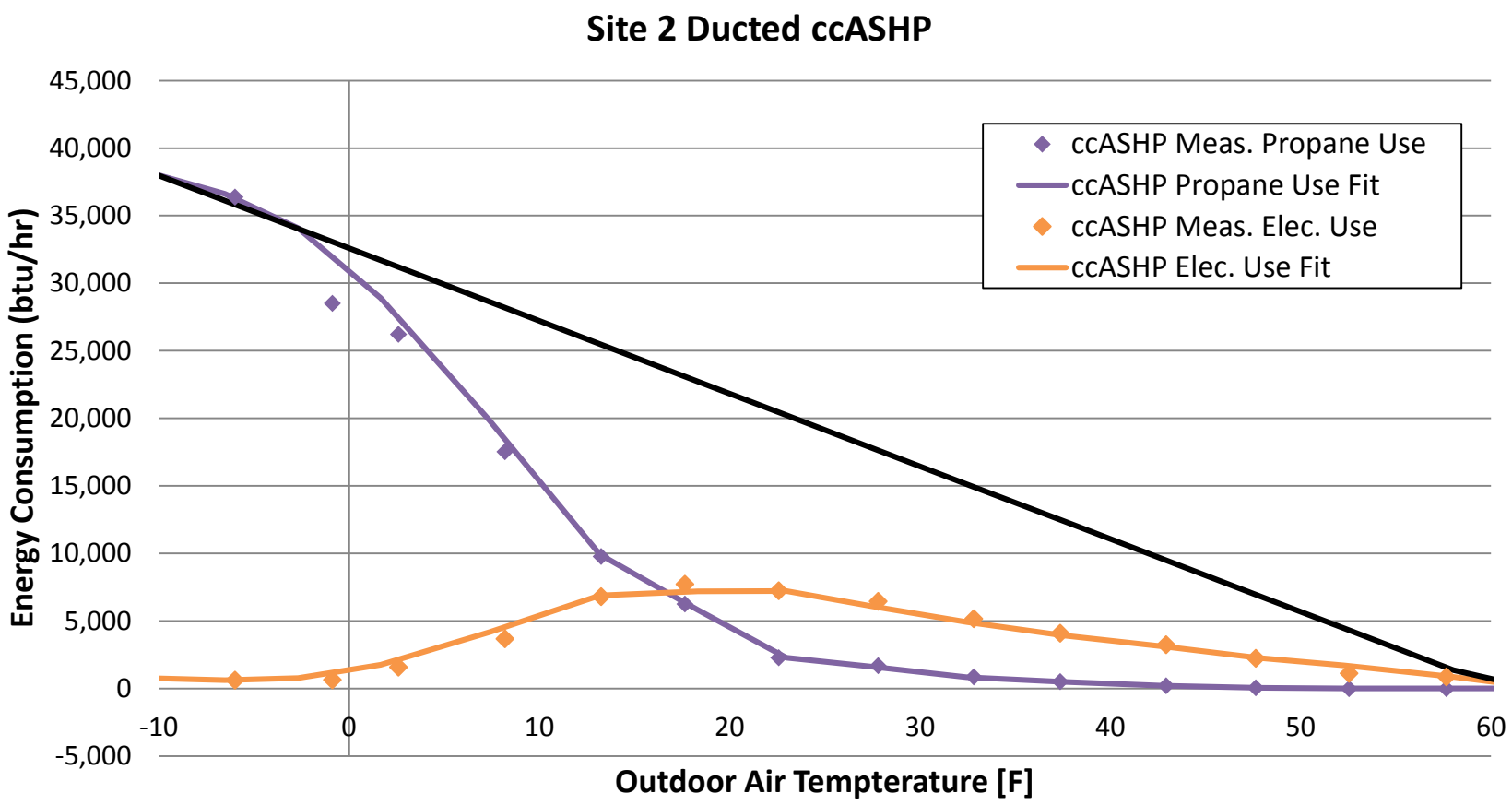
- Ductless systems
  - provided a smaller fraction of the homes energy (by design)
  - operated at lower outdoor temperatures

Energy Use Analysis

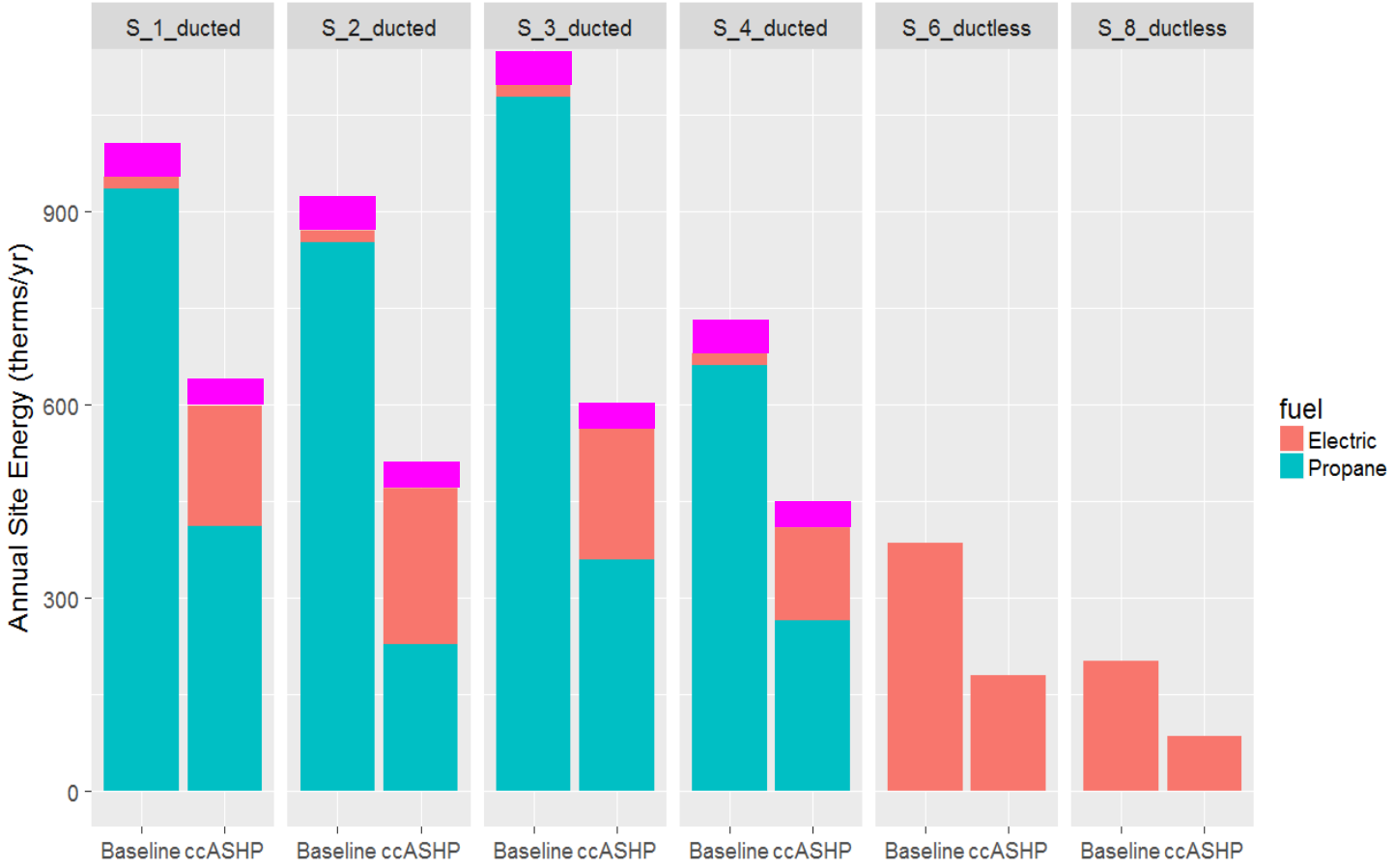
- Measure installed performance data
  - ccASHP with backup mode
  - Baseline mode
- Characterize the heating load of the home
- Create equipment performance models

- Summarize system performance and energy use at each site

Energy Use Vs OAT Models



Annual Energy Use (by Test Site)



Cooling Savings with increased SEER (13.0 to 16.5+)
300 to 500 kWh saved per year or ~$50/year

Annual Characteristics and Savings

Site	Heating balance Point [F]	Heating Design Load [Btu/hr]	Site Energy Reduction	Cost Reduction	Propane reduction	Savings [$/yr]
S_1_ducted	62.6	35,468	**37%**	28%	56%	**$469**
S_2_ducted	60.9	30,046	**46%**	32%	73%	**$497**
S_3_ducted	66.1	24,923	**49%**	40%	67%	**$767**
S_4_ducted	64.5	22,778	**40%**	30%	60%	**$358**
S_6_ductless	70.1	14,200*	**52%**	52%	NA	**$610**
S_8_ductless	59.1	9,400*	**54%**	54%	NA	**$349**

** Design loads for ductless systems are estimated and intended as metric to gauge magnitude of heating load.*

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Install Costs

- For the 4 ducted systems:
  - Our average cost was ~$14,000*
- NREL Residential equipment install database:
  - $6,340 for ducted 3ton ccASHP
  - $4,000 for a new condensing propane furnace ($3,000 for an 80%).
  - $5,540 for a new comparable SEER A/C
- If furnace or A/C needs replacement
  - Incremental cost ~$3,000 will results in paybacks around 6 years
- Hard to calculate paybacks for ductless systems.
  - Costs have high variance.
  - Systems are often not direct replacements

Summary of Results

- Cold Climate ASHPs:
  - **Energy Reduced:** 37% and 54% of site energy consumption
  - **Cost Reduced:** total heating costs 28% to 54%
  - **Heating Load Served:** on average ducted ccASHP met 84% of the homes heating loads
  - **Propane Reduction:** propane consumption down by 64%
    - Less than 500 gallons per year at each house
  - Percentage of heating load for ductless largely dependent on usage & install location
  - Provided more efficient space heating
    - Ducted ccASHP COP of 1.4 & ductless COP of 2.3.
    - Compared to a COP 1.0 for ER

Policy Analysis – Minnesota context

- Lack of structure for achieving delivered fuel savings from ccASHPs for electric utilities
- The fuel switching concern – should not apply in these scenarios
- Precedents: low income CIP
- New program suggestions
  - Net BTU analysis

- Next Steps
  - Further discussion

Conclusions

- Field monitoring confirmed expected performance of ccASHPs
- Freeze protection and integration with auxiliary heating are important
- Ducted ccASHPs can heat below 5F, ductless below -13F
- Paybacks are attractive when existing heating or cooling system need to be replaced

Future Needs

- There is still room for improvement:
  - Reduce unnecessary back-up heating
    - Defrost?
    - Lower change over point?
  - Reduce upfront installation costs
    - Systems with new furnaces cost $15,000
    - Costs are much higher than incremental equipment costs compared to AC systems

Future Needs – Metrics and Programs

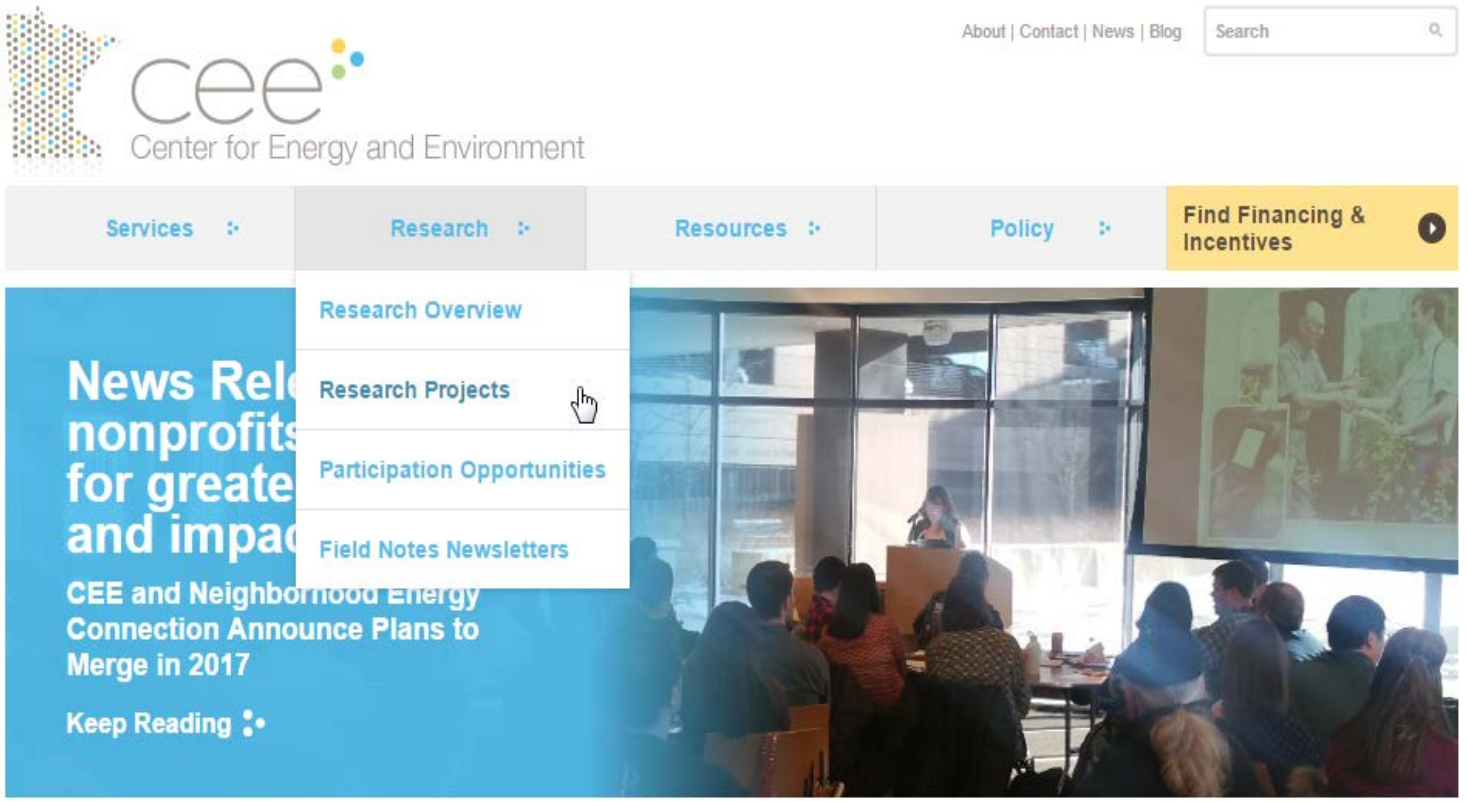
- How should ASHPs be evaluated?
  - Site energy
  - Source energy
  - Carbon reductions
  - Efficiency
  - Homeowner cost
- Impacts of improving equipment
- Impacts of the grid
- Stay tuned for future CEE work

Audience polls

Your Input: What are the market penetration issues?

1. What is the primary issue?
2. What is the secondary issue?

www.mncee.org/heat_pumps



Practical energy solutions for homes, businesses, and communities

THANK you!

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Questions?

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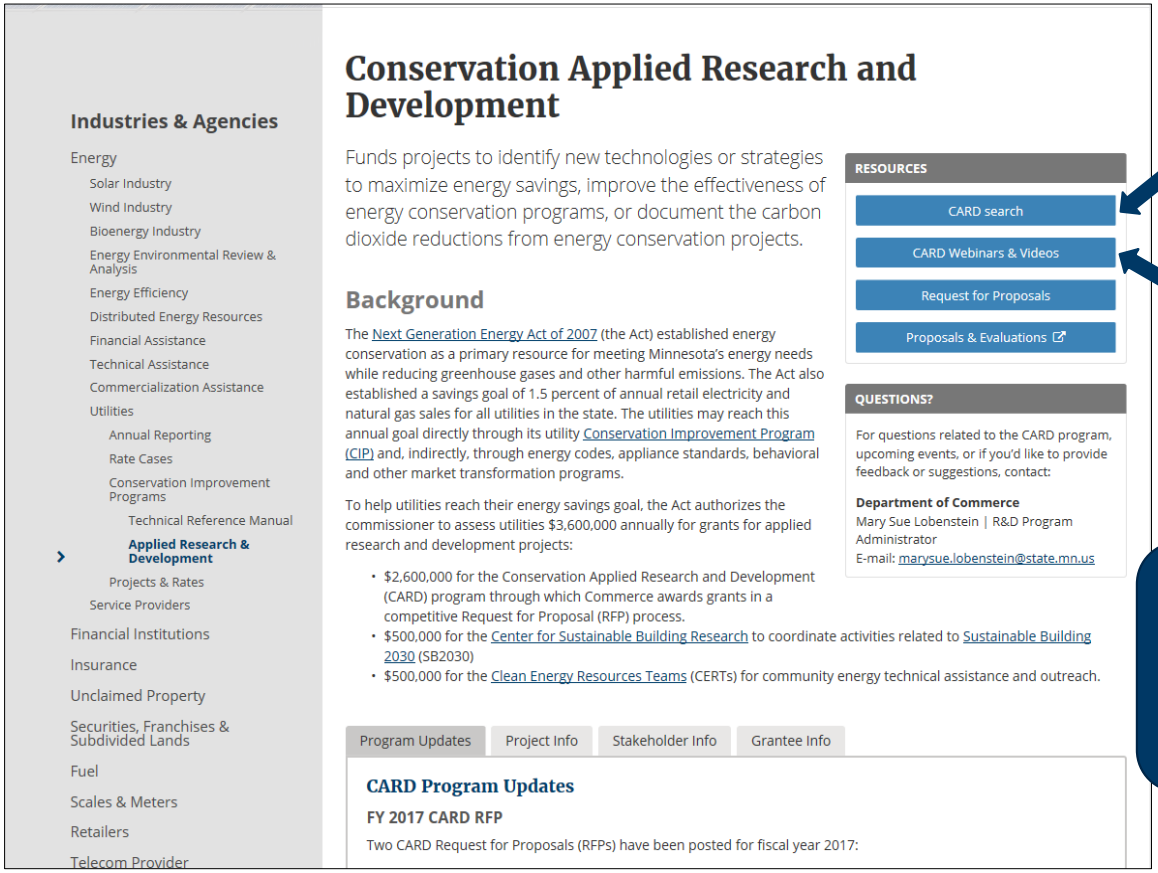
CARD Project Resources



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Webinar Recording & Final Report available in few weeks

R&D Web Page (https://mn.gov/commerce/industries/energy/utilities/cip/applied-research-development/)

Thanks for Participating!

Upcoming CARD Webinars:

- **Nov 14:** Energy efficient operation of indoor swimming pools
- **Nov 29:** Performance-based design & procurement in new construction
- **Dec 7:** Ongoing commissioning in out-patient medical clinics
- **Dec 14:** Evaluation of moisture & heat transfer furnace retrofit

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If you have questions or feedback on the CARD program contact:

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