



Welcome

Conservation Applied Research & Development (CARD)
Webinar

October 5, 2017

Cold Climate Air Source Heat Pump Field Study



Mary Sue Lobenstein
R&D Program Administrator
marysue.Lobenstein@state.mn.us
651-539-1872



Mark Garofano
Energy Engineer
mark.garofano@state.mn.us



Ben Schoenbauer
Senior Research Engineer
Center for Energy and Environment (CEE)
bschoenbauer@mncee.org



Webinar Basics



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

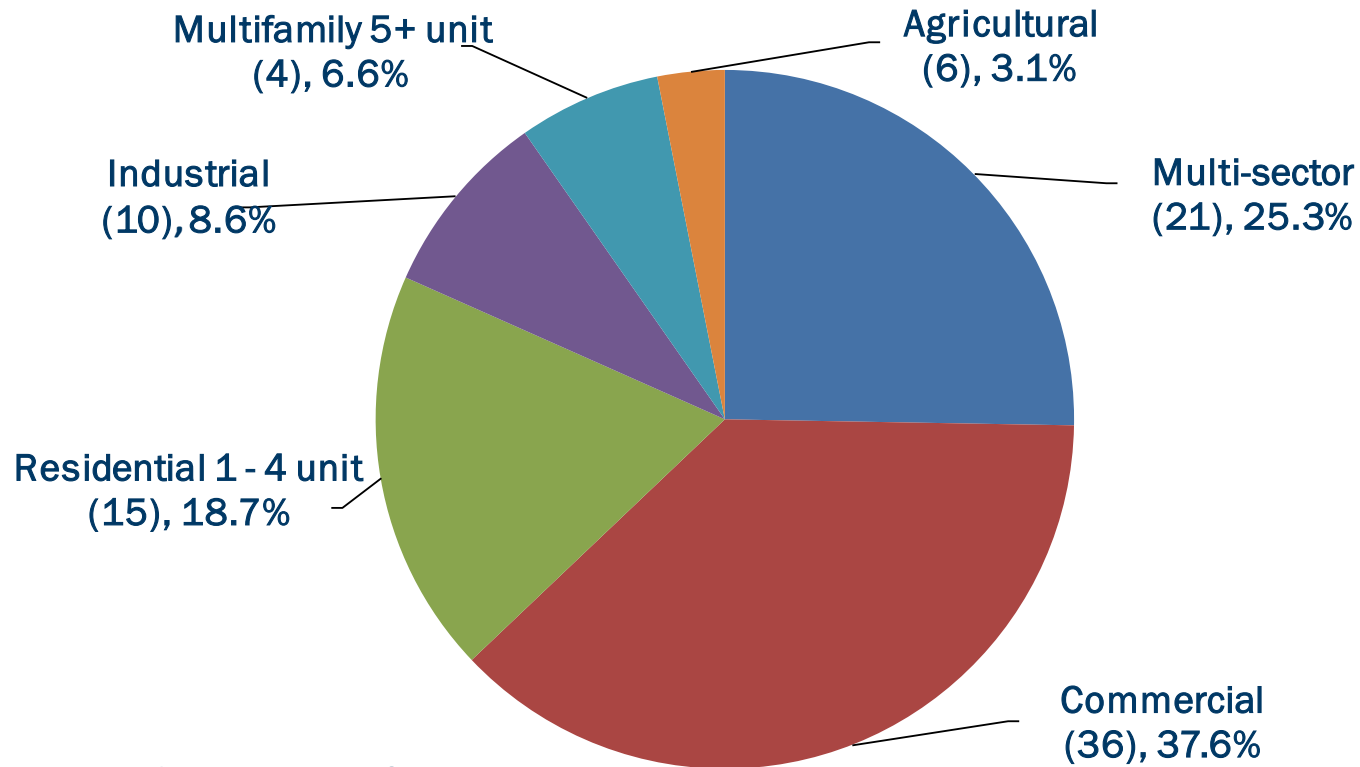


Minnesota Applied Research & Development Fund

- **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 CO₂ 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**



CARD RFP Spending by Sector thru mid-FY2017



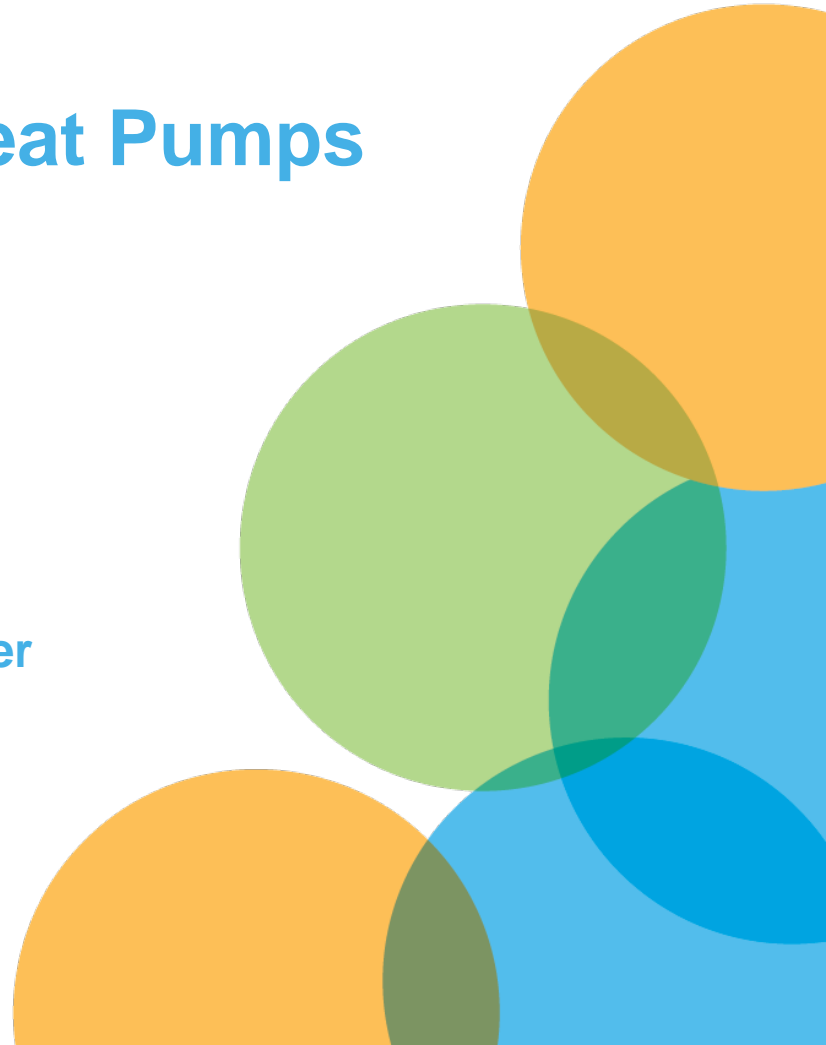
- 8 Funding Cycles
- Nearly 380 proposals
- 92 projects funded

Field Assessment of Cold-Climate Air-Source Heat Pumps

October 2017

Ben Schoenbauer, Senior Research Engineer

Center for Energy and Environment



Discover + Deploy

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





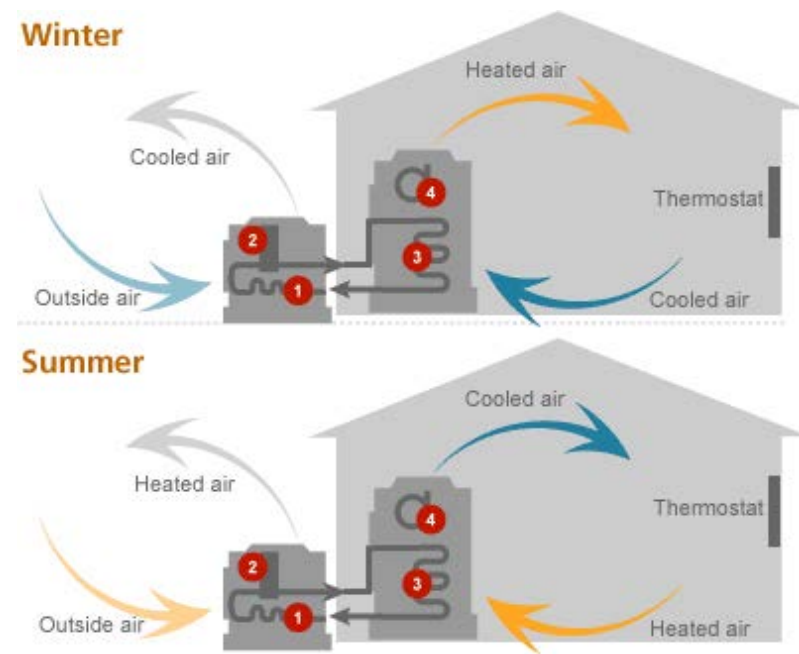
Agenda

- 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.





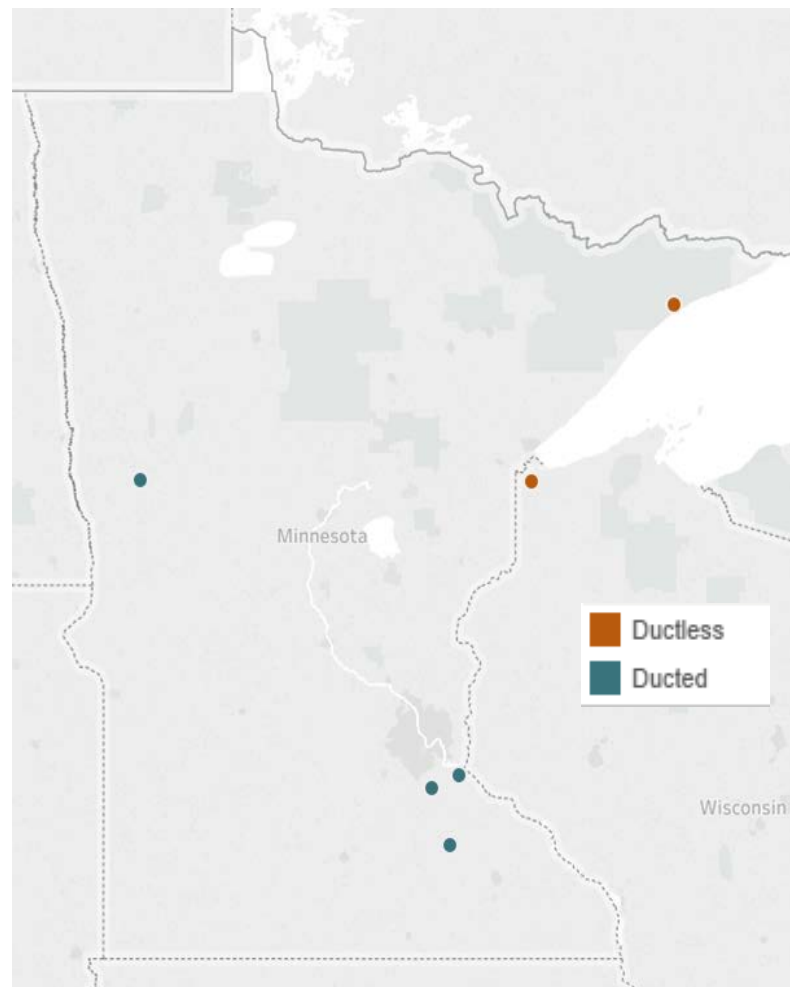
Opportunity

- 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



Instrumentation

Power Measurements:

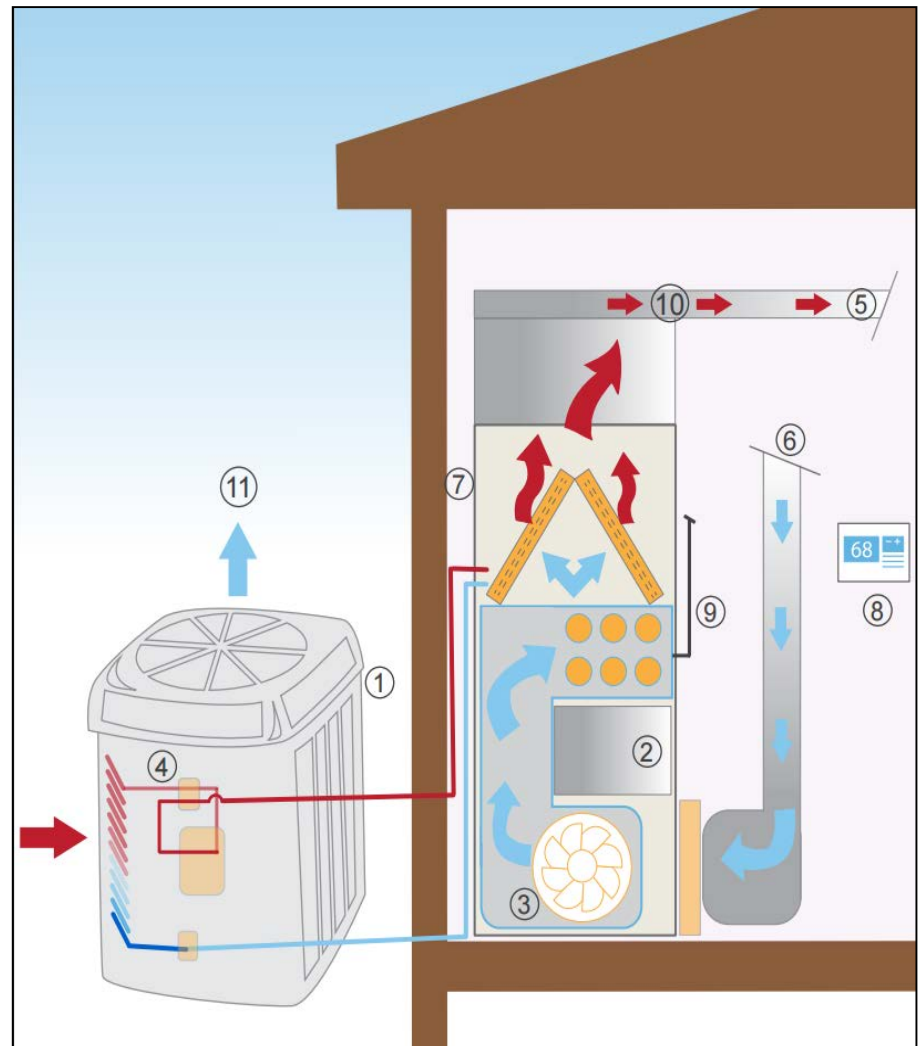
- 1) Outdoor unit
- 2) Indoor unit
- 3) Indoor fan
- 4) Reversing valve

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





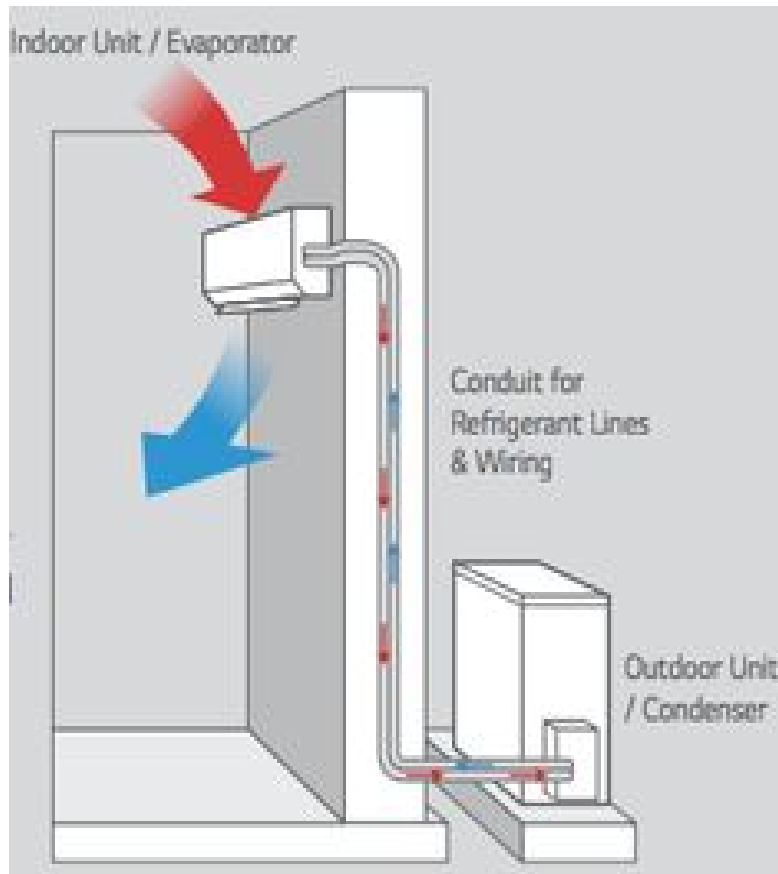
Installation

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

• Ducted Whole House Installation



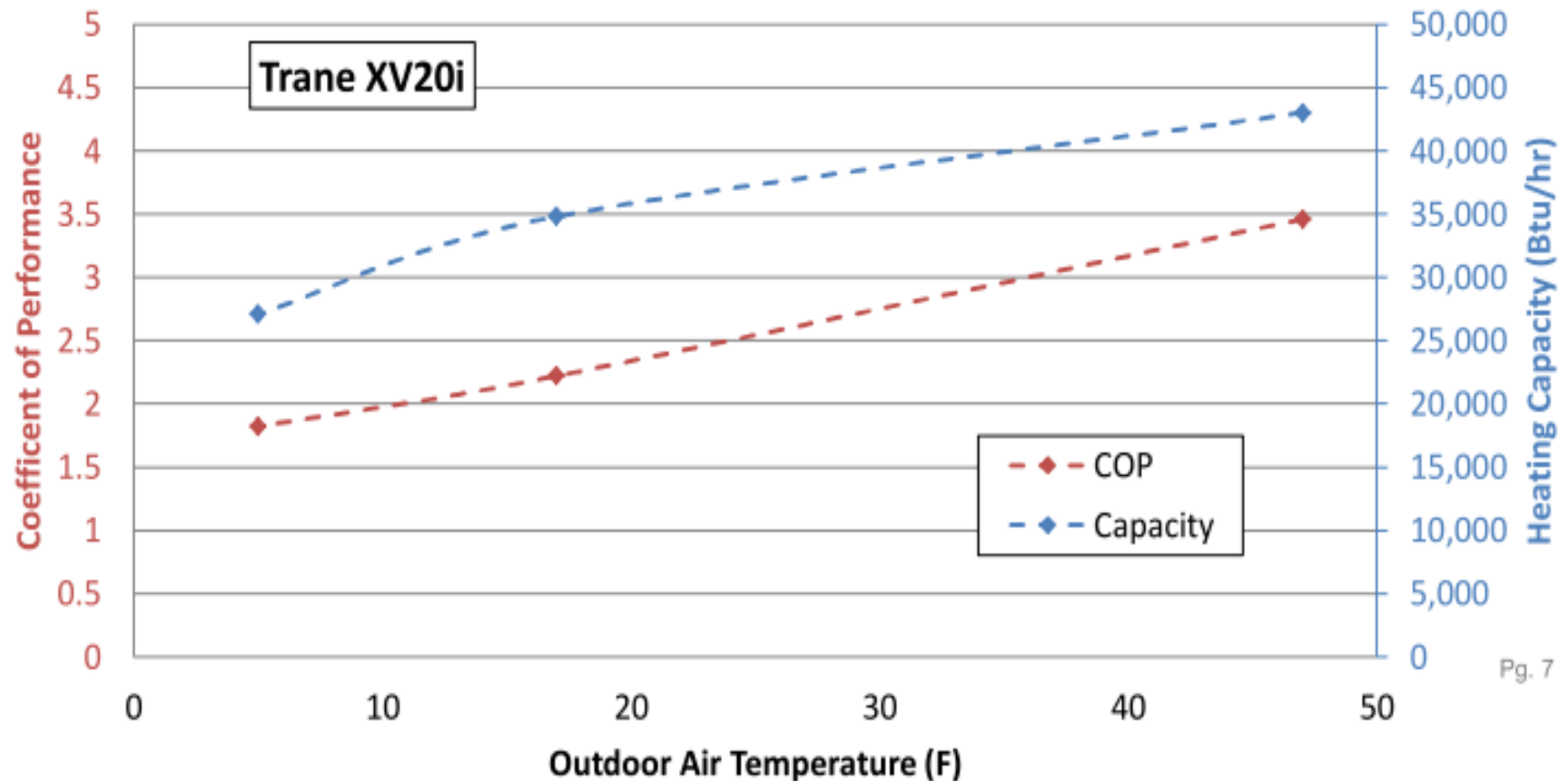
• Ductless Heat Pump Installation



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 [4TWW0036A]	3 ton	Ducted	LP Cond. Furnace
5	Mitsubishi Ductless Hyper Heat [MUZ-FH18NAH]	1.5 ton	Ductless	Electric Resistance
6	Mitsubishi Ductless Hyper Heat [MSZ-FH12NA]	1 ton (2 units)	Ductless	Electric Resistance


Manufacturer Specified Performance




Pg. 7



Cold Climate Specification and Product List



ABOUT NEEP | [INITIATIVES](#) | EVENTS | BLOG/NEWS ROOM | NETWORK | RESOURCES



COLD CLIMATE AIR SOURCE HEAT PUMP

Download Current ccASHP Specification Listing:

 [ColdClimateAir-SourceHeatPumpSpecificationListing-Updated 2.24.17.xlsx](#)

[Skip to details on listing products](#)

On behalf of energy efficiency stakeholders across the Northeast and Mid-Atlantic, Northeast Energy Efficiency Partnerships (NEEP) is pleased to be housing the new Cold Climate Air-Source Heat Pump (ccASHP) Specification and a list of those products that meet the specification's requirements. Those requirements include both specific performance levels as well as a series of reporting requirements.

Energy efficiency stakeholders from the Northeast lack confidence that the existing heating performance metric (HSPF) for air-source heat pumps provides the necessary information to adequately characterize heating performance at low temperatures. In addition, the supplemental information that is provided by manufacturers to demonstrate cold temperature performance is not standardized or consistent. The current performance metric (HSPF) does not include low temperature testing points below 17°F, assumes the use of electric resistance elements, and tests in steady-state operation (as opposed to allowing modulation). These deficiencies add up to measurements that do not accurately reflect performance of the latest generation of air-source heat pumps, designed and optimized to provide heat during cold conditions.

In order to address these concerns, a group of interested stakeholders, working together as part of the

AIR SOURCE HEAT PUMPS

[Cold Climate Air Source Heat Pump](#)

[Subscribe to our Newsletter!](#)

RELATED BLOG POSTS



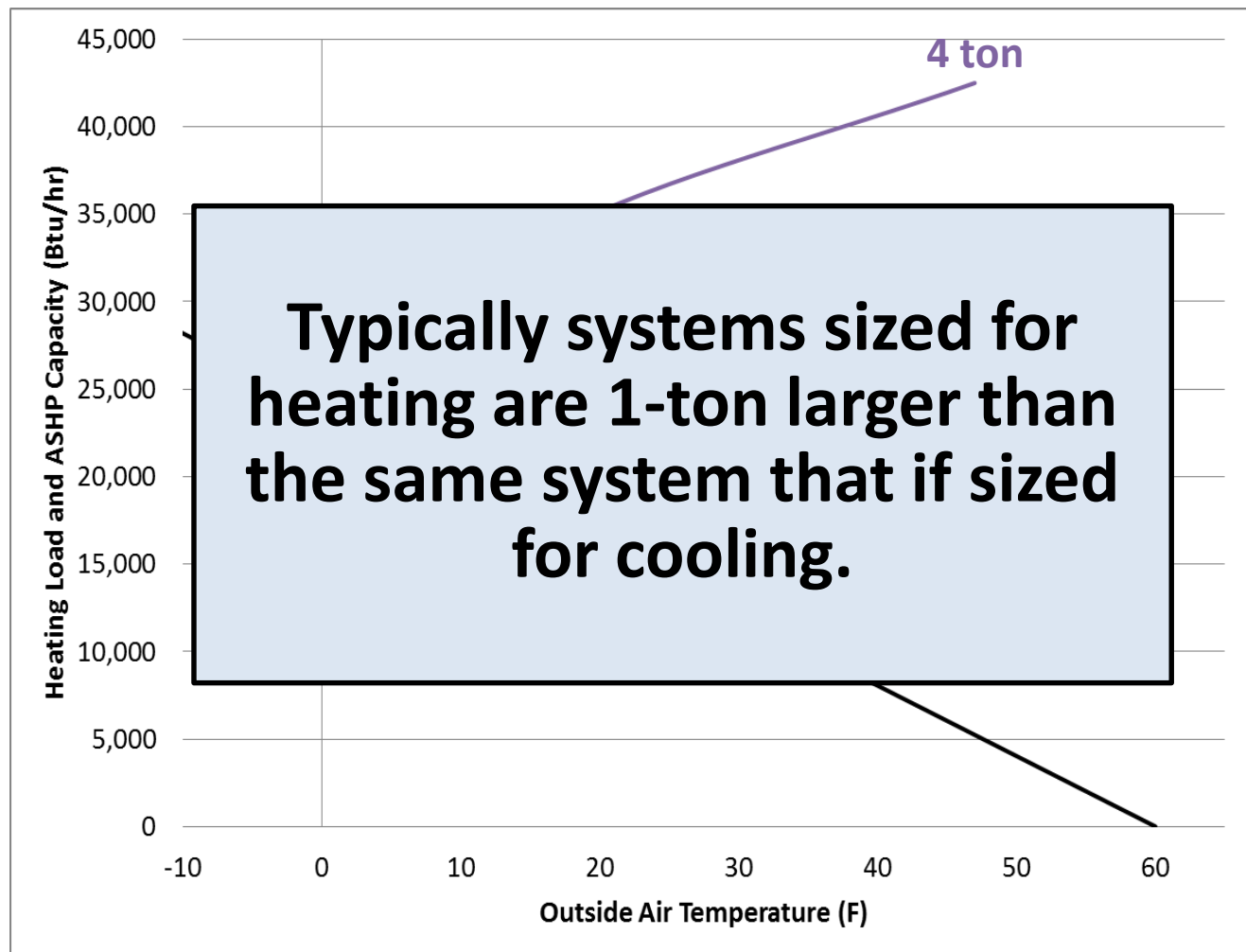
Hot strategies for Cold Climate Air-Source Heat Pumps



NEEP's Greatest Heat Pump Hits



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 ~19 F

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



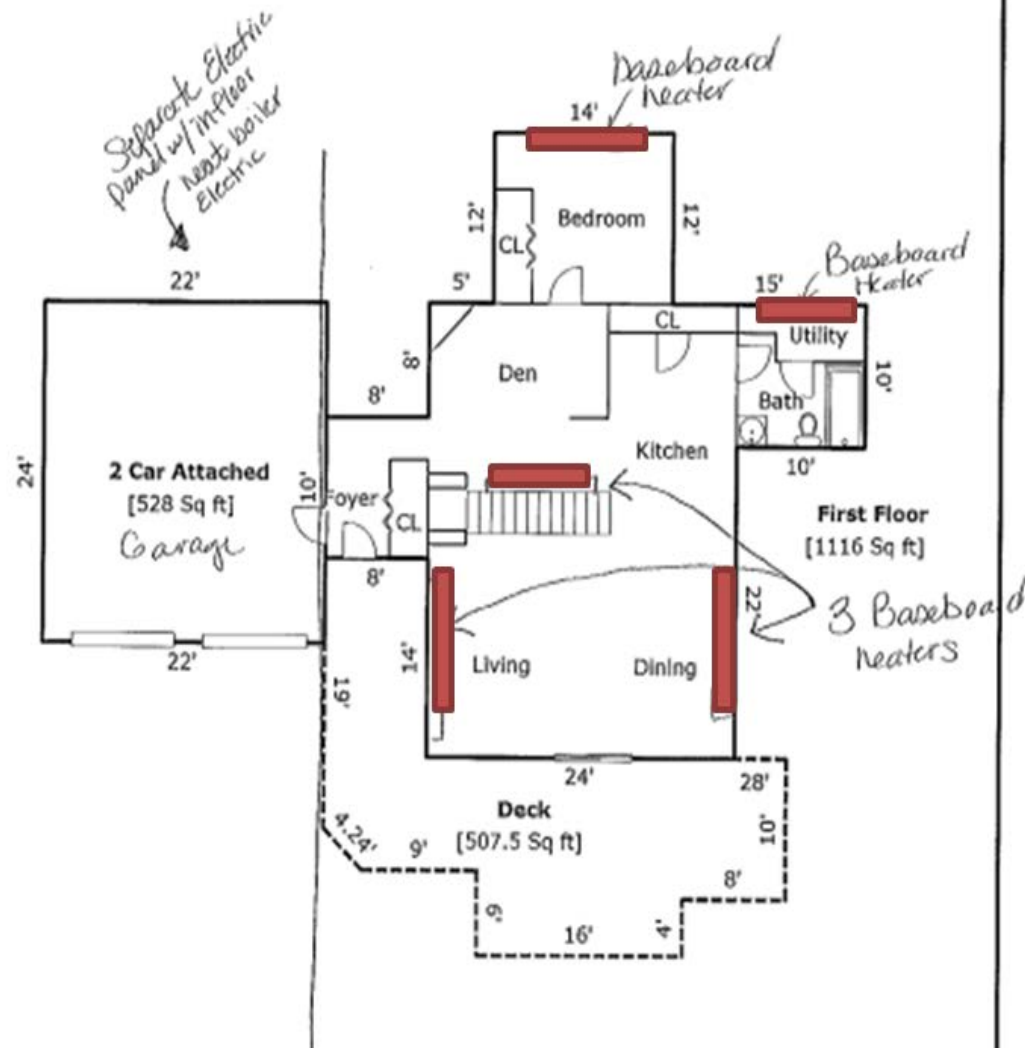
Furnace Integration – Keep or Replace?

- 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



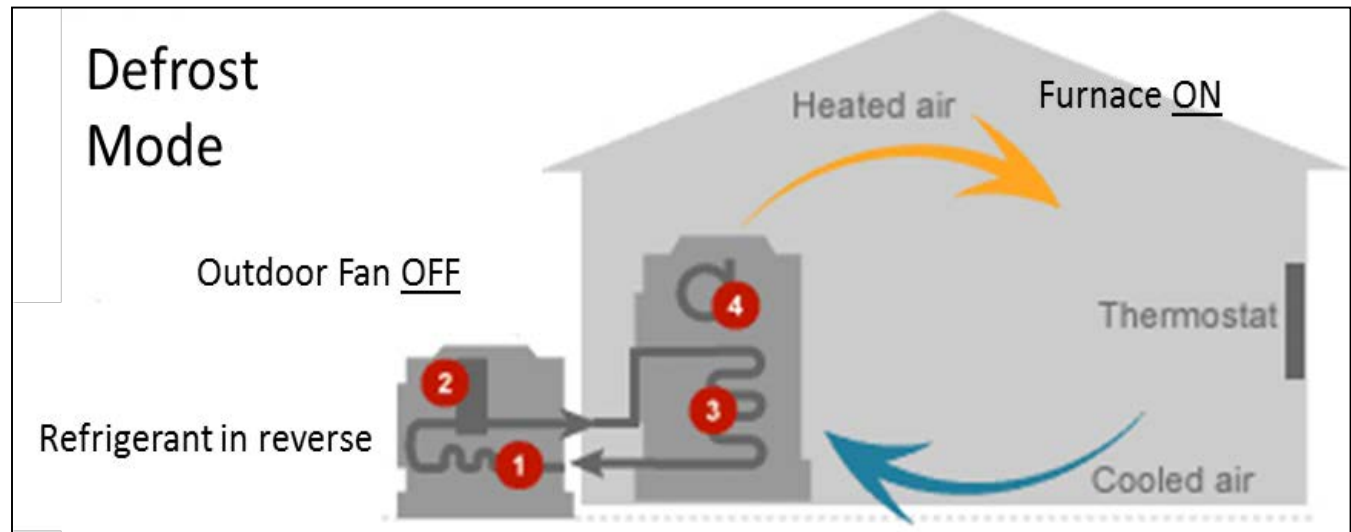


Installation Scenarios

- 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?

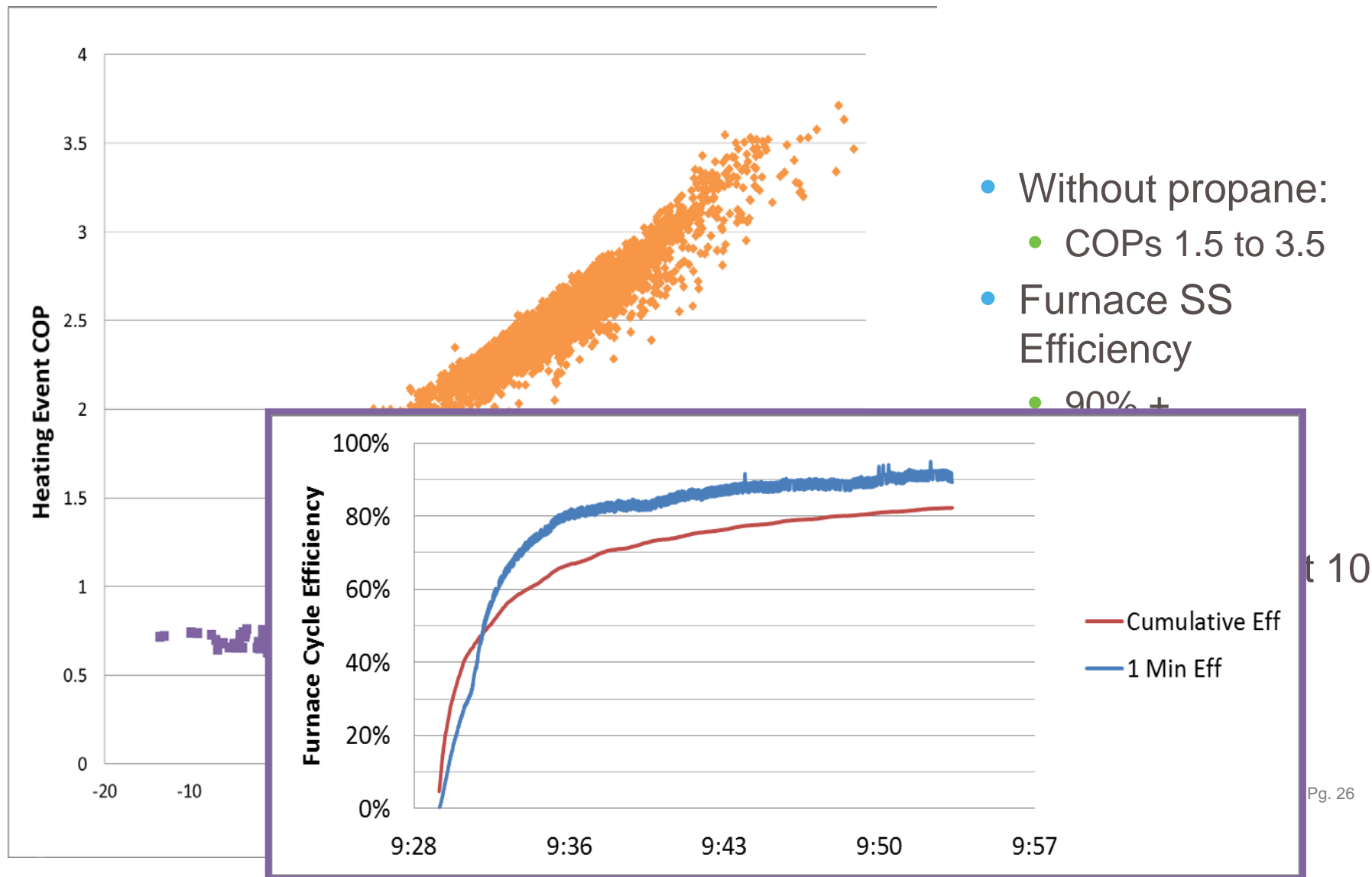
• Modes of System Operation

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

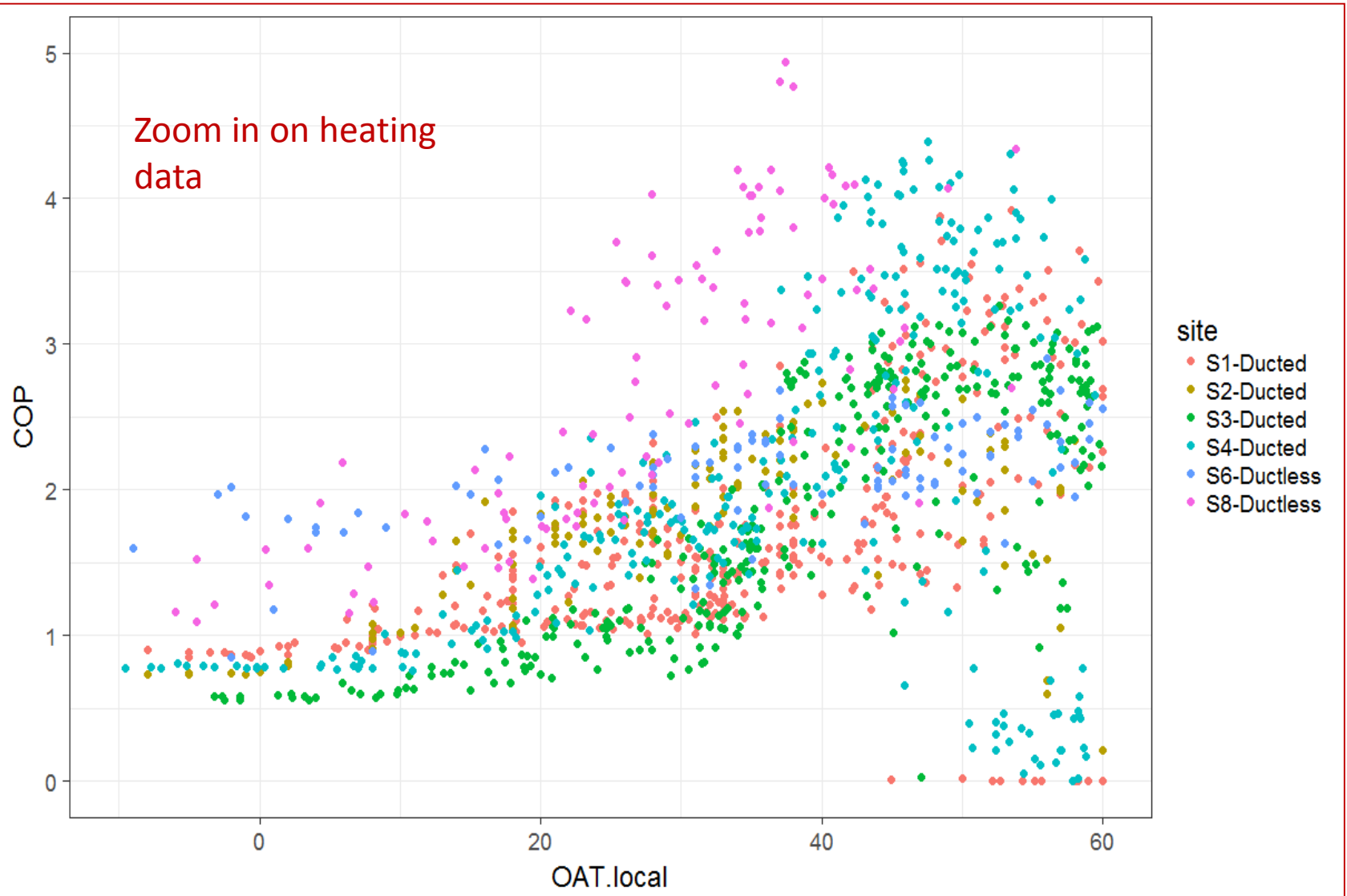




ASHP and Furnace Cycle Efficiency, Site 2



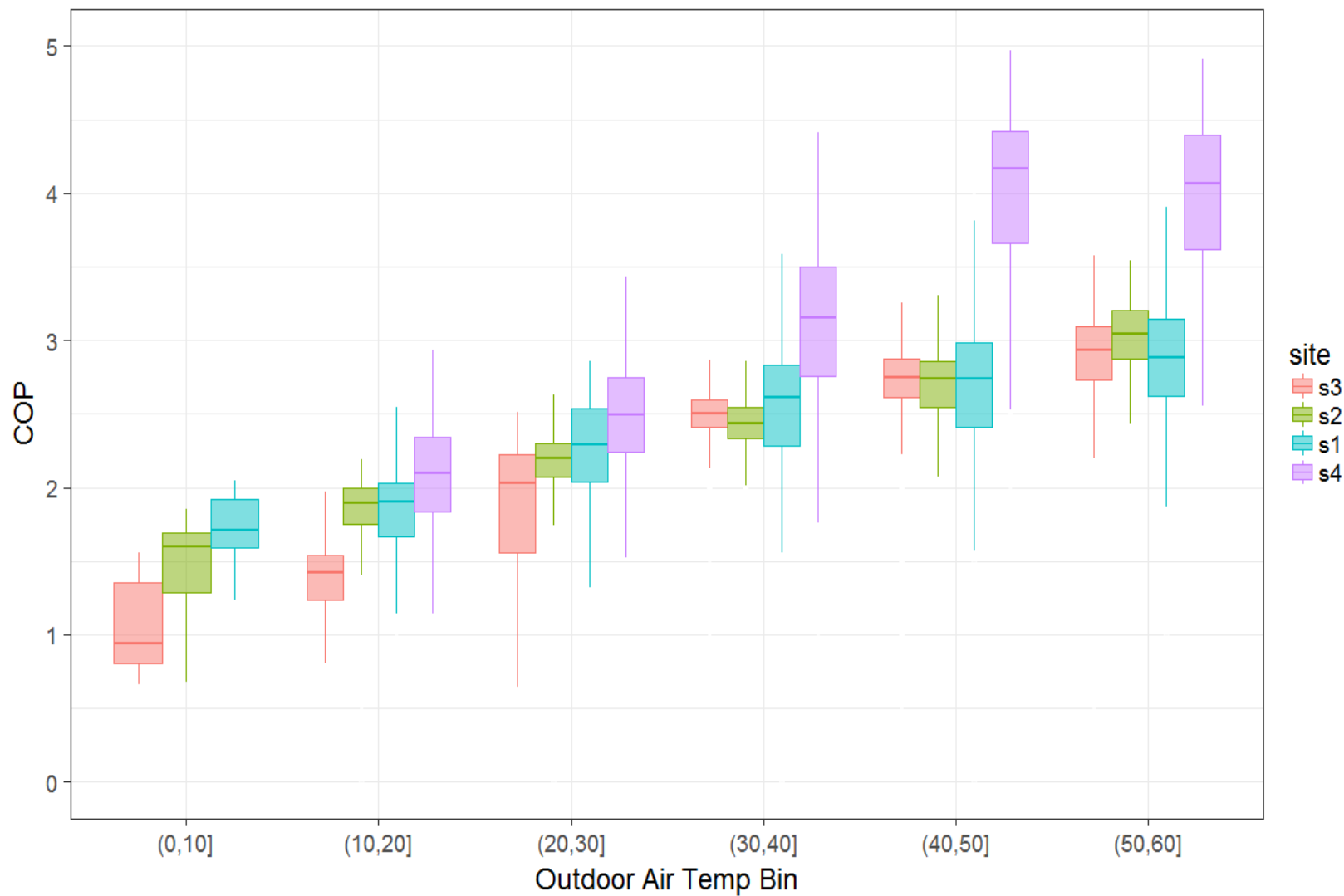
System COP vs OAT





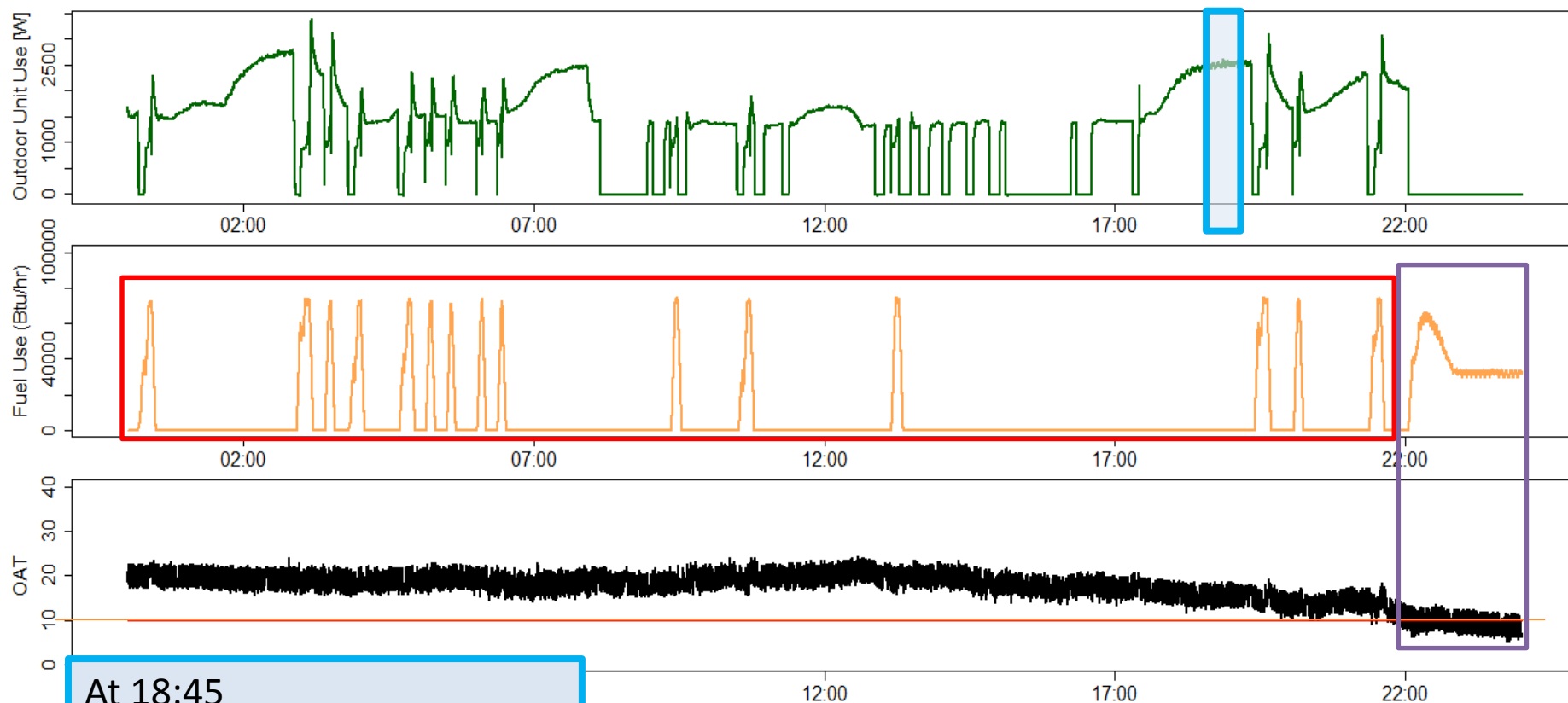
ASHP Performance

ASHP Events





Example: Capacity on a 17 °F day



At 18:45

OAT = 15 F

House load = 15,300 Btu/hr

ASHP Output = 16,700
Btu/hr

ASHP Sup Temp = 89 F

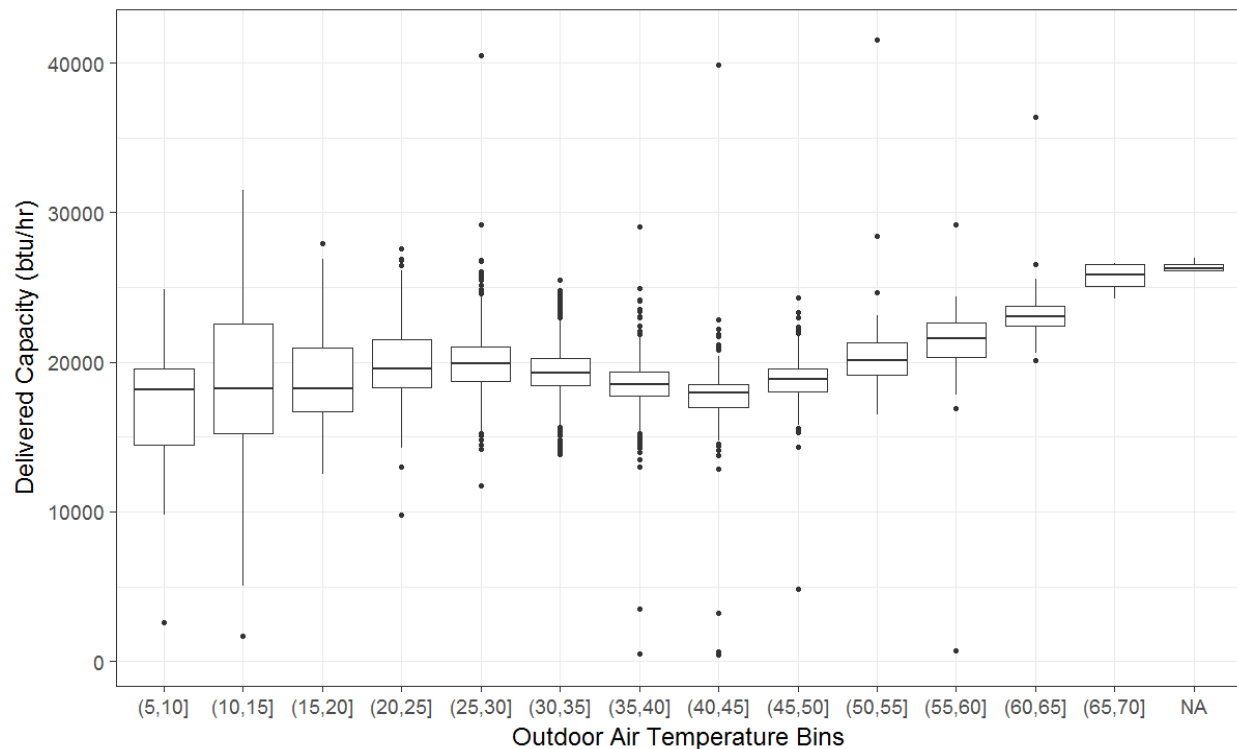
Airflow = 734 CFM

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

Site 02 - Ducted ccASHP - Capacity





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

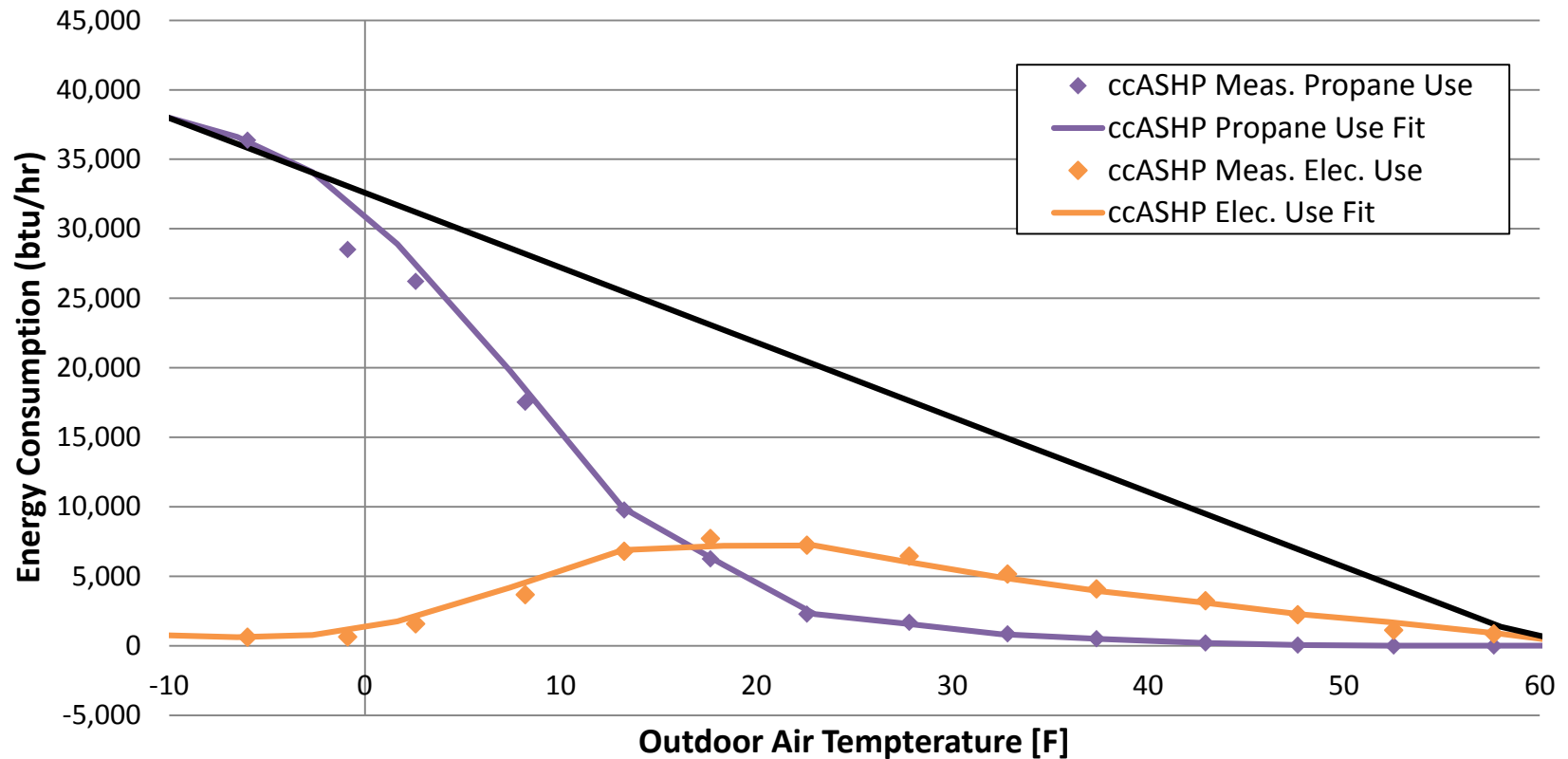


Energy Use Analysis

- 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

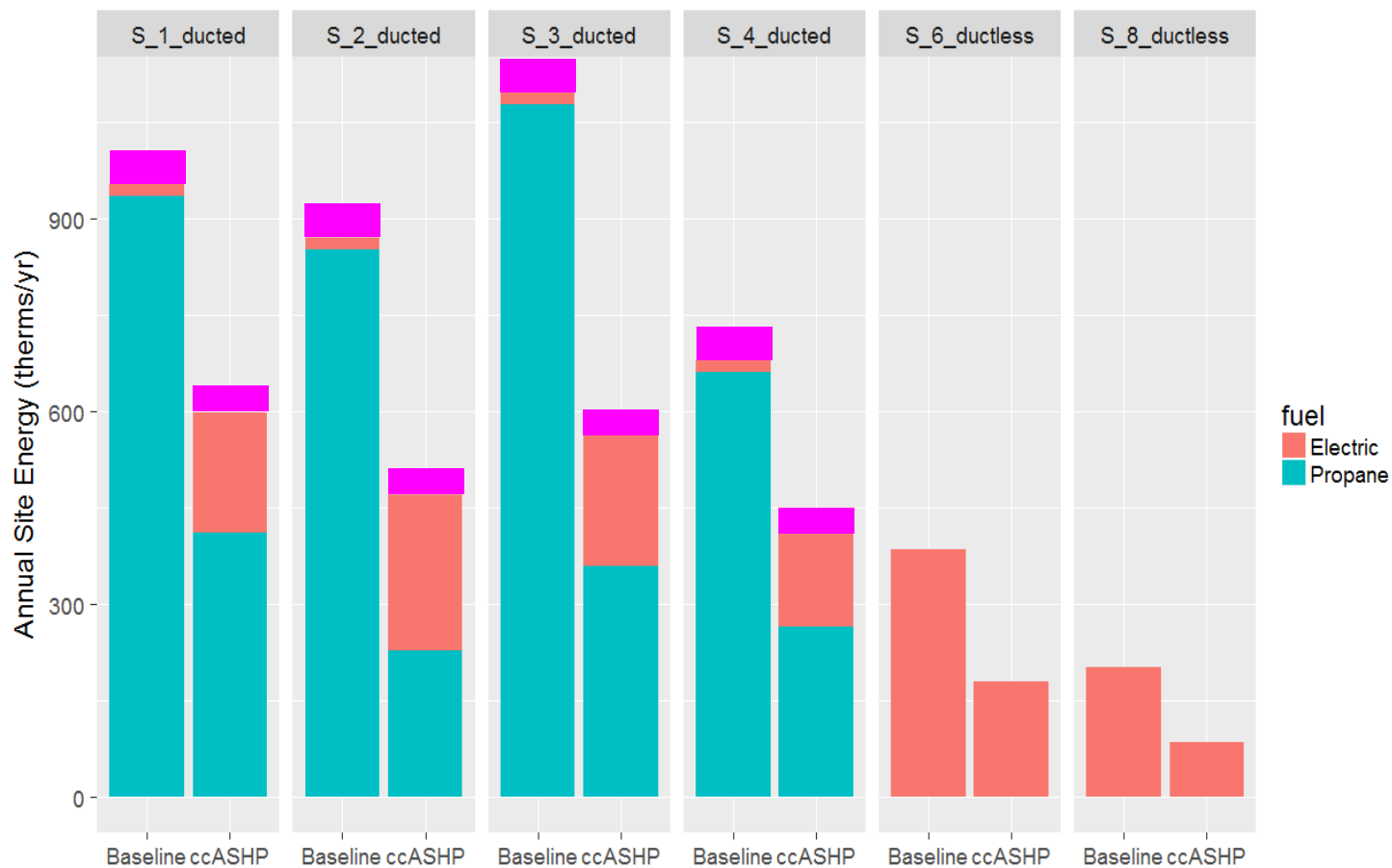
Energy Use Vs OAT Models

Site 2 Ducted ccASHP





Annual Energy Use (by Test Site)





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.*



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



[About](#) | [Contact](#) | [News](#) | [Blog](#)

Search



[Services](#)

[Research](#)

[Resources](#)

[Policy](#)

[Find Financing & Incentives](#)



[Research Overview](#)

[Research Projects](#)



[Participation Opportunities](#)

[Field Notes Newsletters](#)

News Release
nonprofits
for greater
and impact

CEE and Neighborhood Energy Connection Announce Plans to Merge in 2017

Keep Reading



Practical energy solutions for homes, businesses, and communities




Center for Energy and Environment



THANK
you!



Ben Schoenbauer:
bschoenbauer@mncee.org





Questions?

Send us your questions using
GoToWebinar question box

CARD Project Resources

Industries & Agencies

- Energy
 - Solar Industry
 - Wind Industry
 - Bioenergy Industry
 - Energy Environmental Review & Analysis
 - Energy Efficiency
 - Distributed Energy Resources
 - Financial Assistance
 - Technical Assistance
 - Commercialization Assistance
- Utilities
 - Annual Reporting
 - Rate Cases
 - Conservation Improvement Programs
 - Technical Reference Manual
- Applied Research & Development**
 - Projects & Rates
 - Service Providers
- Financial Institutions
- Insurance
- Unclaimed Property
- Securities, Franchises & Subdivided Lands
- Fuel
- Scales & Meters
- Retailers
- Telecom Provider

Conservation Applied Research and Development

Funds projects to identify new technologies or strategies to maximize energy savings, improve the effectiveness of energy conservation programs, or document the carbon dioxide reductions from energy conservation projects.

Background

The [Next Generation Energy Act of 2007](#) (the Act) established energy conservation as a primary resource for meeting Minnesota's energy needs while reducing greenhouse gases and other harmful emissions. The Act also established a savings goal of 1.5 percent of annual retail electricity and natural gas sales for all utilities in the state. The utilities may reach this annual goal directly through its utility [Conservation Improvement Program \(CIP\)](#) and, indirectly, through energy codes, appliance standards, behavioral and other market transformation programs.

To help utilities reach their energy savings goal, the Act authorizes the commissioner to assess utilities \$3,600,000 annually for grants for applied research and development projects:

- \$2,600,000 for the Conservation Applied Research and Development (CARD) program through which Commerce awards grants in a competitive Request for Proposal (RFP) process.
- \$500,000 for the [Center for Sustainable Building Research](#) to coordinate activities related to [Sustainable Building 2030](#) (SB2030)
- \$500,000 for the [Clean Energy Resources Teams](#) (CERTs) for community energy technical assistance and outreach.

RESOURCES

- CARD search
- CARD Webinars & Videos
- Request for Proposals
- Proposals & Evaluations [↗](#)

QUESTIONS?

For questions related to the CARD program, upcoming events, or if you'd like to provide feedback or suggestions, contact:

Department of Commerce
Mary Sue Lobenstein | R&D Program Administrator
E-mail: marysue.lobenstein@state.mn.us

Program Updates

CARD Program Updates

FY 2017 CARD RFP

Two CARD Request for Proposals (RFPs) have been posted for fiscal year 2017:

For Reports use CARD
Search Quick Link

For Webinars use CARD
Webinars & Videos Quick Link

Webinar Recording &
Final Report
available in few weeks

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

[Commerce Division of Energy Resources e-mail list sign-up](#)

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

Mary Sue Lobenstein

marysue.Lobenstein@state.mn.us

651-539-1872