Emerging Technologies for Cold Weather Residential Heating

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Agenda

- Learning Objectives
- Cold Climate Air Source Heat Pump
  - What is different?
  - Opportunity
  - Installation and operation
  - Preliminary results
- Transport Membrane Humidifier (TMH)
  - What is it?
  - Opportunity
  - Installation and operation
  - Preliminary results

Learn about…

- A new retrofit device, TMH, to increase efficiency of residential standard efficiency furnaces
- The installed energy saving potential of TMH
- The installation, optimization, and operation of a TMH for residential furnaces
- How air source heat pumps work and how the recent improvements in their operation benefit cold climate operation
- The proper way to size, install, and operate a ASHP for optimal performance in a heating dominated climates

Learn about…

- The energy savings potential for ASHPs, as well as the potential for offsetting the reliance on delivered fuels in areas where natural gas is unavailable
- The differences in ASHP installed performance compared to the manufacturer specified performance
- The applicability of both technologies to Minnesota's housing stock and the process that can be used to determine where the best potential exists for each technology

Acknowledgements

- These projects are supported in part by grants from the Minnesota Department of Commerce, Division of Energy Resources through a Conservation Applied Research and Development (CARD) program

- The heat pump project was also supported by Great River Energy and the Electric Power Research Institute

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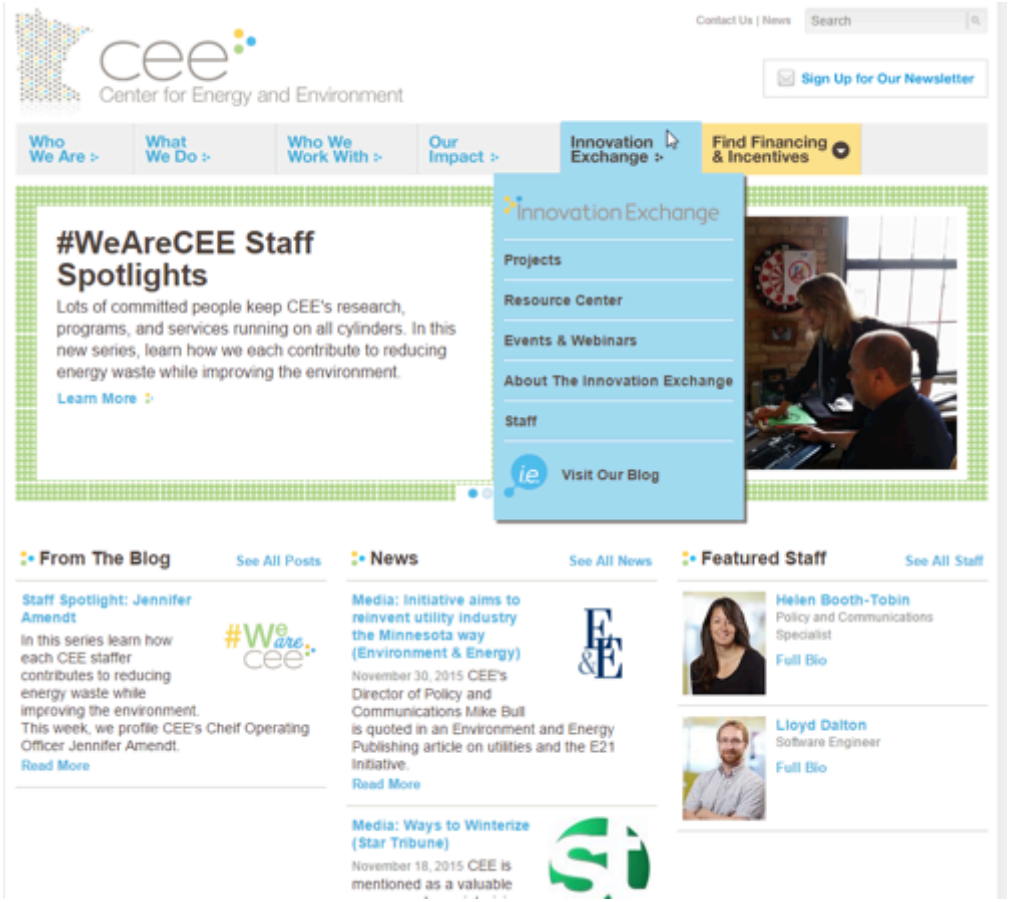


Field Study of a Moisture and Heat Transfer Furnace Retrofit Device

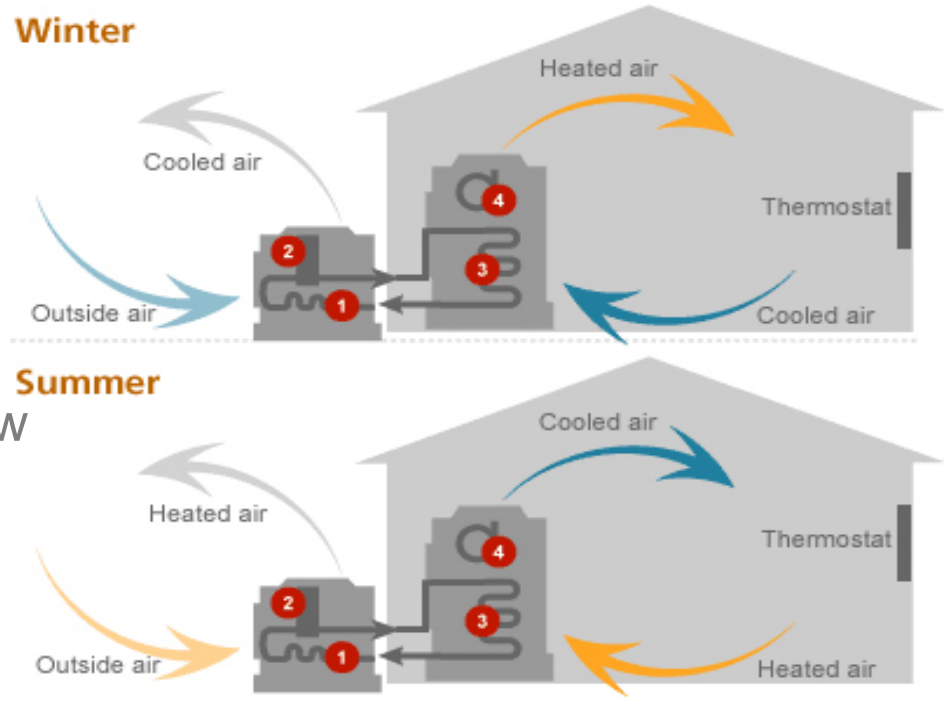
Cold Climate Air Source Heat Pump Field Assessment

Cold Climate Air Source Heat Pump Field Assessment

Center for Energy and Environment

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 0 °F to -13 °F
- ASHPs have the potential to deliver energy and peak saving as well as reduce reliance on delivered fuels.



Opportunity

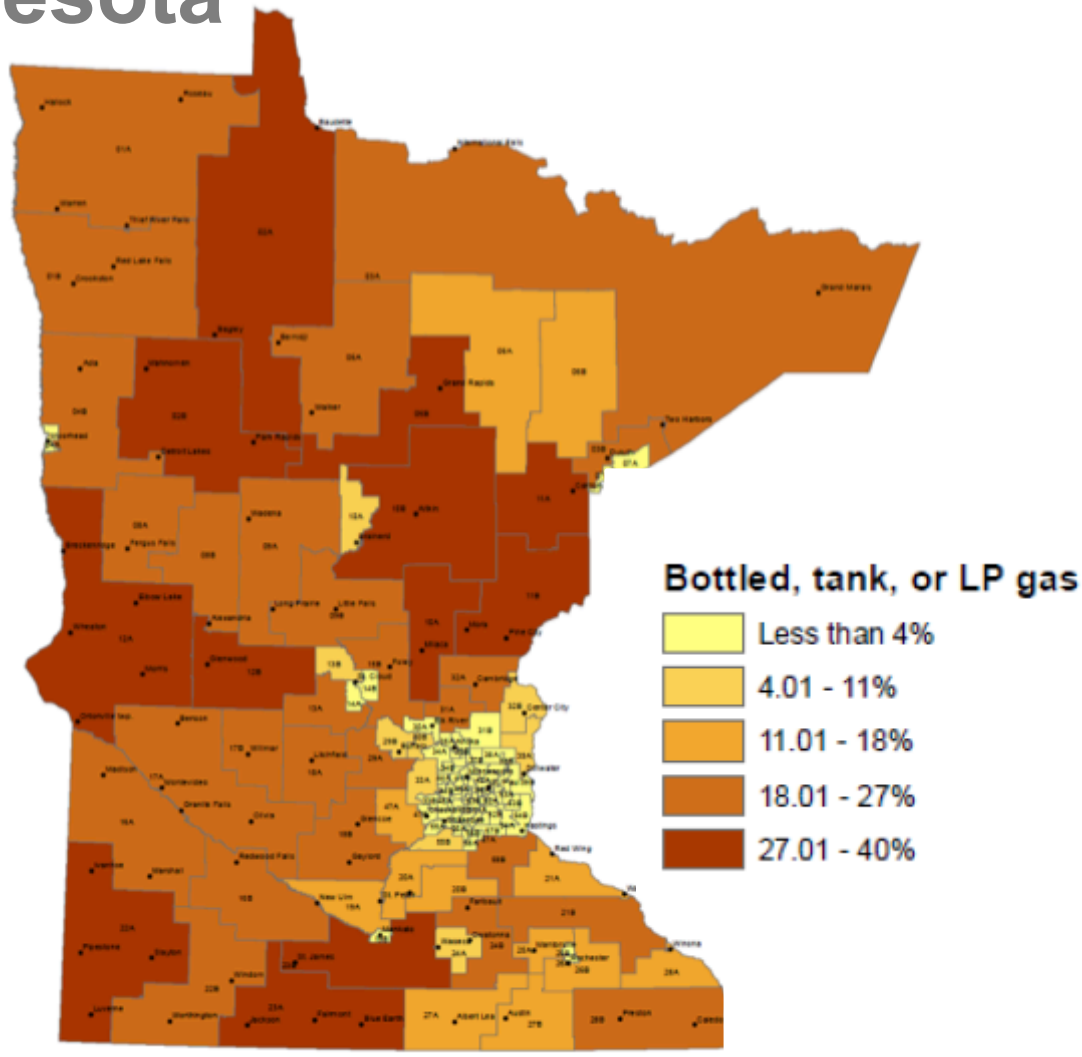
- Winter of 2013/2014 saw delivered fuel shortages in MN
  - Delivered fuel expensive or unavailable
  - Compensation with electric resistance space heaters

- 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)

Opportunity - Minnesota

- Primary Heating with LP[1]
  - Metro, < 4%
  - Outstate, up to 40%

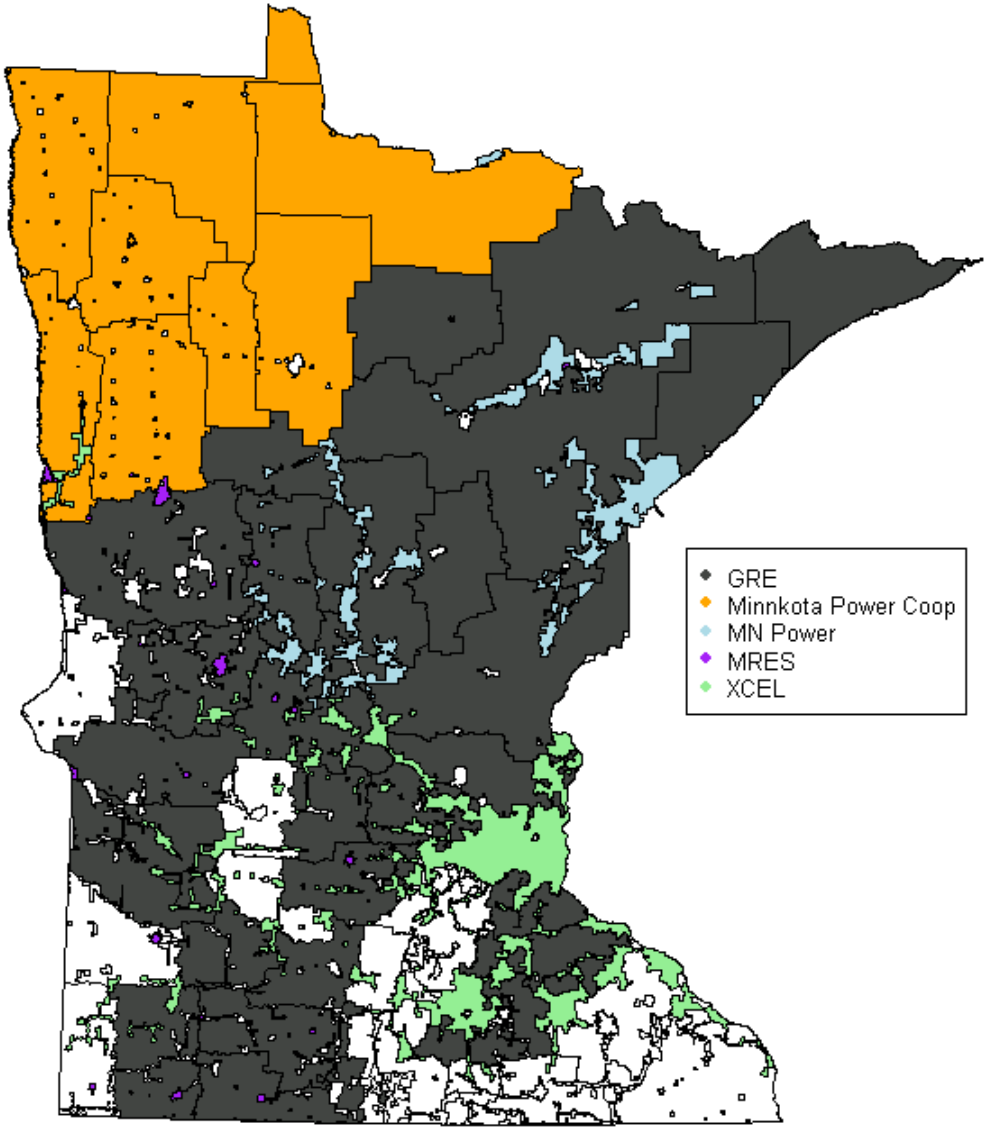
- Primary Heat Sources[2]
  - Utility gas, 67%
  - Electricity, 16%
  - LP, 10%
  - Fuel Oil, 3%
  - Wood, 3%



Source: Levenson-Faulk, Annie. 2015. "Propane Conversion Strategies: Energy Alternatives for Minnesota Users of Propane Gas." St. Paul, MN: Legislative Energy Commission

[1] U.S. Census Bureau. American Community Survey 5-Year Estimates - 2009-2013
[2] U.S. Census Bureau. American Community Survey 5-Year Estimates - 2010-2014

Utilities and Rebates

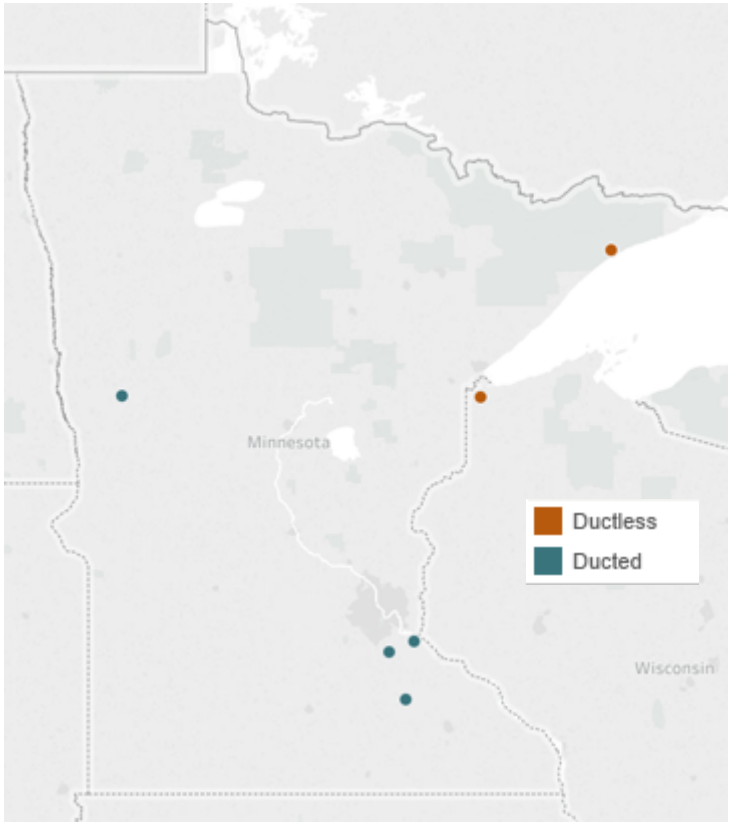


Study Overview

- Field Study
  - Install 6 ccASHP in a variety of MN residences
  - Monitor installed field performance of ASHP and backup
    - Installed performance (COP, capacity, etc)
    - Installed energy savings vs backup
    - Customer satisfaction and delivered comfort
- Incorporate into CIP and Energy Efficiency Programs
  - Working with ACEEE and DER to look into the policy and program implications of ccASHPs
  - Not covered in this talk, but updates will be available shortly at:
    - mncee.org/heat_pumps

Study Overview

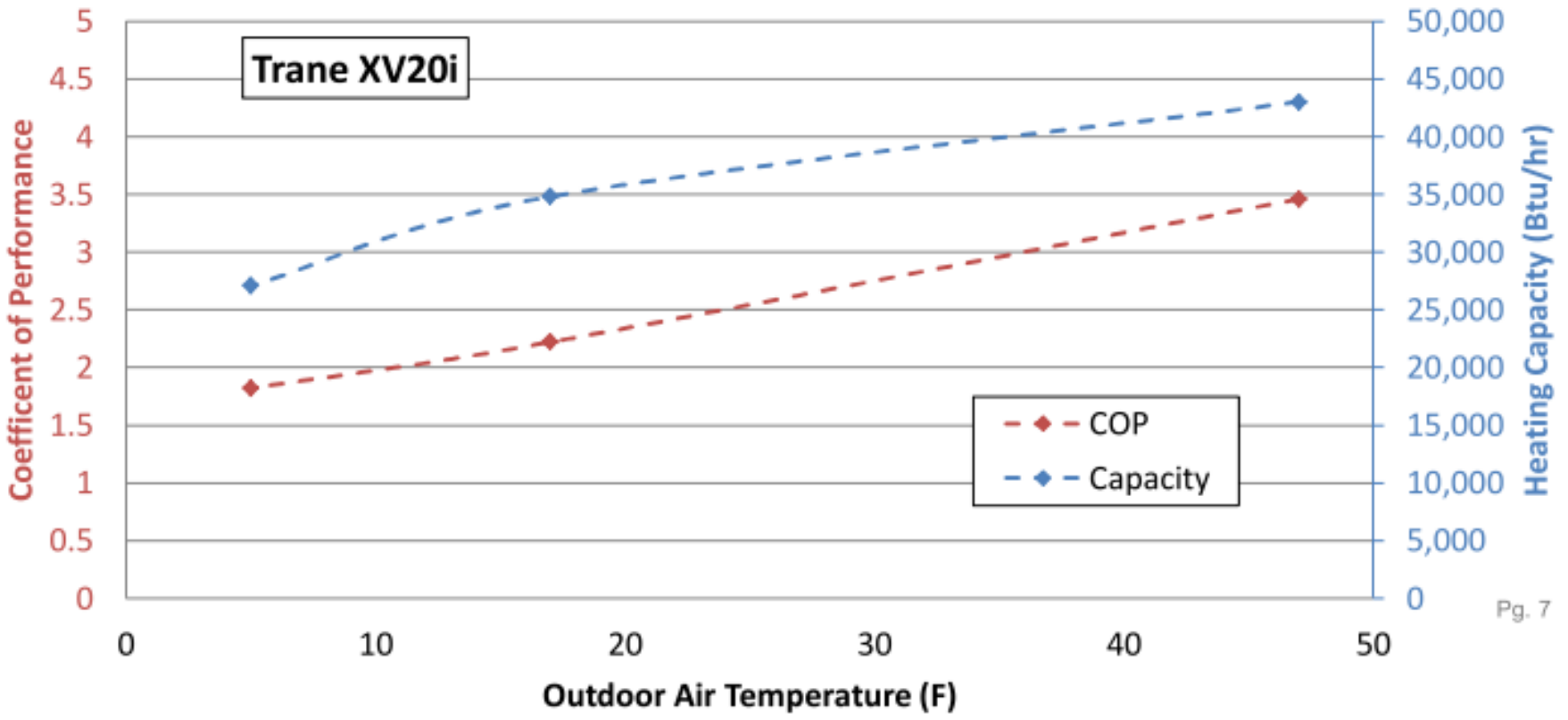
- Field Study
  - 6 ccASHP in a variety of MN residences
    - 3 installed for the 2015-2016 heating season
  - Monitor installed field performance of ASHP and backup
- Incorporate into Conservation Improvement Program (CIP)
- Climate zones 6 & 7



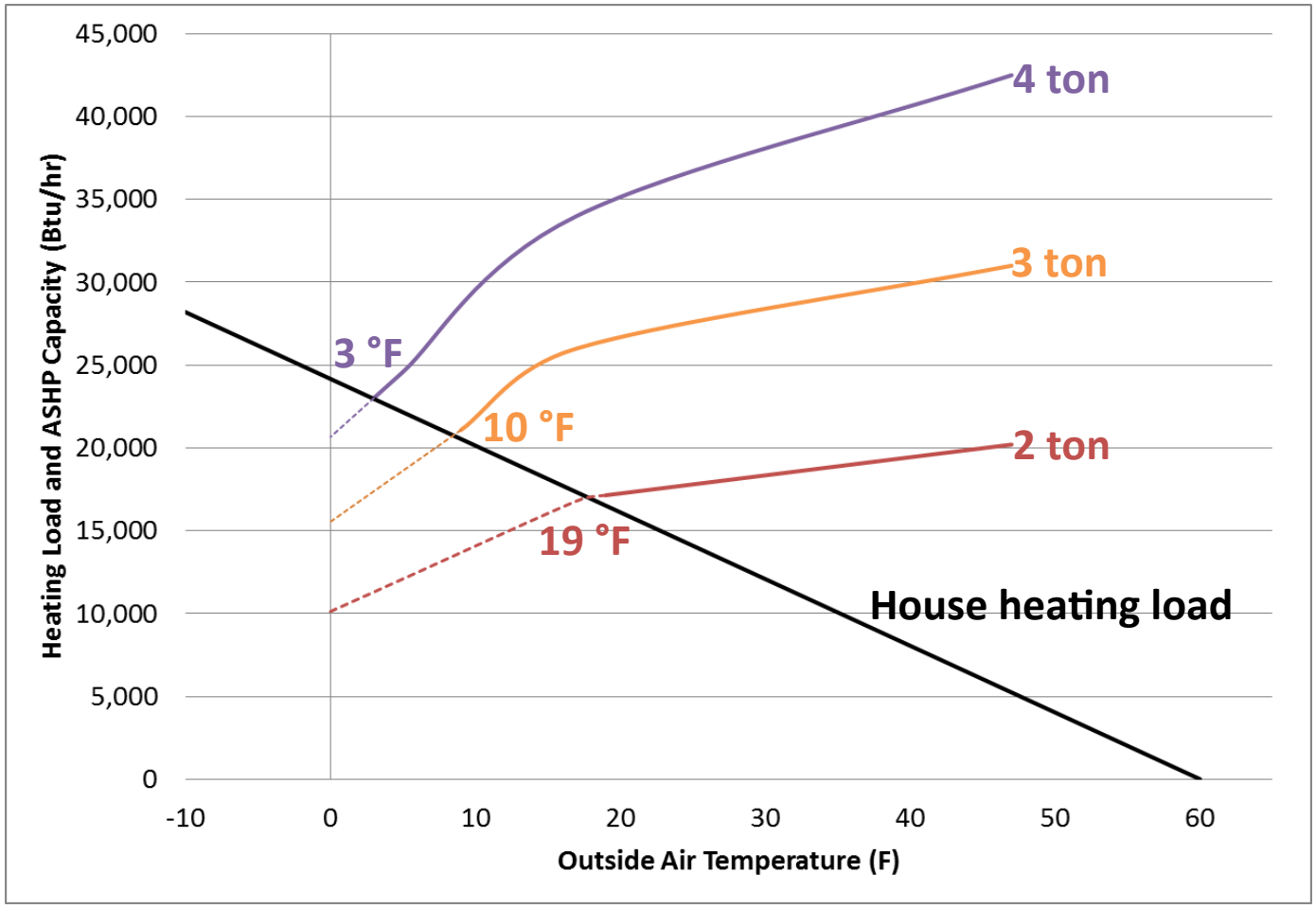
Installation

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

Manufacturer Specified Performance



System Design



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%

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?

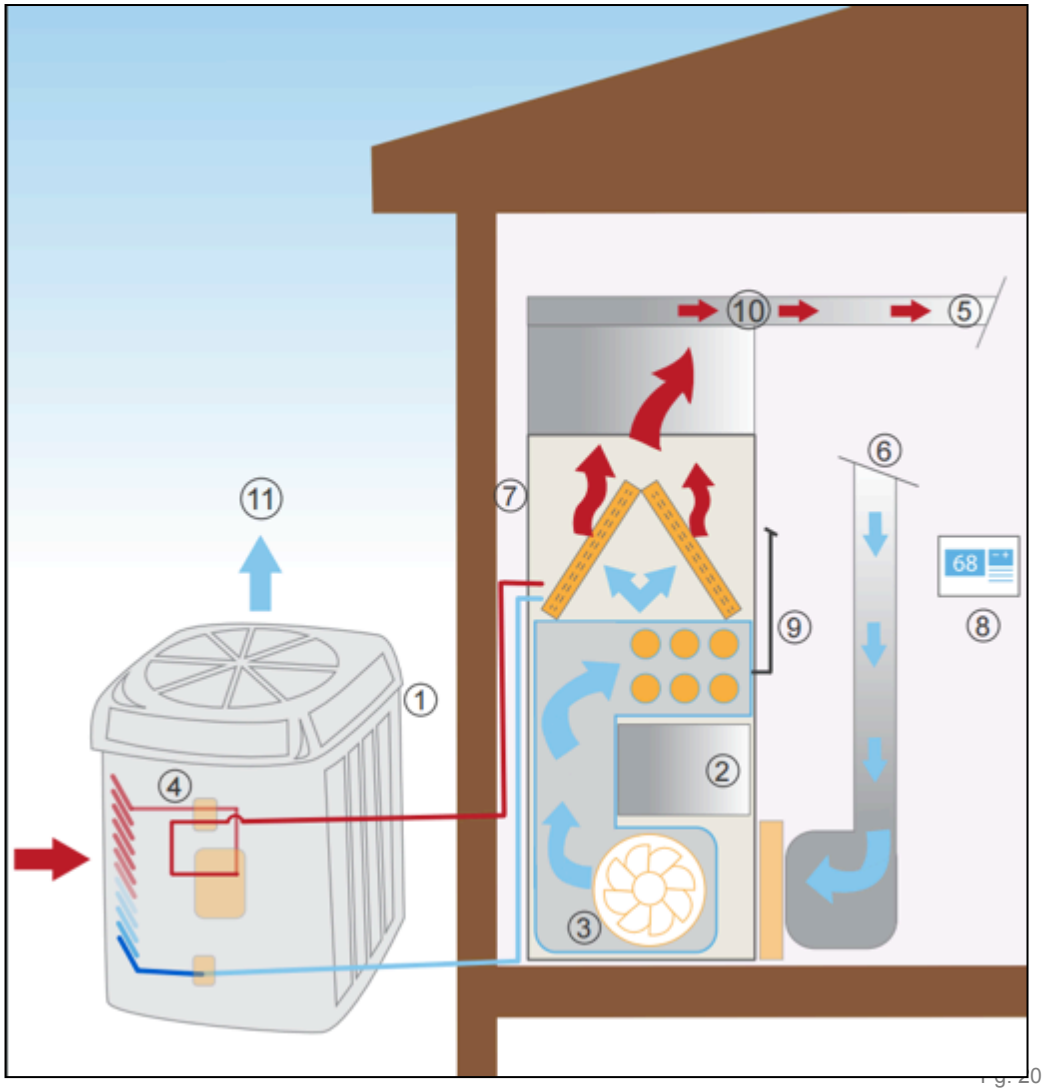
- Issues:
  - Air handler requires a multi-stage fan to achieve the full capability of the ccASHPs
  - Furnace and heat pump require integrated controls
- Proposed Solutions:
  - New condensing furnace with control integration
  - New 80% AFUE with multi-stage fan with control integration
  - Retrofit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

Instrumentation

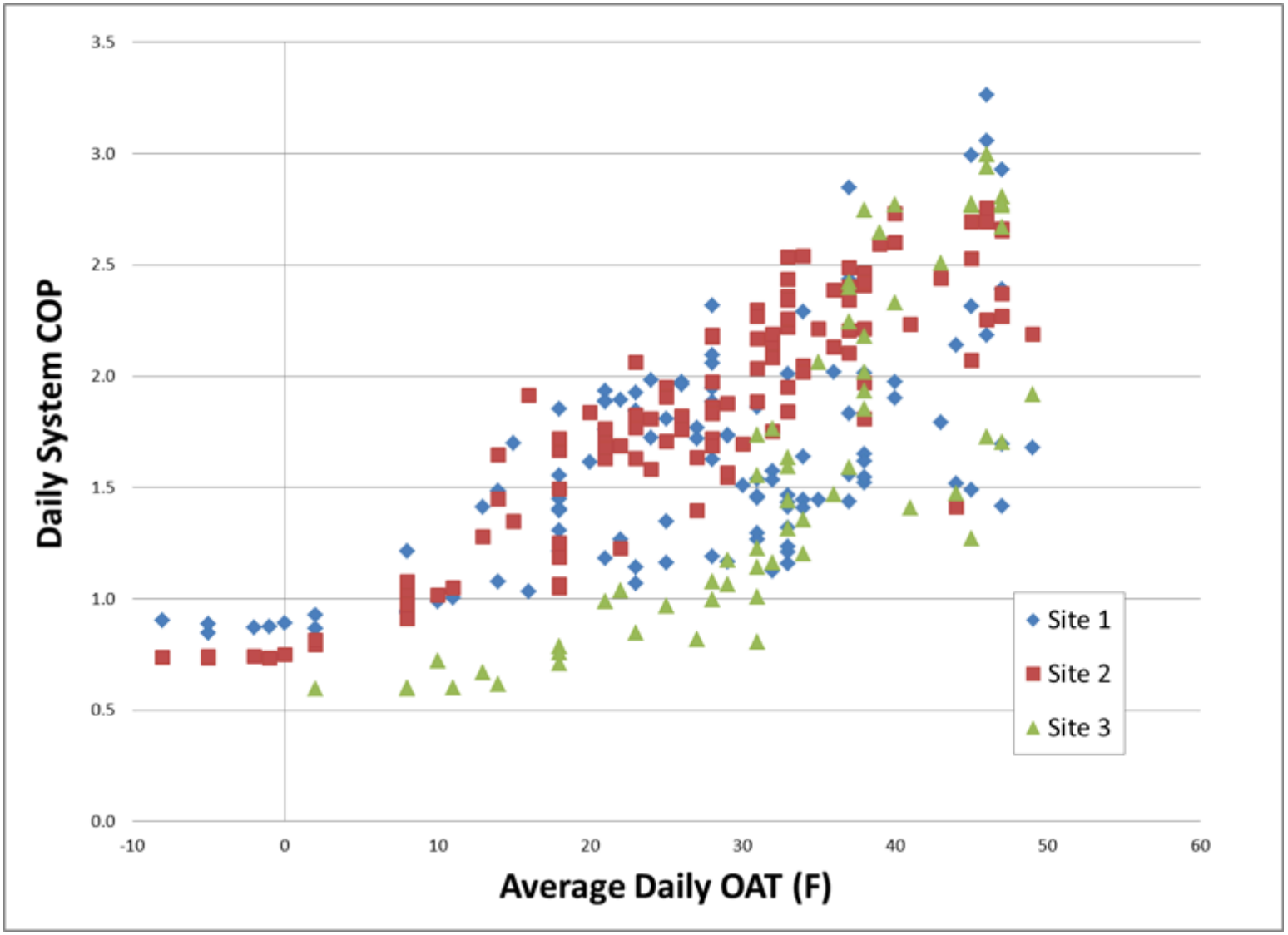
Power Measurements:
1) Outdoor unit
2) Indoor unit
3) Indoor fan
4) Reversing valve

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

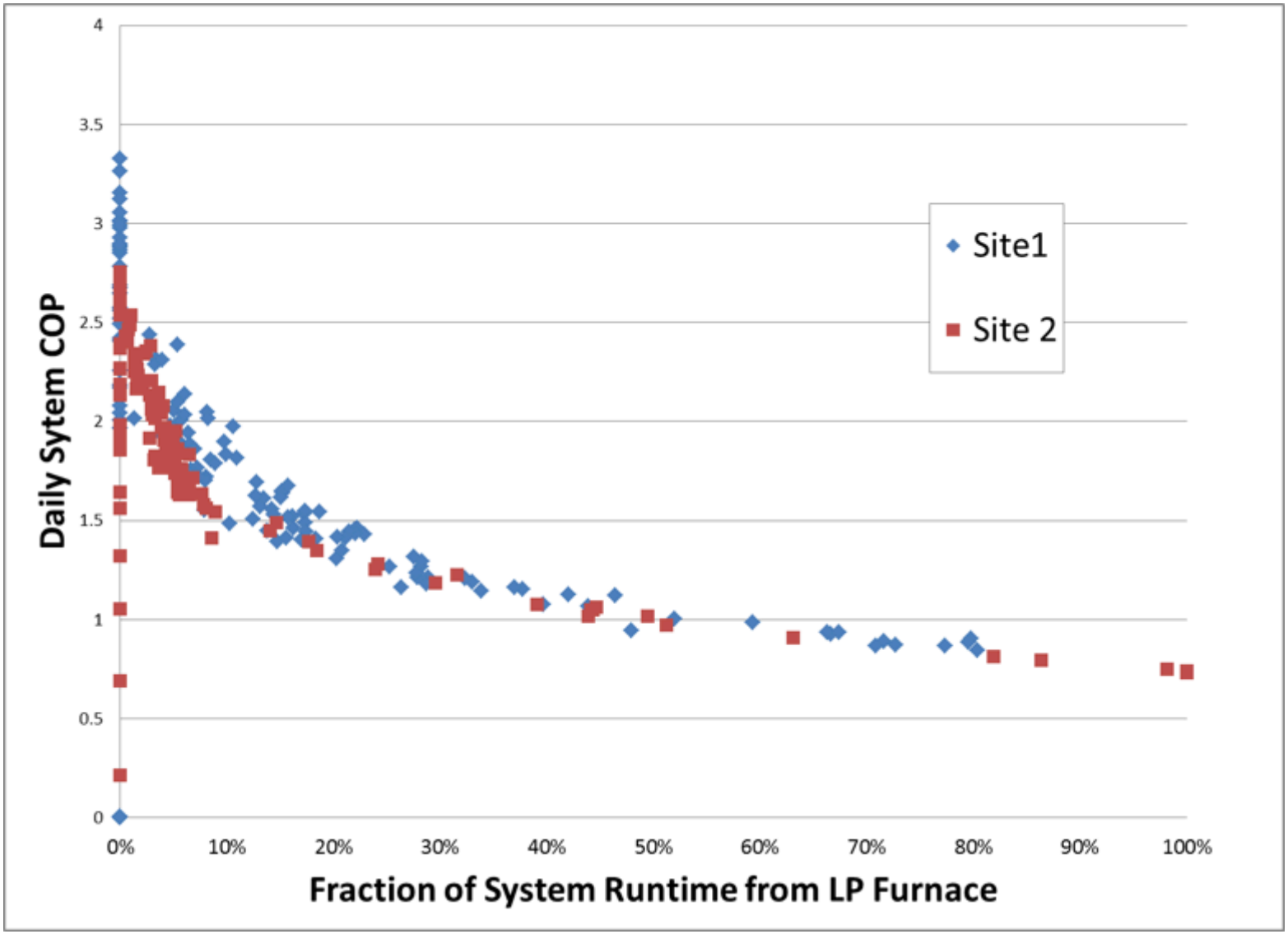
Additional:
9) Back up fuel consumption
10) Delivered air flow
11) NOAA data



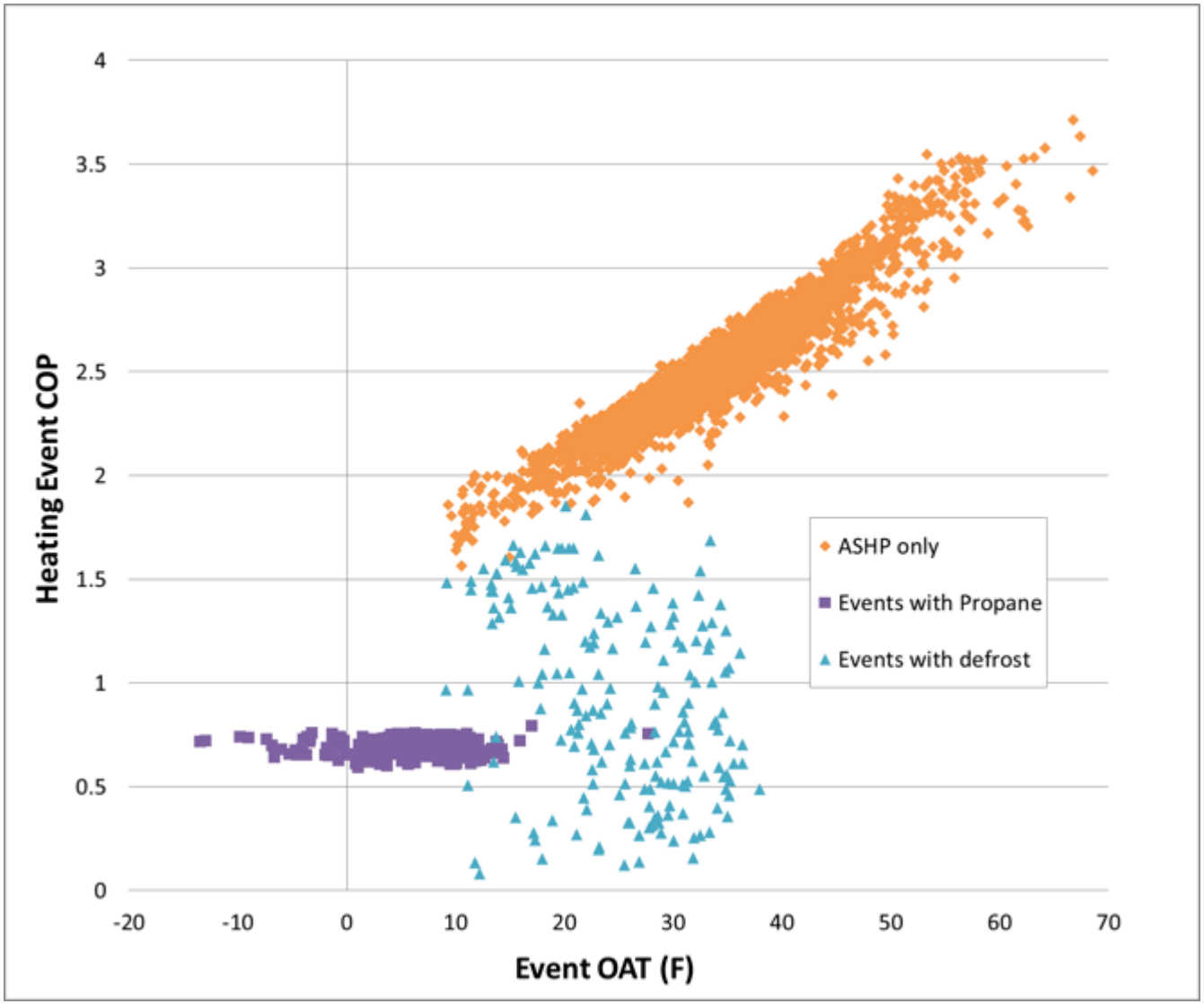
System COP vs OAT



System COP vs Furnace runtime

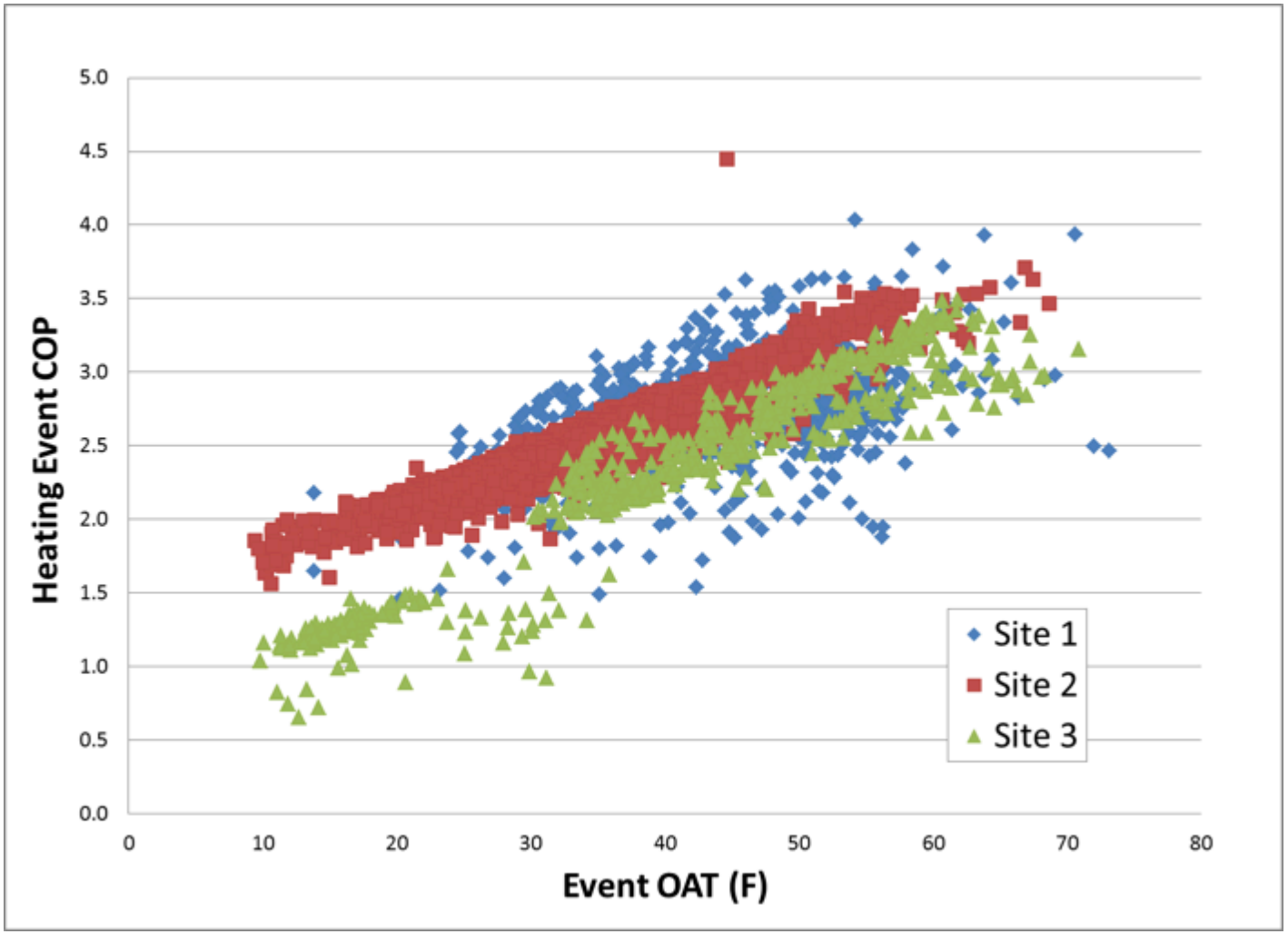


ASHP and Furnace Cycle Efficiency



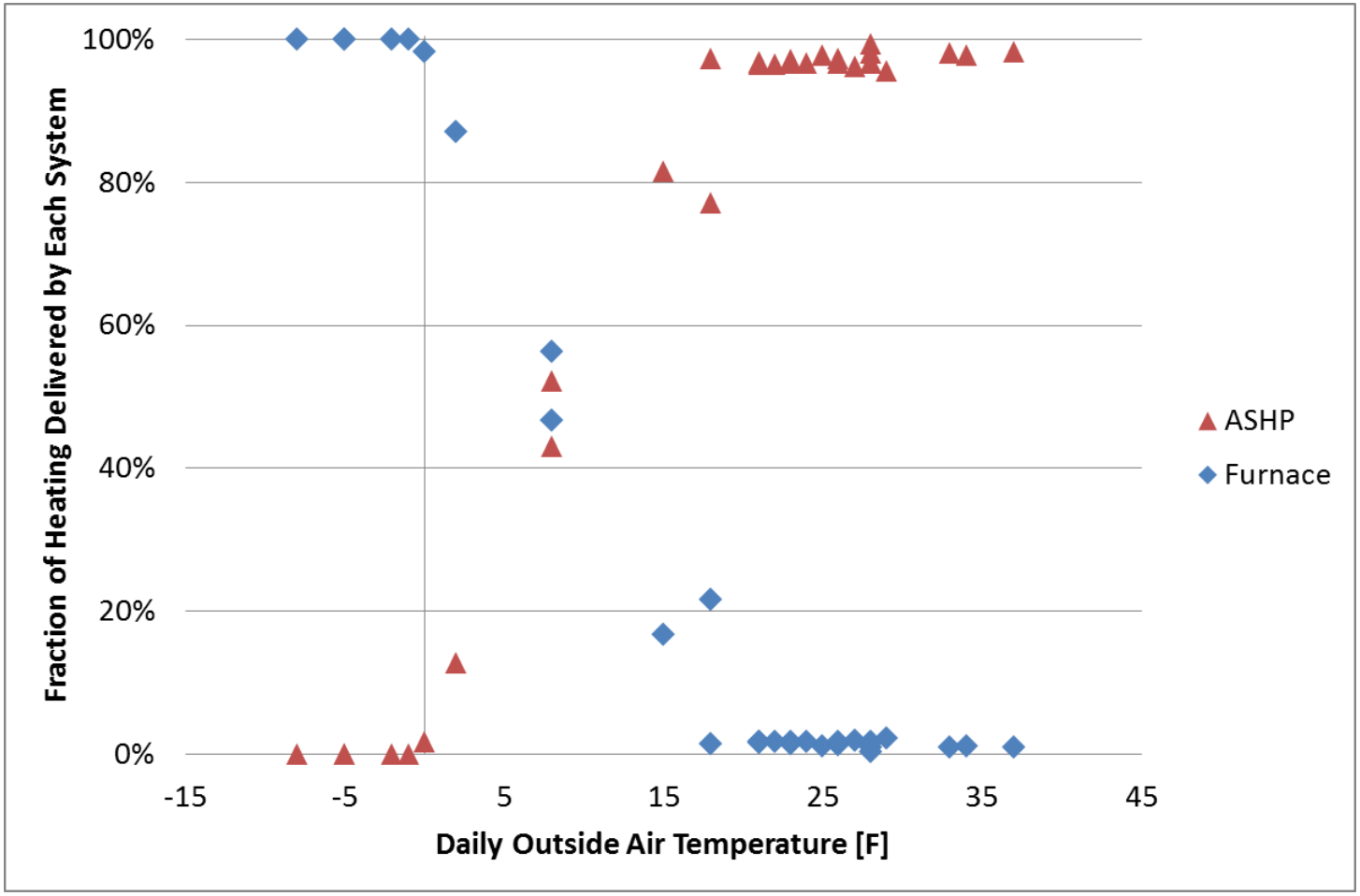
- Without propane:
  - COPs 2.0 to 3.3
- Furnace Efficiency
  - 80%
- Freeze protection bringing some events down < 0.5

ASHP Performance

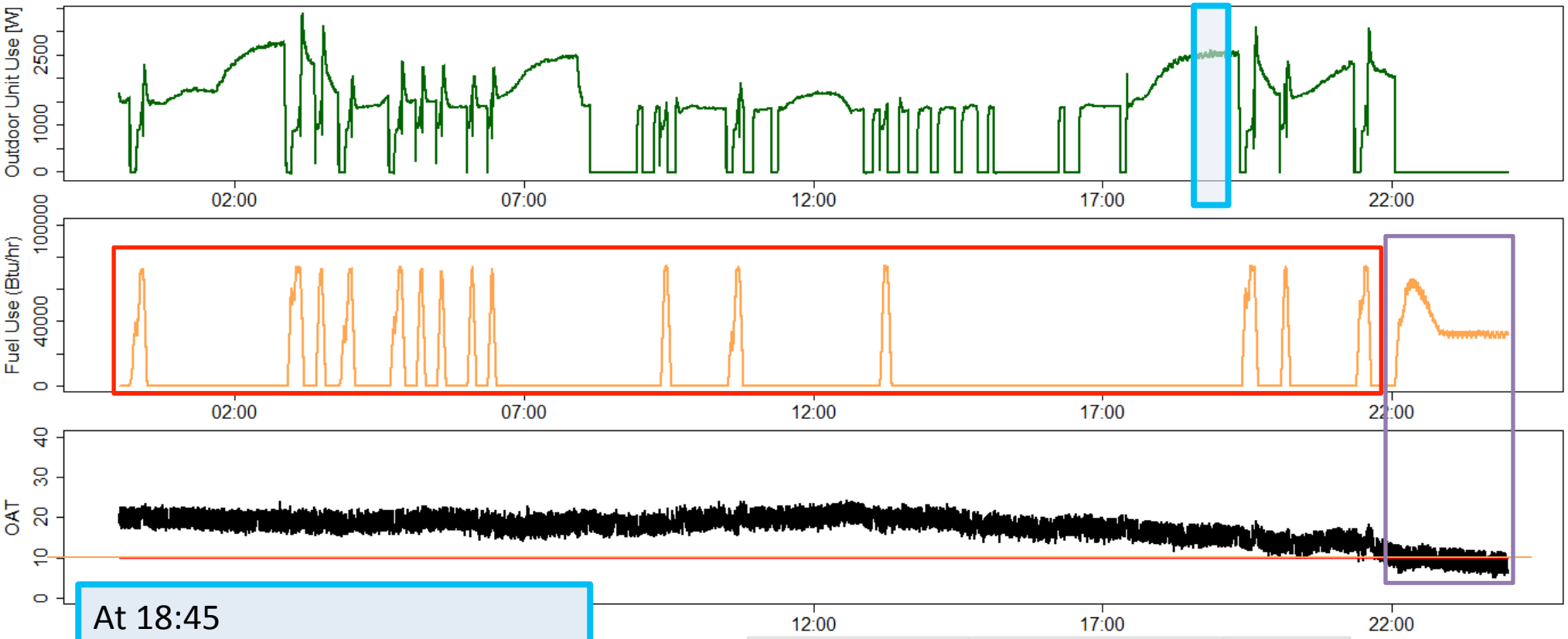


- Rated COPs of 3.0-3.5 at 47 F
- COP observed
  - 1.5-3.5 (site 1 & 2)
  - 1-3.5 (site 3)

Can ASHP Meet Capacity?



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%

Preliminary Results

- Compared to LP furnaces the ccASHPs
  - Reduced between 40% and 65% of site energy consumption
  - Reduced total heating costs 19% to 35%
  - On average ccASHP met 84% of the homes heating loads
  - Reduced propane consumption by around 60%, up to 89% at one site
- Compared to Electric Resistance Heat
  - Provided more efficient space heating (COP of 1.6, compared to 1.0)
  - Savings are largely dependent on usage and install location

Conclusions

- Systems should sized for heating, typically results in 1-ton larger system that if sized for cooling
  - With proper sizing ccASHPs are capable of meeting the loads in typical MN homes at or below 10 ^{o}F outdoor temps.
- Preliminary results show ccASHP COPs of 1.5-3.5 and annual system COPs between 1.4 and 1.8.
- ccASHPs will reduce delivered fuel consumption enough to avoid costly winter refueling in most MN homes

- There is still room for improvement:
  - Reduce unnecessary back-up heating
  - Reduce upfront installation costs

Field Study of a Moisture and Heat Transfer Furnace Retrofit Device

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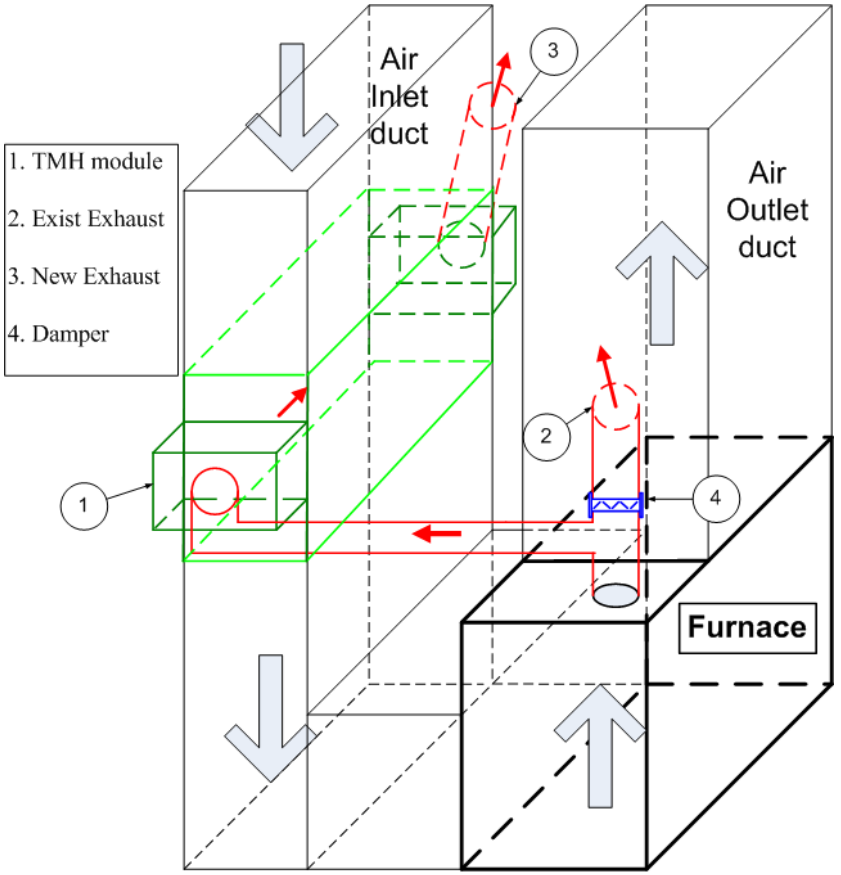
Transport Membrane Humidifier (TMH)

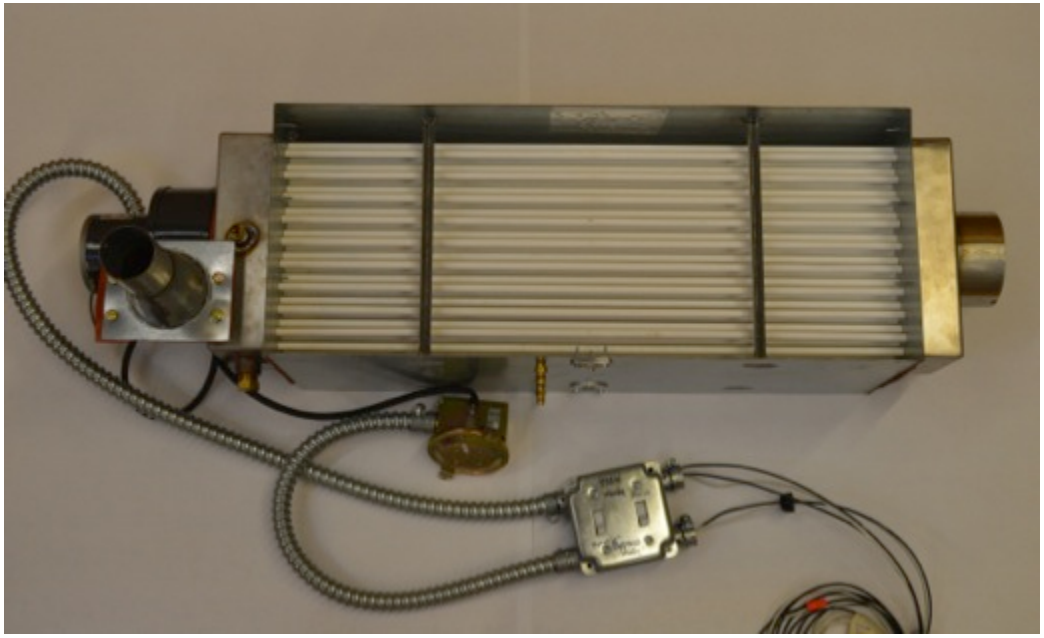
- Furnace retrofit device
- Extracts heat and moisture from flue gas
- Preheats and humidifies return air
- Improves furnace efficiency by 12 - 15%
- Increases indoor humidity by ~3 - 7% RH

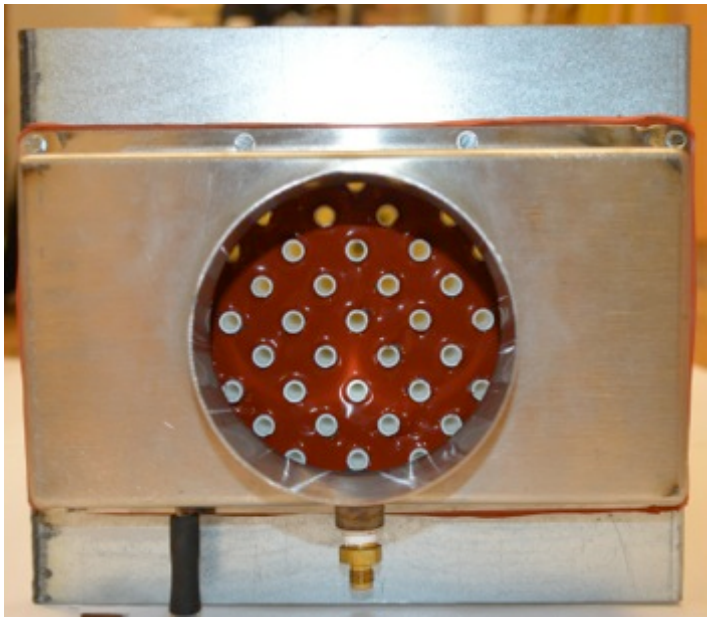


TMH Installation diagram for mid-efficiency furnace

EXISTING RESIDENTIAL FURNACE

Transport Membrane Humidifier (TMH)

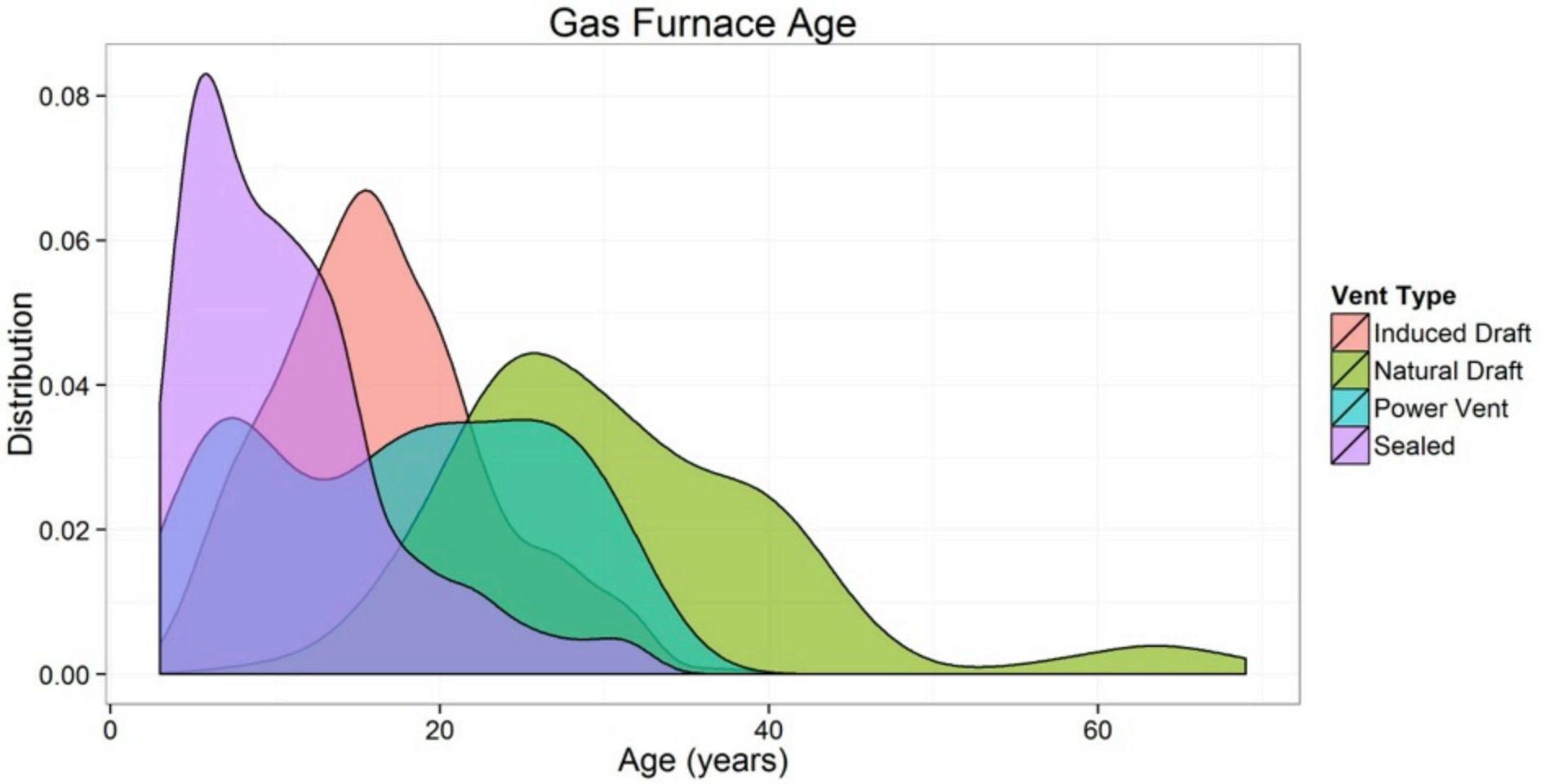




Opportunity

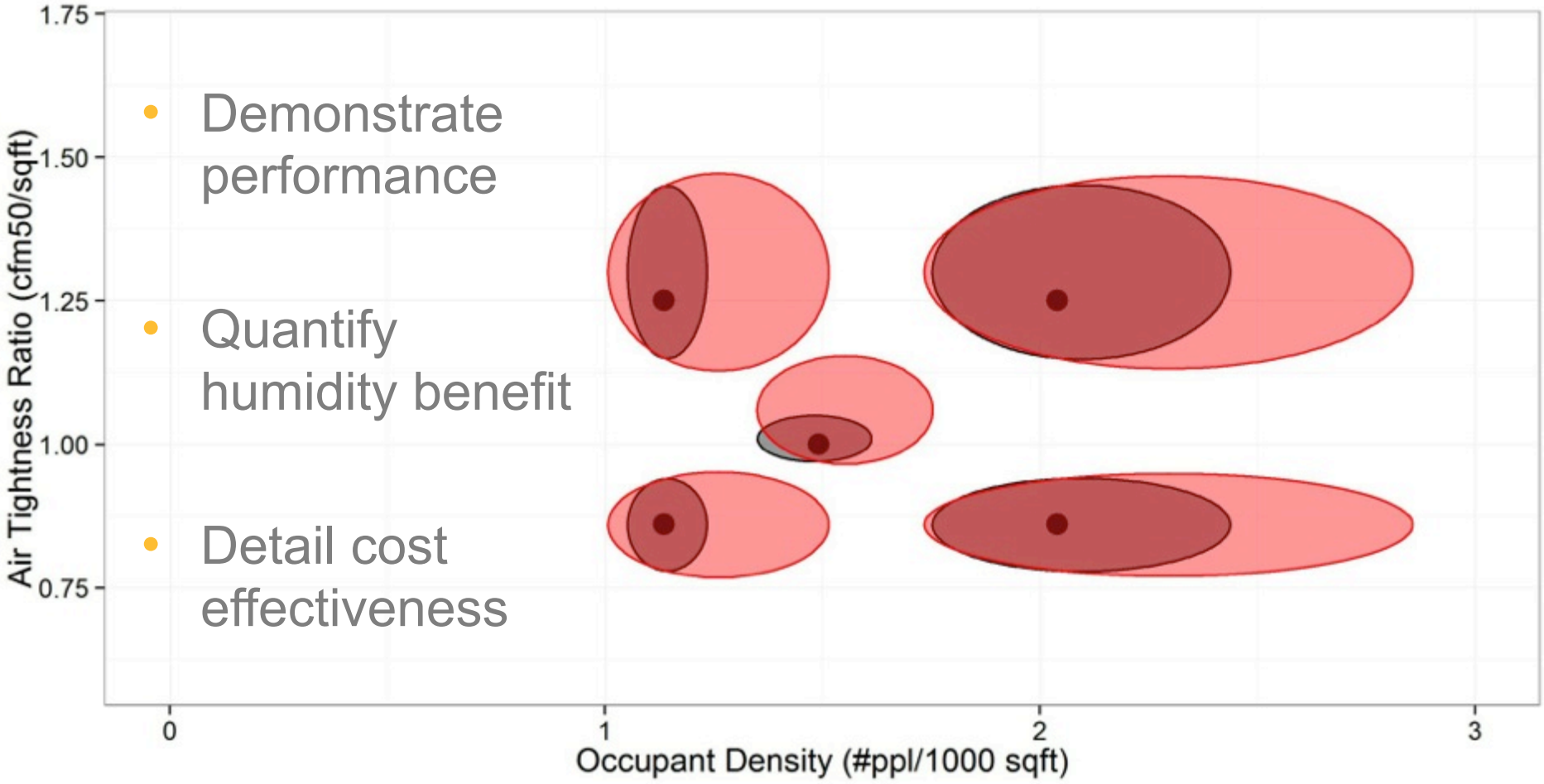
- Large Market:
  - ~800,000 80% efficiency units in Minnesota (EIA, 2009)
  - 50%+ of national market is standard efficiency (D+I, 2015)
  - High efficiency heating penetration still 20-30 years out, potentially further as standard efficiency units maintain dominant market share
- High savings potential:
  - Hundreds of millions of dollars in MN
  - Billions of dollars nationally

Furnace Age


Gas Furnace Age
0.08
0.06
0.04
0.02
0.00
Distribution
0
20
40
60
Age (years)
Vent Type
Induced Draft
Natural Draft
Power Vent
Sealed

Minnesota Pilot

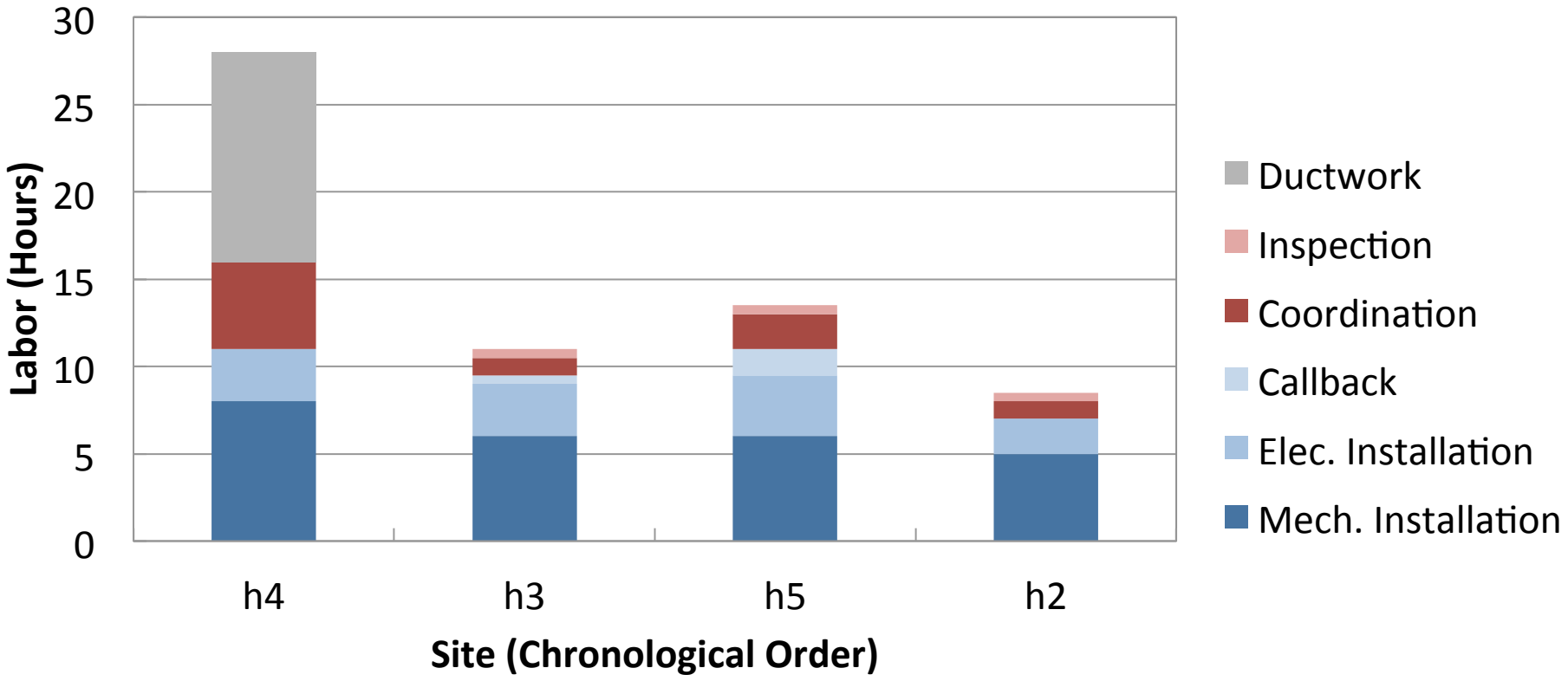
- Demonstrate performance
- Quantify humidity benefit
- Detail cost effectiveness



Installation

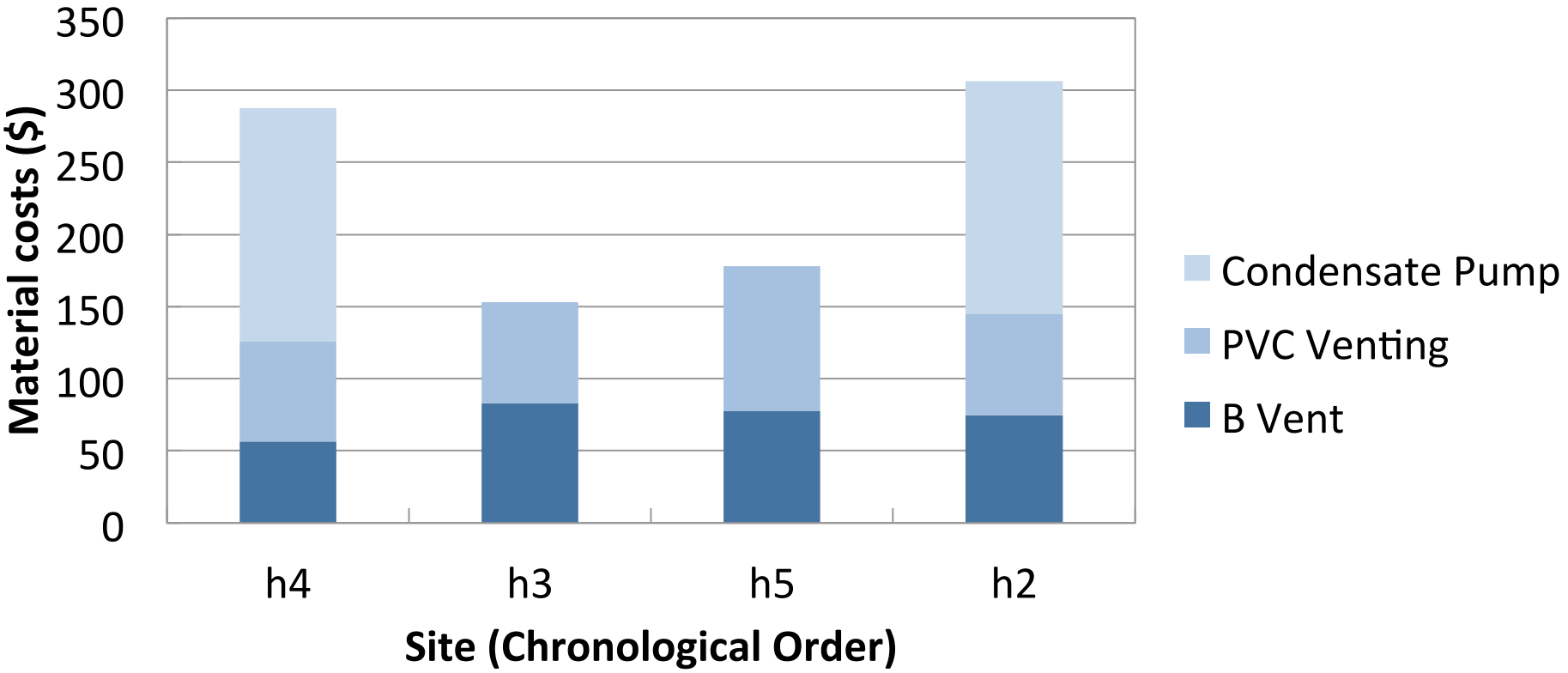
Installation

Installation



	h4	h3	h5	h2	Avg
Labor - Min	11	9.5	11	7	10
Labor - Max	16	10.5	13	8	12

Installation



	h4	h3	h5	h2	Avg
Materials - Cost	$ 95	$ 51	$ 59	$ 101	$ 76
Materials - Basic	$ 288	$ 153	$ 178	$ 306	$ 231
Materials w/ Tune up	$ 397	$ 262	$ 287	$ 306	$ 313

Operation

Instrumentation

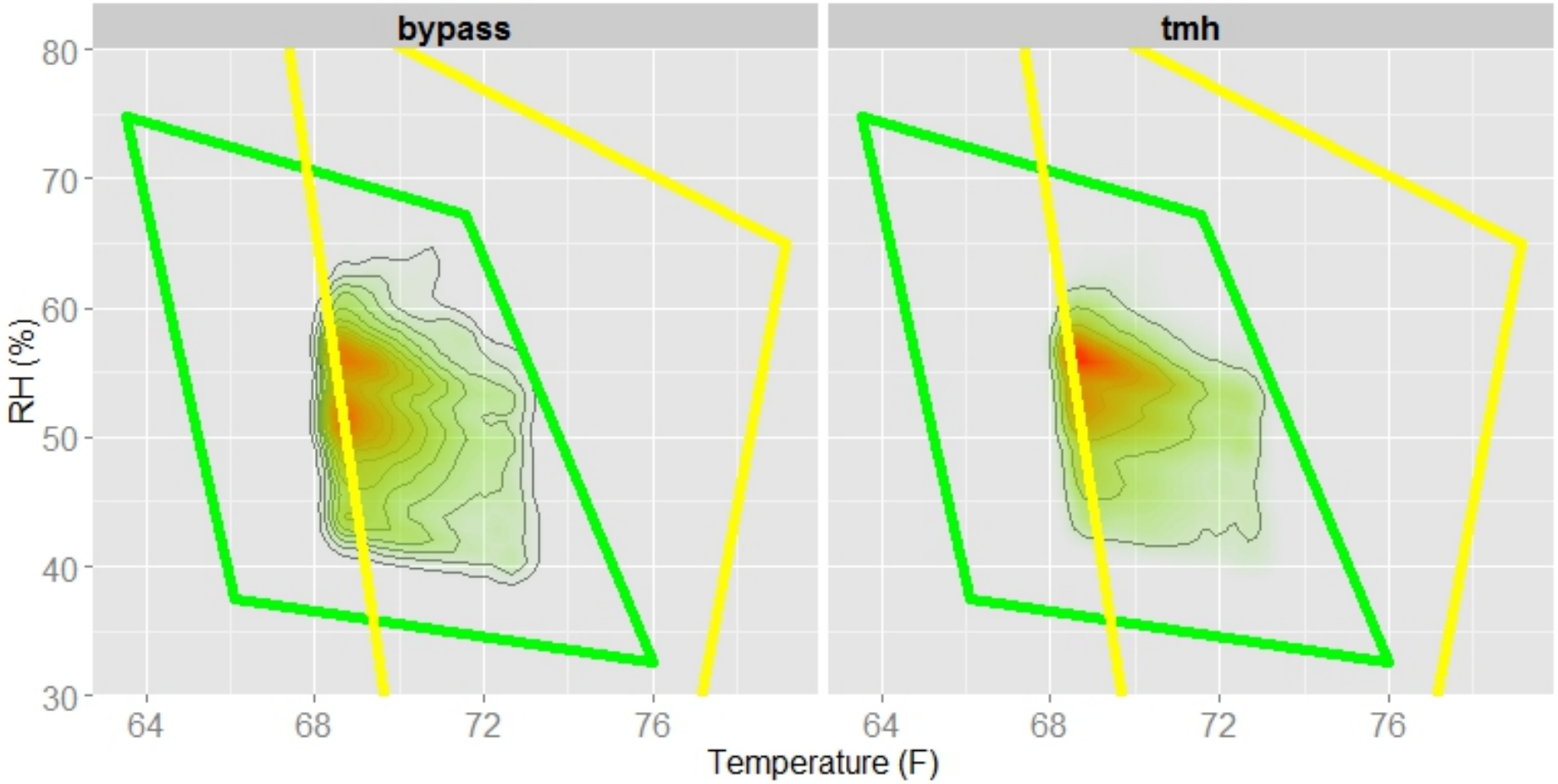
	Characterization Measurements
1	Furnace Airflow
2	House Envelope Tightness
3	Supply and Return Duct Pressures

	Ongoing Furnace Measurements
4	Return Air Temperature and Humidity
5	TMH Temperature and Humidity
6	TMH Flue Gas Temperature (In)
7	TMH Flue Gas Temperature (Out)
8	Supply Air Temperature
9	Furnace Runtime
10	Supply Air CO & Alarm

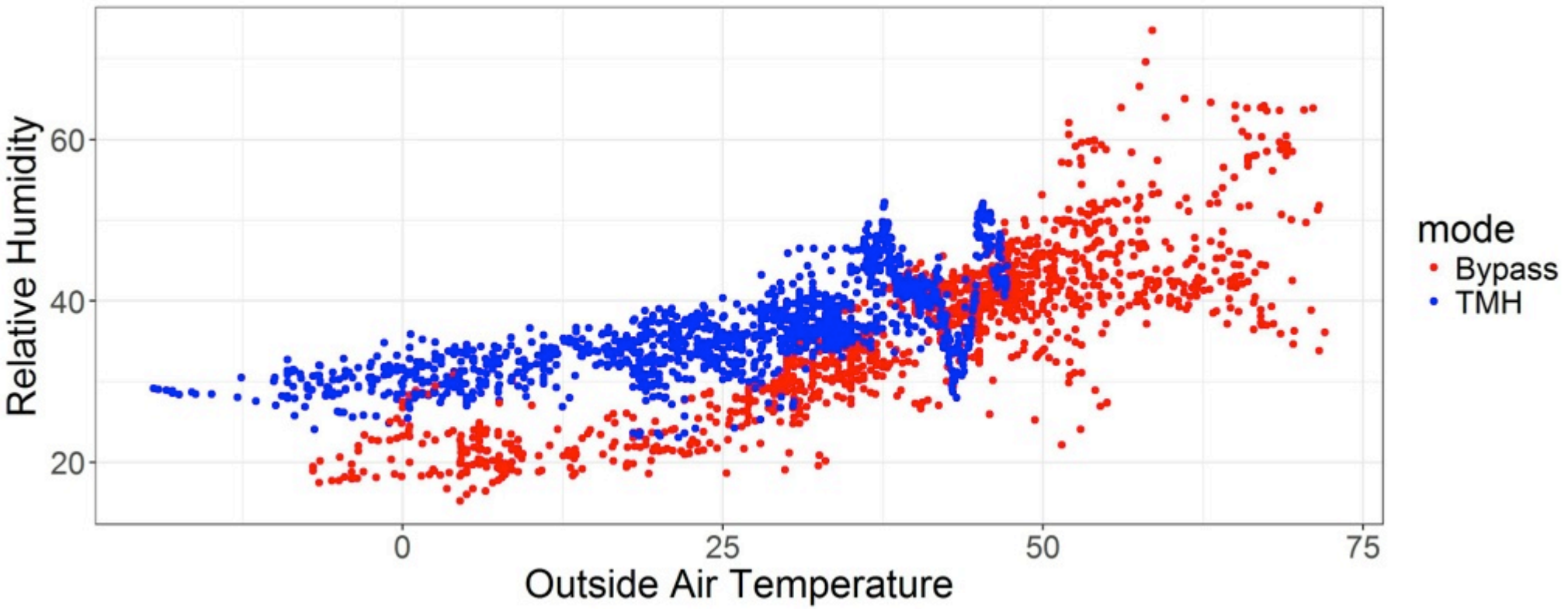
	Ongoing Household Measurements
11	Common Space Temperature, Humidity, and Wood Moisture
12	Basement Space Temperature, Humidity, and Wood Moisture
13	Attic Space Temperature, Humidity, and Wood Moisture

Preliminary Results

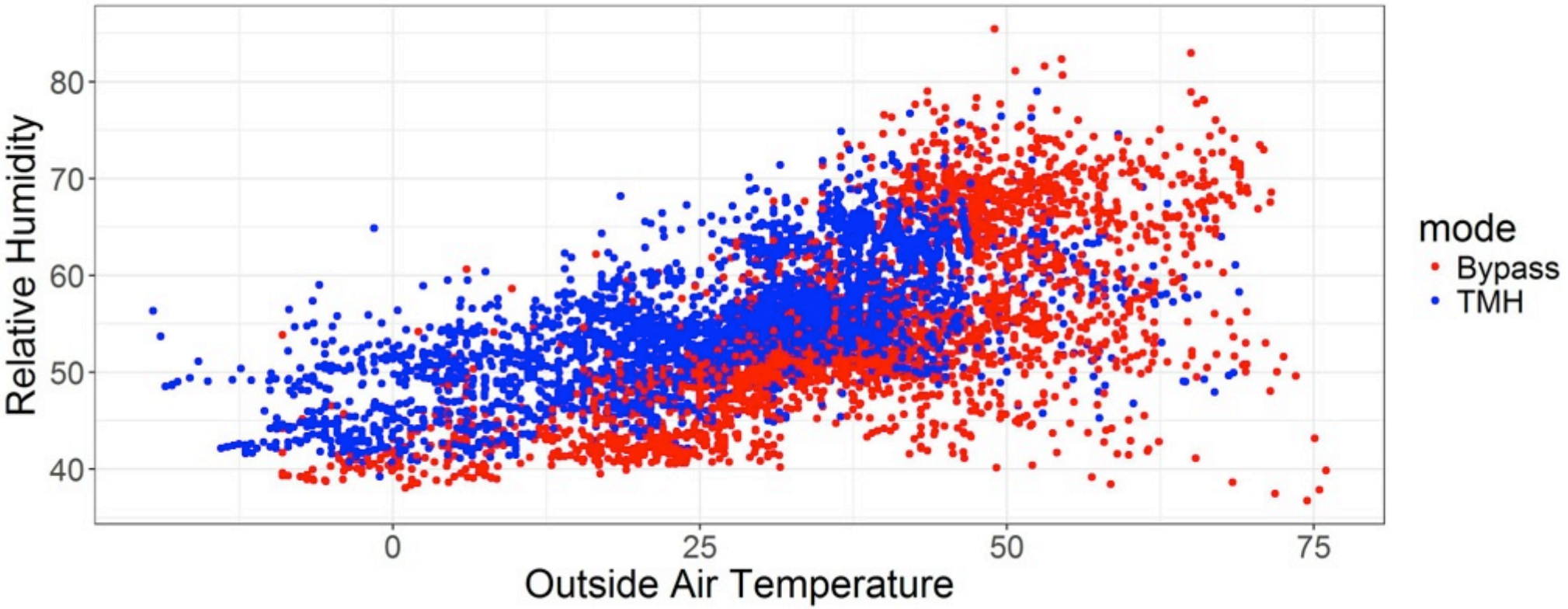
Preliminary Comfort IAQ / Results



Indoor Humidity – Low RH Home



Indoor Humidity – High RH Home



Conclusions

- Project is demonstrating performance, quantifying changes in humidity, determining cost effectiveness
- Installation time is a few hours
- Preliminary data shows an improvement in net system efficiency between 12-14%
- Preliminary data shows predictable increase in relative humidity

- **TMH retrofit is a viable alternative path for energy savings from ID furnaces**

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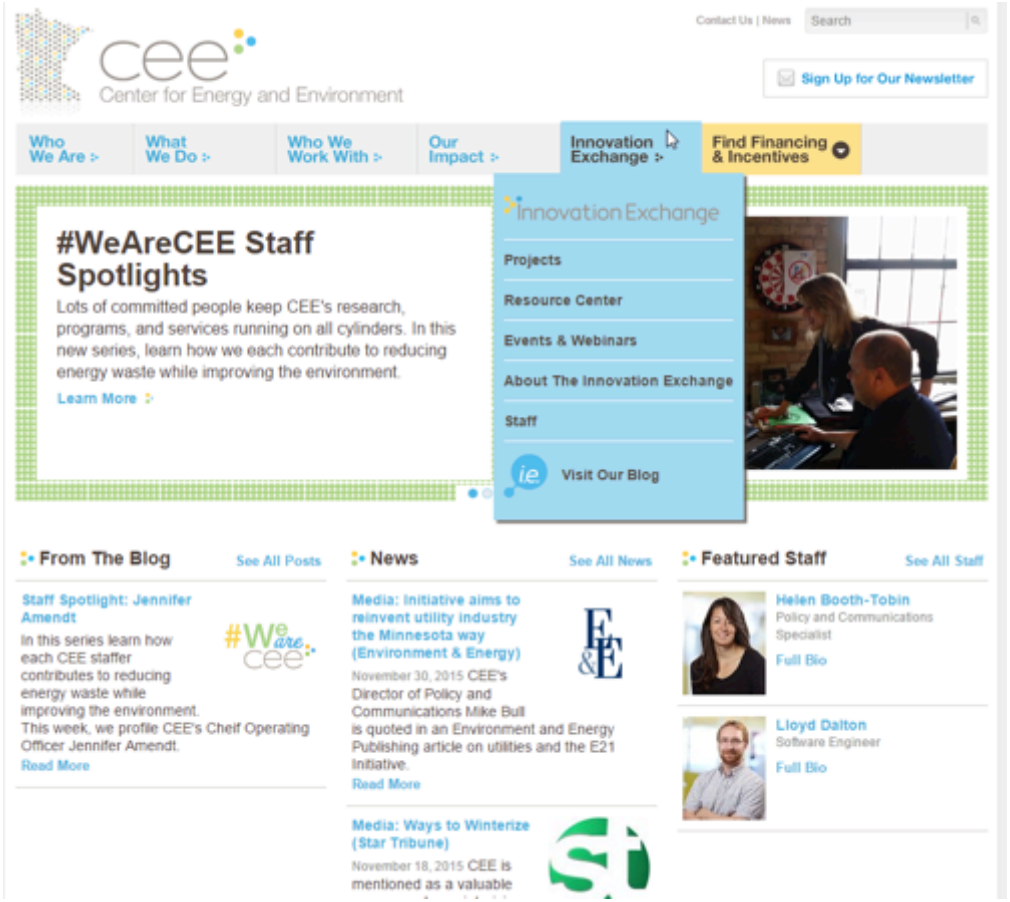

Field Study of a Moisture and Heat Transfer Furnace Retrofit Device

Cold Climate Air Source Heat Pump Field Assessment

THANK *you!*