Emerging Technologies for Cold Weather Residential Heating

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Center for Energy and Environment

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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

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Minnesota Department of Commerce
Division of Energy Resources

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

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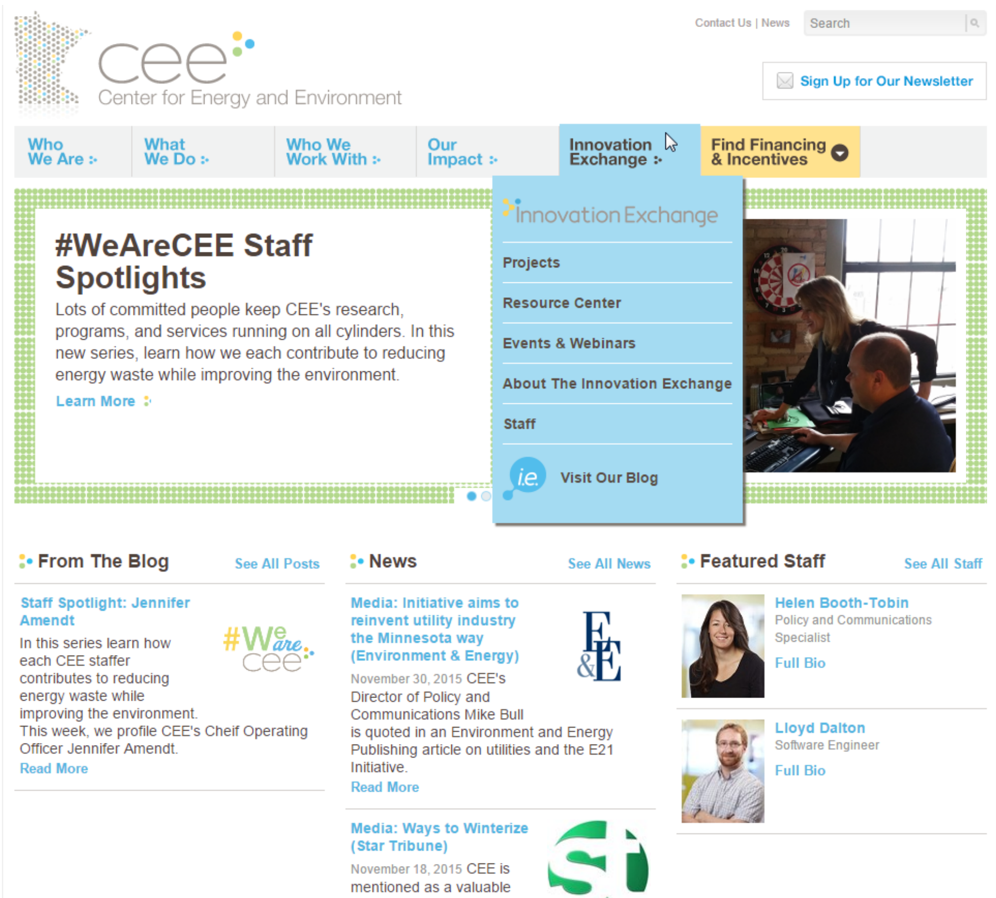

Field Study of a Moisture and Heat Transfer Furnace Retrofit Device

Cold Climate Air Source Heat Pump Field Assessment

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Cold Climate Air Source Heat Pump Field Assessment

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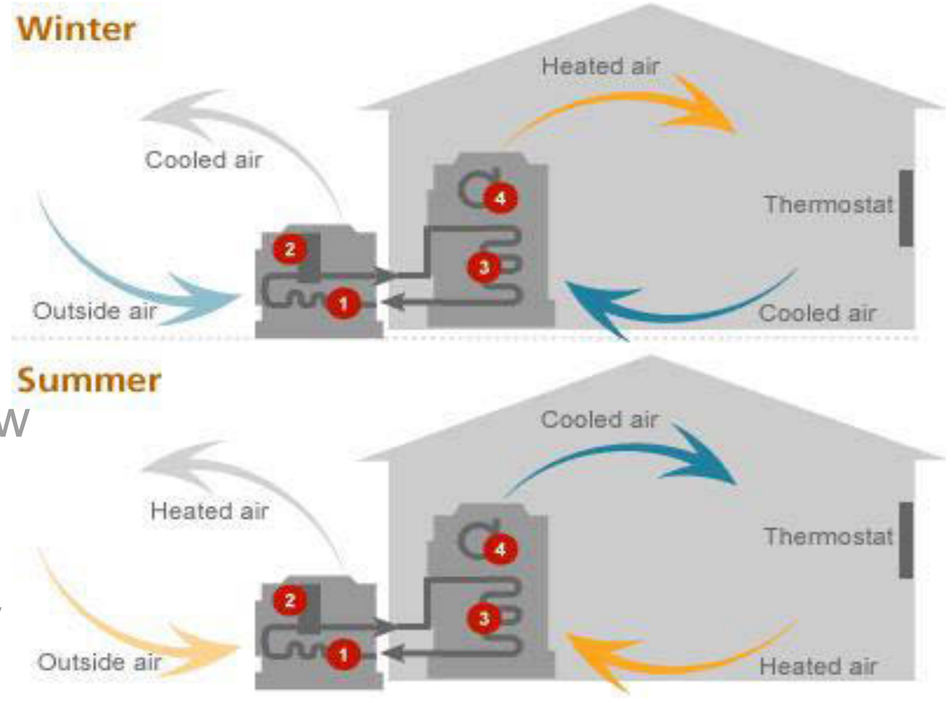
Cold Climate Air-Source Heat Pump?

- 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.

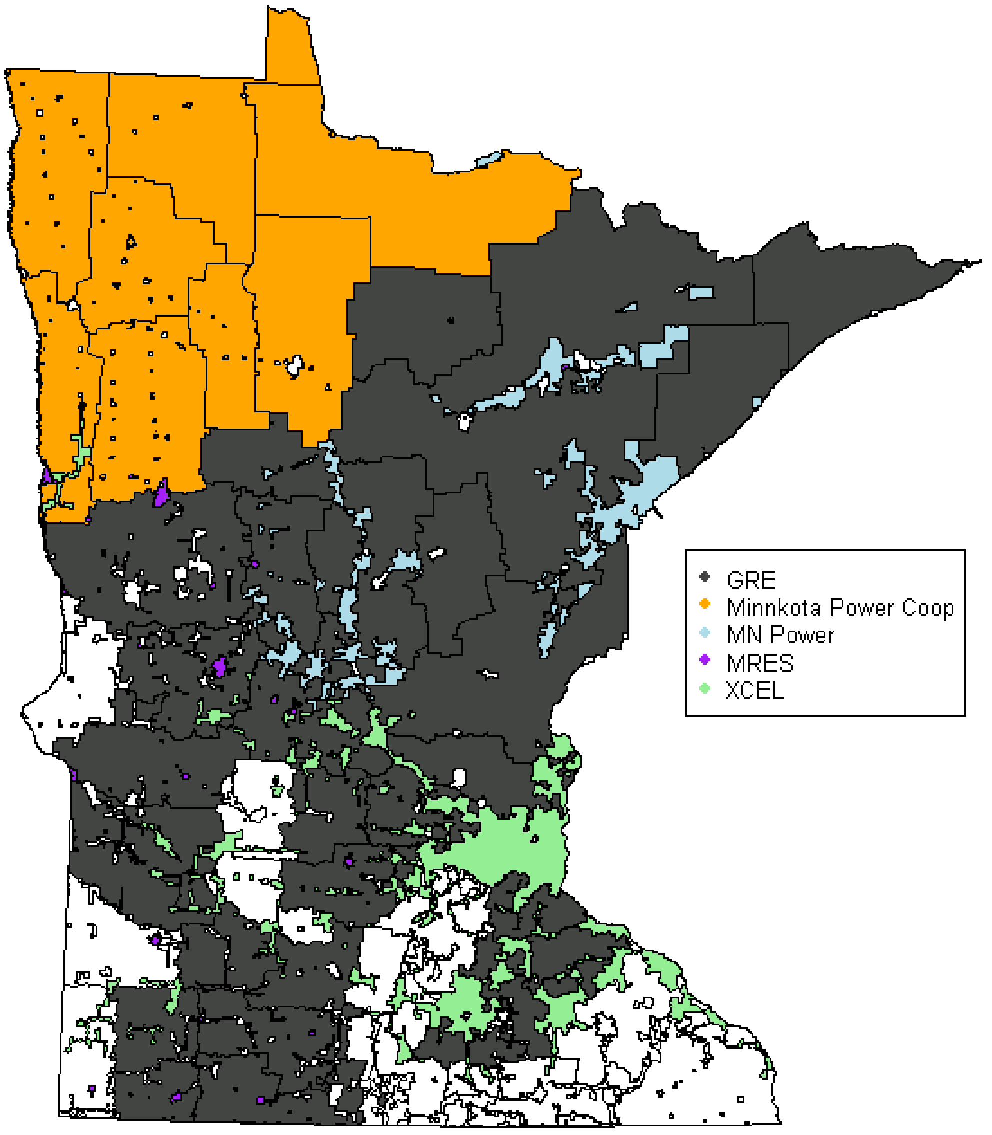


Opportunity

- Winter of 2013/2014 saw delivered fuel shortages
  - 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)

Utilities and Rebates

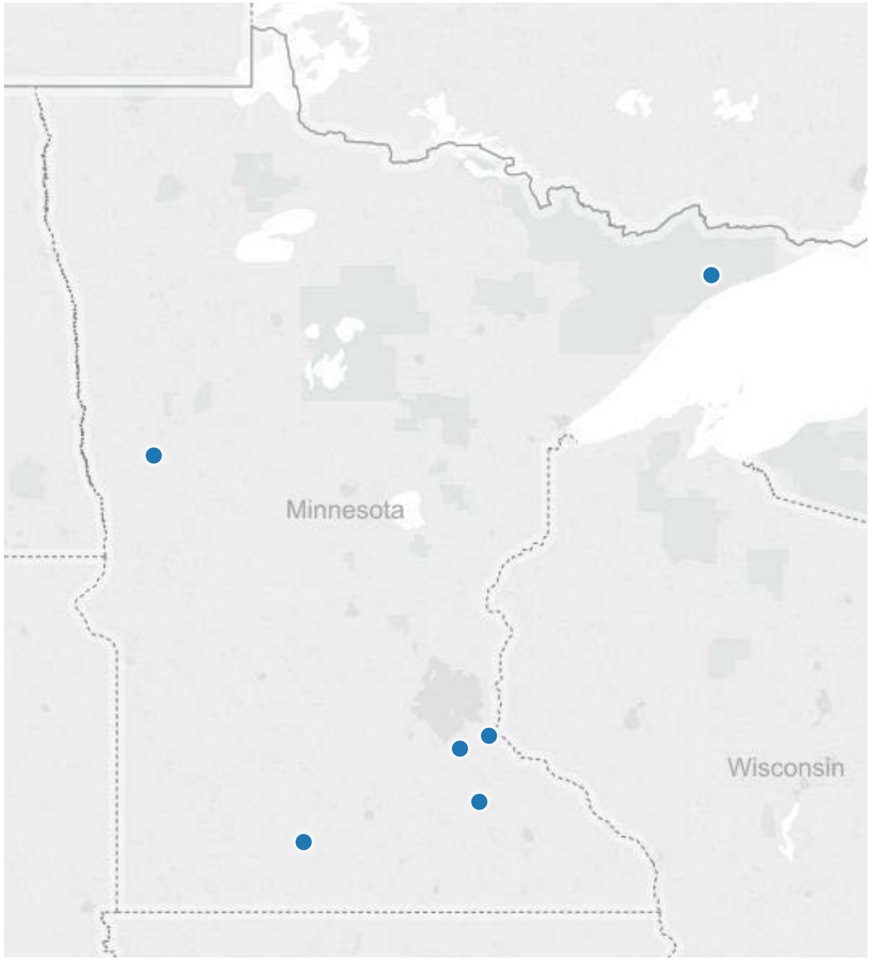


Study Overview

- Field Study
  - Install 6 to 8 ccASHP in a variety of MN residences
    - 3 installed to date
  - 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

Installation

- 5 ducted systems
  - Delivered fuel backup
- 1 ductless mini-split
  - Electric resistance backup

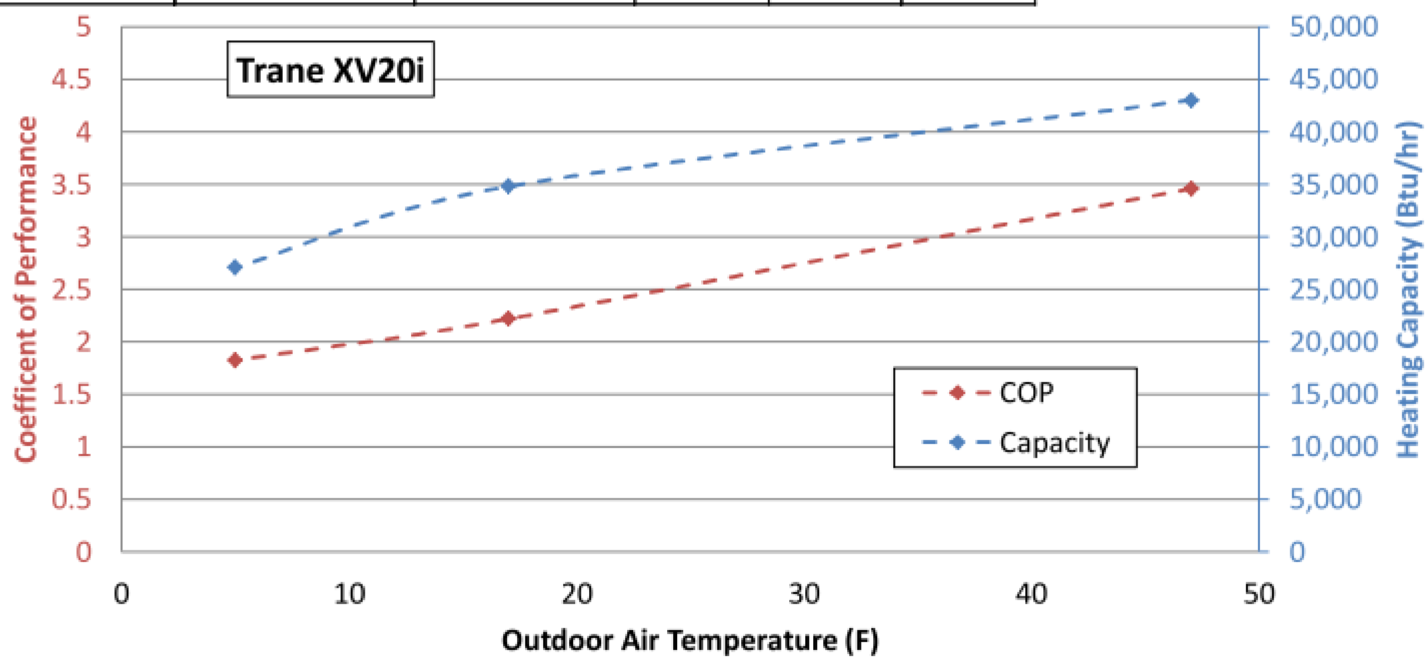


Installation

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

Manufacturer Specified Performance

Manufacturer	Trade Name	Type	Multi-zone or Single-zone	Variable Capacit	HSPF (Region	SEER
American Standard	Platinum ZM	Ducted	Singlezone	Yes	10	18
Trane	XV20I	Ducted	Singlezone	Yes	10	18
Carrier	Infinity with Greenspeed	Ducted	Single-zone	Yes	13	20.5
Lennox	XP25	Ducted	Single-zone	Yes	10.2	23.5
Daikin	LV Series - Wall Mount	Ductless mini-split	Single-zone	Yes	12.5	20
Fujitsu		Ductless mini-split	Multi-zone	Yes	10.3	20
Fujitsu		Ductless mini-split	Single-zone	Yes	13.4	25.3
Haier		Ductless mini-split	Single-zone	Yes	10	20
Mitsubishi		Ductless mini-split	Multi-zone	Yes	11	18.9
Mitsubishi		Ductless mini-split	Single-zone	Yes	10.3	20.2



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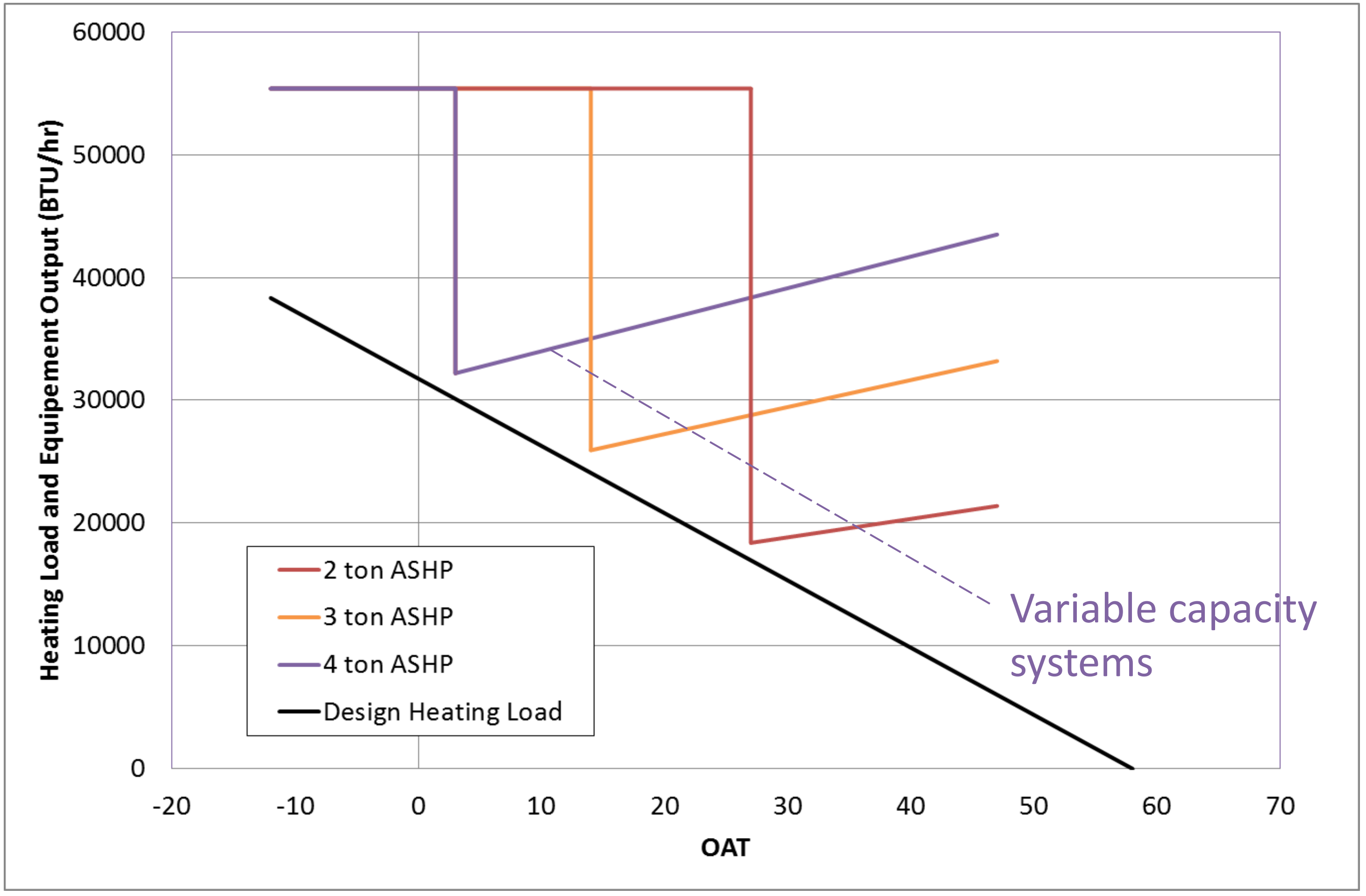
Sizing



The OAT for the systems to switch to back up:
4ton ~3 F,
3ton ~14 F,
2 ton ~27F

Percentage of heating load meet by ASHP:
4ton ~ 86%,
3ton ~ 74%
2 ton ~ 40%

Operation

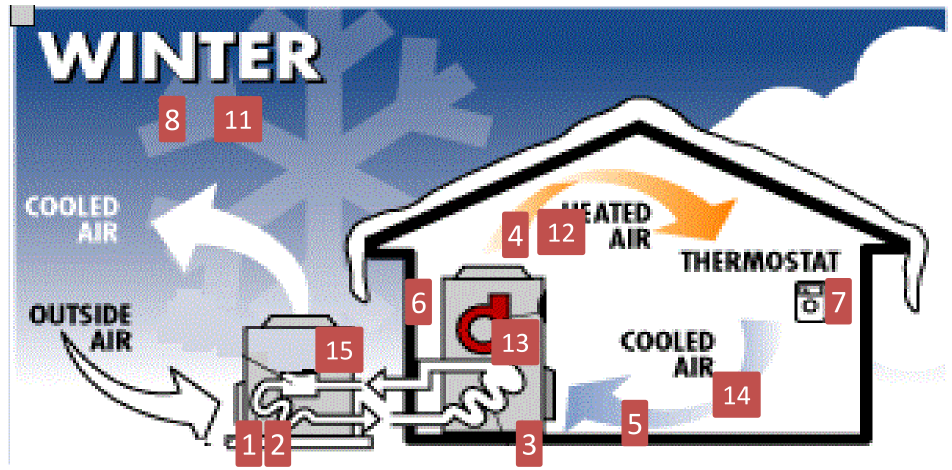
- Switchover set point:
  - Ducted Systems: 10 degrees F
  - Ductless Systems: -13 degrees F
- Controls:
  - Ducted Systems: automated controls to bring up backup
  - Ductless Systems: manual action by homeowner
- Interaction with back-up systems
  - Ducted Systems: Integrated installs with shared controls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

Integration with Back-Up

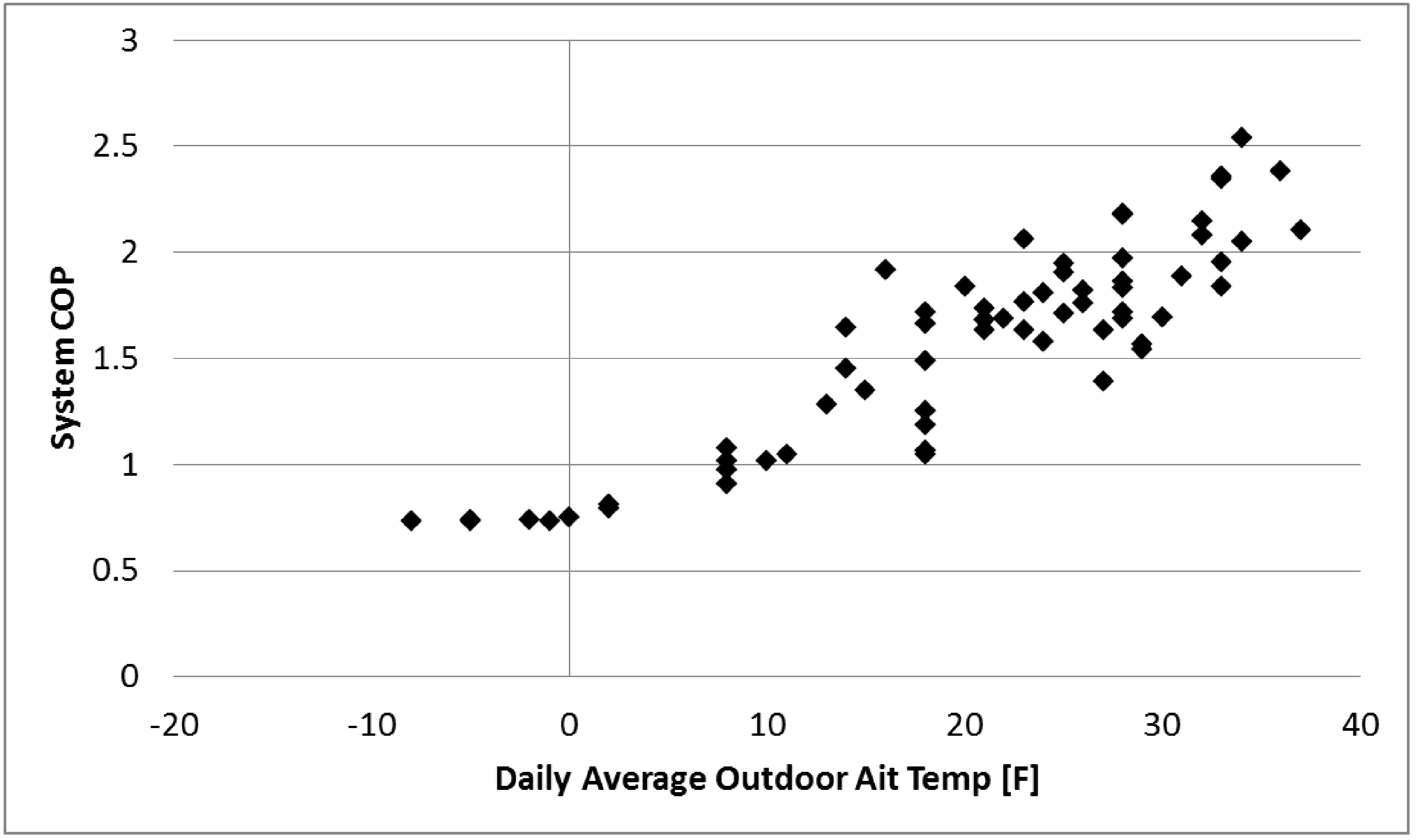
- To be successful for cold climate heating ASHPs need:
  - Variable speed capacity: inverter driven compressors
    - Allows a higher capacity stage of operation to be used at colder temperatures ensuring enough output during a majority of the heating season
  - To achieve the full capability of ccASHPs a multi-stage fan is necessary
    - Most 80% AFUE and older condensing furnaces have a fixed speed fan

Instrumentation

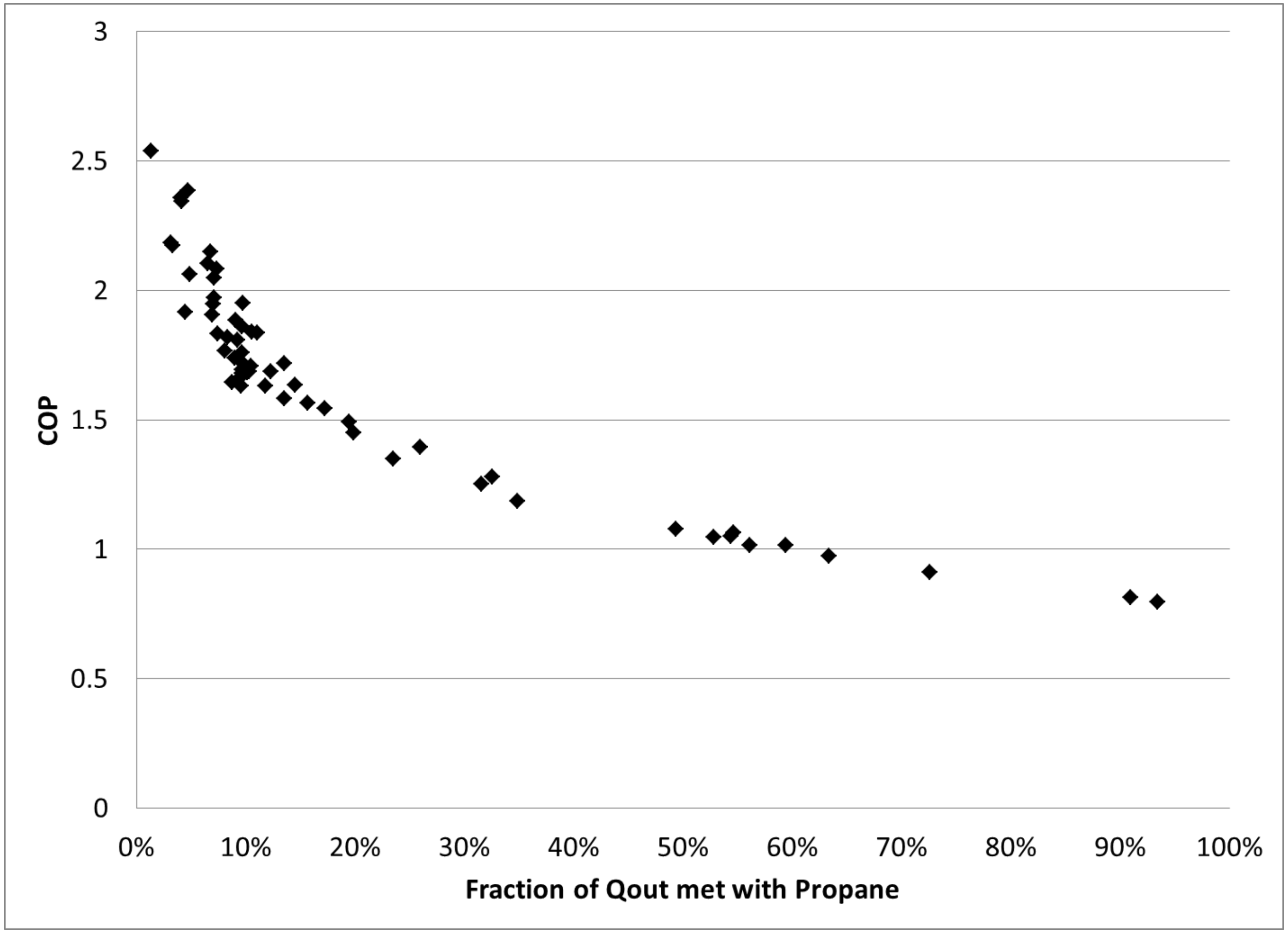
	Power Measurments
1	Outdoor unit
2	Defrost heater
3	Indoor Unit
	Temepratures
4	Supply air
5	Return air
6	Mechanical area ambient
7	Conditioned space (t-stat)
8	Outdoor (NOAA)
	Additional
9	Backup fuel consumption
10	Duplicate sensors for backup if necessary
11	Outdoor relative humdity (NOAA)
12	Deliveried air flow
13	Fan runtime
	Optional
14	Return air relative humdity
15	Pressure difference in outdoor loop (deforst)



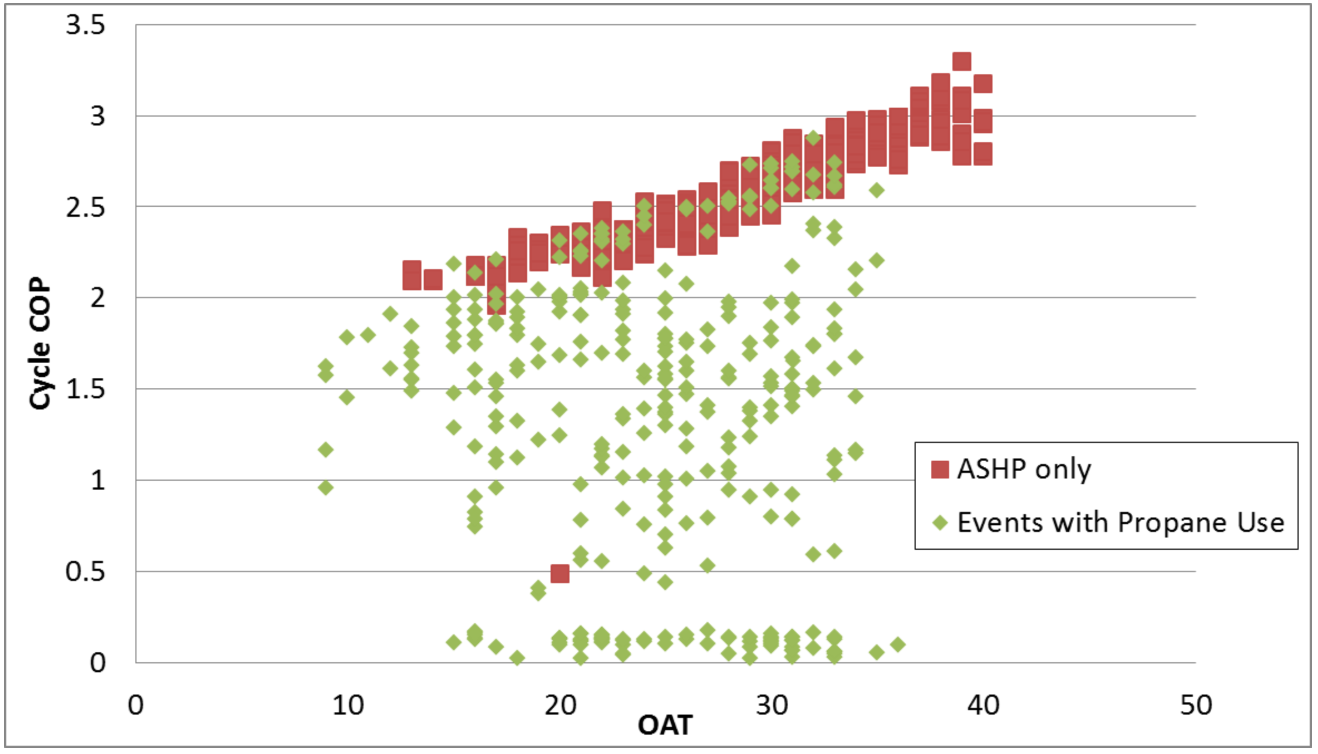
Preliminary Results



Preliminary Results

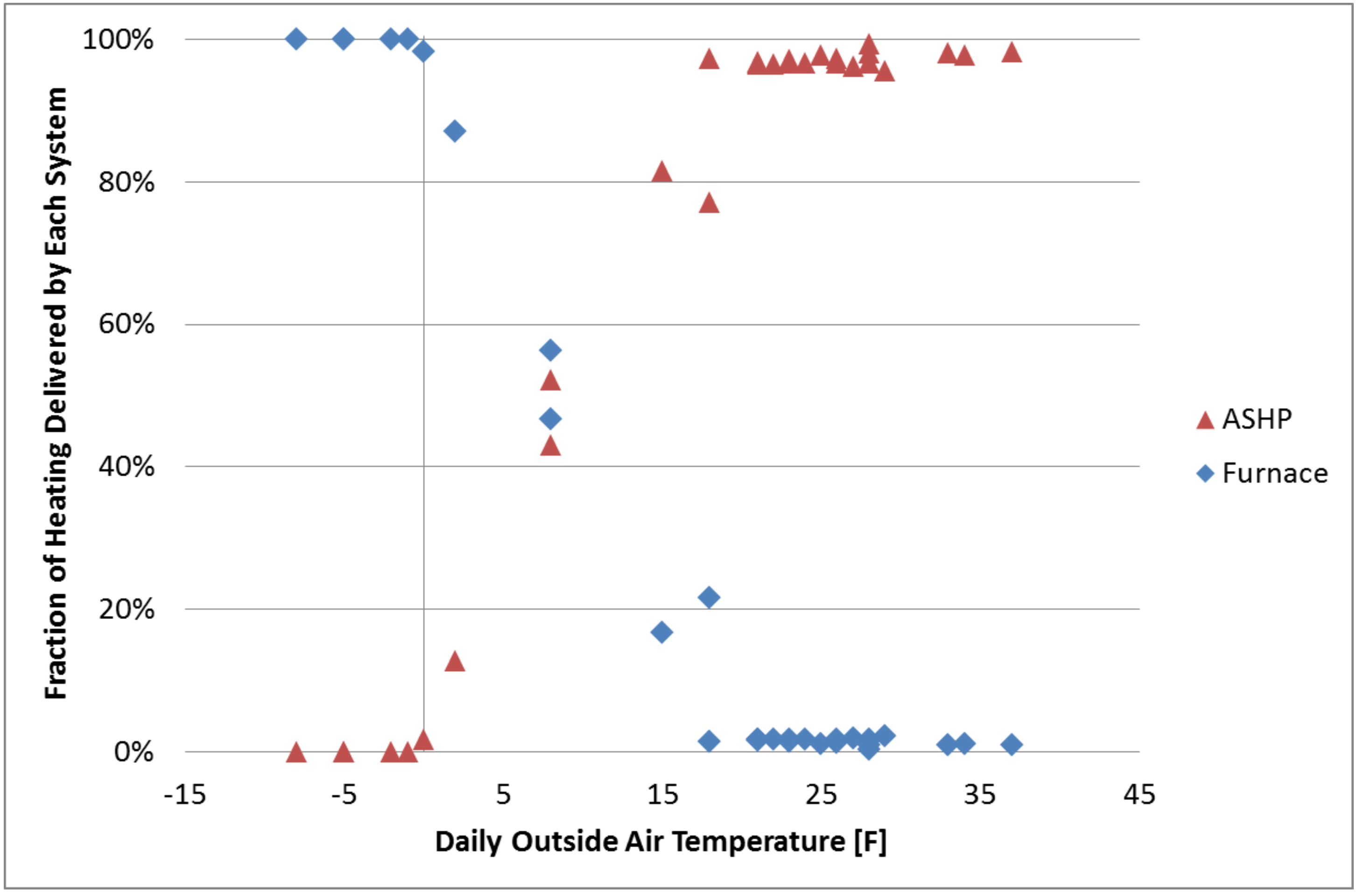


ASHP and Furnace Cycle Efficiency



- Without propane:
  - COPs 2.0 to 3.3
- Furnace Efficiency
  - 90%
- Freeze protection bringing some events down < 0.5

Can ASHP Meet Capacity?



Energy Use and Costs

- Assumptions:
  - 40,000 Btu/hr design heating load
  - Minneapolis TMY3
  - Equipment specifications

			LP Use	Electric Use	Annual Cost
	Avg COP	%ASHP	therms/yr	kWh/yr	$/yr
Propane Furnace	0.80	0%	876	0	$1,732
Propane Furnace	0.95	0%	735	0	$1,453
ASHP w/30°F Change-over	1.18	27%	528	1,898	$1,272
ASHP w/10°F Change-over	1.81	79%	152	6,859	$1,124
ASHP w/0°F Change-over	1.97	89%	84	7,958	$1,120

Conclusions

- ccASHPs are more efficient during cold weather than traditional systems
- Systems will be oversized for cooling in order to be properly sized for heating
- Preliminary results show the ccASHPs can meet the heating load of a home down to 10 deg F with little assistance from the backup
- Preliminary results show ccASHP COPs of 2.0-3.3

Forward work

- Three more installs are planned
- Continued monitoring of current sites
- Further analysis to quantify heating energy savings potential
- Working with ACEEE and DER to look into the policy and program implications of ccASHPs

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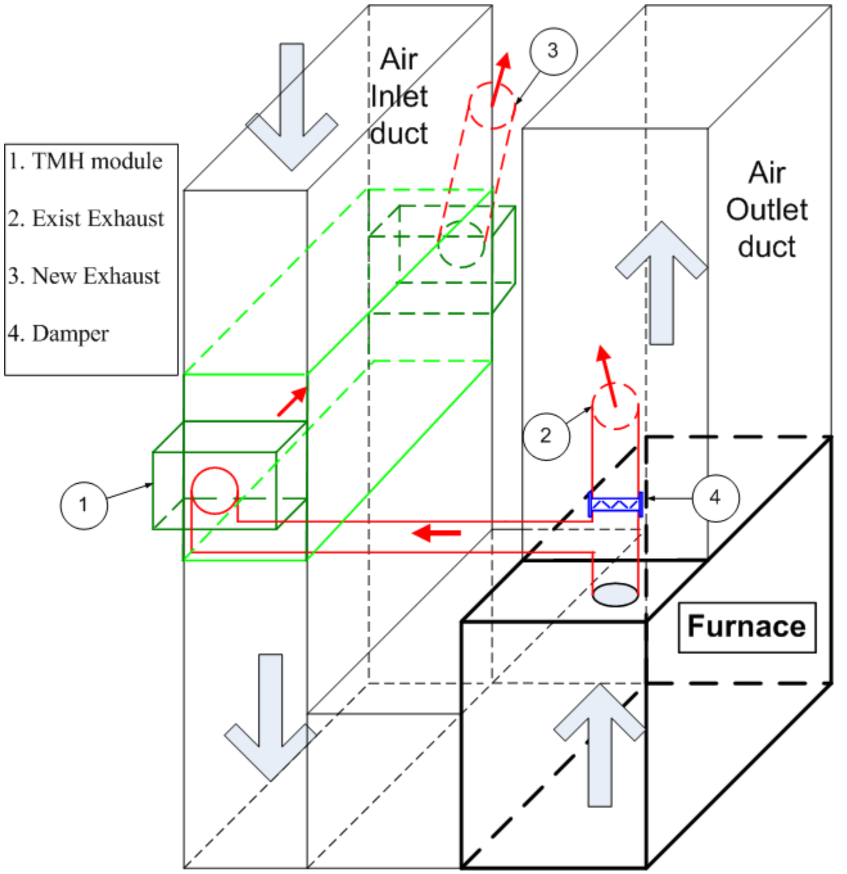
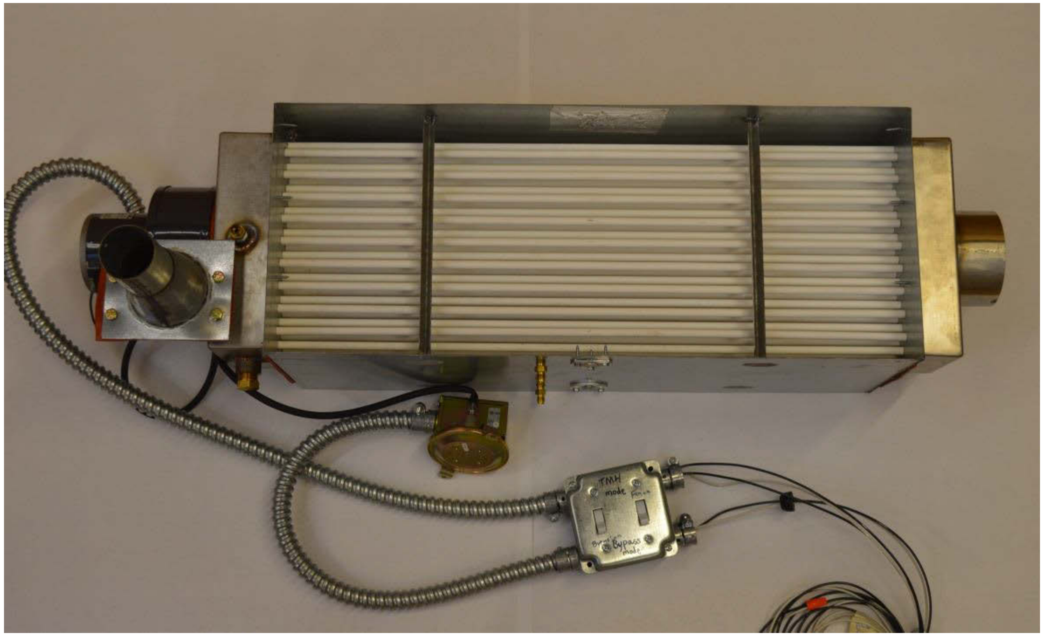
Transport Membrane Humidifier (TMH)

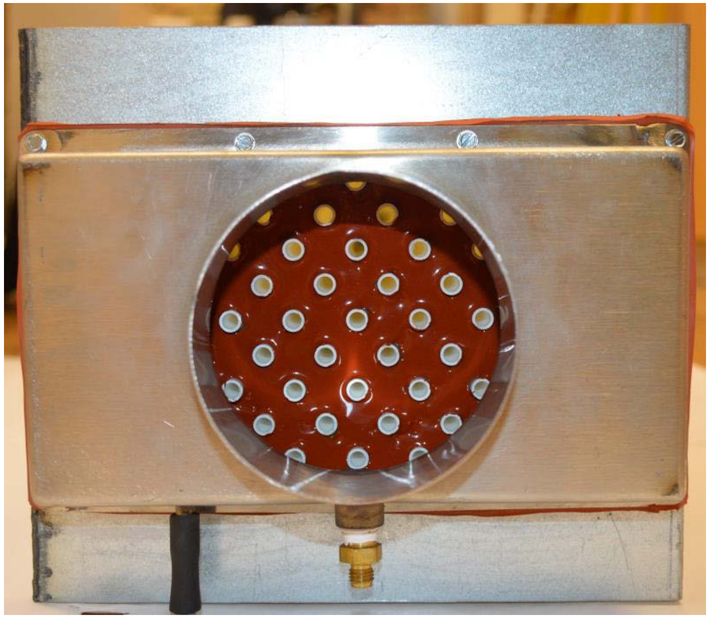
- Furnace retrofit device
- Extracts heat and moisture from flue gas
- Preheats and humidifies return air
- Improves furnace efficiency by 12 - 15%
- Increases indoor humidity by ~7% RH



TMH Installation diagram for mid-efficiency 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

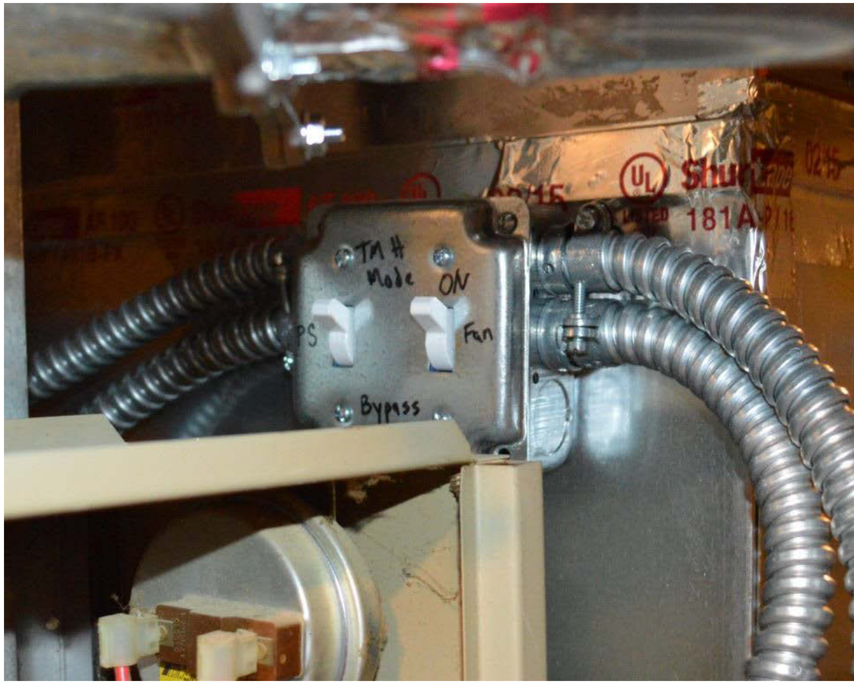
Minnesota Pilot

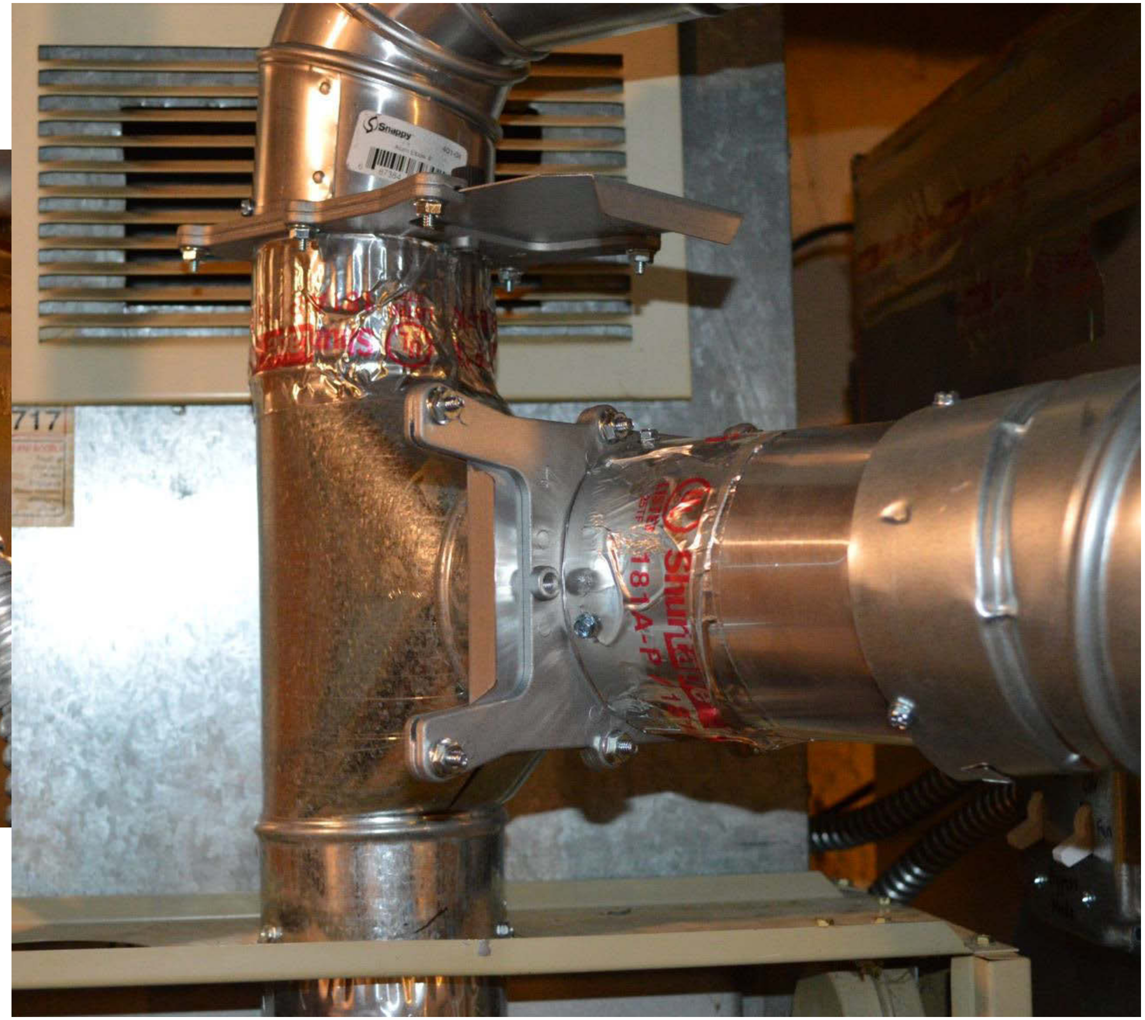
- Demonstrate performance
- Quantify humidity benefit
- Detail cost effectiveness

Installation

Installation

Operation

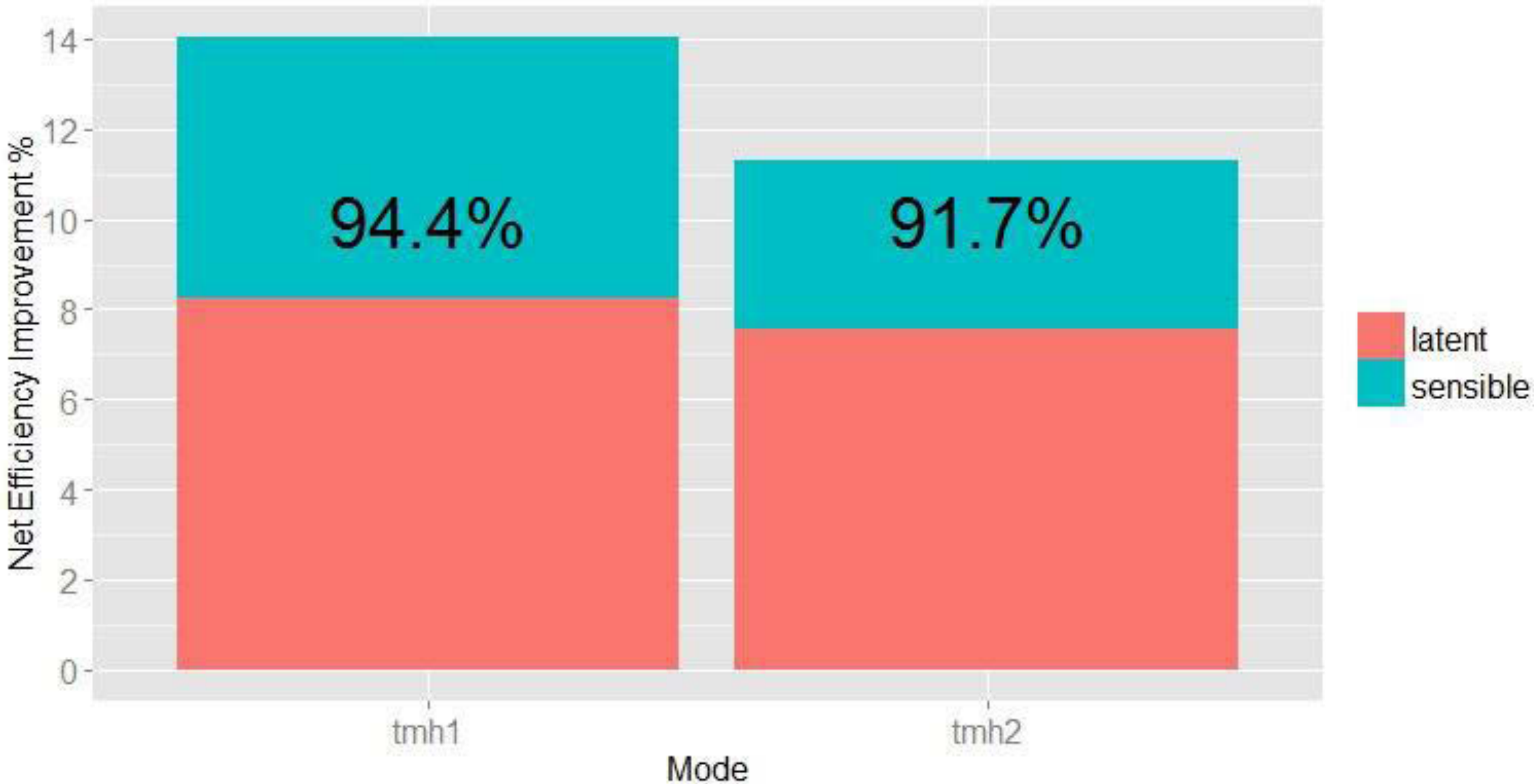




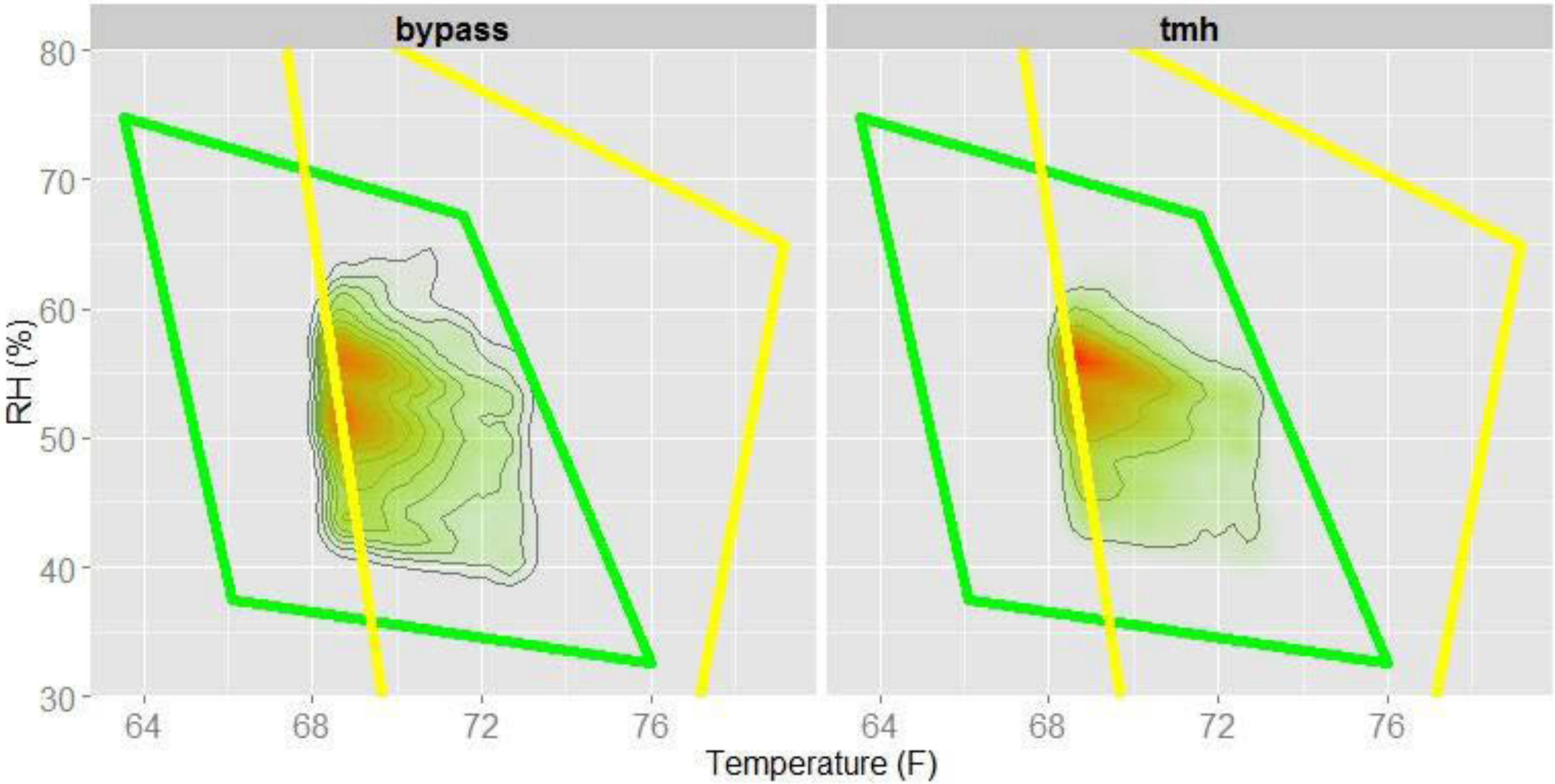
Instrumentation

	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

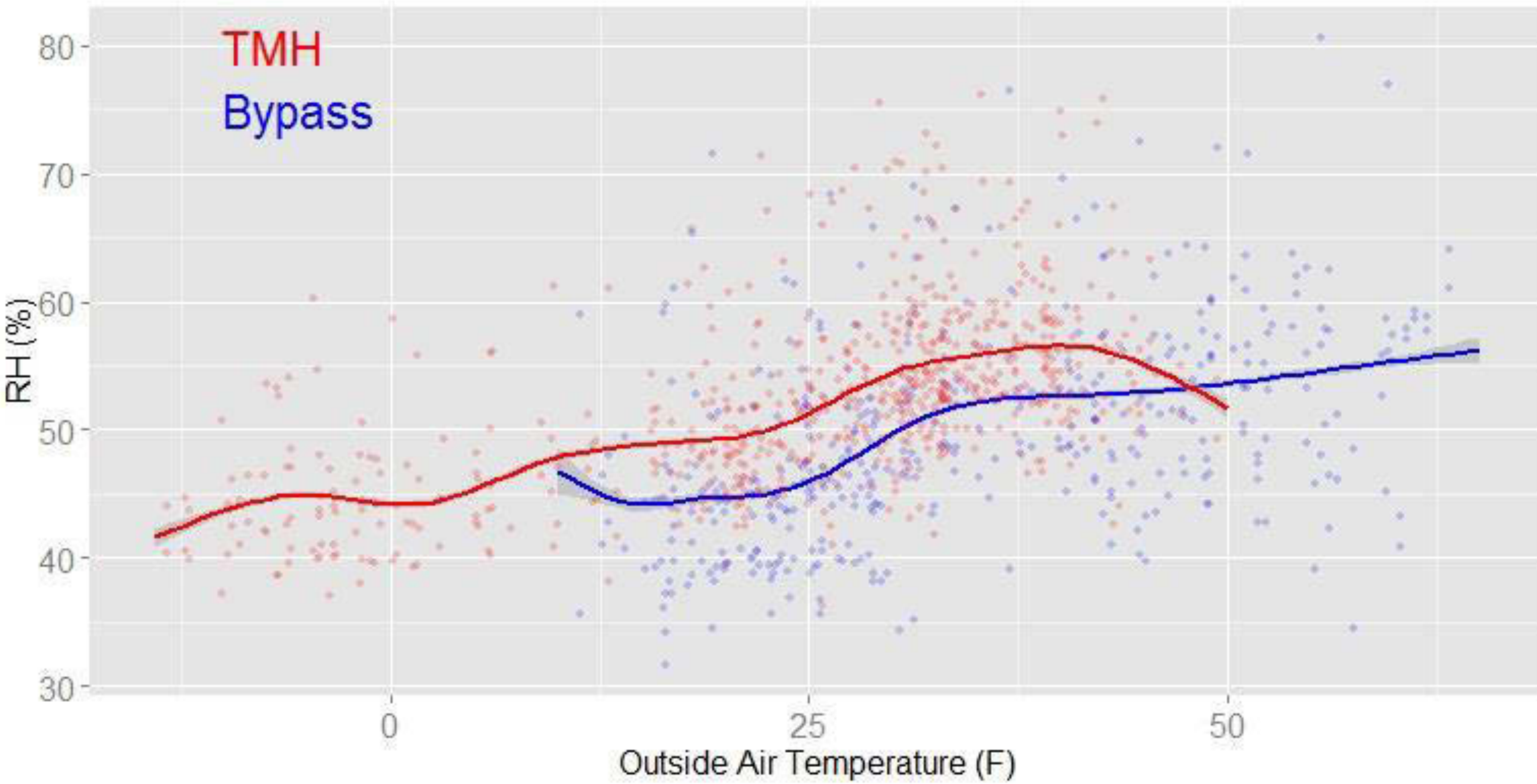
Preliminary Results



Preliminary Comfort IAQ / Results



Relative Humidity Trend



Conclusions

- TMH is a furnace retrofit
- 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 comfortable increase in relative humidity

Forward work

- Four more planned installations
- Continued monitoring of current site
- Further analysis to quantify the humidity benefit and the change to system efficiency
- Further analysis to detail cost effectiveness of implementing on a larger scale

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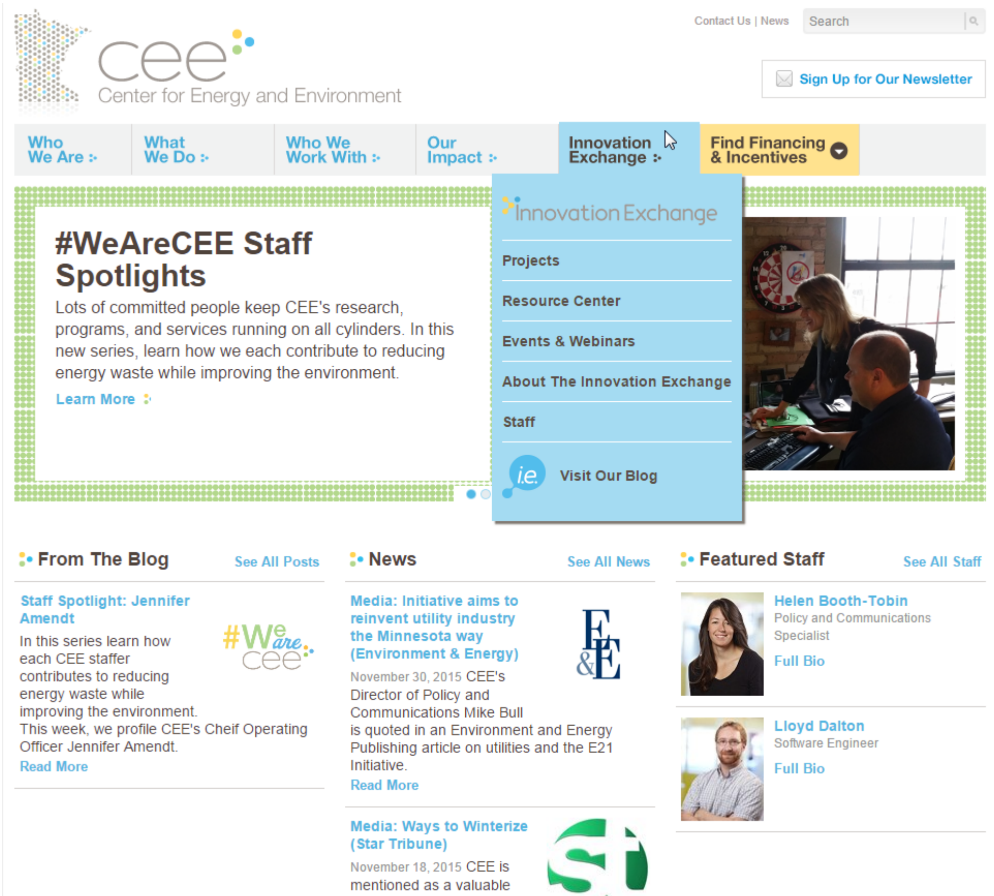

Field Study of a Moisture and Heat Transfer Furnace Retrofit Device

Cold Climate Air Source Heat Pump Field Assessment

THANK *you!*

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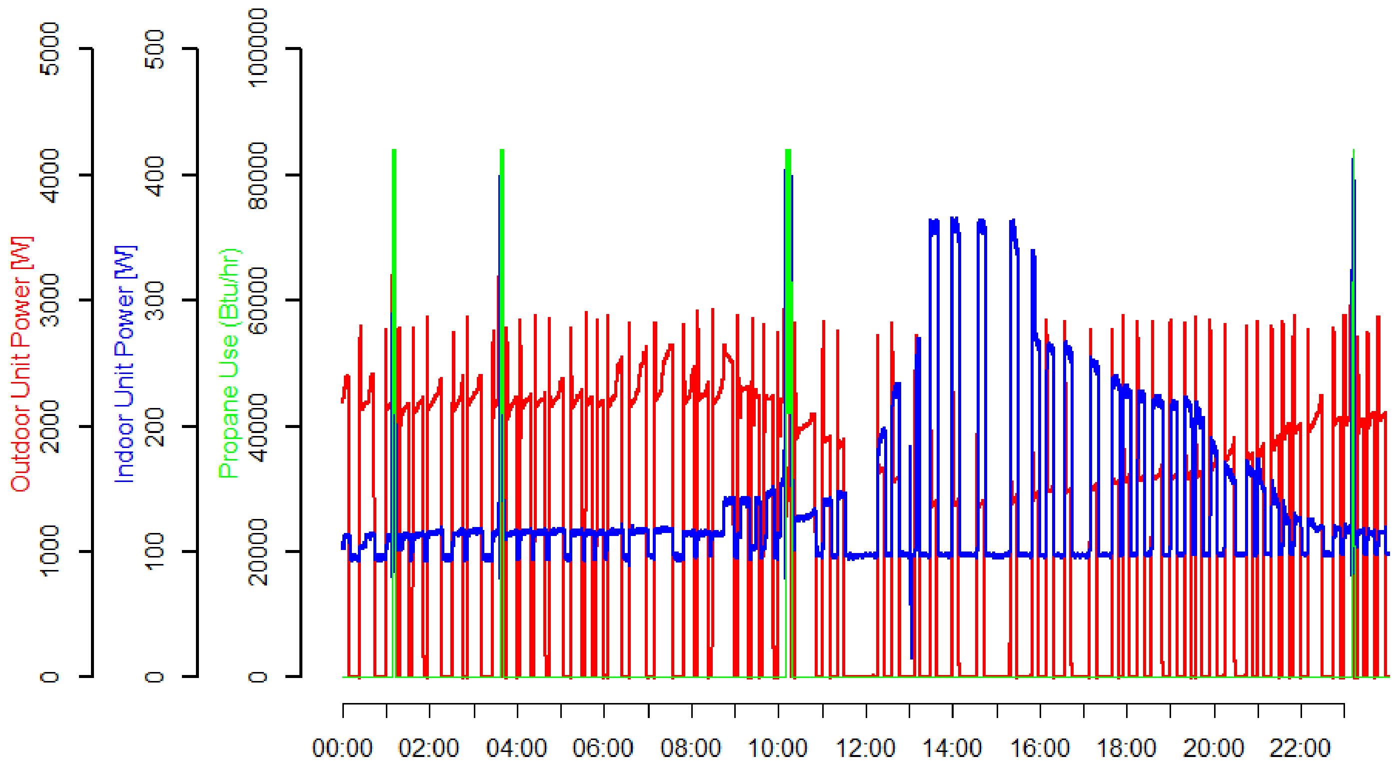
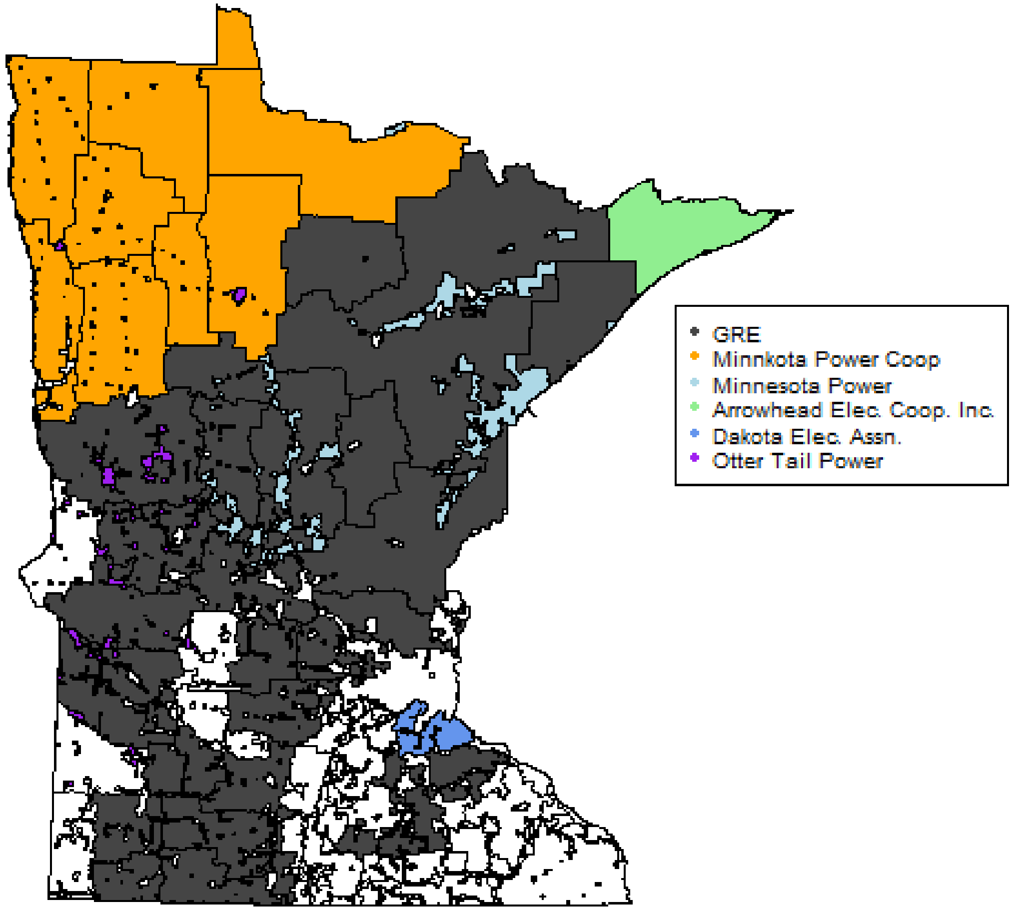
Preliminary Field Results

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