In accordance with the Department of Labor and Industry's statute 326.0981, Subd. 11,

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Are you pumped up? Achieving widespread quality installations of cold climate air source heat pumps

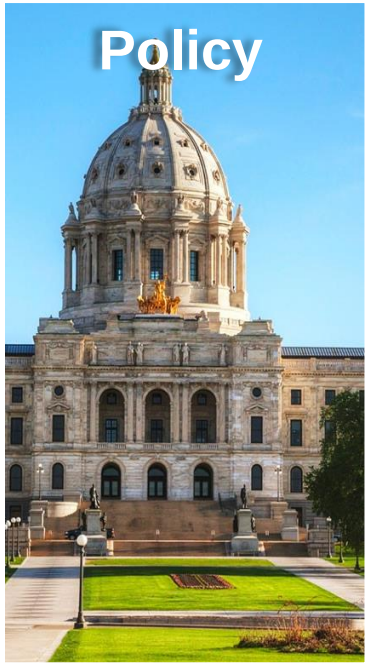
Keeping up with Trends: The Latest in ASHP Technology

Alex Haynor, Research Analyst

Center for Energy and Environment

Discover + Deploy

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



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

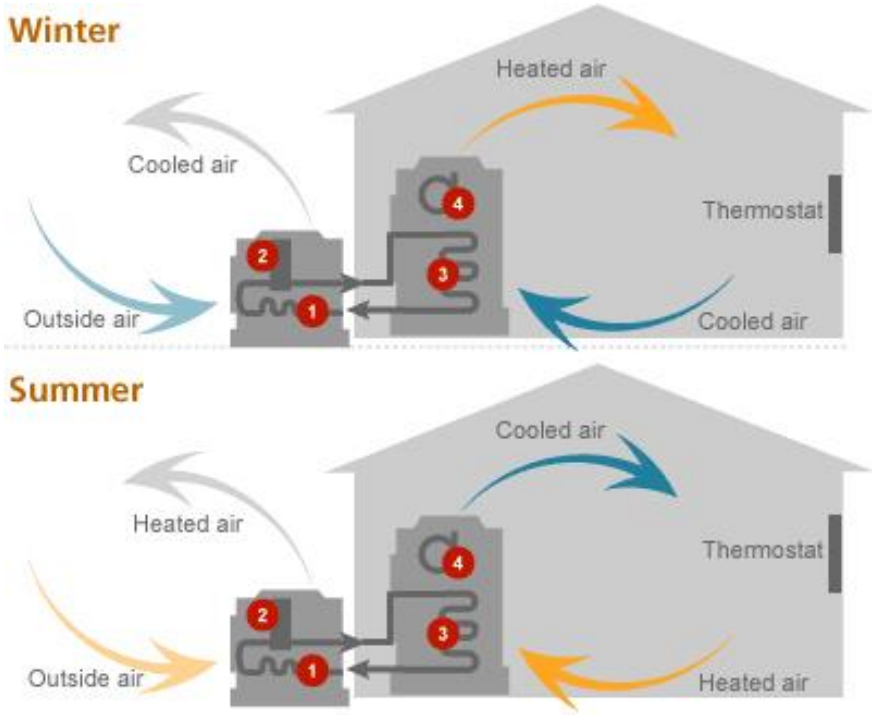
- ***Additional Support from:***
  - ***Great River Energy***
  - ***Electric Power Research Institute***
  - ***Xcel Energy***

Agenda

- What are Air Source Heat Pumps?
- Why should we care about them in MN?
- Application Types
- CEE Research Summary
  - Installation and operation
  - Results
  - Conclusions
- CEE's Next Steps

Cold Climate Air-Source Heat Pump?

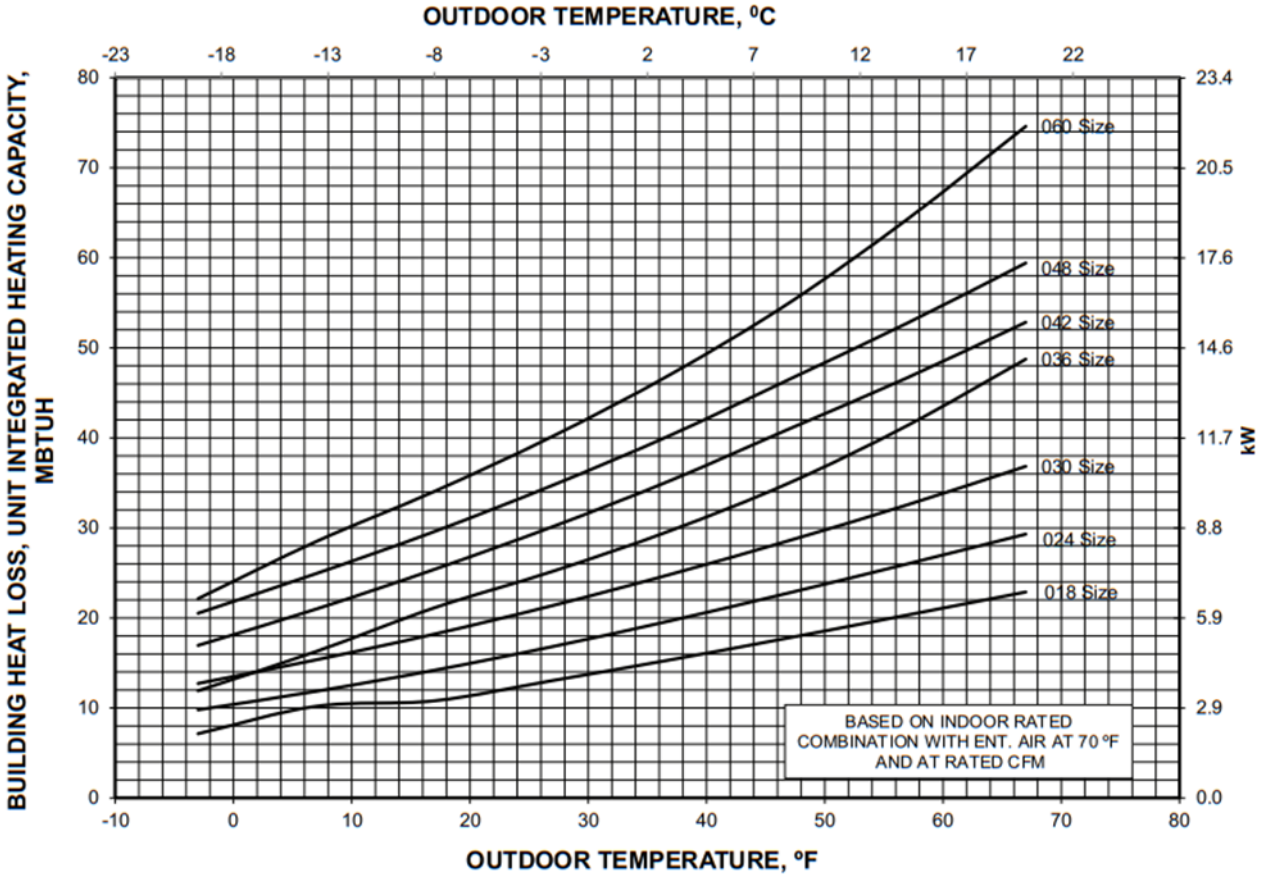
- An ASHP uses a refrigerant system involving a compressor, condenser, and evaporator to absorb heat at one place and release it at another.
- Delivery of both heating and cooling via forced air distribution
- New generation systems can operate as low as -20 °F
- ASHPs have the potential to deliver energy and peak saving as well as reduce reliance on delivered fuels.



Really… In Minnesota?

- Heat transfer performance of heat pumps reduces as outdoor temps drop
- Variable capacity advancements have greatly expanded cold climate performance
- Development of a cold climate performance spec
- Manufacturers claim performance down to -20 F
- CEE has documented systems delivering heat as cold as -25 F

Really… In Minnesota?



Opportunity

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

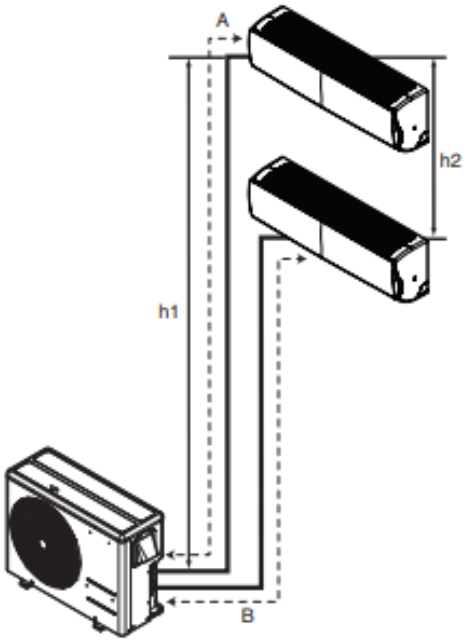
- Market:
  - Delivered fuel are the primary space heating fuel for more than 40% of homes in MN, IA, SD, ND (RECS, 2009)
  - Over 25% of Midwest homes rely on fuels other than natural gas for space heating (RECS, 2009)
  - Over 47% of homes in the US rely on fuels other than natural gas for space heating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

Ducted Whole House Installation Flex Fuel

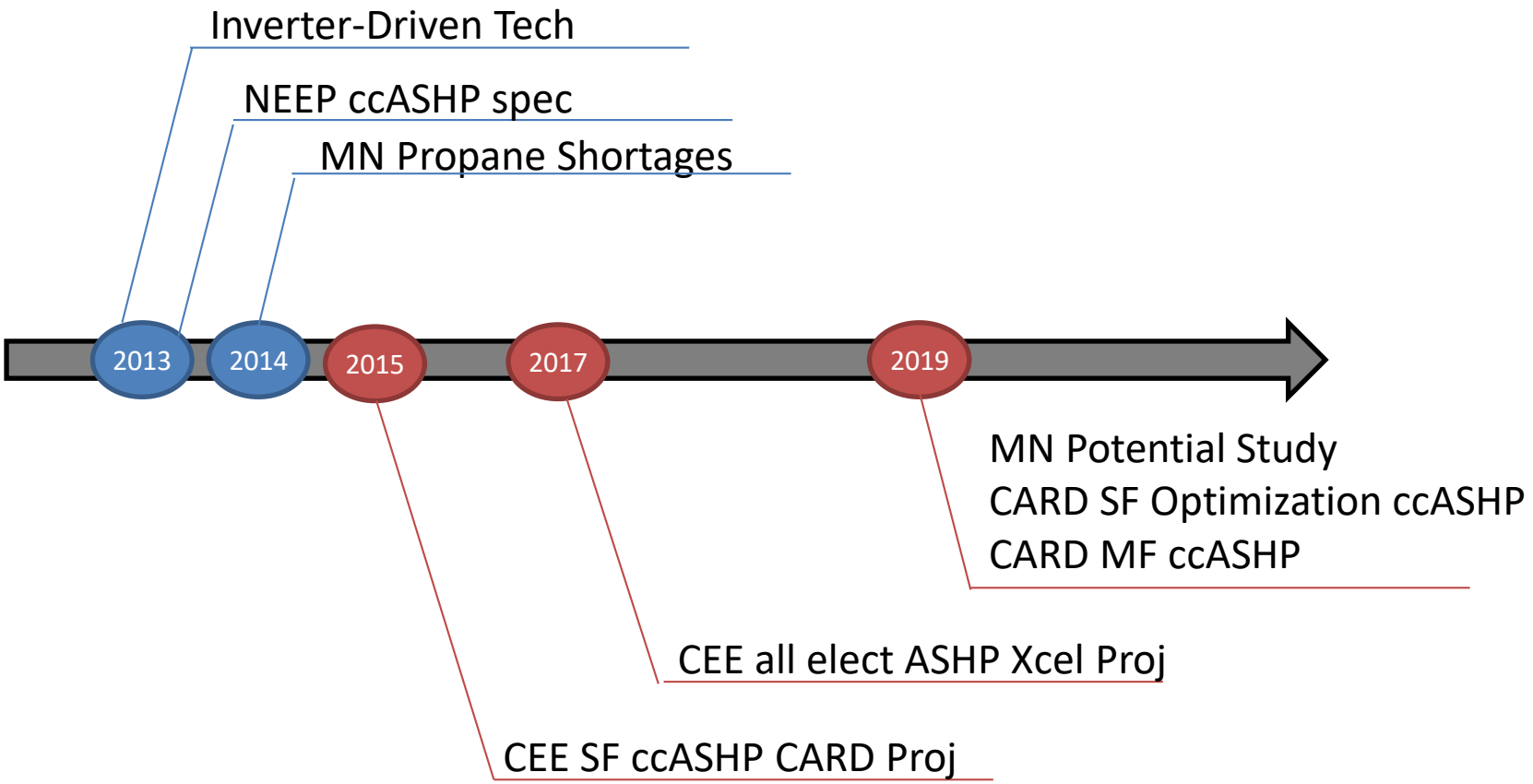
Ducted Whole House Installation
All Electric

Ductless (Mini-Split) Heat Pumps

Variations on the Mini-Split



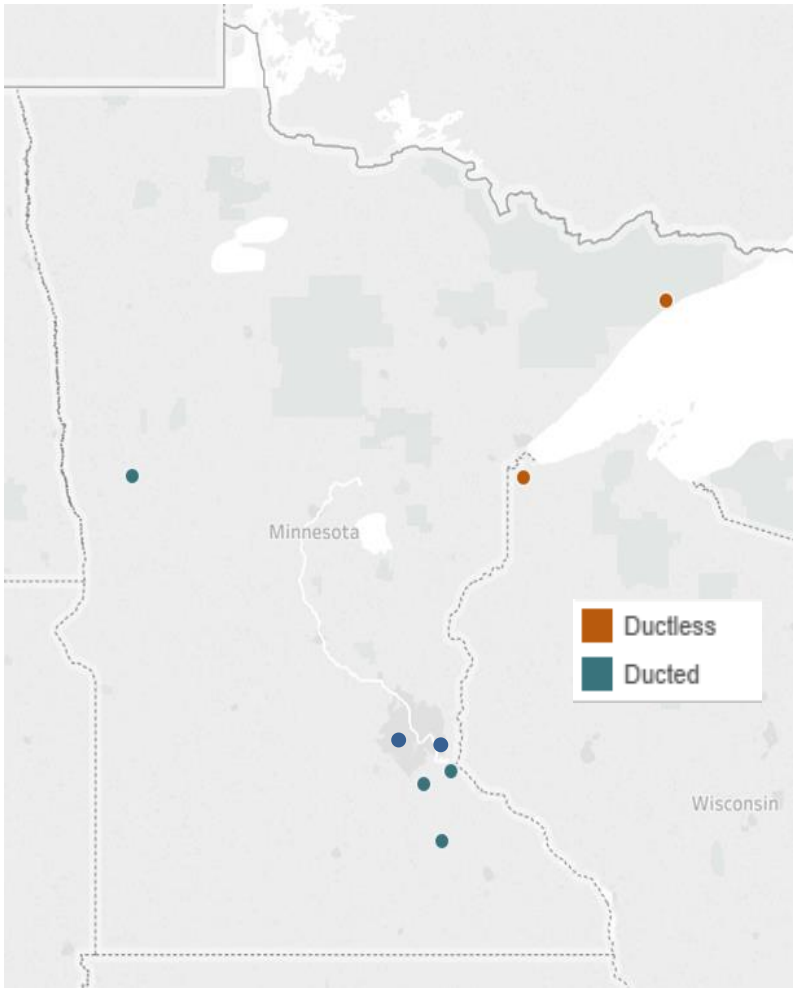
CEE's ccASHP Research Timeline



2015 Study Overview

- Field Study
  - 8 ccASHP in a variety of MN residences
    - 6 ducted whole house system
    - 2 ductless mini-split systems
  - Monitor installed field performance of ASHP & backup
- Each site had detailed data collection
- Installs in climate zones

  6 & 7

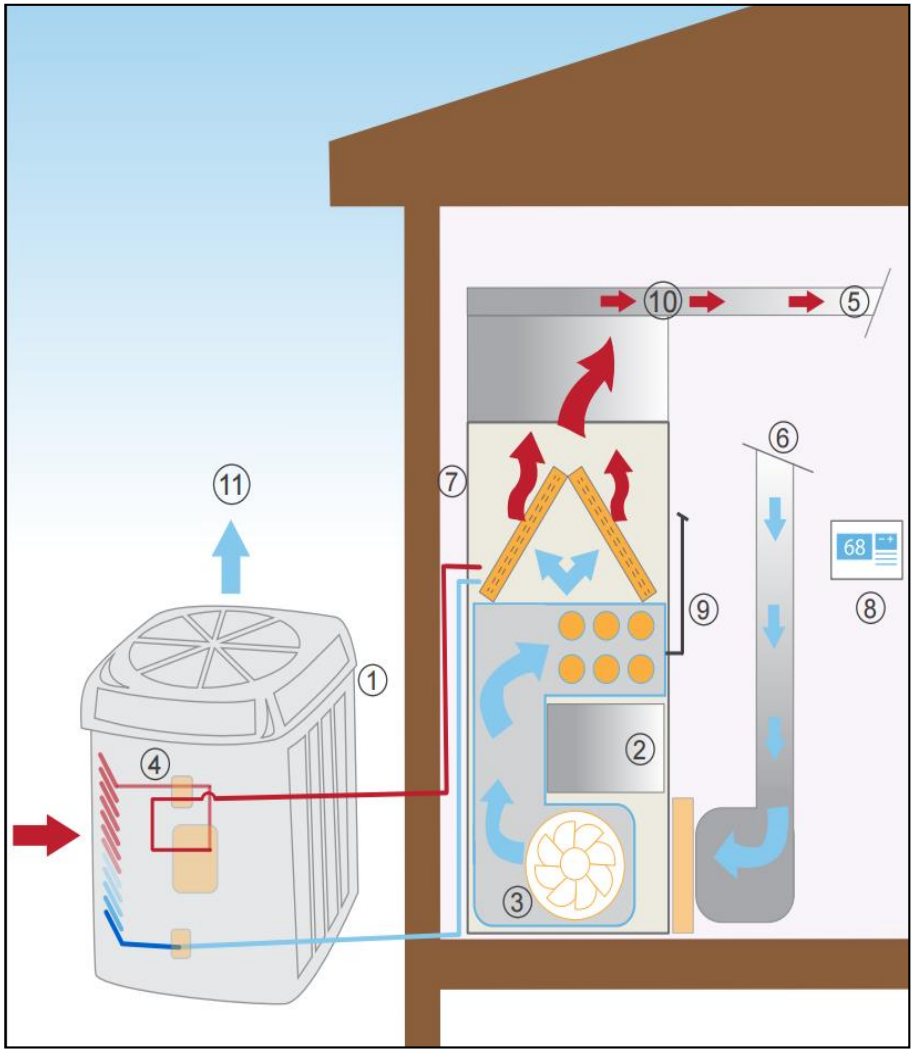


Instrumentation

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



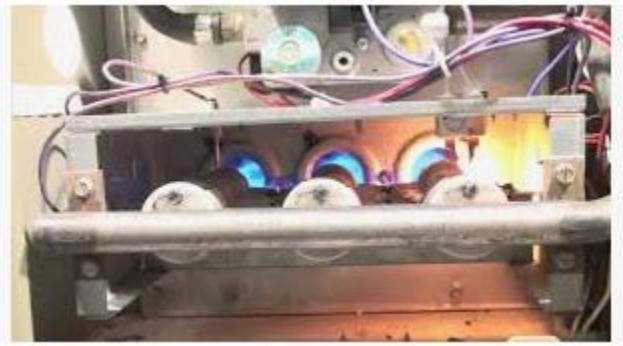
Site Equipment

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
7	Mitsubishi Hyper Heat System [PVA-A30AA7]	3 ton	Ducted	Electric Booster
8	Mitsubishi Hyper Heat System [PVA-A30AA7]	3 ton	Ducted	Electric Booster

Installation Considerations

Control and Operation

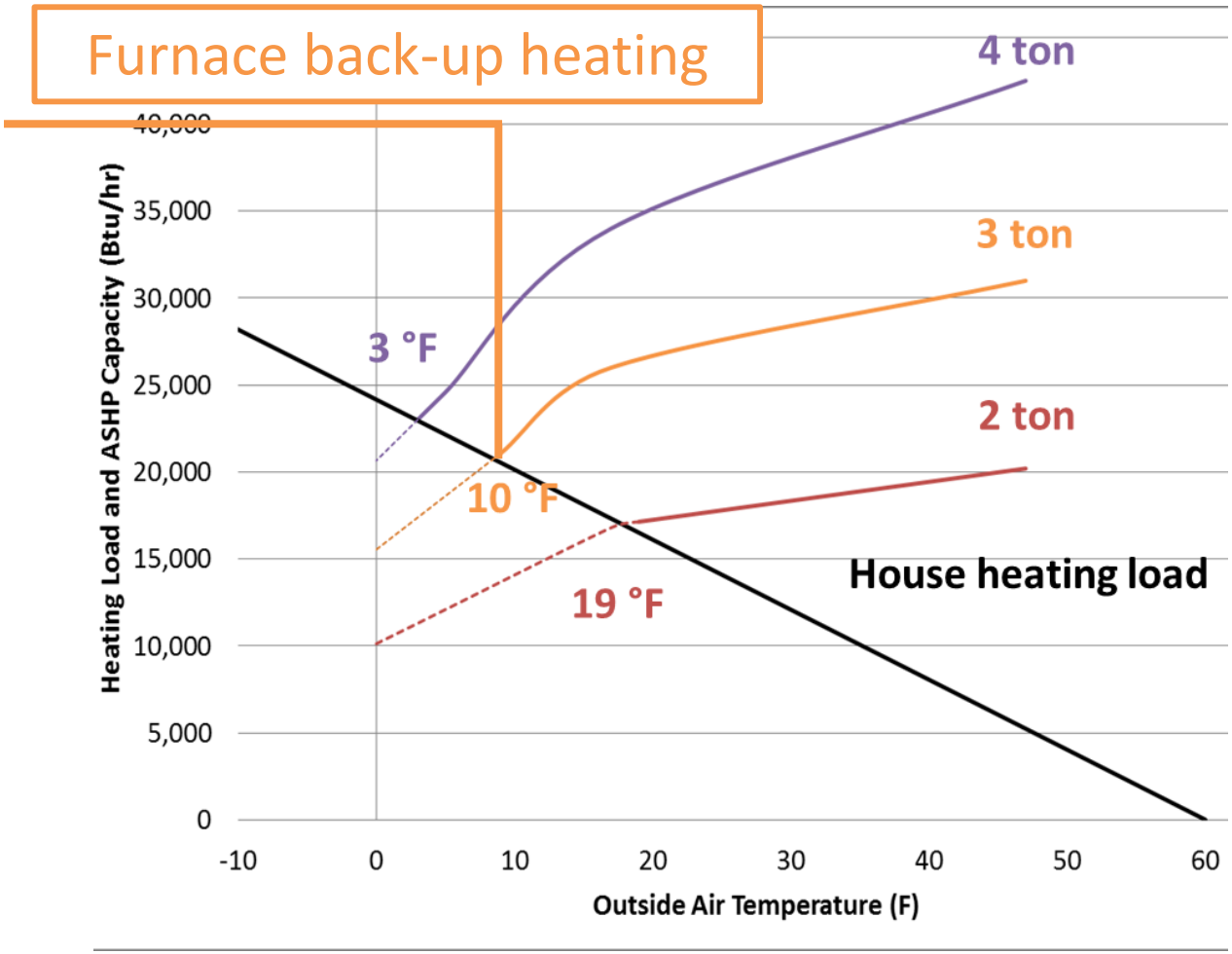
Integration with backup



Sizing

Design and Sizing for Ducted Systems

- Trade-offs between HP size and fraction of heating load meet
- Rule of thumb: Sizing for heating increases HP size by 1-ton over sizing for cooling
- Percentage of heating load meet by ASHP:
  - **4 ton ~ 86%,**
  - **3 ton ~ 77%**
  - **2 ton ~ 60%**



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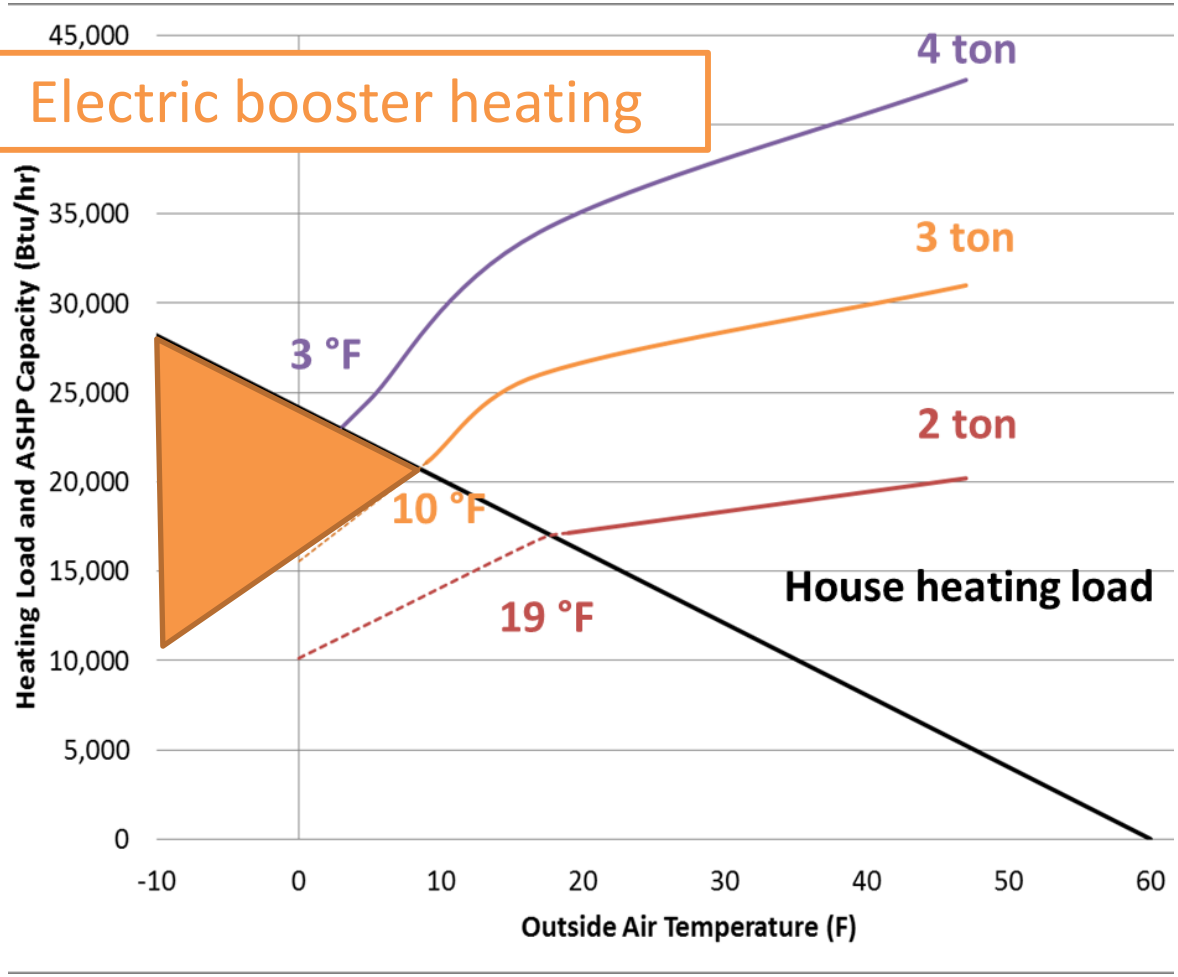
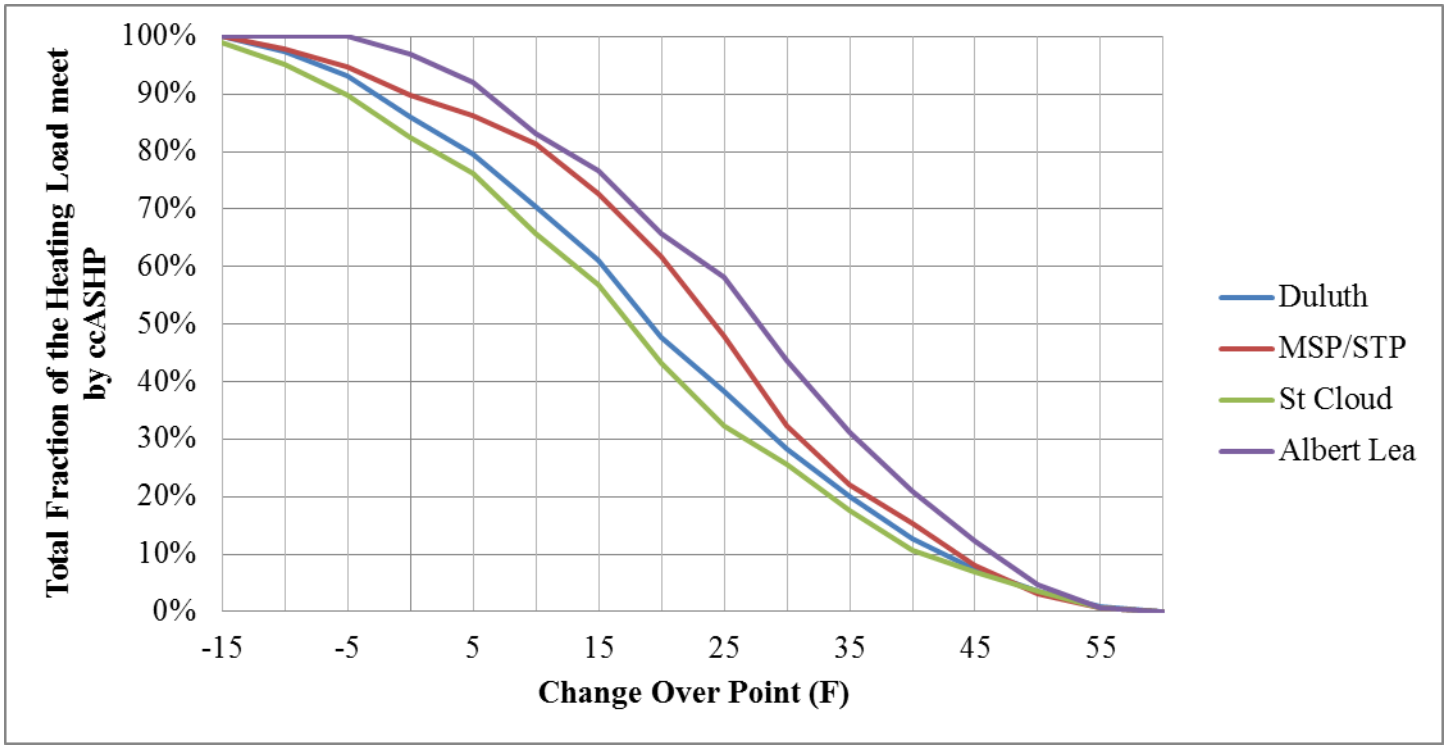


Impact of Change-Over Set Point



Furnace Integration – Keep or Replace?

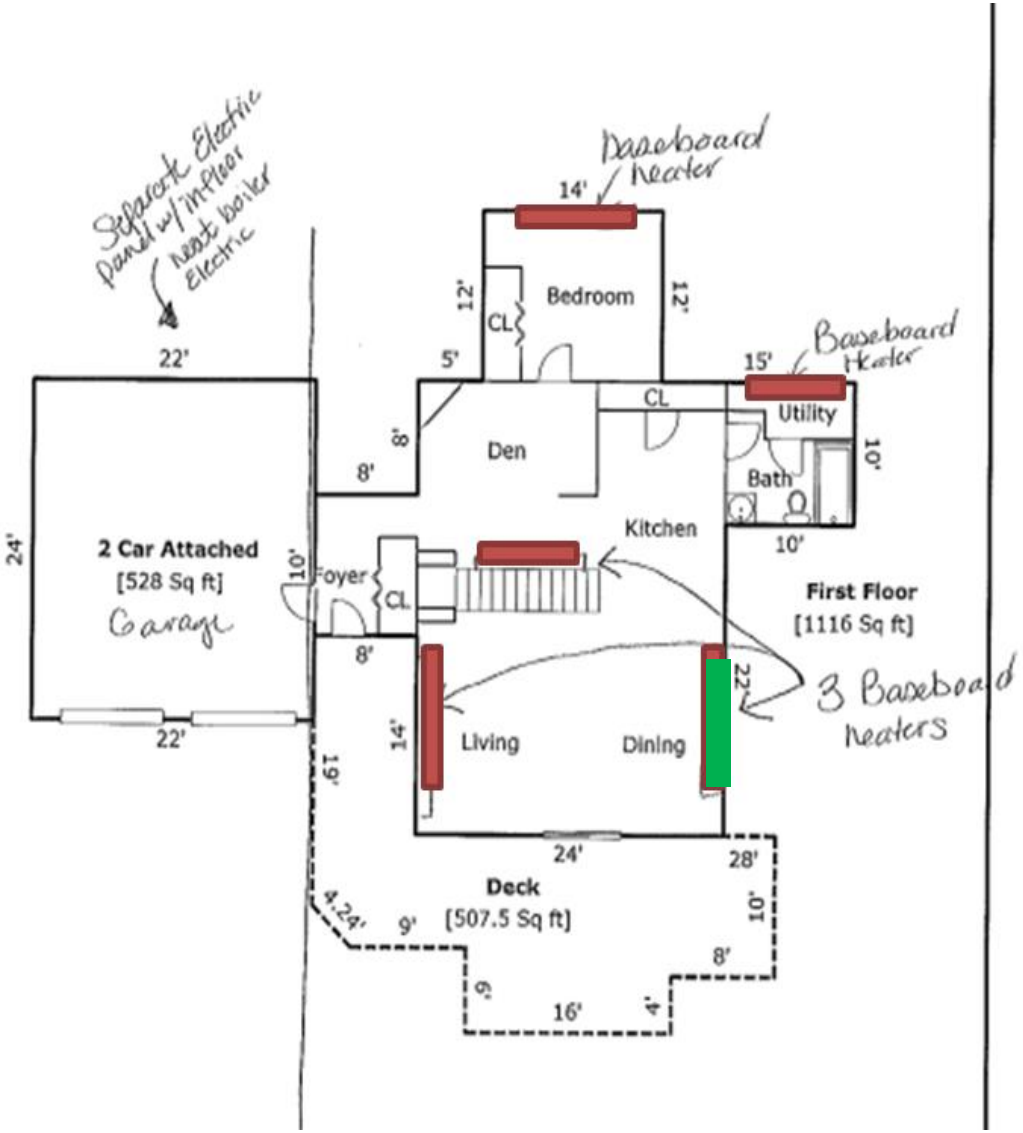
- Issues:
  - Air handler requires a multi-stage fan to achieve the full capability of the ccASHPs
  - Furnace and heat pump require integrated controls
- Proposed Solutions:
  - New condensing furnace with control integration
  - New 80% AFUE with multi-stage fan with control integration
  - Plenum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

- Several manufacturers are working on solutions to pair new ASHPs with existing furnaces

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

Ductless: Install Location



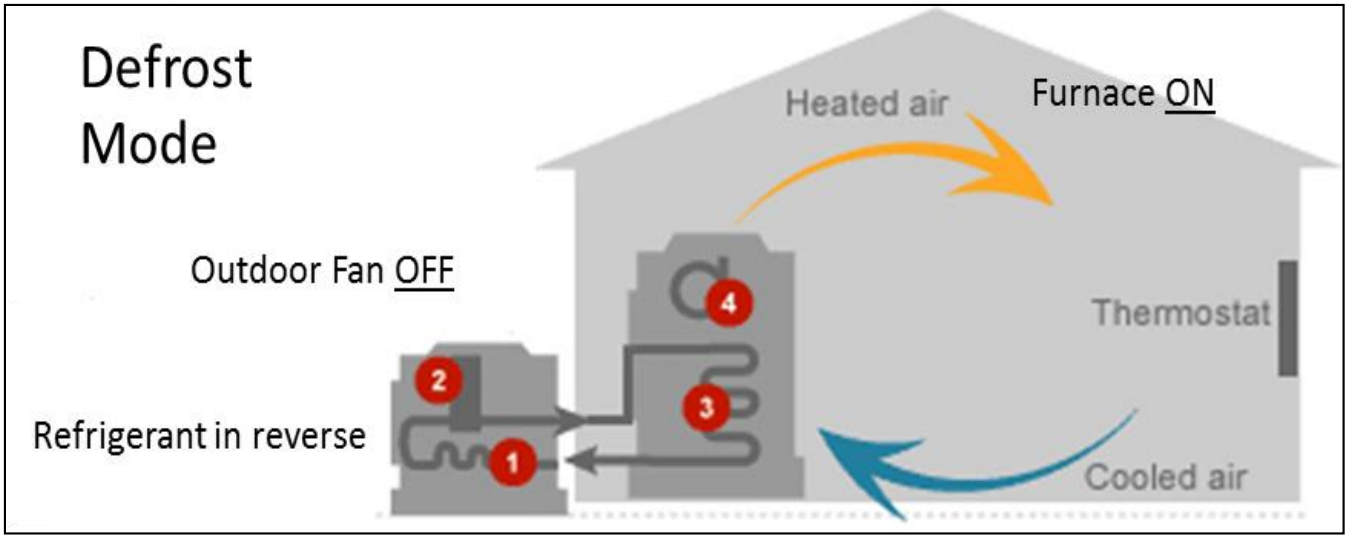
Time for Some Heat Pump Data!

- To date we've monitored 8 different installs
- Collected over 16 months of data on each
- Approximately 20 measurements per site
- One second collection interval

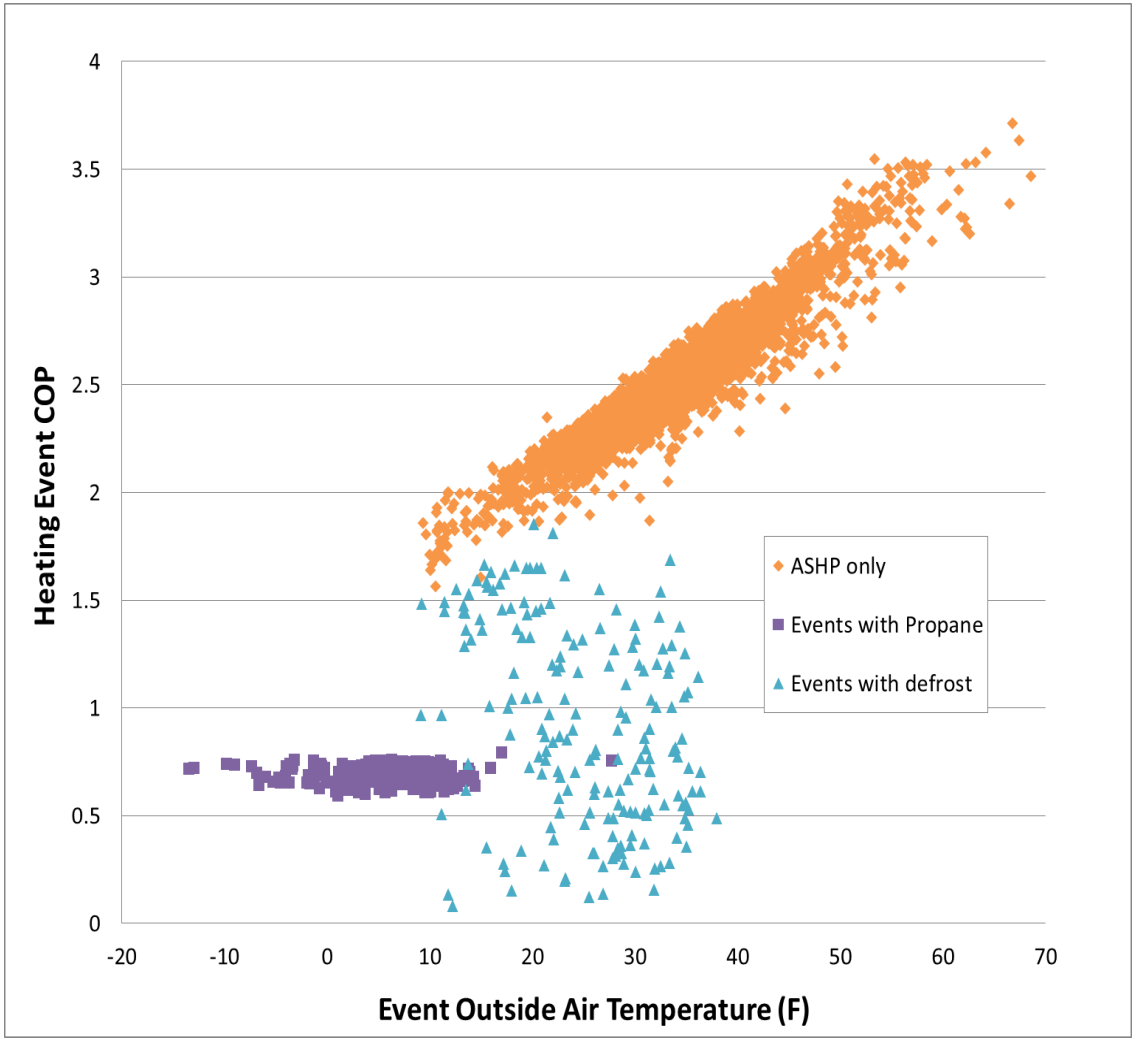
- LOTS of data!

Modes of System Operation

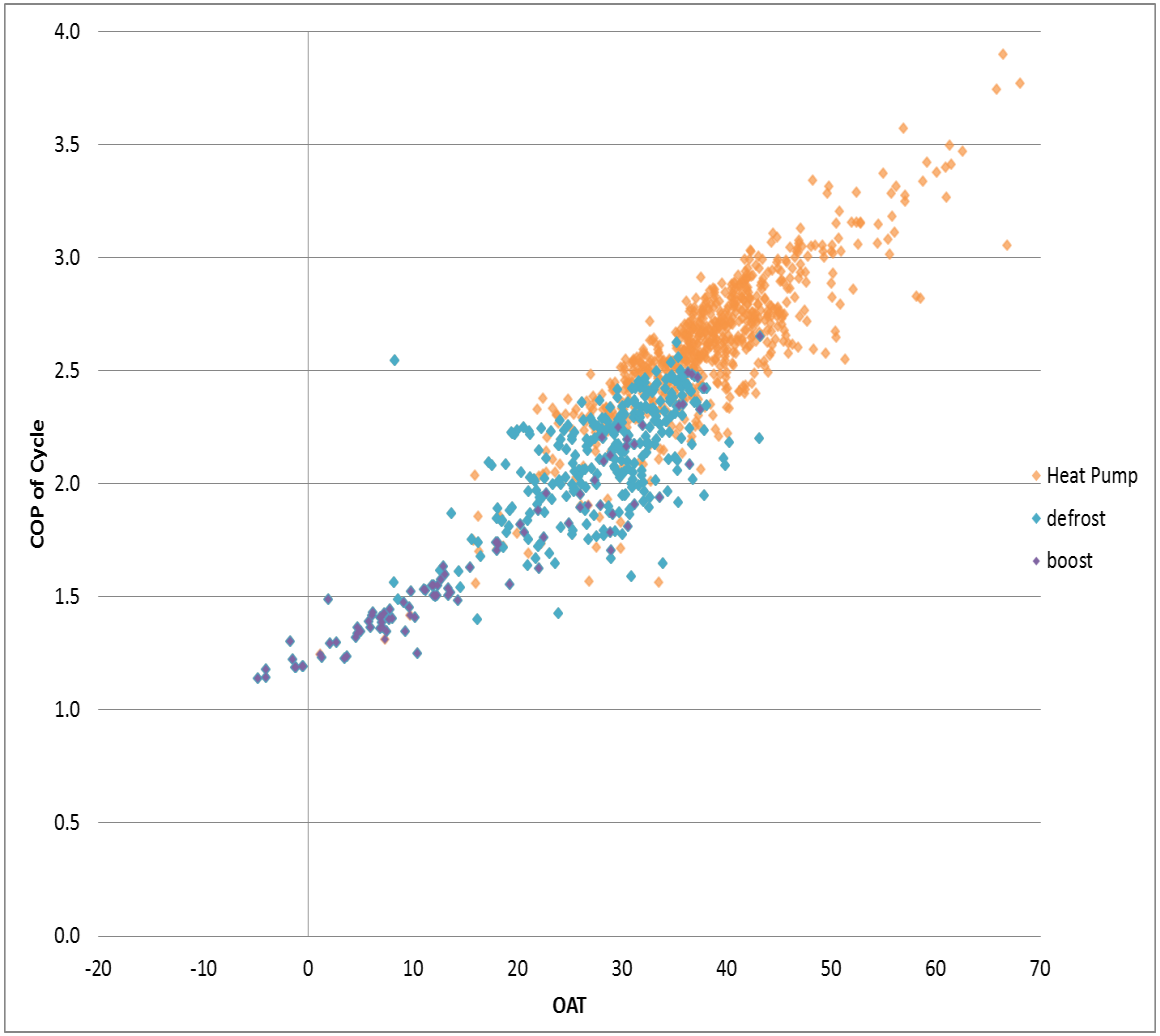
- Heating system has 3 modes of operation
  - ASHP heating
  - Back up heating
  - Defrost



Heating cycle COP of a Flex Fuel System



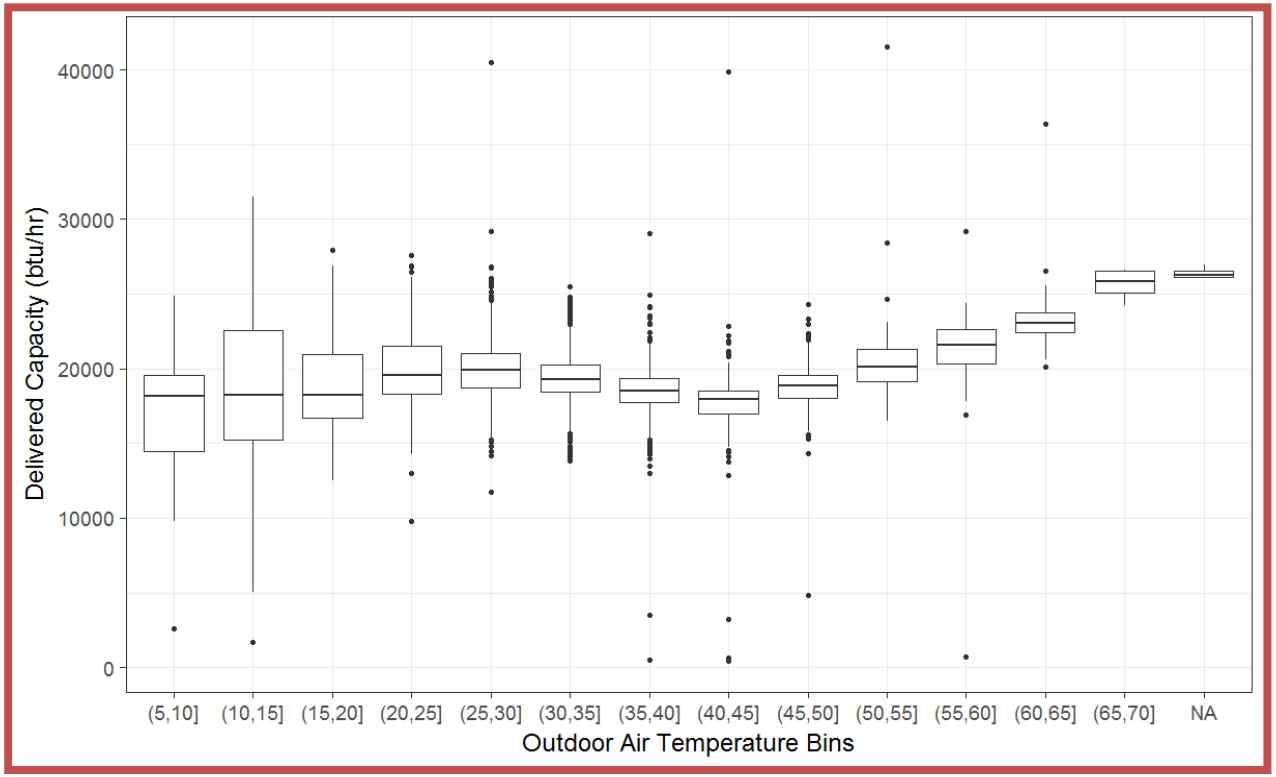
Heating Cycle COP of All Electric



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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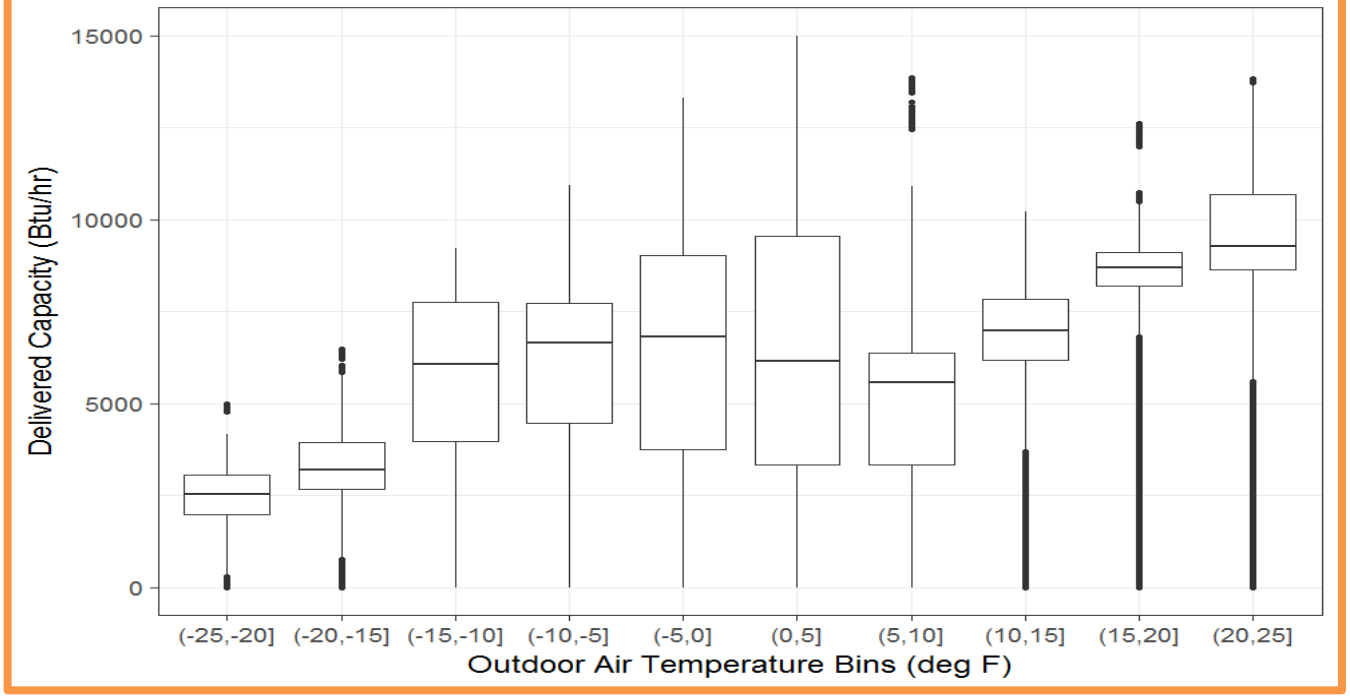
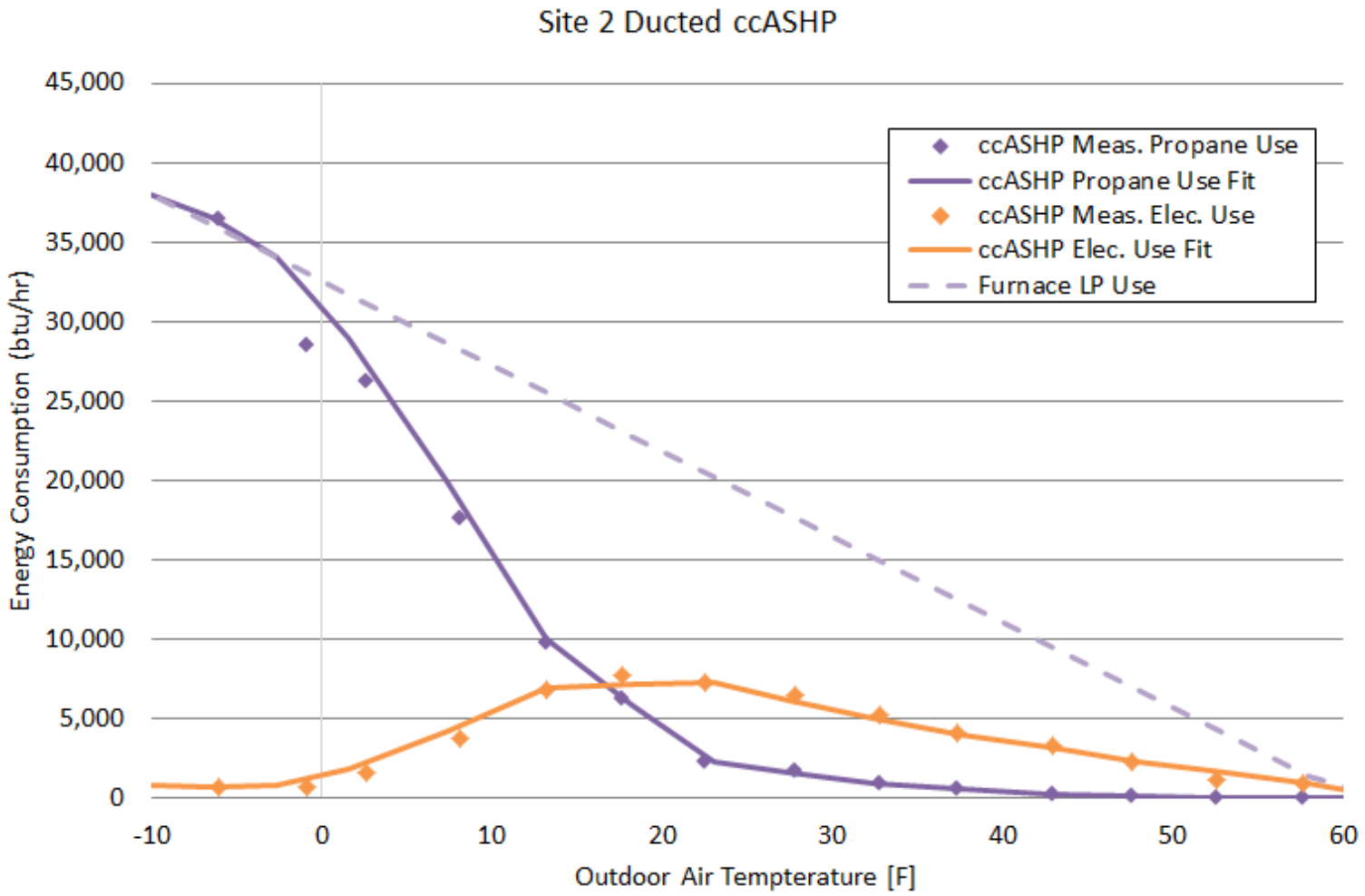
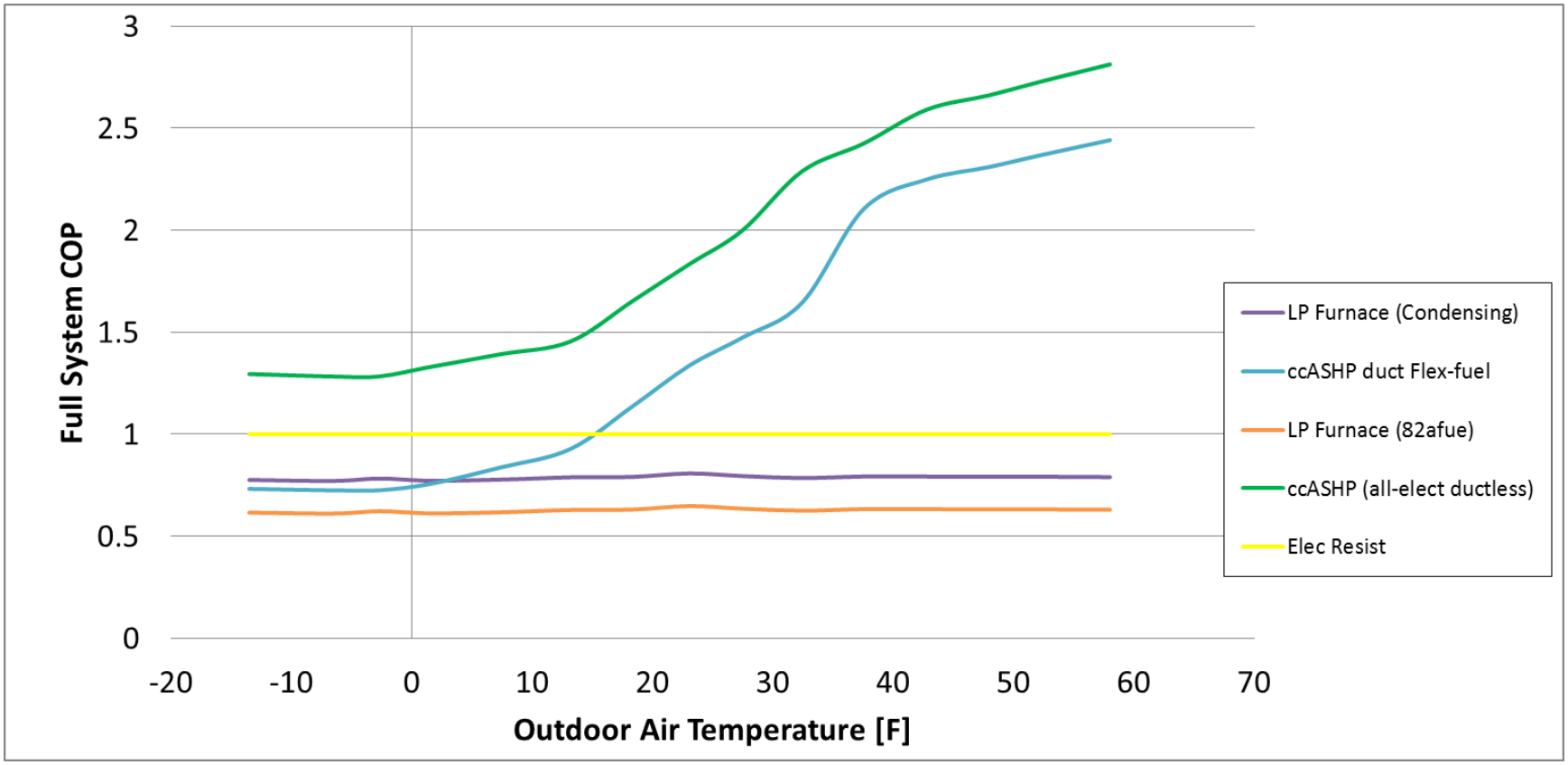


Energy Use Vs OAT Models



System Performance



Replacement System 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%).
    - $10,340 Total
  - $5,540 for a new comparable SEER A/C
    - $800 incremental for ccASHP

- Limited installs leading to higher costs
- Requirement for new air handler or furnace increases costs considerably

Annual Characteristics and Savings

- Ducted Flex fuel ccASHP compared to condensing furnace (LP)
  - Annual COP improved to 1.3 (over 0.85)
  - ~40% site energy reduction
  - ~30% cost reduction
  - ~60% reduction in propane use
  - ~5% reduction in emissions
- All-electric Ducted ccASHP
  - Annual COP ~1.9
  - ~60% site energy reduction

Conclusions

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

	COP
Ducted flex fuel ccASHP	1.3
Ducted electric ccASHP	1.8
Ductless ccASHP	2.1
Baseline Electric Resistance	1.0
Baseline Furnaces	0.72 to 0.92

Summary of Results

- Cold Climate ASHPs:
  - Reduced energy consumption
  - Reduced operating cost
  - On average ducted ccASHP met 84% of the homes heating loads
  - 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

Next Steps

- Programmatic
  - Heating application installation guidelines
  - Beneficial electrification
  - Product specification and rating
  - Ensure savings
- Continued Research from CEE

2019 Research

- Projects:
  - Optimized installations of ASHP for single family [CARD]
  - Cold climate ASHP for multifamily applications [CARD]
  - Field validation of ASHPs in heating applications: dual fuel systems in SF homes [DOE]

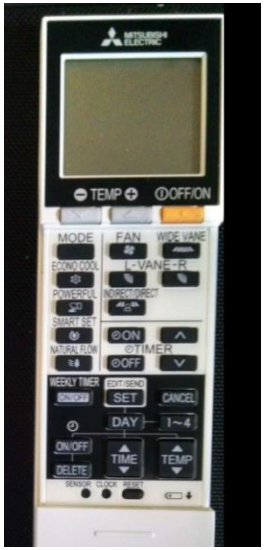
- Focus:
  - Better understand homes/buildings with electrical heat
  - Design guides for optimized ASHP installs
  - Develop tools to estimate ASHP savings
  - Monitor the performance of these systems to demo performance

Multifamily progress

- Working with stakeholders to understand barriers
- Identifying buildings
  - Partnered with 4 utilities and building owner/manager groups
  - Identified over 30 MN buildings so far
    - Conducted 10 site visits
- Developing selection criteria for field installs

Barriers

- Contractor willingness to bid and install
- Split incentives and up front costs
- Technical installation issues
  - Integration with envelop and existing HVAC
  - Controls

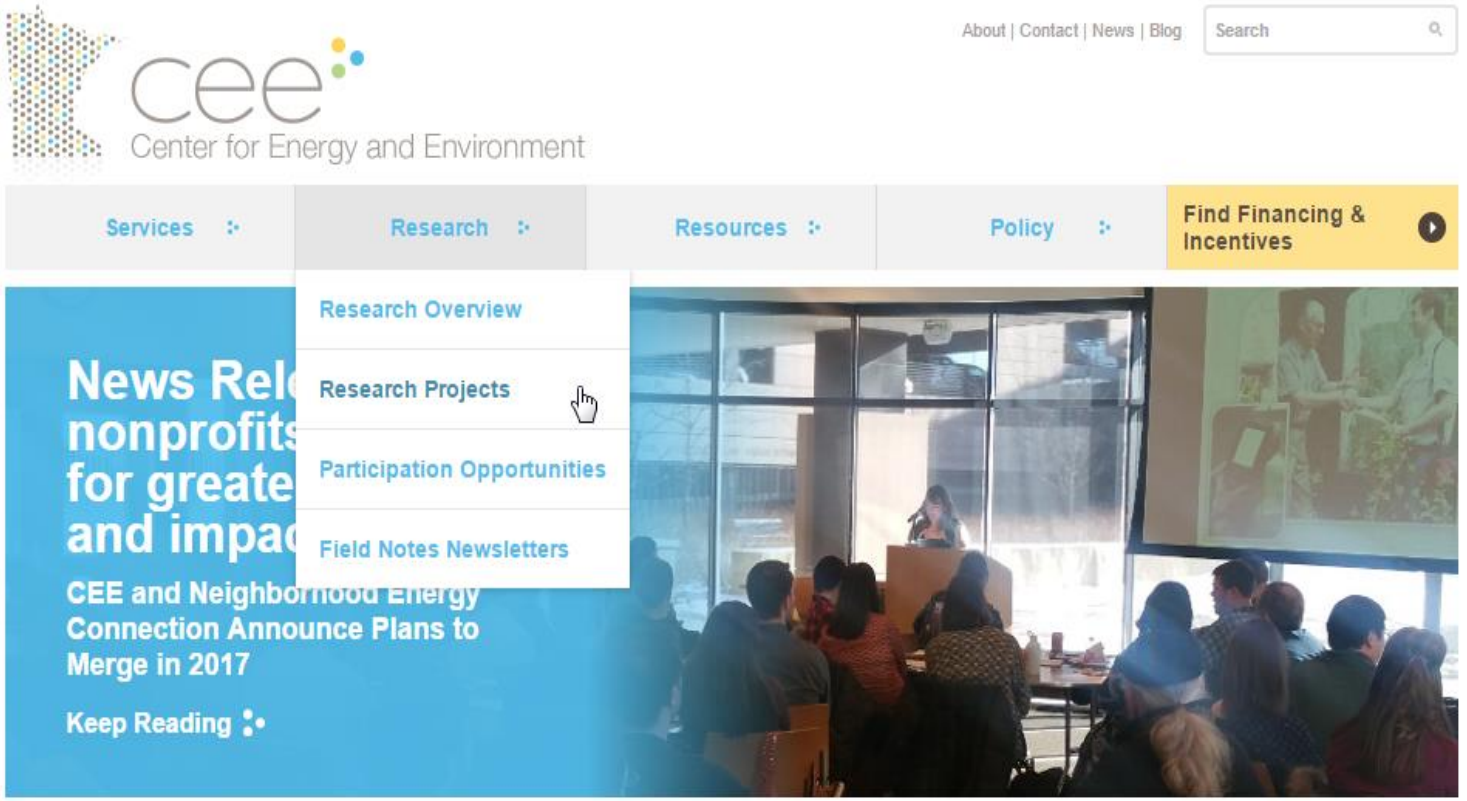


Buildings

- Lots of electric heat types

- Mix of rural, small city, suburban, and metro buildings
- Mix of building sizes from 3 units to 60 + units

www.mncee.org/heat_pumps



Practical energy solutions for homes, businesses, and communities

THANK you!

Alex Haynor:

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