February 24, 2021

AIR SOURCE HEAT PUMPS – MINNESOTA OPPORTUNITIES

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Agenda

- Introduction to ASHP technology – Emily
- How they perform in MN and beneficial application types – Alex
  - Electric homes
  - Propane homes
  - Natural gas homes
- Residential case studies – Alex
- Resources and support – Peter
- Q&A

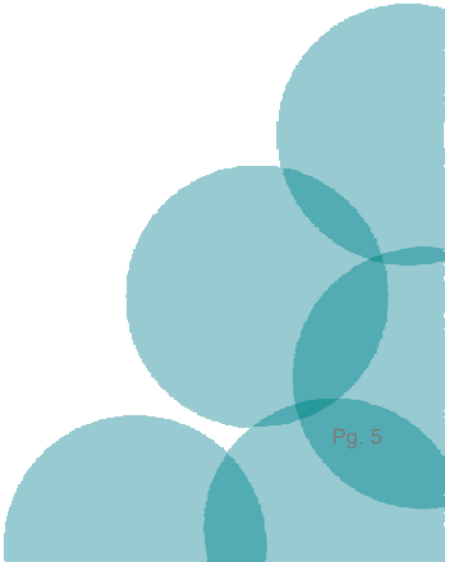
Today's Speakers

Emily McPherson (CEE)

Alex Haynor (CEE)

Peter Gephart (CEE)

What is an ASHP?



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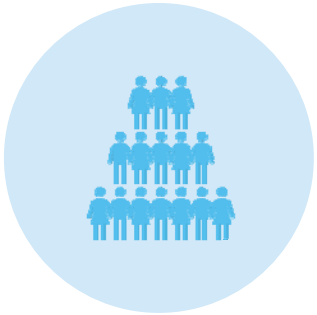
Why all the buzz about ASHPs?

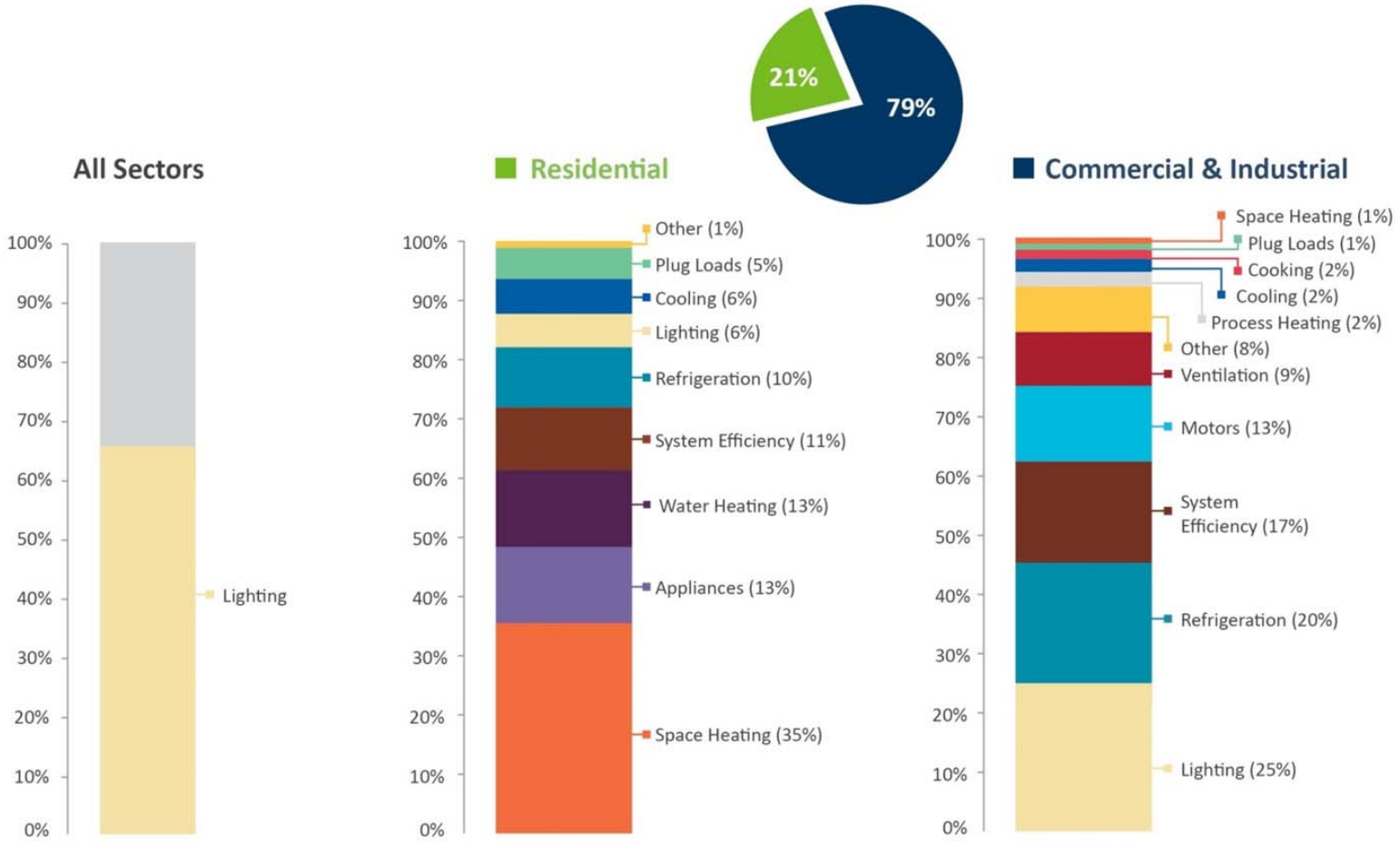


CUSTOMER BENEFITS

ENERGY BENEFITS

DECARBONIZATION BENEFITS

Minnesota Statewide Electric Savings Potential 2020-2029



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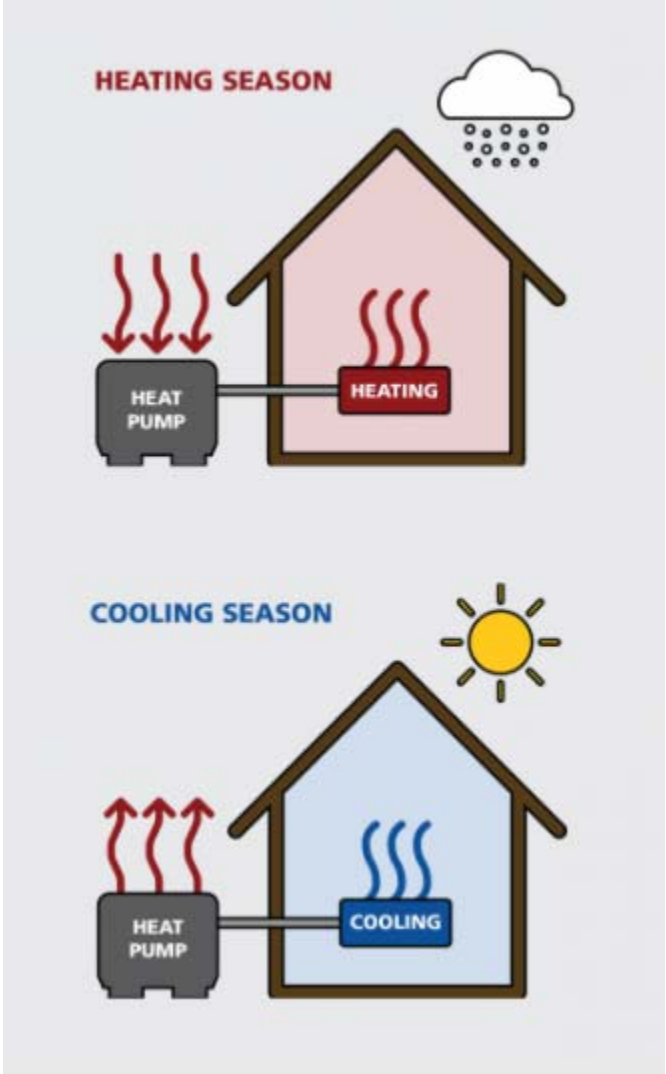
What is an Air-Source Heat Pump?

- Uses a refrigerant system including:
  - Compressor
  - Condenser
  - Evaporator
- Absorbs heat from the outside and transfers it to inside the home rather than generating heat directly.
- This process of transferring heat is why the technology is so efficient offering COPs as high as 4.
- Delivery of both heating and cooling via forced air distribution
- Potential to deliver energy and peak saving & reduce reliance on delivered fuels.



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ASHP facts

They operate much like a refrigerator, but can reverse the cycle

They are efficient because they move heat from one location to the next rather than generating it directly

They are typically between 200% and 300% efficient and can go upwards of that as well

ASHP Definitions

Compressor types

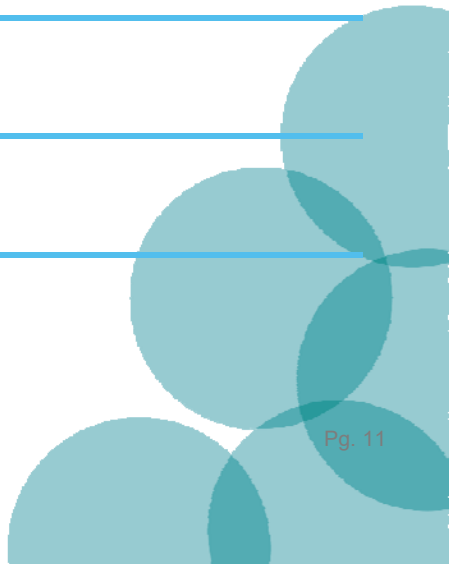
- Single stage – on off
- Two stage – low/high
- Inverter driven - inverter driven motors enable variable speed control of compressor and fans

System types

- Ductless mini-splits
- Centrally ducted systems with dual fuel back up
- Centrally ducted systems with electric back up

Factors that go into product selection

- Climate
- House load
- Existing heat type
- Customer fuel rates (electric rate, natural gas rate, propane costs etc.)
- Homeowner pain points or heating/cooling issues
- Capacity vs. ambient temperature
- Efficiency vs. ambient temperature
- System design



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Ductless Mini-splits

Ductless ASHPs don't require ductwork

- Indoor units are mounted on the wall, floor or ceiling.
- The individually-controlled indoor units allow for zoned heating and cooling.

Good fit when:

- Already heating with radiators, in-floor, or electric baseboard
- Getting rid of window A/C units or adding home cooling

Centrally Ducted System

- Use existing ductwork to distribute heated and cooled air.
- The outdoor condenser is connected to the indoor furnace's fan.
- Central ASHPs provide both heating and cooling in a single system.
- **Good fit when:**
  - Already heating with forced air (with ductwork in place)
  - Replacing central A/C or adding it for the first time

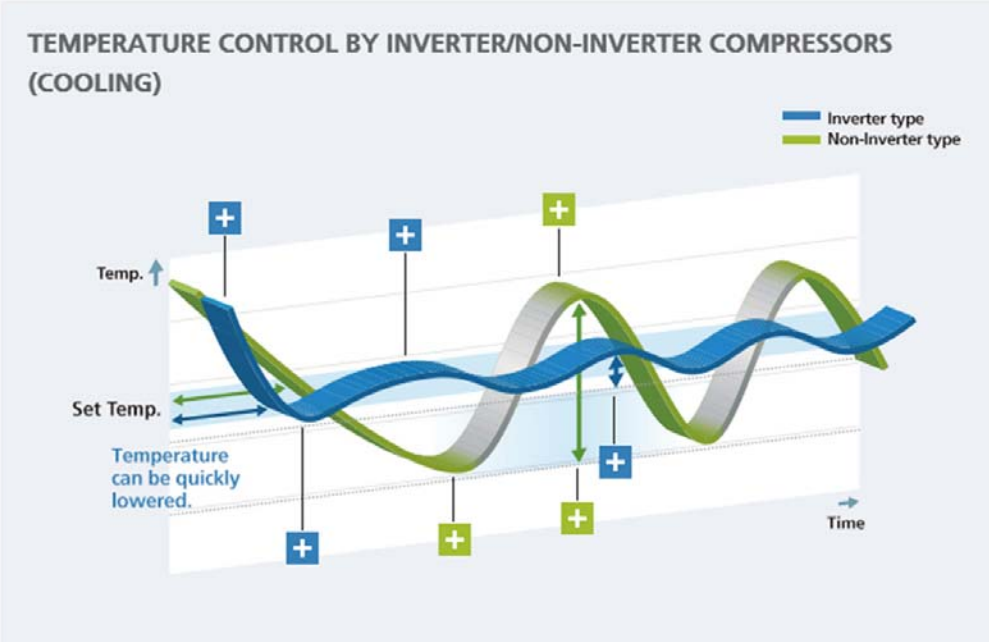
Types of Residential ASHPs

Ducted Whole-House Installation, Dual Fuel

Key Benefits

Cold Climate Heat Pump vs. Propane

- Cozy heat and cooling in one
- More reliable fuel source
- Costs less to run
- Whisper quiet



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Types of Residential ASHPs

Ductless / Mini-Split Installation

Key Benefits

Cold Climate Ductless Heat Pump vs Baseboard

- Cozy heat and cooling in one
- Simple and easy
- Costs less to run
- Whisper quiet

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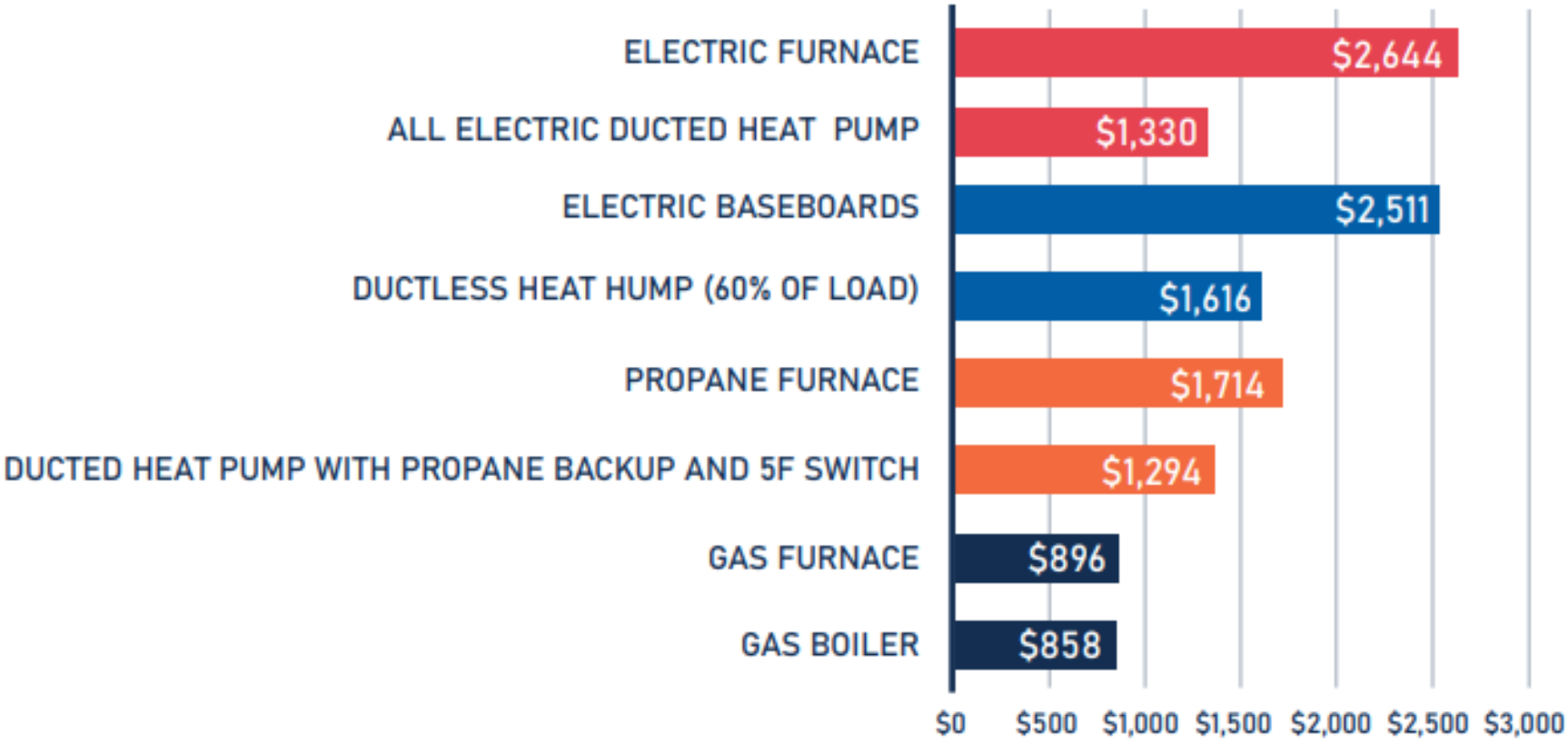
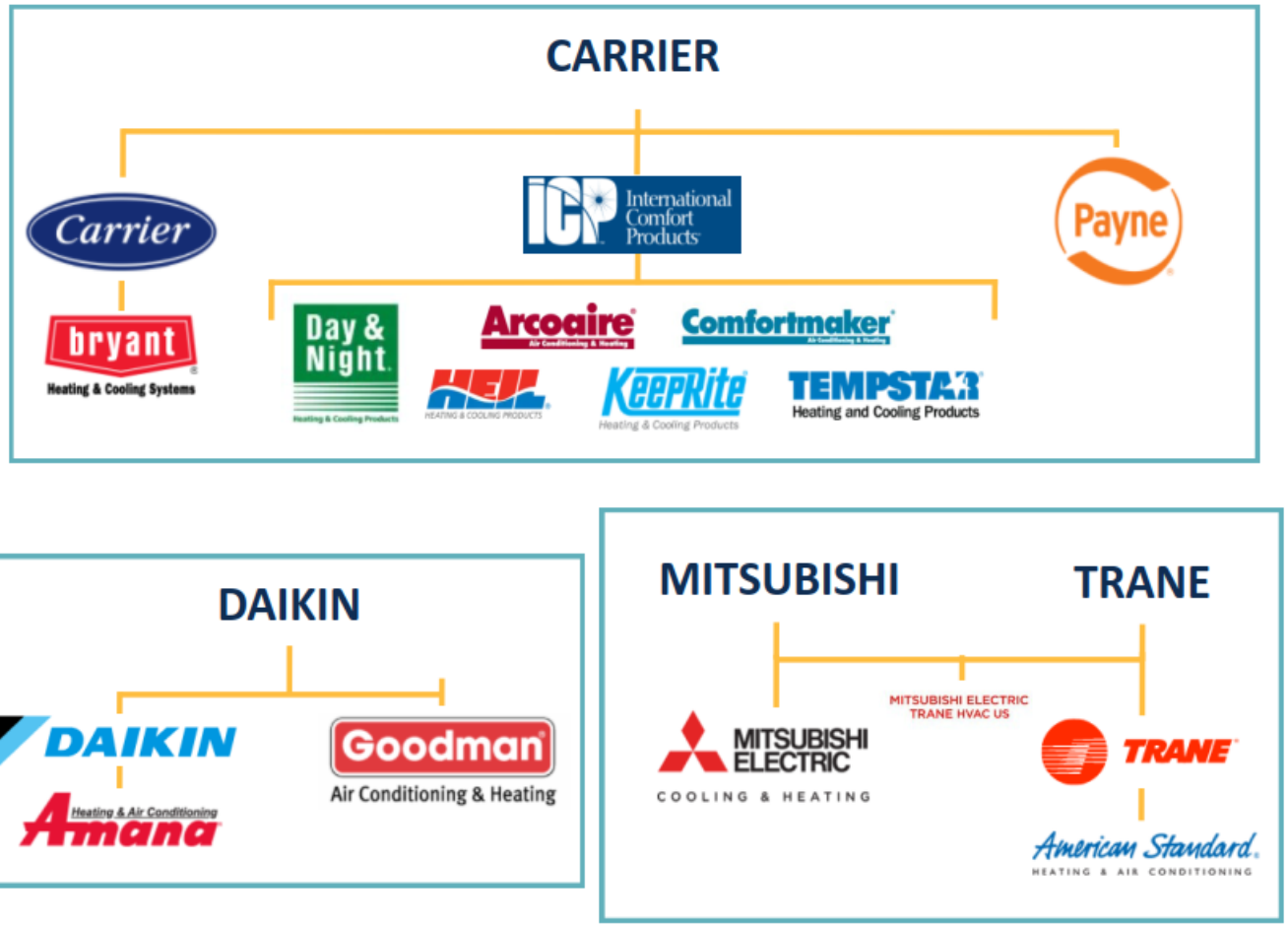
Types of Residential ASHPs

Ducted Whole-House Installation, All-Electric

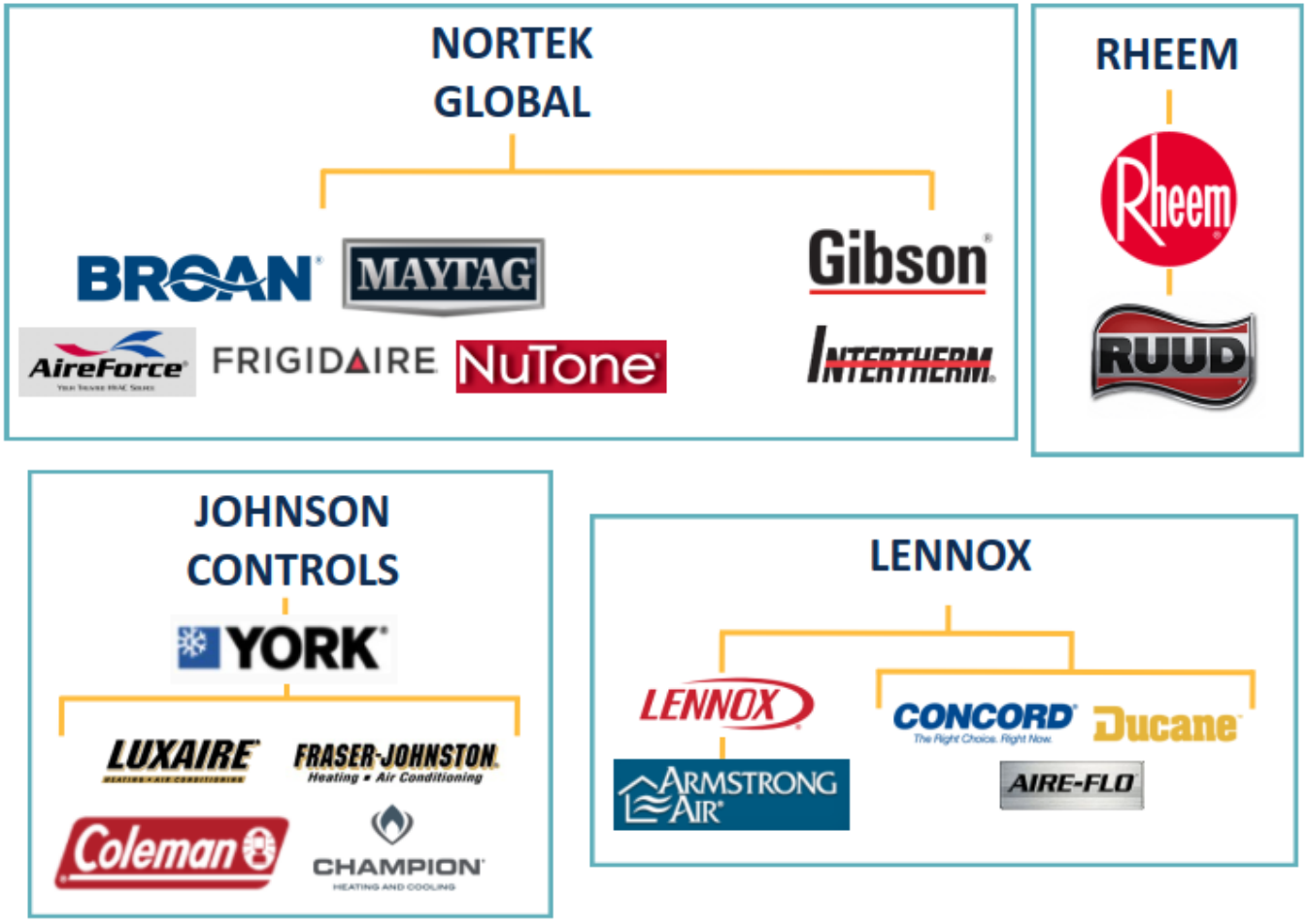
How do system types stack up?



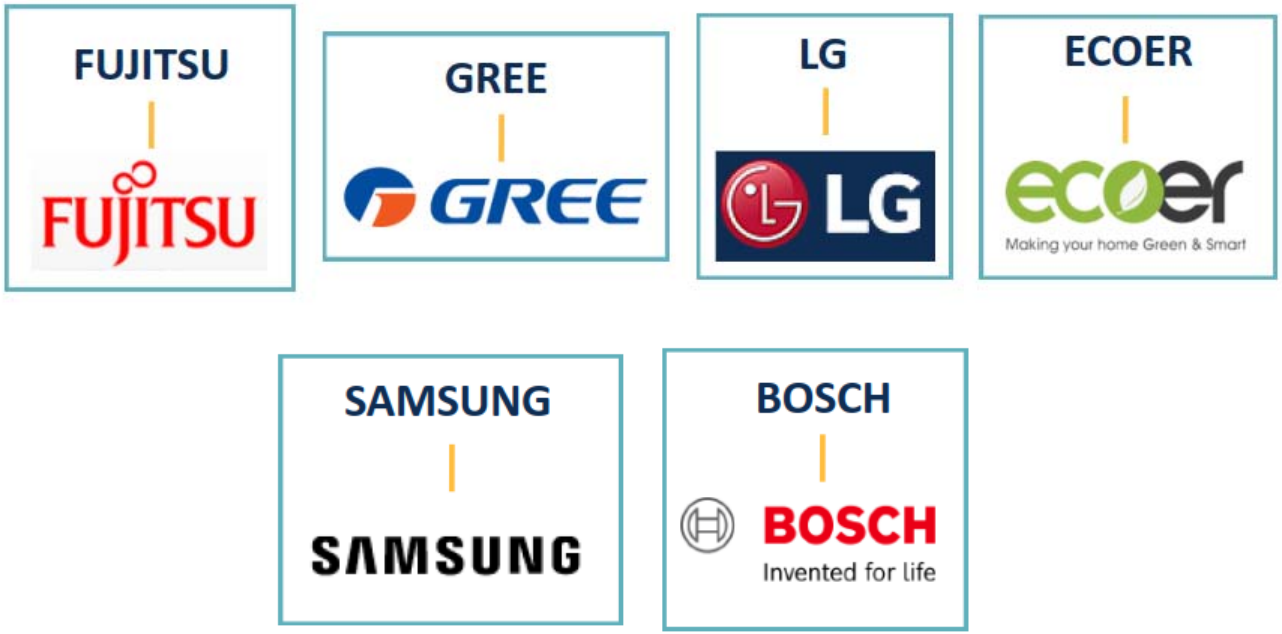
Manufacturer Family Tree



Manufacturer Family Tree



Manufacturers



Mini-Split Only:

Panasonic

Haier

FRIEDRICH

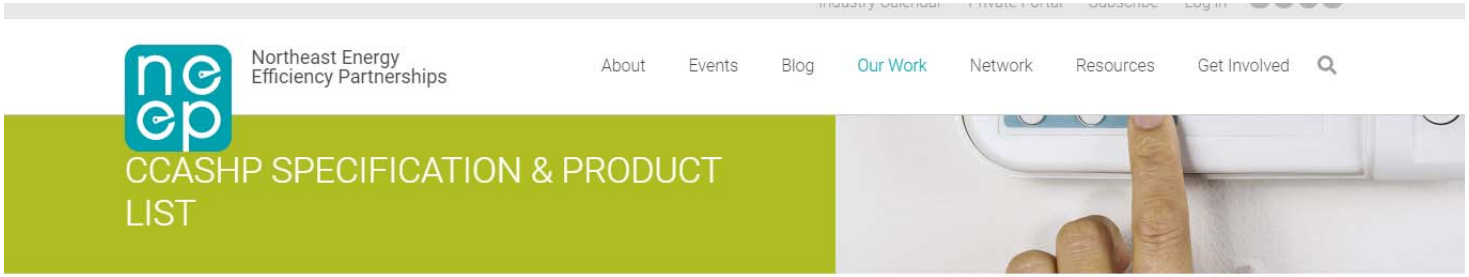
Really… in cold climates?

- Typically, ASHP heat transfer performance of reduces as outdoor temps drop
- However, 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

What is ccASHP technology?

- Product specification – what makes an ASHP cold climate?
  - Inverter driven – variable capacity allows for more efficient operation
    - This technology improvement allows for operation at lower temps
    - Now applicable for heating in Minnesota
  - Rebate specifications often used to specify cold climate –
    - Greater than ≥15 SEER
    - Greater than ≥9 HSPF (ducted) or ≥10 HSPF (ductless)
    - COP of ≥1.75 at 5° F
  - Northeast Energy Efficiency Partnership (NEEP) cold climate product list

NEEP Cold Climate Product List



Click here to access

NEEP'S COLD CLIMATE AIR SOURCE
Heat Pump List

On behalf of energy efficiency stakeholders, NEEP is pleased to be housing the ***Cold Climate Air Source Heat Pump (ccASHP)*** **Specification** (now on V3.0) and **Product List**. Background on the development of the ccASHP specification and details on listing products are below:

- Background on the development of the ccASHP specification and List
- Why List Products on the ccASHP Product List
- 2020 Manufacturer Product Listing Information
- FAQ on Listing Products

Background

Clean Energy and energy efficiency stakeholders from the region lack confidence that the existing heating performance metric (HSPF) for air source heat pumps provides the necessary information to adequately characterize heating performance across the heating season, particularly at low temperatures. In addition, supplemental information provided by manufacturers to demonstrate performance in cold temperatures 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

HIGH PERFORMANCE AIR SOURCE HEAT PUMPS

ccASHP Product List & Specification

Installer and Consumer Resources

Subscription Details

FAQ

ASHP/VRF Resource Center

RELATED BLOG POSTS

Heat Pumps, Smart Controls, VRFs, Oh My!

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Cold Climate ASHP

Specification

Variable capacity

COP ≥1.75 at 5° F

HSPF ≥10 for ductless

HSPF ≥9 for ducted

SEER ≥15

Applications and Benefits

Displace zonal electric heat or electric forced air furnace

Replace or displace propane furnace

Delivers heat in outdoor temps. as low as –20° F

Typical Change over temperature 0-5° F

Standard ASHP

Specification

Any ASHP product below the threshold of ccASHP

Can be ducted or ductless

Typical Change over temperature 30-40° F

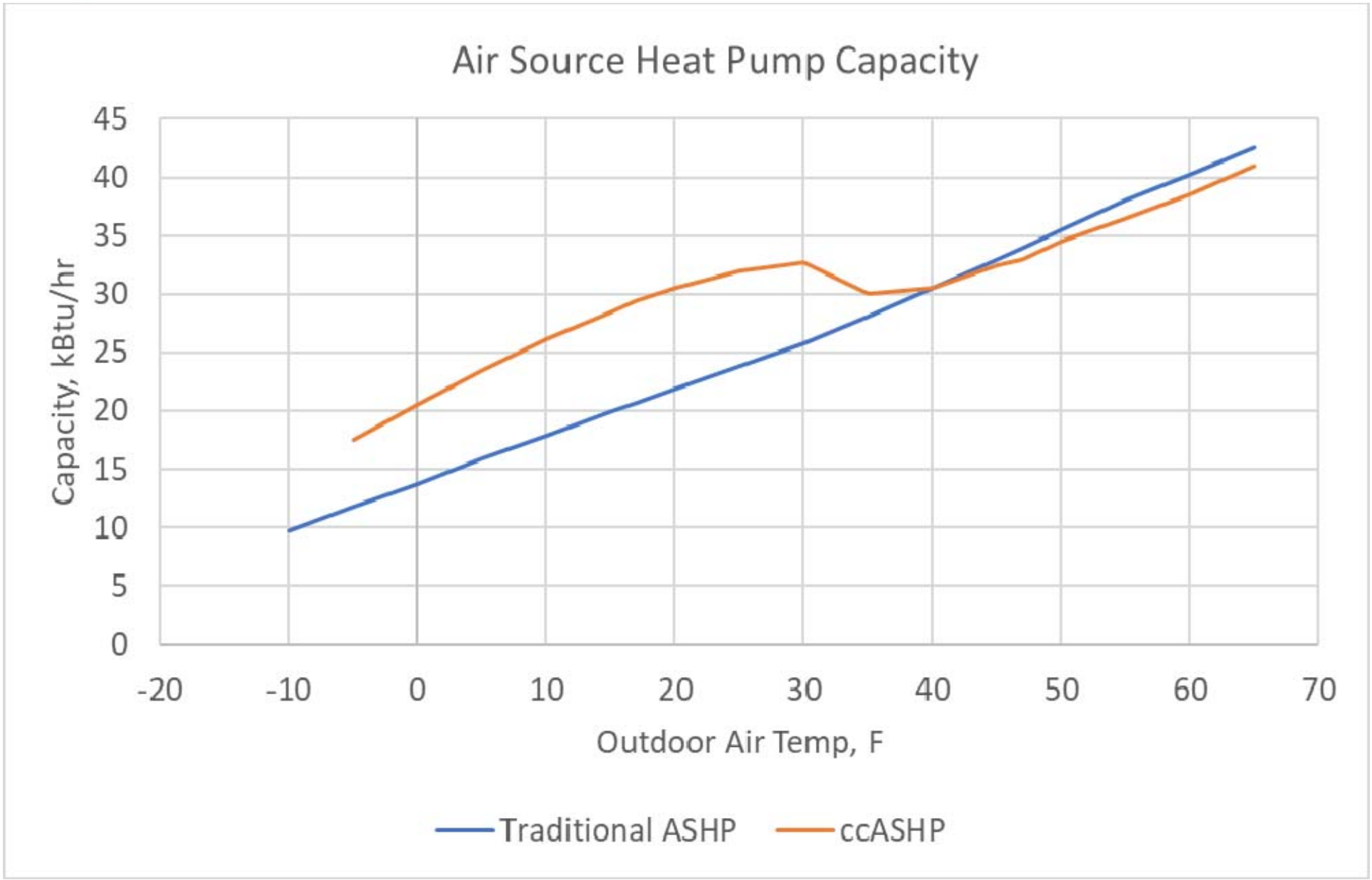
May cost less than ccASHP equipment but will meet a smaller fraction of the heat load

Applications and Benefits

Ideal replacement for central AC

Delivers energy savings for cooling

Delivers cost effective shoulder season heating down to 30-40° F


Air Source Heat Pump Capacity
Capacity, kBtu/hr
45
40
35
30
25
20
15
10
5
0
-20
-10
0
10
20
30
40
50
60
70
Outdoor Air Temp, F
Traditional ASHP
ccASHP

CEE's Field Research Results

✓ Significant savings for replacing propane and electric resistance

Percentage Reductions for ccASHPs				
	Site Energy	**Source Energy**	**Homeowner Cost**	**Emissions**
Dual fuel ASHP vs Prop. Furn.	40%	10%	30%	5%
All elect. ducted & ductless vs elect. resistance	55%	55%	55%	55%

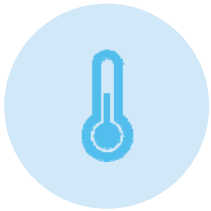
✓ Technology continues to improve

- New generation systems can operate as low as -20° (efficiently as low as -13)

ASHP Application Types

Existing HVAC	ASHP Options	Considerations	Market Size
Electric Baseboard	ccDHP	Sizing, home configuration, number of heads	**270,610** homes
Electric furnace	Ducted ccASHP	Sizing and electric plenum backup	**87,230** homes
Propane furnace	Ducted dual-fuel ccASHP	Sizing and change over temperature	**253,814** homes
AC Replacement – without ductwork	ccDHP	Sizing, comfort needs, product cost	**318,320** homes
AC Replacement – with ductwork	Ducted ASHP	Sizing, energy costs, product cost, change over temperature	**1,165,130** homes

ASHP Benefits- In Summary



Heating and cooling all in one system

Saves on heating and cooling operational costs

Improved comfort

Air filtration

Can reduce carbon emissions

Opportunities Driving ccASHPs

Energy use-driven opportunities

- Cost effective replacement of traditional electric heat
- Cost effective replacement of delivered fuels
- Off-set some natural gas heating

Non-energy benefits-driven opportunities

- Home additions and underserved areas
- Adding cooling

Performance and Beneficial Application Types

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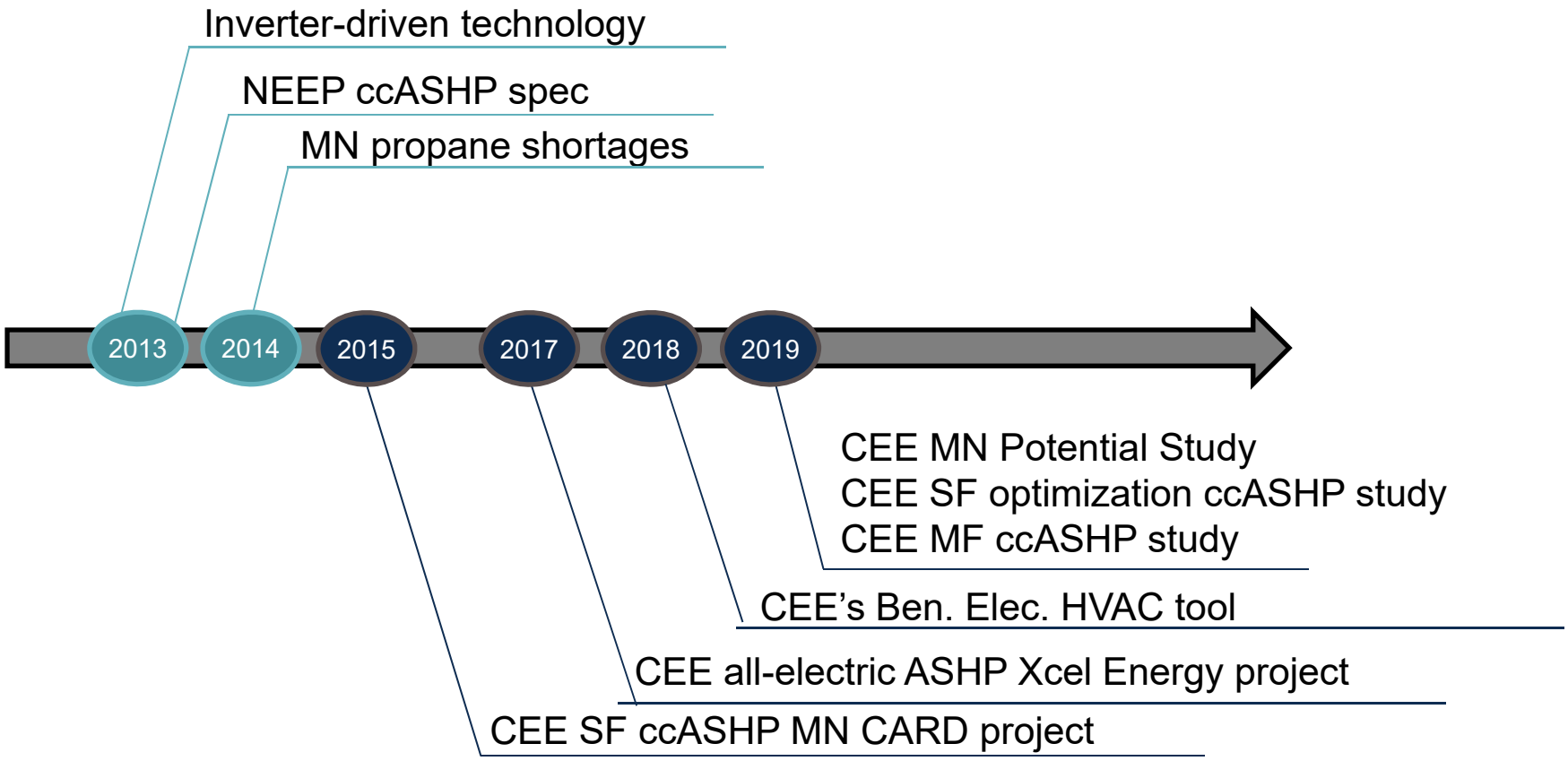
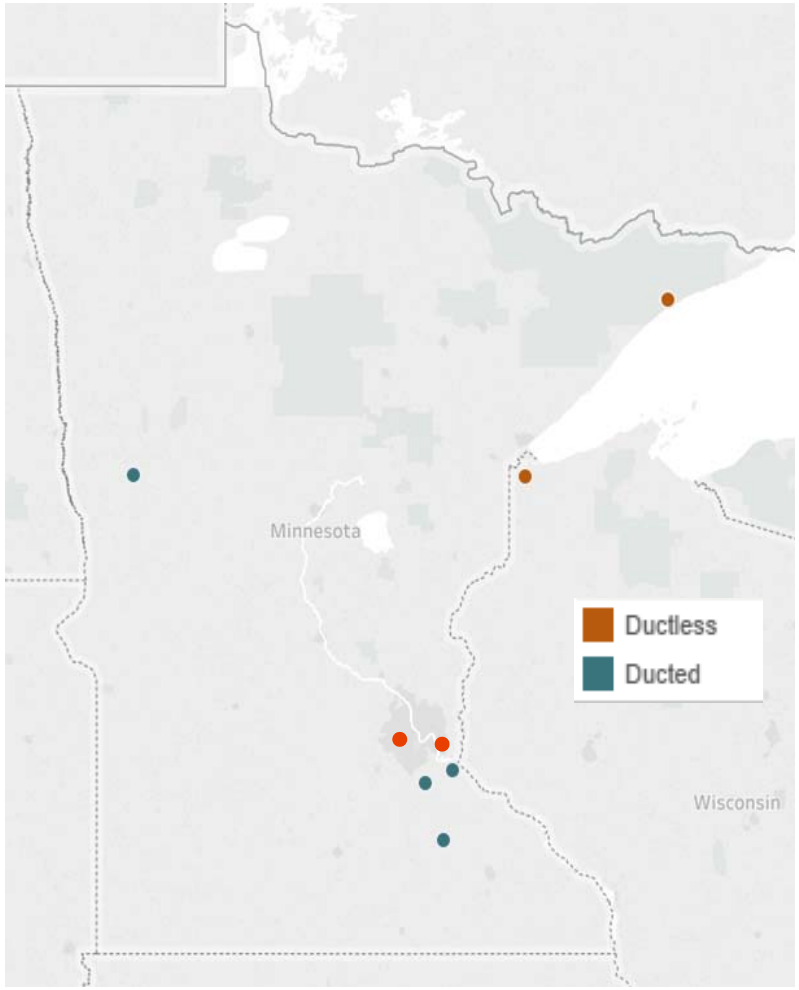
CEE's ccASHP Research Timeline



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



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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

Whole house ducted systems

Ducted Whole House Installation, Dual Fuel

Ducted Whole-House Installation, All-Electric

Ductless / Mini-Split Installation

Instrumentation

Power Measurements:

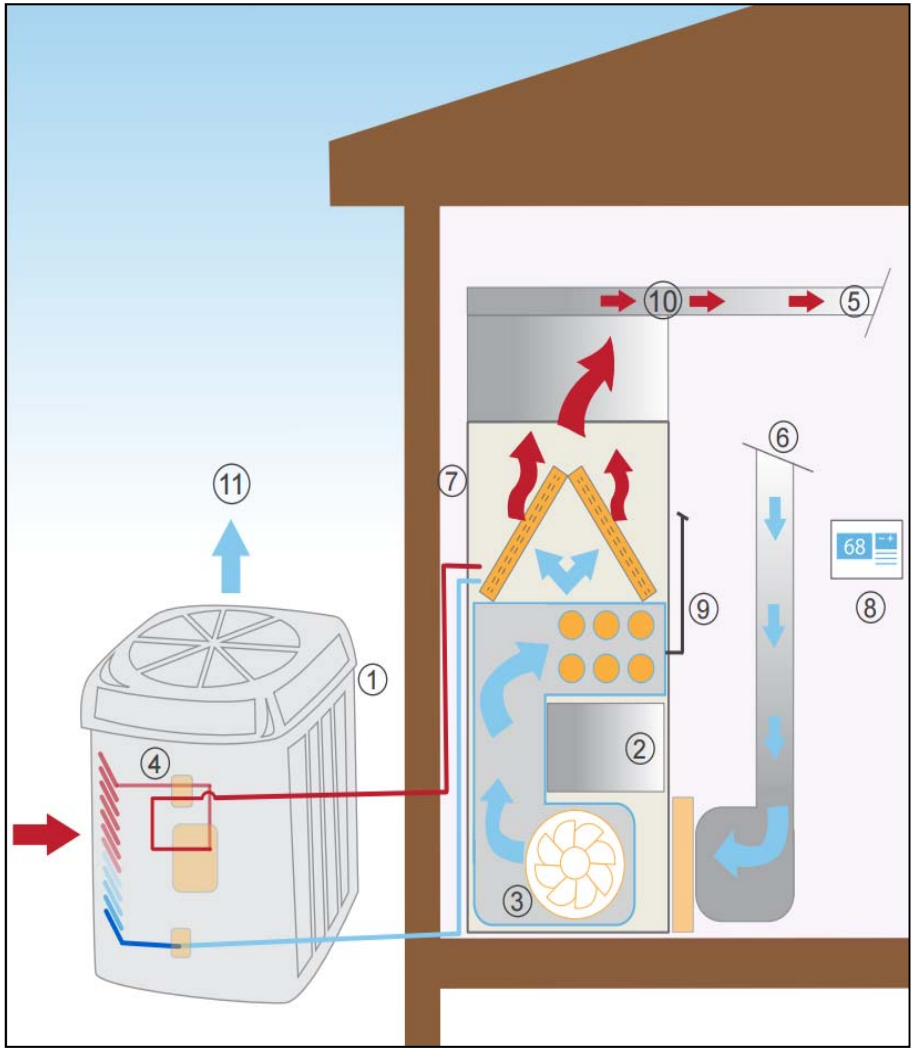
1. Outdoor unit
2. Indoor unit
3. Indoor fan
4. Reversing valve

Temperatures:

5. Supply Air
6. Return Air
7. Mechanical area ambient
8. Conditioned space

Additional:

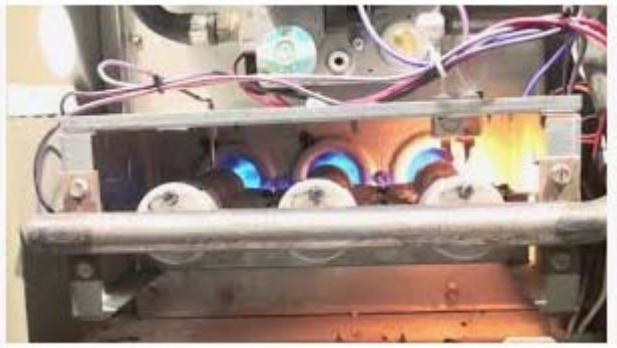
9. Back up fuel consumption
10. Delivered air flow
11. NOAA data



Installation Considerations

Control and Operation

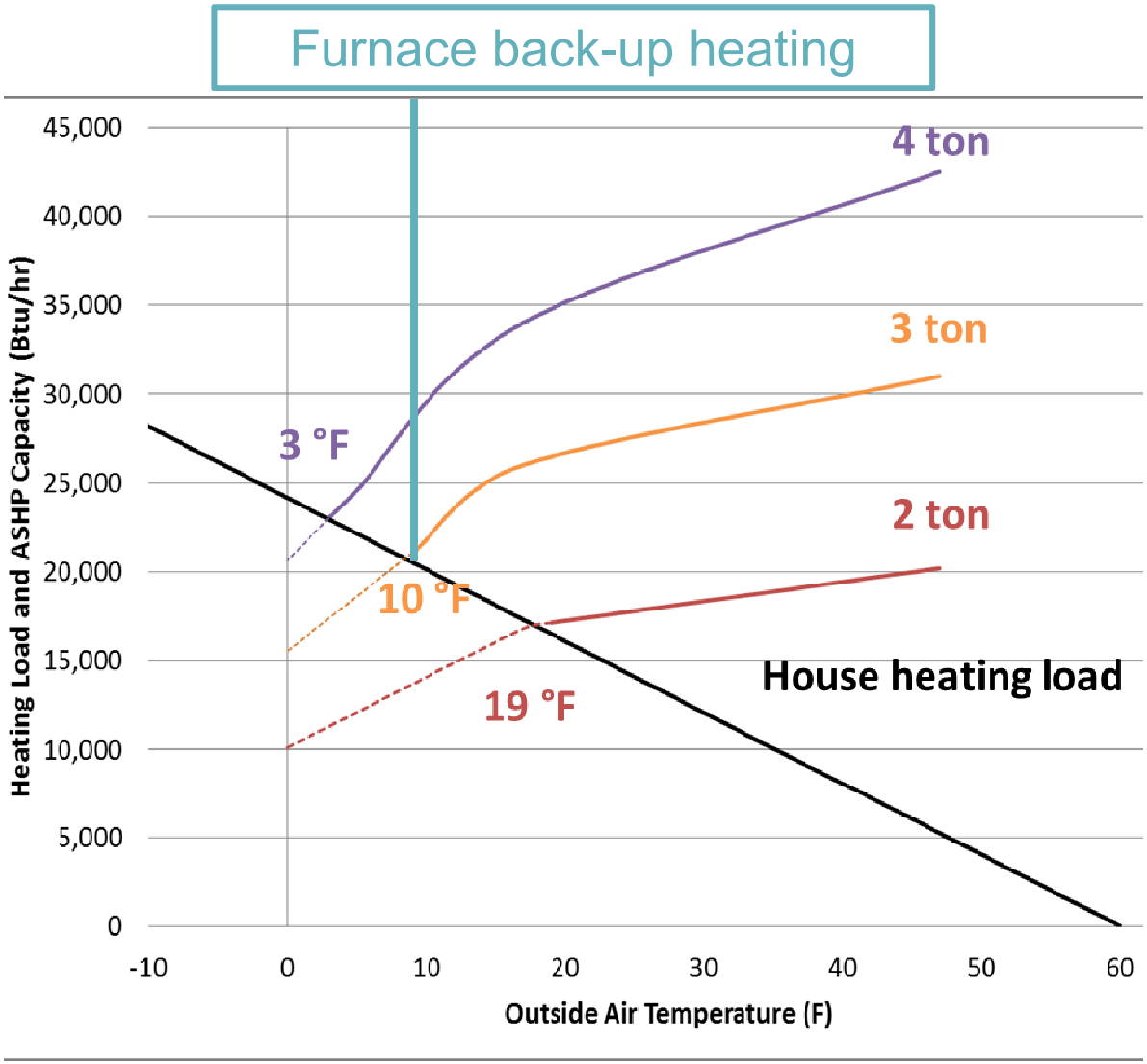
Integration with backup



Sizing

Design & 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
- Percent heating load met by ASHP:
  - **4 ton ~ 86%**
  - **3 ton ~ 77%**
  - **2 ton ~ 60%**



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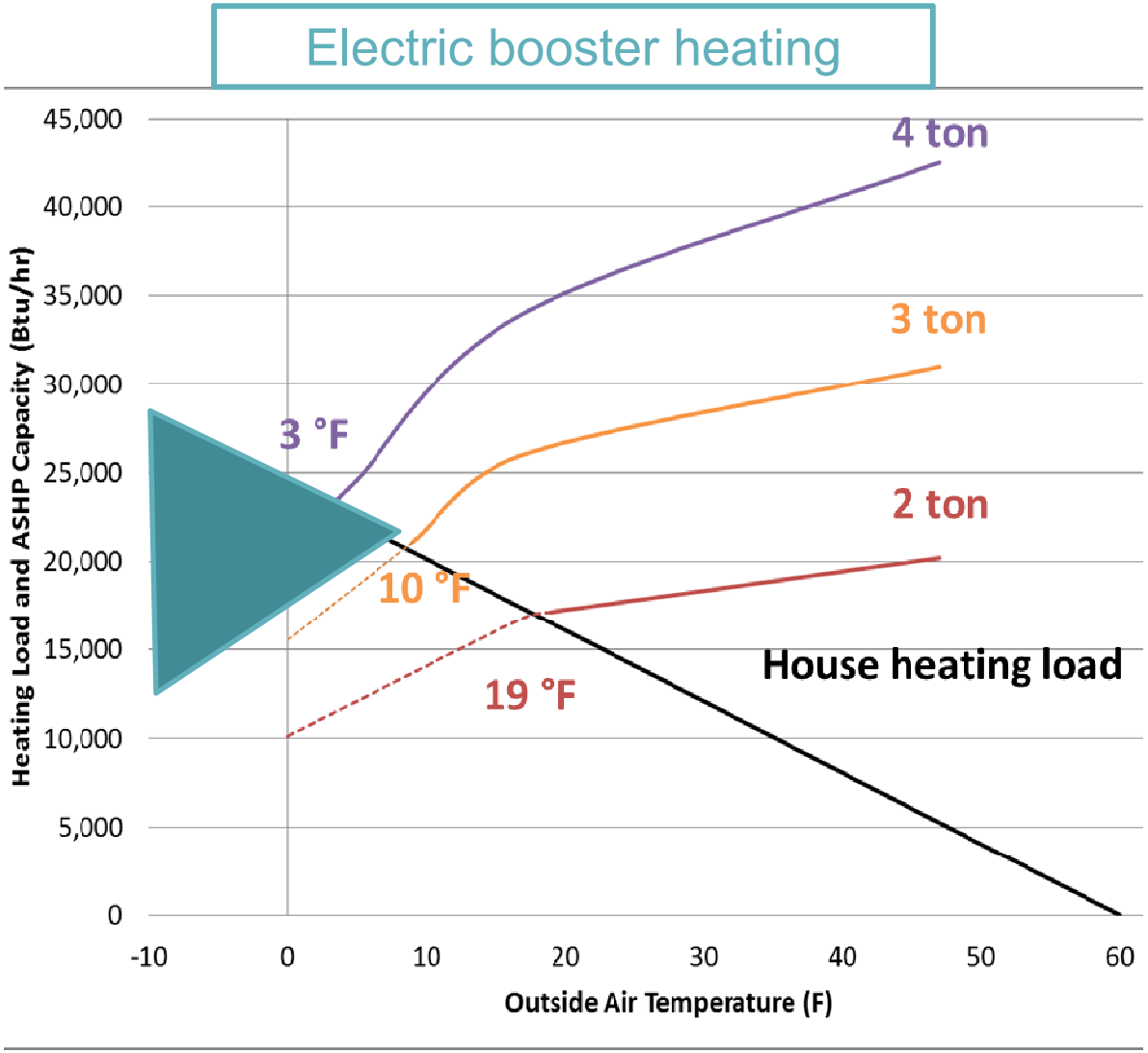

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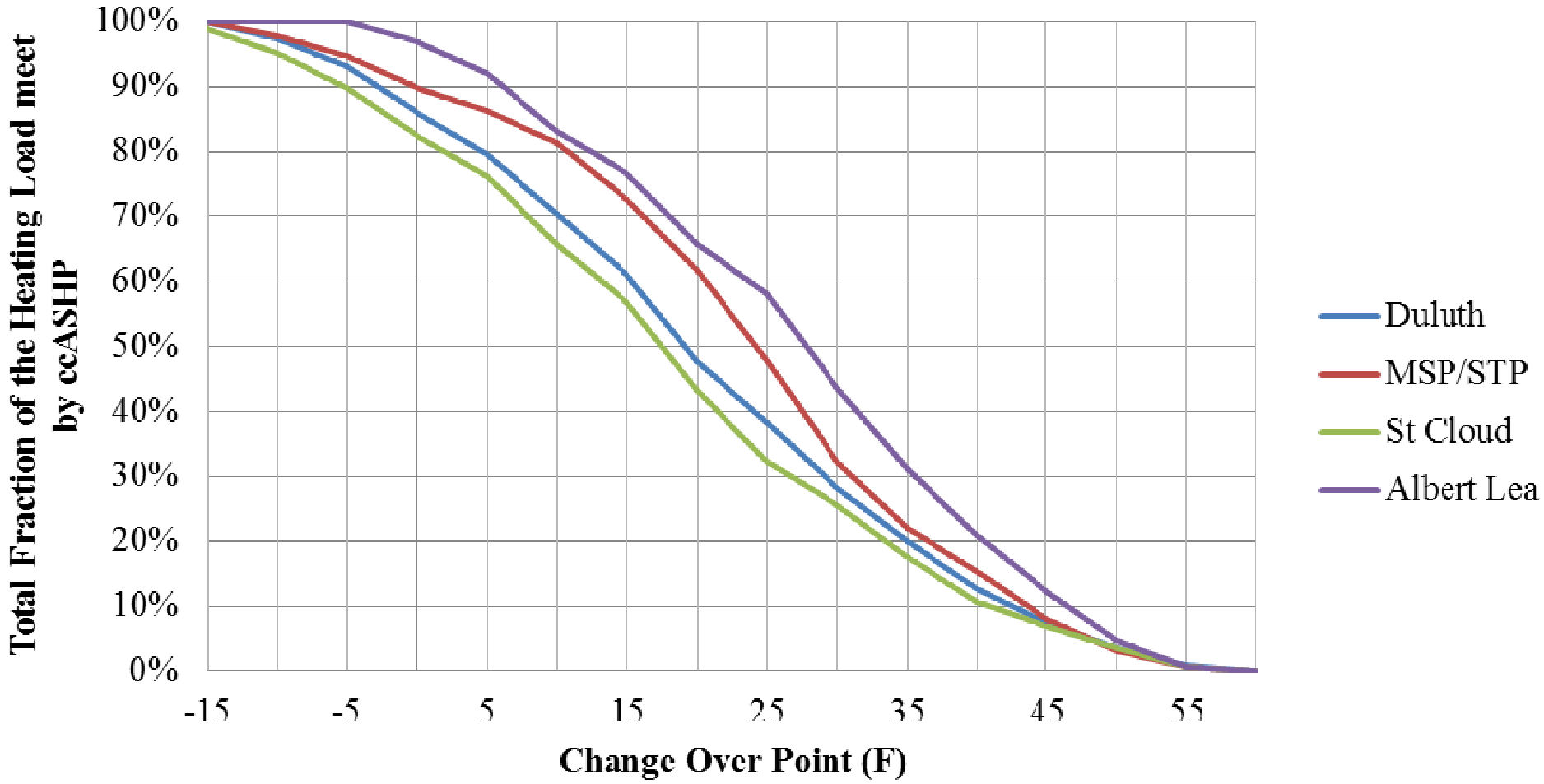
Impact of Change-Over Set Point



ASHPs + 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 (NEW)
- Plenum electric resistance heater

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

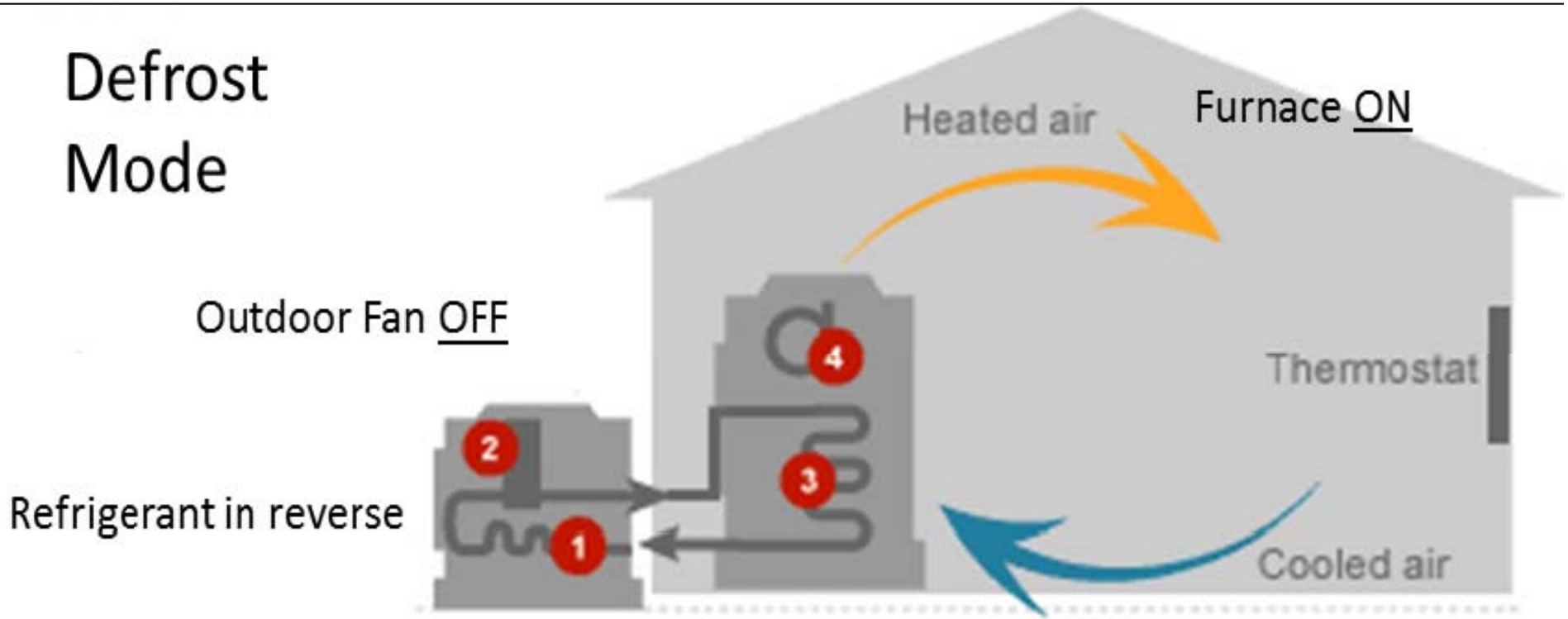
ASHP Data!

- 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!**

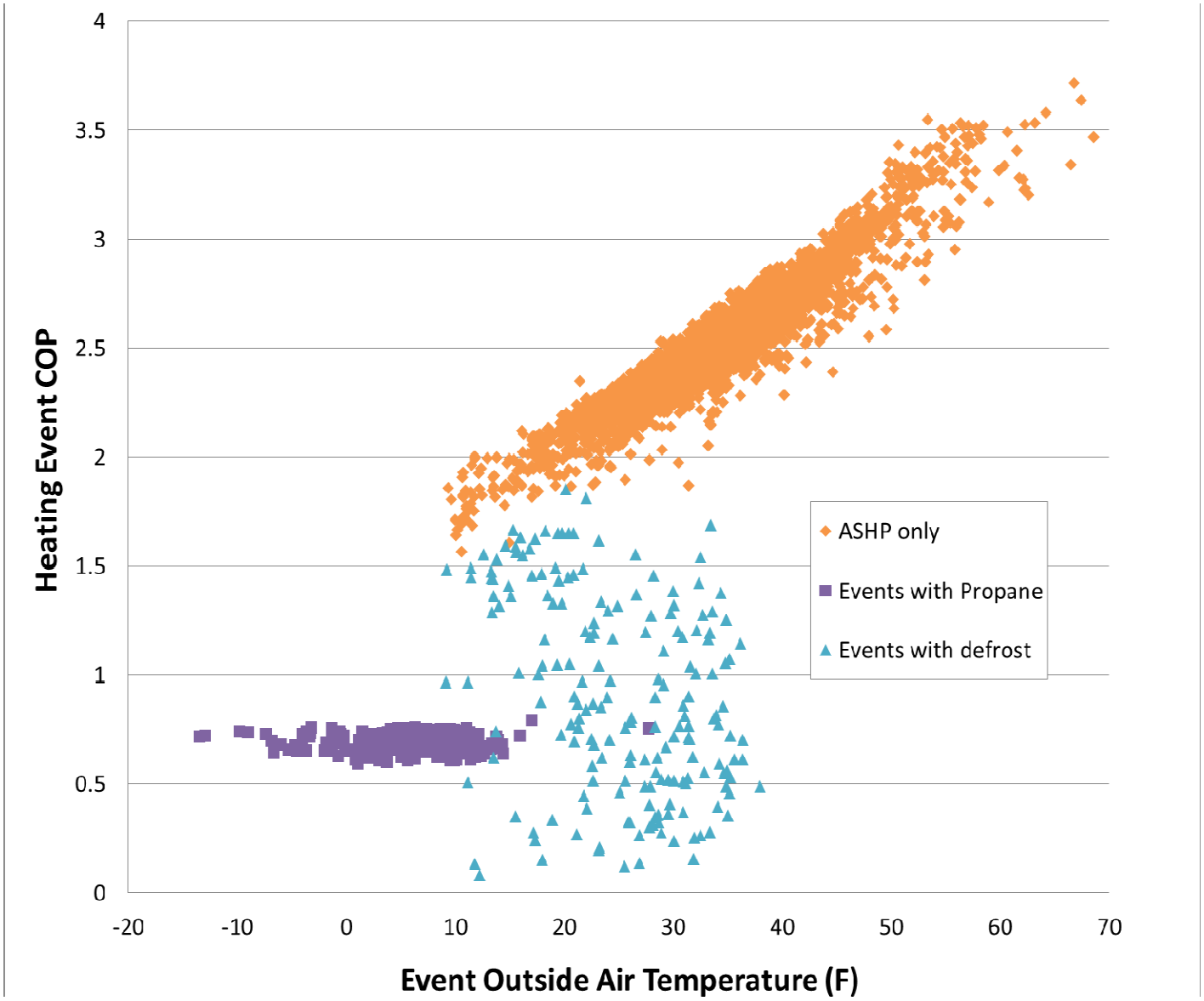
Modes of System Operation

Heating system has three modes of operation:

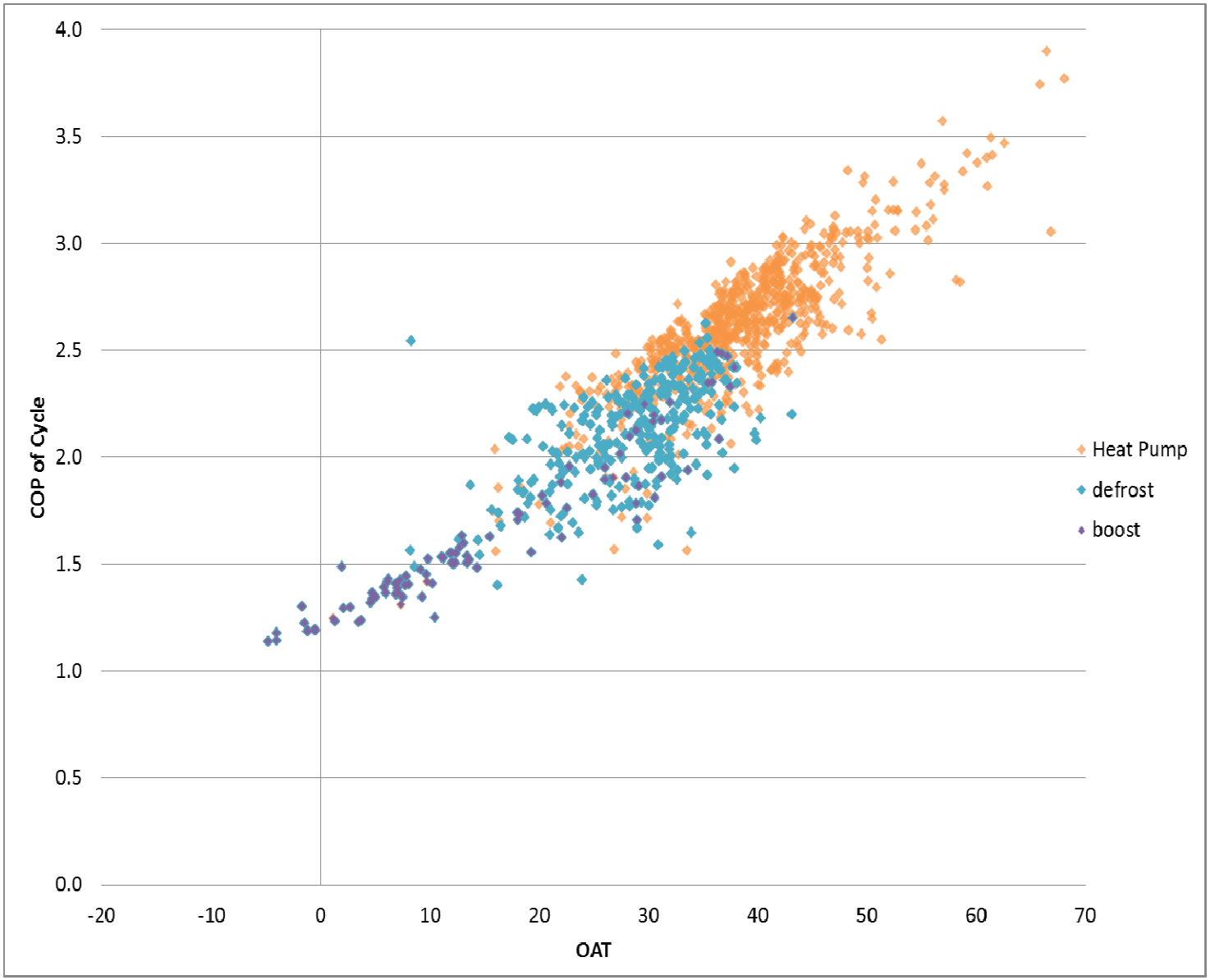
- ASHP heating
- Back up heating
- Defrost



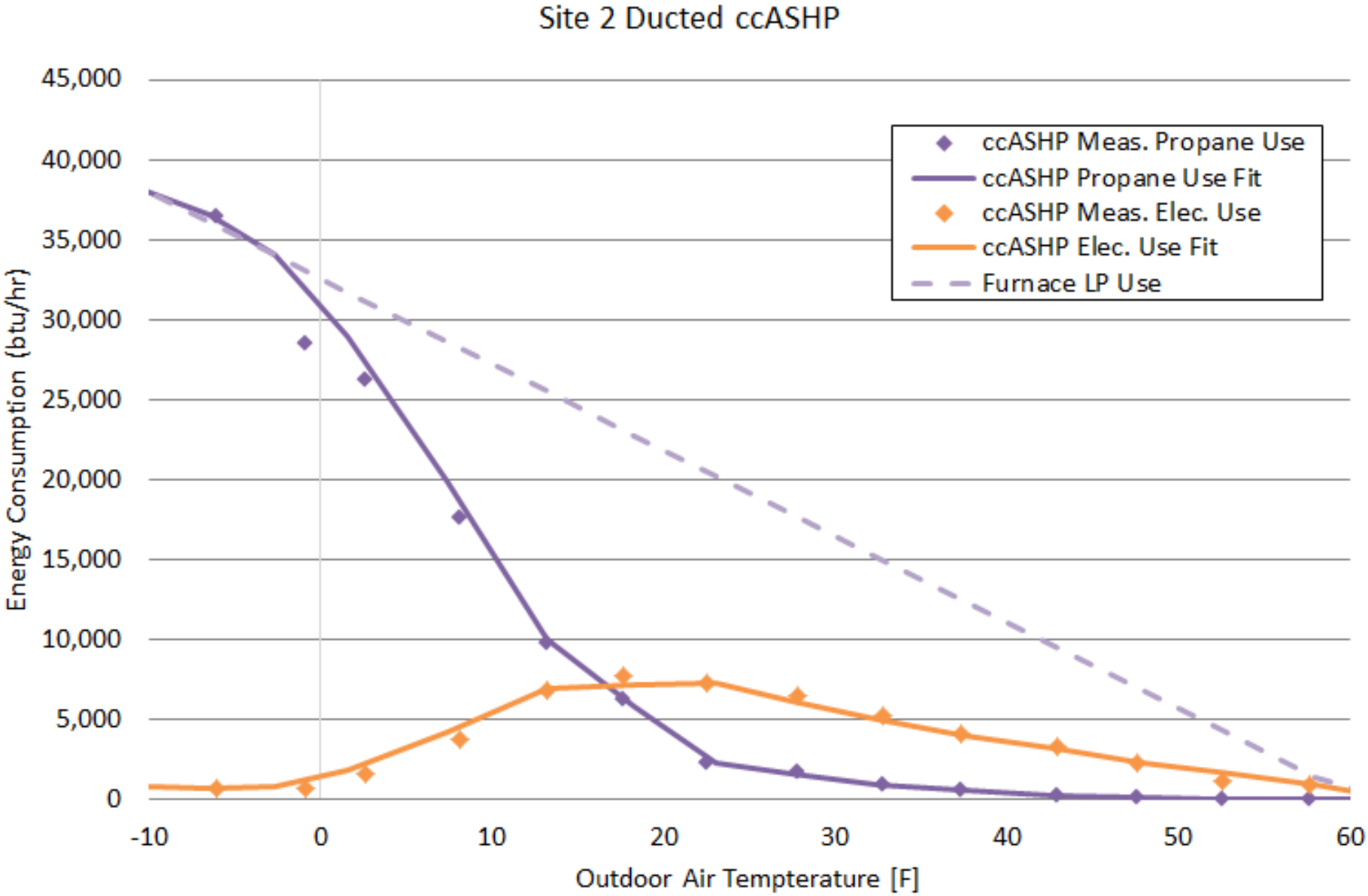
Heating Cycle COP of Dual Fuel System



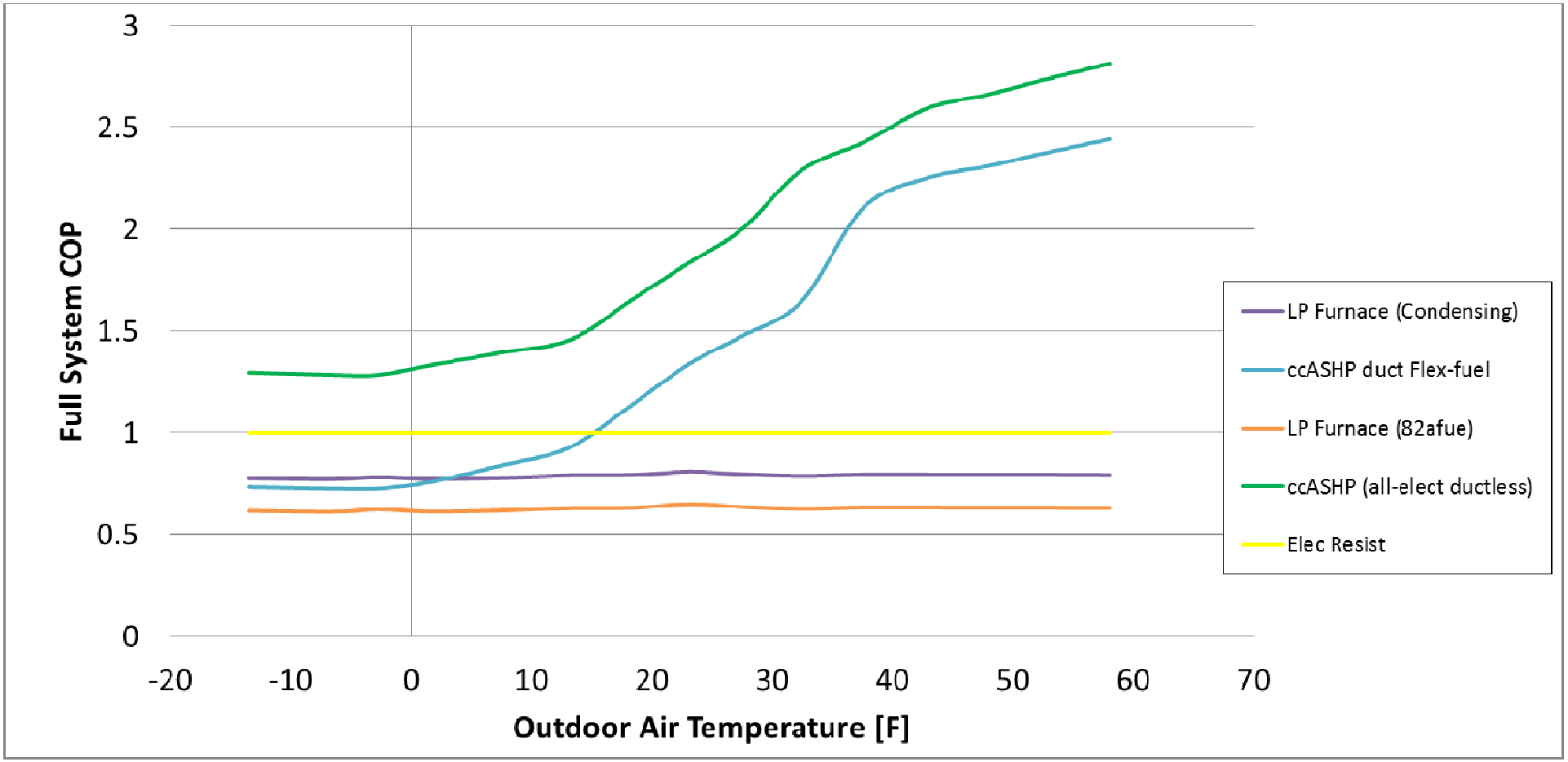
Heating Cycle COP of All-Electric



Energy Use vs OAT Models



System Performance

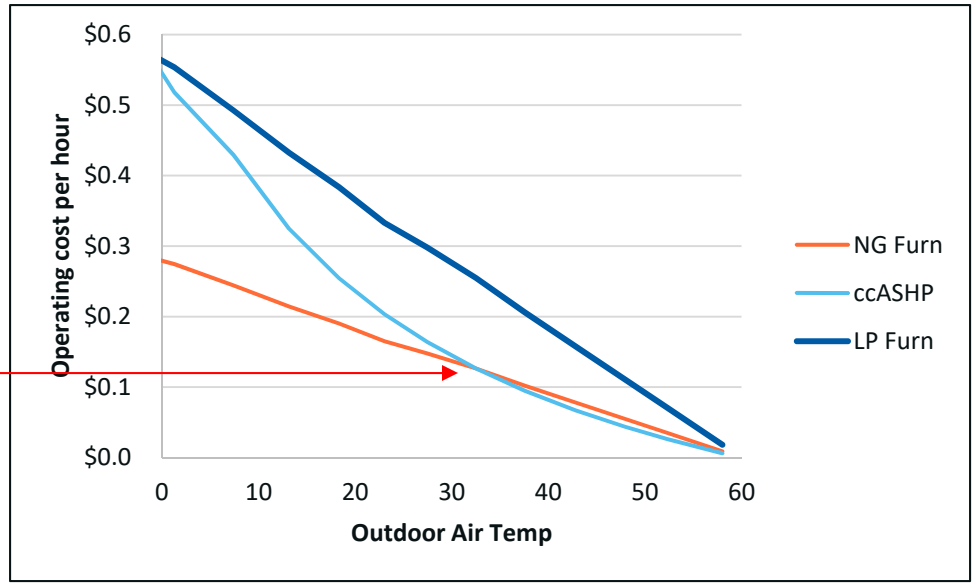


ASHP and Natural Gas Systems

- ccASHP as a central air conditioner replacement
  - ASHP heats home above 15° F

	Energy Use			Cost
	Nat. Gas	Electric	Total Site	
	therms/yr	kwh/yr	Mmbtu/yr	$/yr
ccASHP with furnace back-up	200	7500	45.6	$808
90% NG furnace with SEER13 AC	810	1200	85.1	$791
Savings			46%	-2%

Fuel Costs	
$0.085	$/kWhr
$0.850	$/therm



32°F

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Replacement System Install Costs

- **For the 4 ducted systems in CEE research:**
  - Our average cost was ~$14,000*
- **NREL residential equipment install database:**
  - $10,340 total for dual-fuel ccASHP and furnace install
    - $6,340 for ducted, 3-ton ccASHP
    - $4,000 for a new, condensing propane furnace ($3,000 for an 80%).
  - $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 dual 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

Summary of ccASHP Research Results

- 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

Additional Conclusions

- Freeze protection and integration with auxiliary heating are important
- Dual fuel ccASHPs can heat below 5F, all-electric systems below -13° F
- Paybacks are attractive when existing heating or cooling system need to be replaced

System Type	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

Upcoming Research

- Single family and multi family optimization
- Air-to-water field research
- AC replacement modeling and market study

Next Steps - 2021 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 site assessments on all buildings
- Installed baseline monitoring equipment at 2 sites – 8 units
- Working to get heat pumps installed at all sites
  - Currently 2 heat pumps installed and collecting data

Single Family 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 site assessment on all buildings
- Installed baseline monitoring equipment at 7 sites
- Working to get heat pumps installed at all sites
  - Currently 1 heat pump installed collecting data

Research Case Studies

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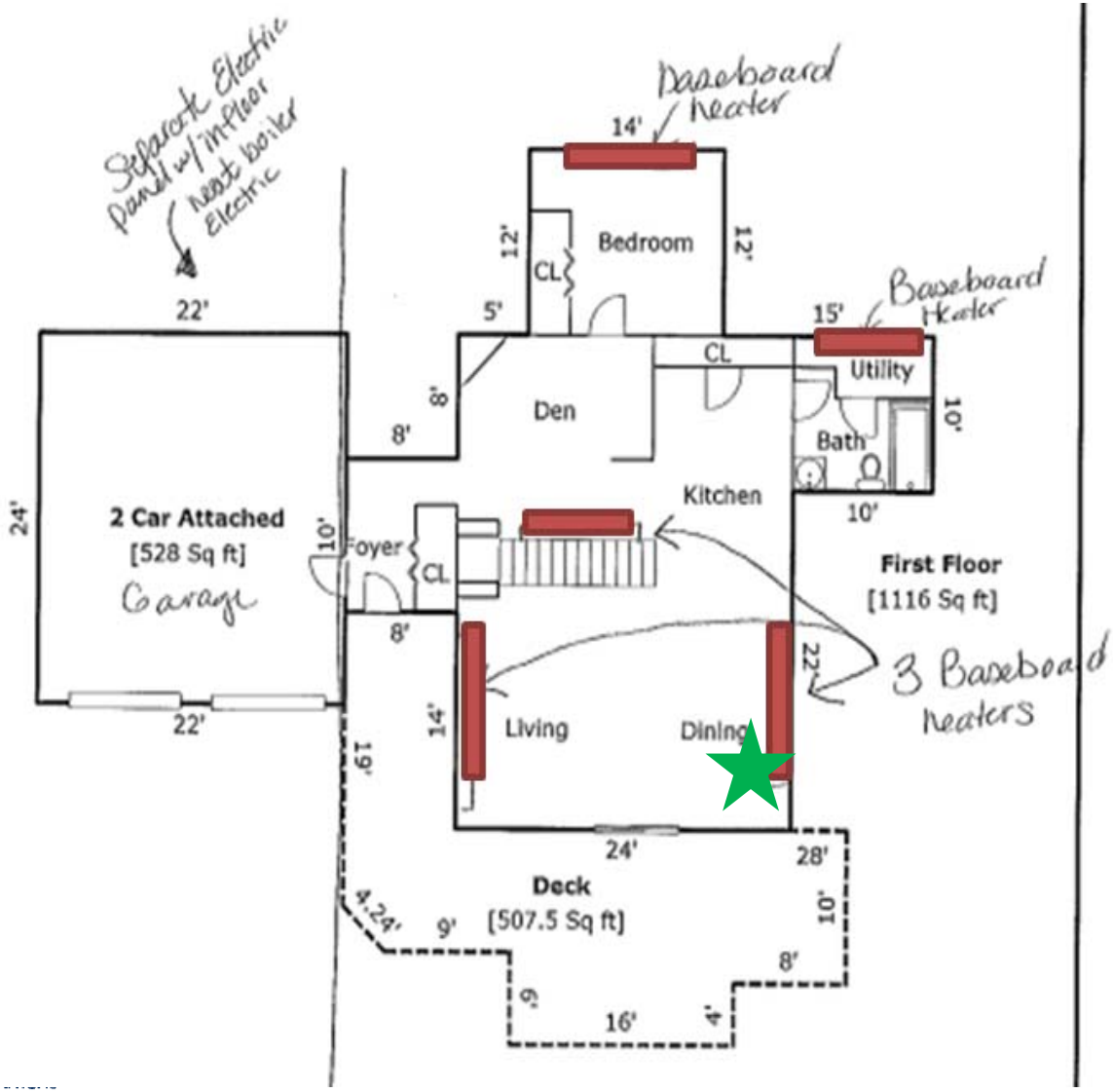
Ductless: Install Location



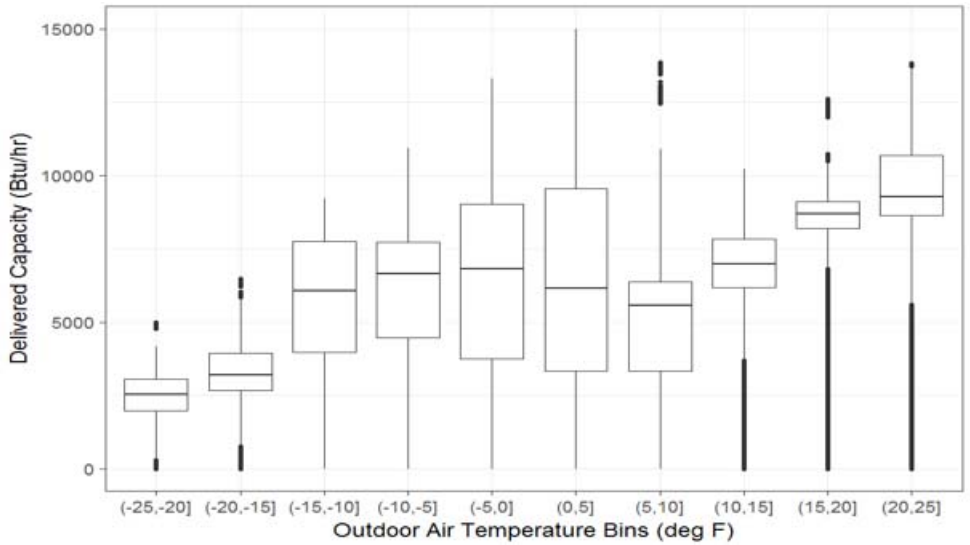
Mini-Splits Displacing Baseboards

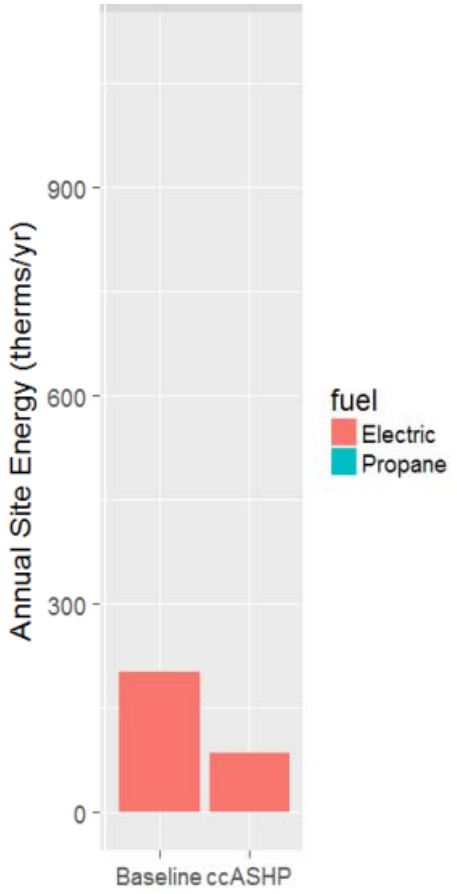
- House Characteristics
  - Three-bedroom split level single-family home
  - Located in Superior, WI
  - Two occupants
  - Two levels (one indoor head on each level)
  - Fireplace

Mini-Splits Displacing Baseboards

Ductless systems
operated below -13 F.

- Homeowner in WI has removed several ER baseboards





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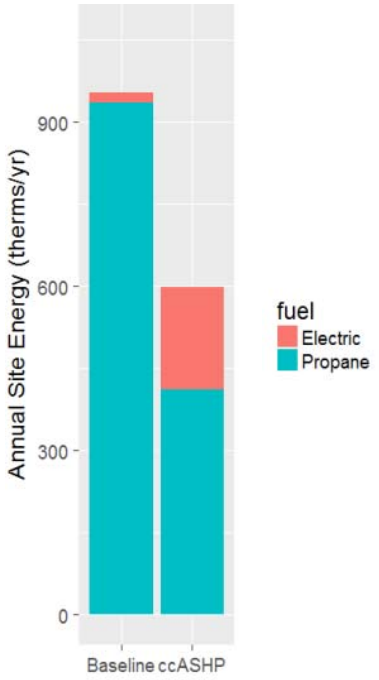
Central System Displacing Propane

- House Characteristics
  - Three-bedroom single story single-family home
  - 2,200 square feet
  - Located in Farmington, MN (south metro)
  - Three occupants

Central System Displacing Propane

ASHP System	ASHP Size	ASHP Type	Backup
Carrier Infinity with Greenspeed [25VNA048A003]	4 ton	Ducted	LP Cond. Furnace

Air Source Heat Pump	Baseline	Location	Site Energy Reduction	Cost Reduction	Propane Reduction
Ducted	Condensing LP Furnace	Metro	**41%**	30%	63%



All Electric System

- House Characteristics
  - Two-bedroom, one bath, 1.5 story single-family home
  - 1,600 square feet
  - Located in Minneapolis, MN
  - Two occupants
- Homeowner was interested in converting to an all-electric home
  - Solar panels
  - Heat pump water heater

All Electric System

Make	Model	Rated Capacity (Btu/h)		SEER	HSPF	COP at 47 °F	COP at 17 °F	COP at 5 °F
		Cooling	Heating					
Mitsubishi Electric	PUZ-HA36NHA5	33,000	38,000	17.8	11.0	3.48	2.62	1.82

- Overall 50% energy savings
- ASHP met 90% of total heat load

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MN ASHP Collaborative

Program Overview

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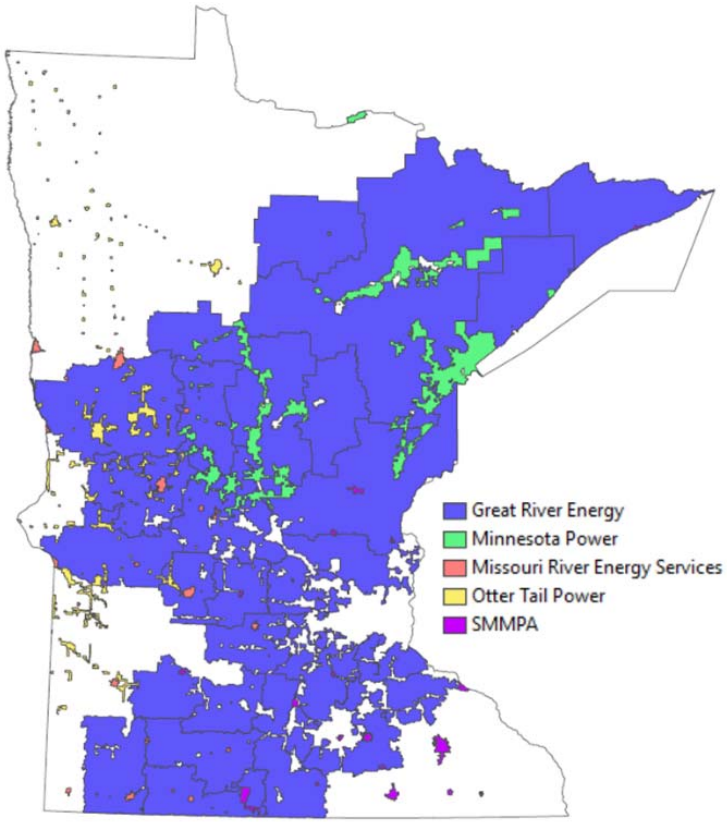
ASHP Collaborative Members



cee
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OTTER TAIL POWER COMPANY

minnesota power

GREAT RIVER ENERGY.

MISSOURI RIVER ENERGY SERVICES

Southern Minnesota Municipal Power Agency

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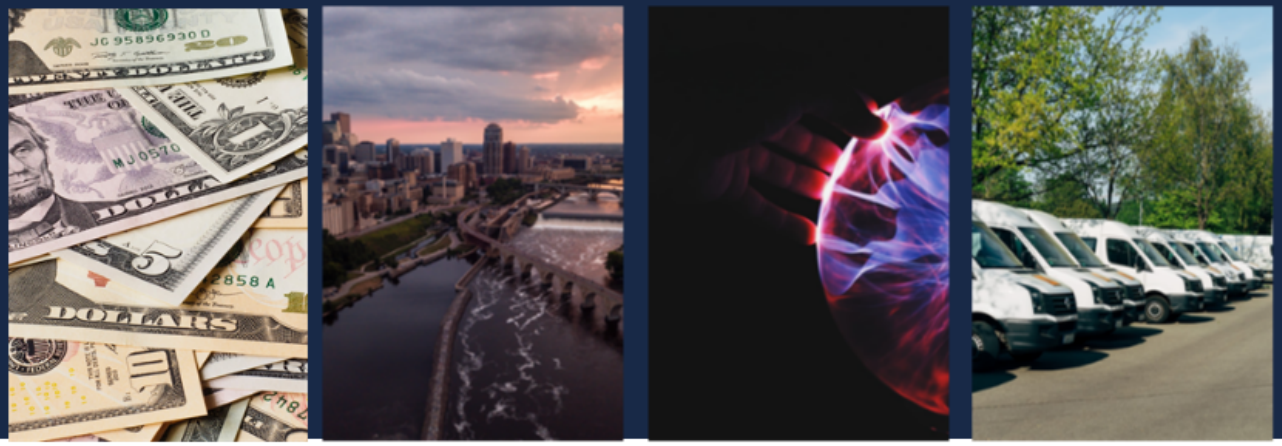
About the Program

Minnesota ASHP Collaborative



Maximize

ASHP installations and energy savings

Coordinate

Minnesota utility programs

Promote

Technology to consumers

Support

Trade industry to adopt ccASHPs and integrate into their business models

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ASHP Collaborative Website

mnASHP.org

Website: Contractor Resources

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HVAC Contractor Resources

As an installation contractor, you play a critical role in customers' HVAC product selection. When customers make smart, energy efficient selections such as cold-climate ASHPs, they will see an increase in home comfort and cost savings and a decrease in energy use and spending as well as greenhouse gas emission.

With the support of a leading ASHP research engineer, residential energy efficiency experts, and installation contractors, we developed the following best practice guides, online trainings, and utility rebate tools to support increased sales and installations of ASHP technologies.

Online Trainings | Resources | Utility Rebate Map

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Website: Contractor Resources

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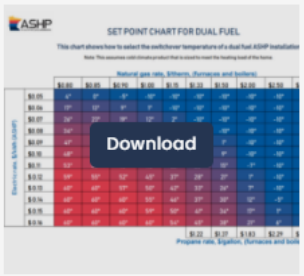
Resources and Guides

We developed the guides below that provide instructions on cold-climate ASHP installation best practices and design considerations. These guides complement manufacturer product training by providing energy-specific guidance that will maximize homeowner benefits.

Installation Best Practices Guide

Switchover Temperature Guide



Case study for a new build in Clearwater, MN

Design Guide (Forthcoming)

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Website: Contractor Trainings

- Training Module 1: ASHP Potential and Utility Rebates
  - This introductory module is beneficial for business owners to learn high-level technology information and tools/resources to promote the technology.
- Training Module 2: Tips and Tricks for Installing ASHPs
  - This module provides research-based recommendations on installing ccASHP systems for optimized energy performance.
- Training Module 3: Leads and Marketing for Air Source Heat Pumps
  - This module teaches how to generate low cost, high close rate leads for air source heat pumps though proven techniques developed by a successful heat pump only business owner.
- Training Module 4: Sales and Value Proposition for Air Source Heat Pumps
  - The companion training to Leads and Marketing, attendees will learn how to convert leads into sales by using value propositions.
- Training Module 5: ASHP Design Considerations (Forthcoming)
  - This module will cover product selection, sizing and controls strategies. It will be useful for sales staff who specify installation details and installation technicians.

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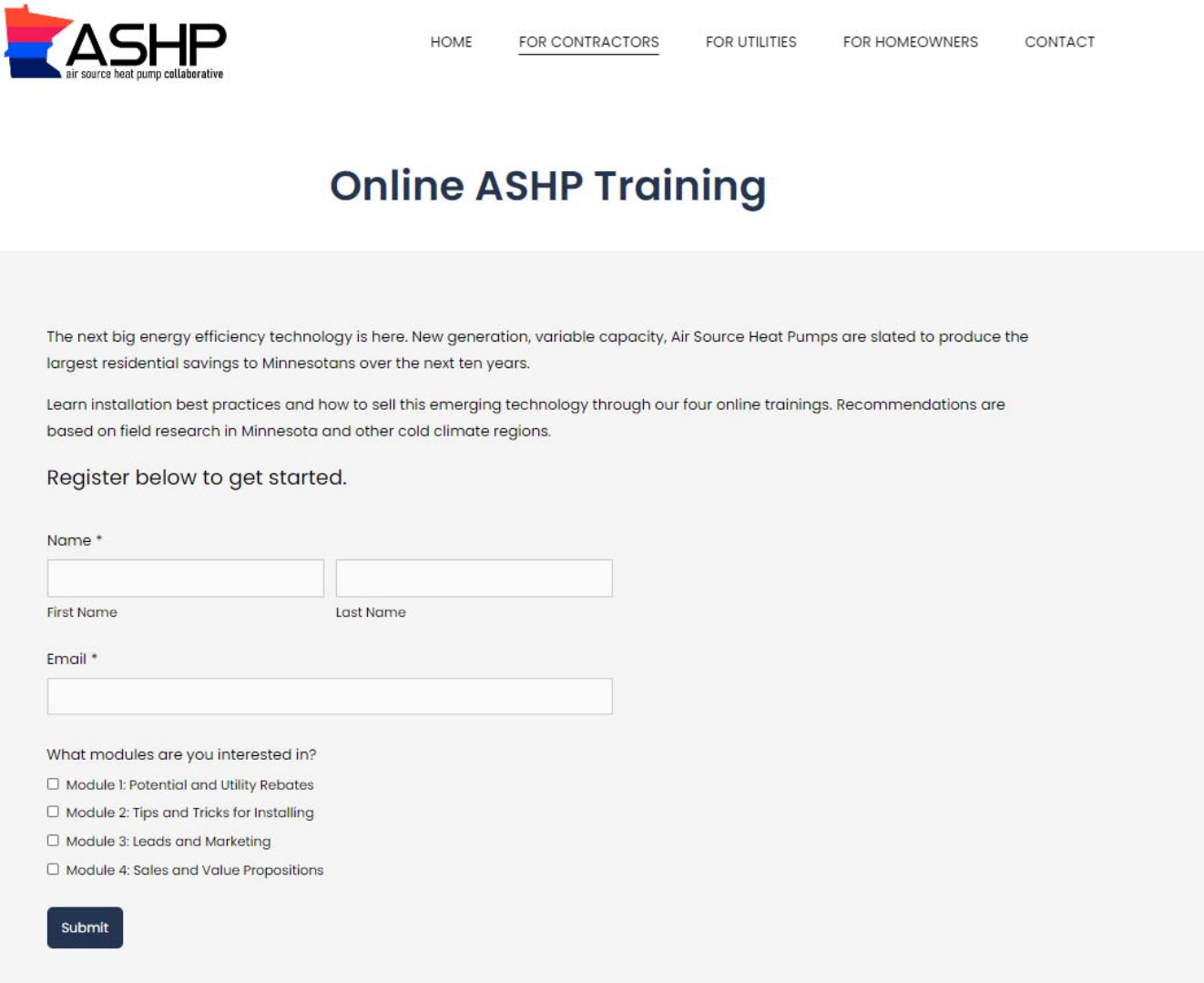
Website: Contractor Trainings



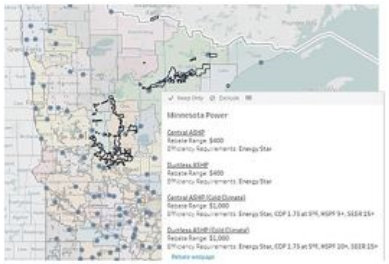
Website: Contractor Newsletter Sign Up

Heating Up

Quarterly updates, tools, and resources to help you stay on the cutting edge of air source heat pump (ASHP) technology

Get Ahead of the Curve - New Trainings Available!

Homeowner demand for ASHPs is growing in Minnesota. Learn installation best practices and selling tips during our series of free online trainings for contractors. **Learn more**



Tools: Utility Rebate Map

Find out what residential ASHP rebates are available in your area with our interactive utility rebate map.
View the map

Sign up to stay up-to-date on ASHP training, guides, and utility connections

* indicates required

Email Address *

Company *

First Name

Last Name

Title

Phone Number

( ) - (###) ###-####

Subscribe

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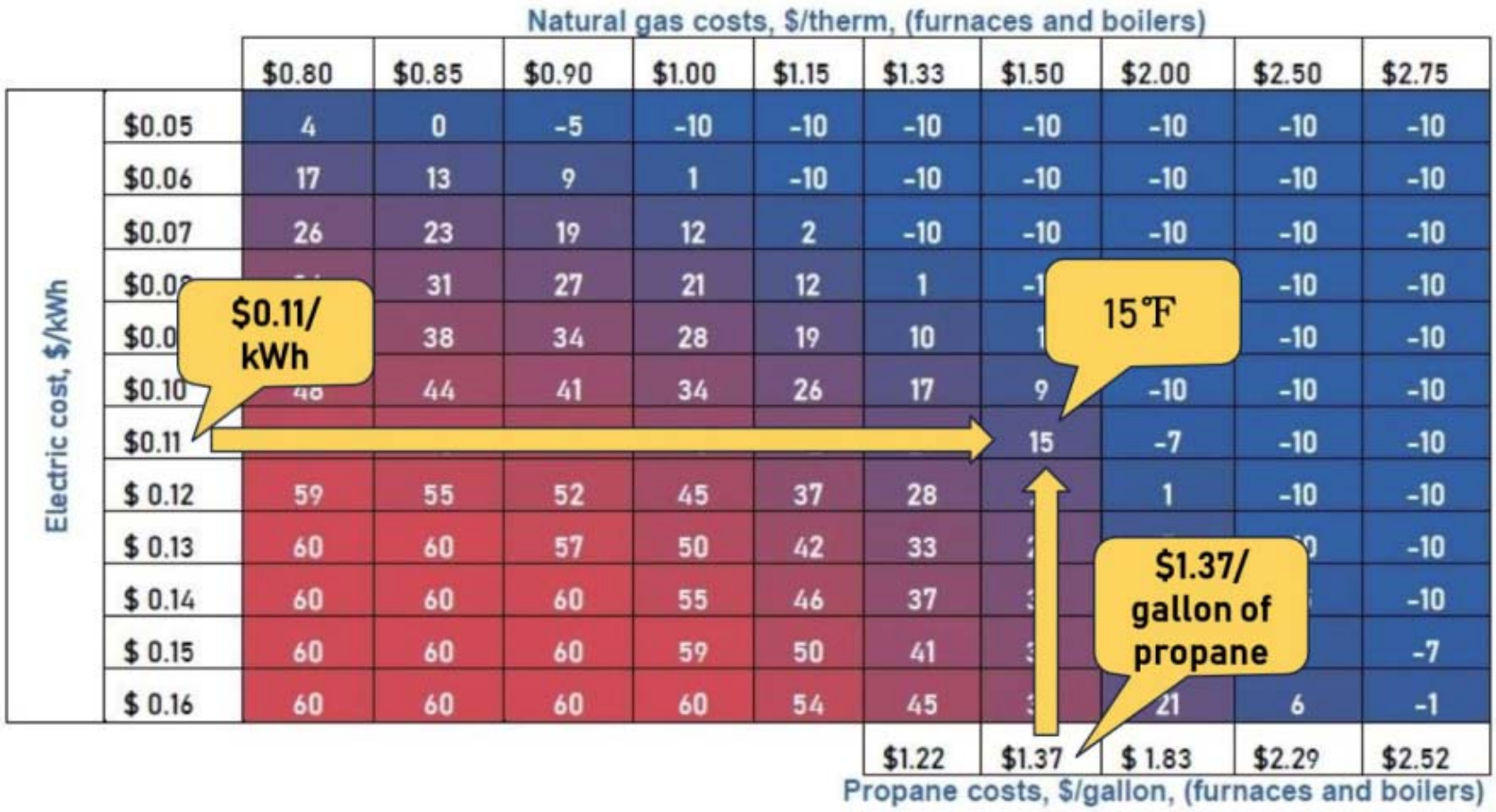
Website: Switchover Temperature Guide



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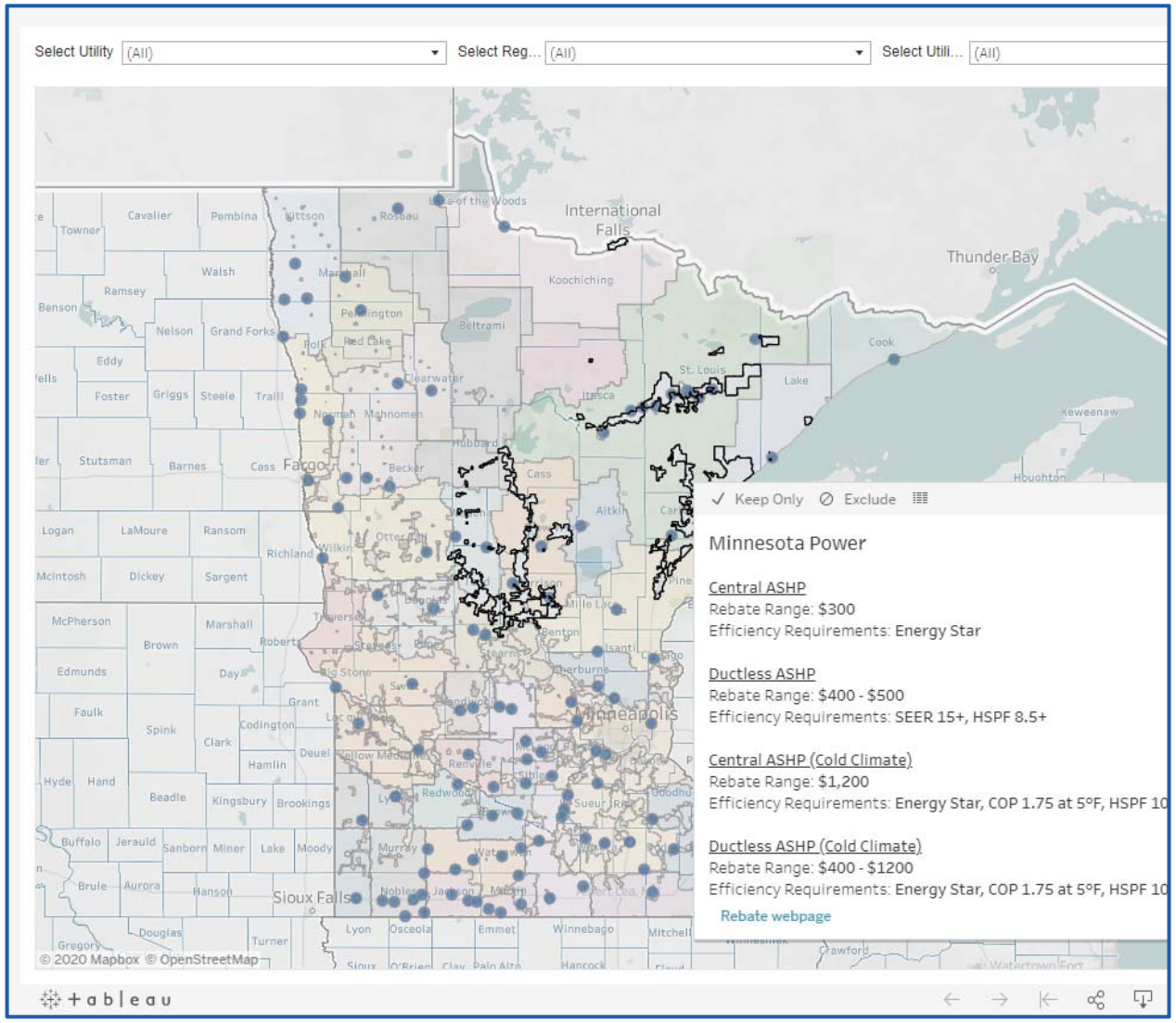
Typical Switchover Temps. By Application

Application	Typical switchover temp
ccASHP displacing baseboard heat	0-5° F (or lower depending on sizing)
ccASHP displacing propane furnace	0-15° F (depending on cost of propane and sizing)
ASHP displacing natural gas furnace	30-40° F

Website: Interactive Utility Rebate Map



Federal Tax Credit

- **$300 Federal Tax Credit** available through December 31, 2021
- Must be an existing home and principal residence
- Must be Energy Star rated and meet the following requirements

Split system

- HSPF>=8.5
- EER>=12.5
- SEER>=15

Package Systems

- HSPF>=8
- EER>=12
- SEER>=14

https://www.energystar.gov/about/federal_tax_credits/non_business_energy_property_tax_credits

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Site Inspection Findings

- 24 site visits in 2020 (Oct – Dec)
- Overall good installations and satisfied homeowners
- Some key takeaways:
  - **Homeowner education lacking** - Most homeowners didn't have a full understanding of controls and setpoints
  - **Many systems were not optimized for heating** - could have been set up to heat down to lower temperatures than what they were.

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Installer Experiences

- Many contractors want more training on sales techniques and soft skills for techs.
- Energy data is a huge selling point with homeowners.
- Homeowner education is critical, so having our resources and research data helps sell ASHPs in many cases.

Additional Resources

- Clean Energy Resource Teams: https://www.cleanenergyresourceteams.org/ashp

- Northeast Efficiency Partnership: https://neep.org/blog/heat-pump-buying-guidance-everyday-consumer

Contractor Next Steps

Practice installations at employee homes to gain experience with the technology

Attend manufacturer training

Attend ASHP collaborative training

Learn about local utility rebates

THANK YOU!

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