Decarbonizing Minnesota's Natural Gas End Uses

Meeting 7 – Exploring Technologies Part II

June 12th, 2020

Via Zoom

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Agenda

9:00	Welcome and Introductions
9:15	Discussion on Factors to Evaluate Decarbonization Options
9:45	Presentation and Q&A: Midcontinent Power Sector Collaborative
11:00	BREAK
11:15	Presentation and Q&A: Opportunities and Challenges for Air Source Heat Pumps in a Cold Climate
12:00	LUNCH
12:45 in a	Discussion of Opportunities and Challenges for Air Source Heat Pumps Cold Climate
1:30	Discussion of Electrification
2:30	ADJOURN

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Meeting Goals

1. **Build a shared understanding of the current state and future potential for electrification to help decarbonize natural gas end uses:**
2. **Identify the following through facilitated discussion:**
   a. What are the group's collective conclusions about electrification as a strategy to decarbonize natural gas end uses.
   b. What are the group's collective remaining (unanswered) questions about electrification?
   c. What are the perceived challenges and opportunities for electrification, with respect to the Guiding Principles?

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Discussion of Decarbonization Evaluation Factors

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TOP CERTAINTIES	TOP UNCERTAINTIES

• Decarbonization is important
• Pandemic Impacts
    • Residential sector end usage served by NG will be inelastic, reinforced by pandemic (focus here in near-term)
    • Commercial sector upheaval in near-term (e.g., no building convention centers, hotels, retail spaces)
    • Any solutions must consider pandemic impacts (e.g., reduce costs, create jobs, support recovery, public health impacts)
	• Price of natural gas (low vs high), driving comparative cost of alternatives (today $1.91/mmbtu). Connected to price of oil, since gas is byproduct of oil extraction.
	• Policy (favorable vs unfavorable)
	    • Carbon pricing – could change price of NG.
	    • Externality costs
	    • Does a green new deal recovery bill happen or not? Would create policy frameworks to support decarbonization. If not, path forward to decarb NG becomes more uncertain and difficult.
	    • Opps for new technology

DRAFT SCENARIOS

		Natural Gas Prices	
		Low	High
Policy Favorability to NG Decarb. Tech and Approaches	Unfavorable	A	B
	Favorable	C	D

Factors to Understand and Evaluate Strategies

	Electrification	RNG	Geothermal	Hydrogen
Cost				
Scalability				
Decarb. Potential				
Equity				
Commercially available				

- Keep in mind that we're breaking these down to better understand them, but actual solutions will likely be mixes of these technologies/approaches

Defining Key Factors

	Definitions
Cost Effectiveness	
Scalability	
Decarb. Potential	
Equity	
Commercially available	
Economic Development	

Midcontinent Power Sector Modeling Presentation and Q&A

Franz Litz, Great Plains Institute

Jessi Wyatt, Great Plains Institute

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Midcontinent Power Sector Collaborative (MPSC)

Buildings Decarbonization Roadmap Summary and Modeling Outputs

12 June 2020

Presented by: Franz Litz and Jessi Wyatt, Great Plains Institute

Overview of Presentation

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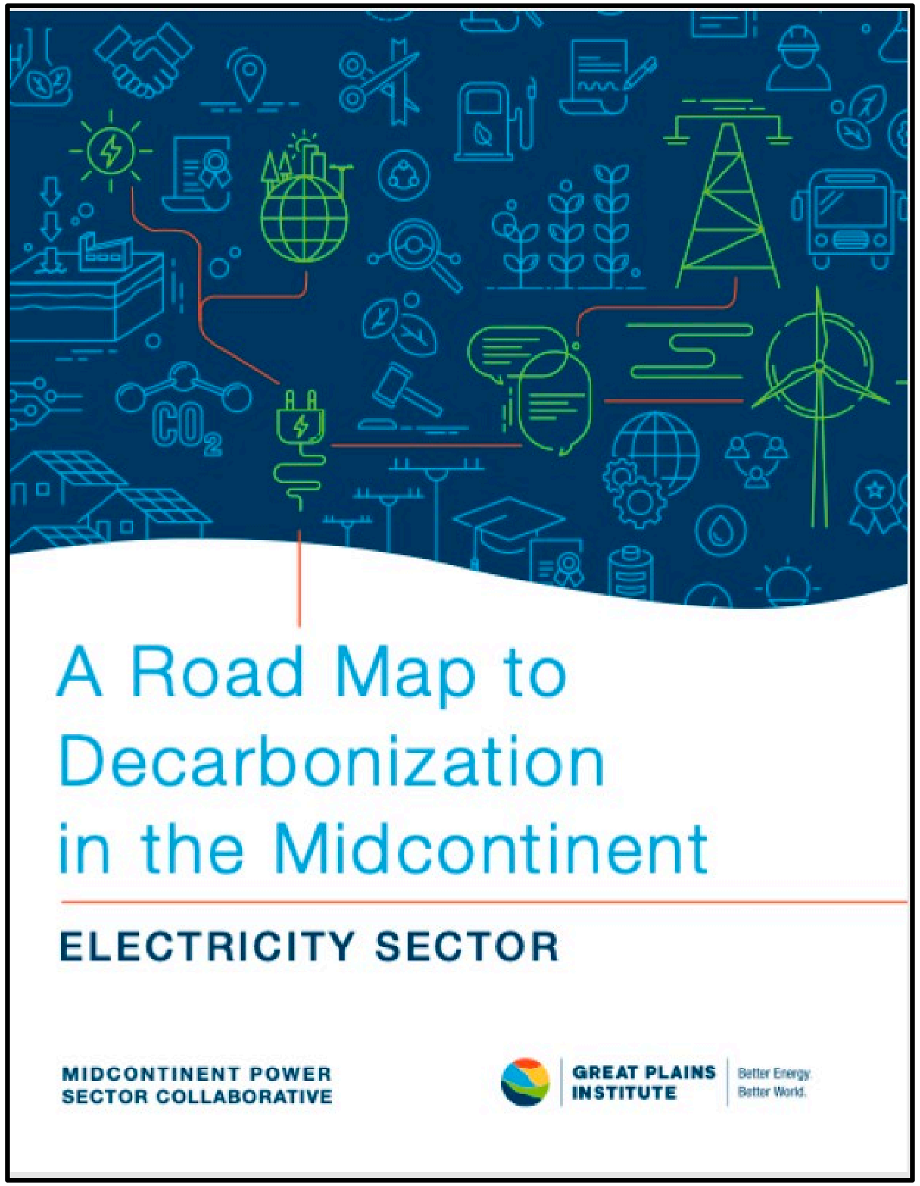
- The Midcontinent Power Sector Collaborative
- The FACETS Model and Analytical Approach
- Important Context: Electricity Sector Decarbonization
- Decarbonization and Buildings in the Region
    - Emissions
    - Building Envelope Improvements
    - Heat Pump Penetration
    - The Need to Hedge Our Bets: Alternatives to Natural Gas
- Some Minnesota-specific Results
- Questions

The Midcontinent Power Sector Collaborative

Diverse Group from Across Region:

- Power Companies: Xcel, GRE, Otter Tail, Alliant, EDP renewables, MidAmerican, Entergy, Madison Gas & Electric, WEC Energy, Dairyland, Wolverine, WPPI Energy, DTE Energy
- Environmental groups: NRDC, EDF, Clean Wisconsin, Ecology Center, TNC, UCS, Clean Air Task Force, Iowa Envt'l Council
- Some states: MN, MI, IL, WI, AR, LA


A Road Map to Decarbonization in the Midcontinent
ELECTRICITY SECTOR
MIDCONTINENT POWER SECTOR COLLABORATIVE
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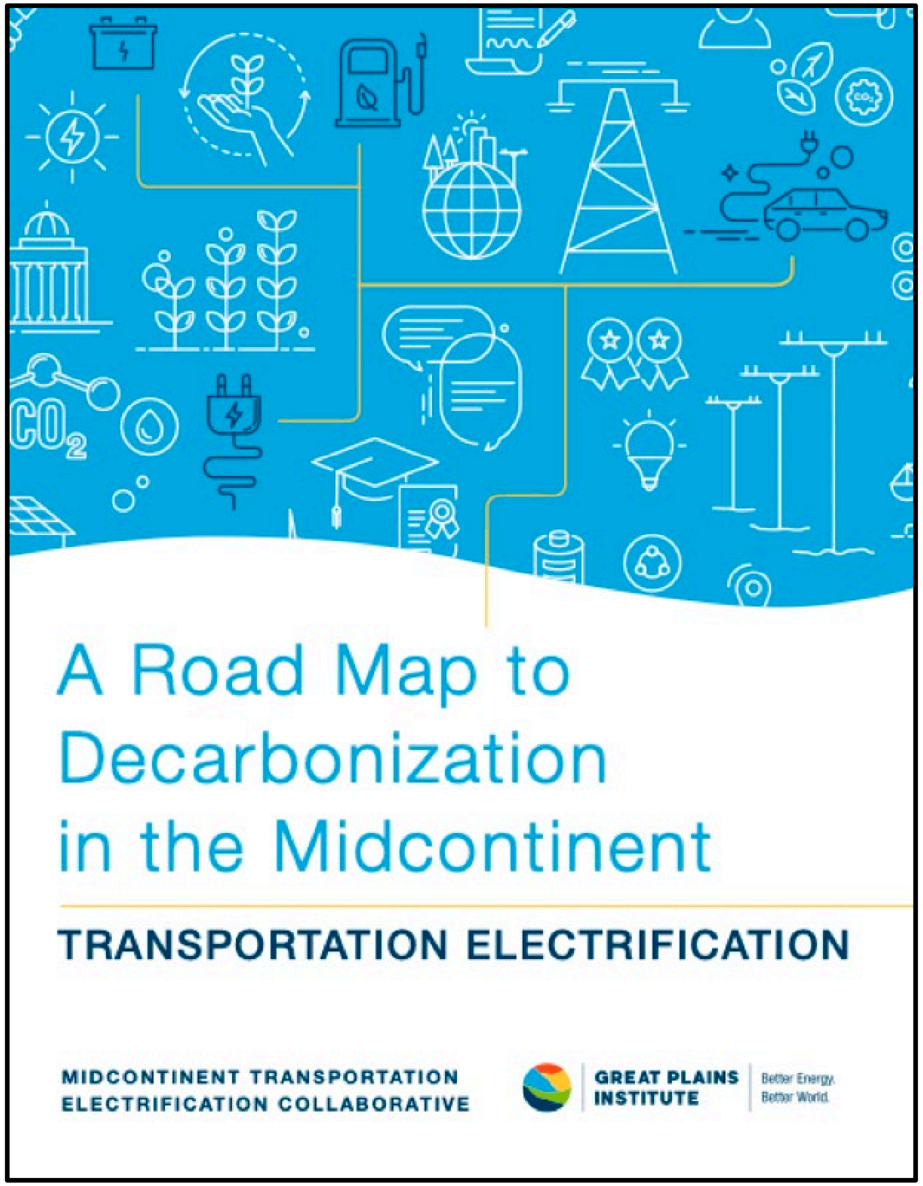
A Road Map to Decarbonization in the Midcontinent
TRANSPORTATION ELECTRIFICATION
MIDCONTINENT TRANSPORTATION ELECTRIFICATION COLLABORATIVE
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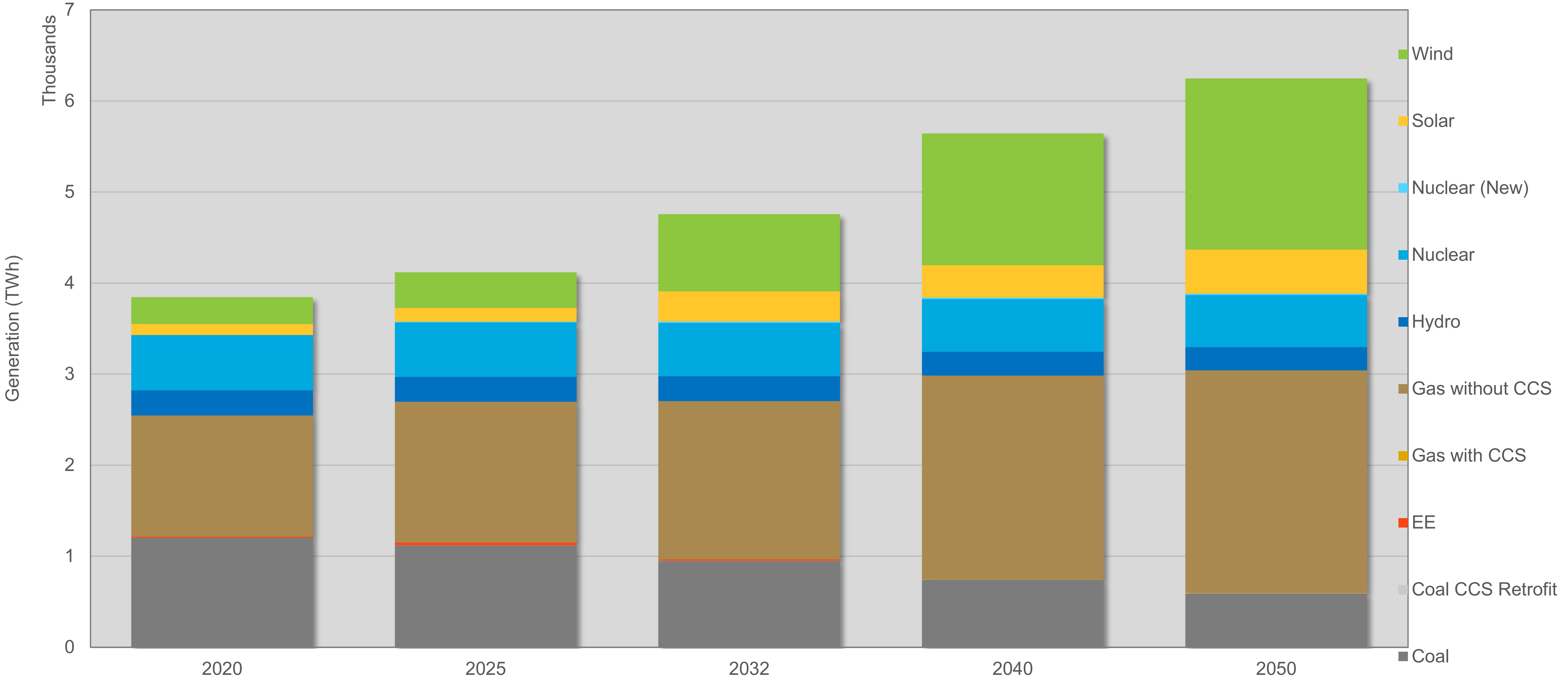
The FACETS Model

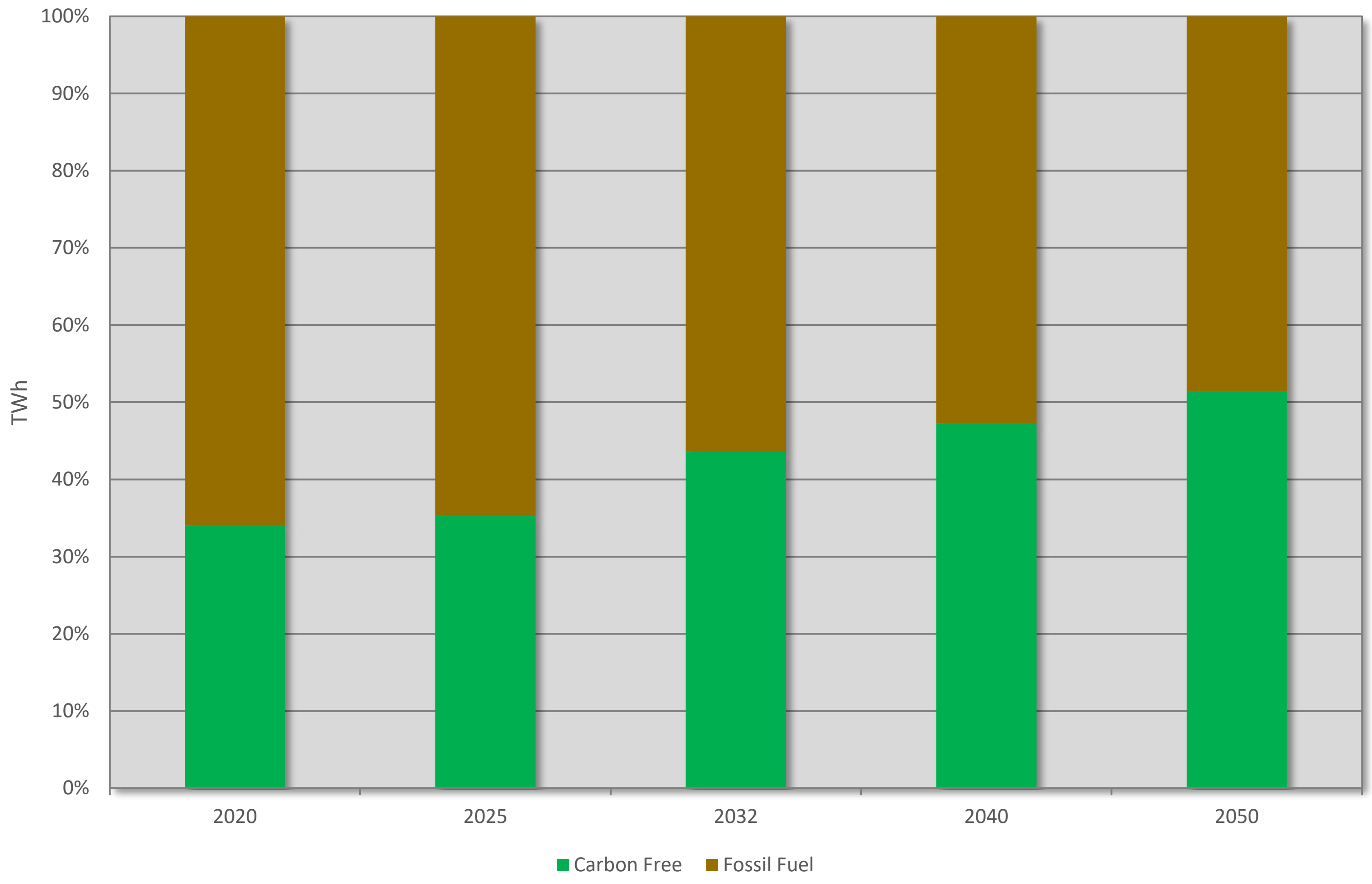
- The analysis was modeled using the Framework for Analysis of Climate-Energy-Technology Systems (FACETS)
- FACETS is a multisector, multi-region model for U.S. policymakers
- For the MPSC, FACETS has robust power sector, transportation and buildings modules.
- FACETS is an economic model—it chooses least-cost outcomes given assumptions and technologies made available to the model
- Modeling was done by Evelyn Wright of Sustainable Energy Economics and Amit Kanudia of KanORS-EMR.

What to Expect from the Electricity Sector Business as Usual

Less Coal: More Wind, Solar and Natural Gas

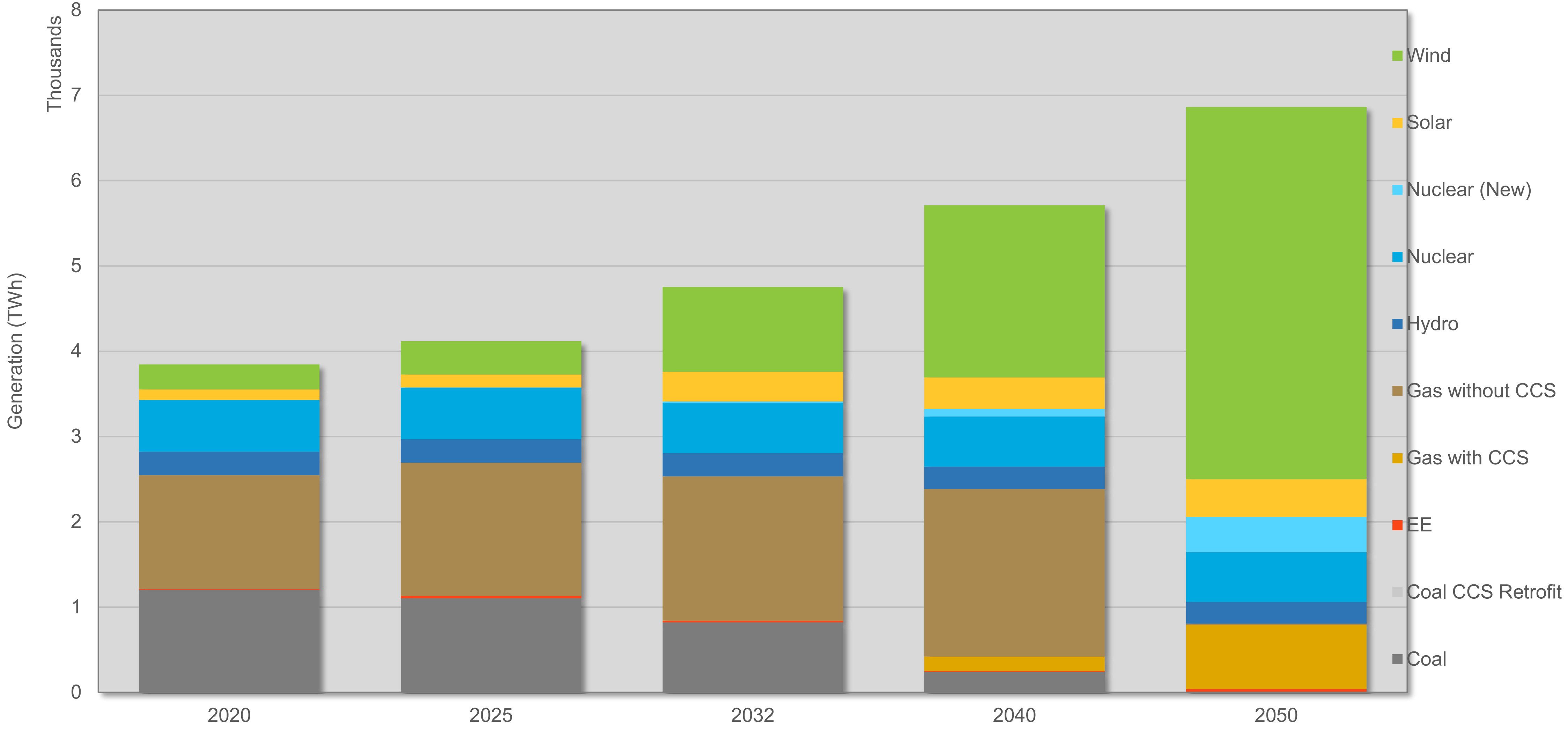


Share of Carbon Free Generation Business as Usual through 2050

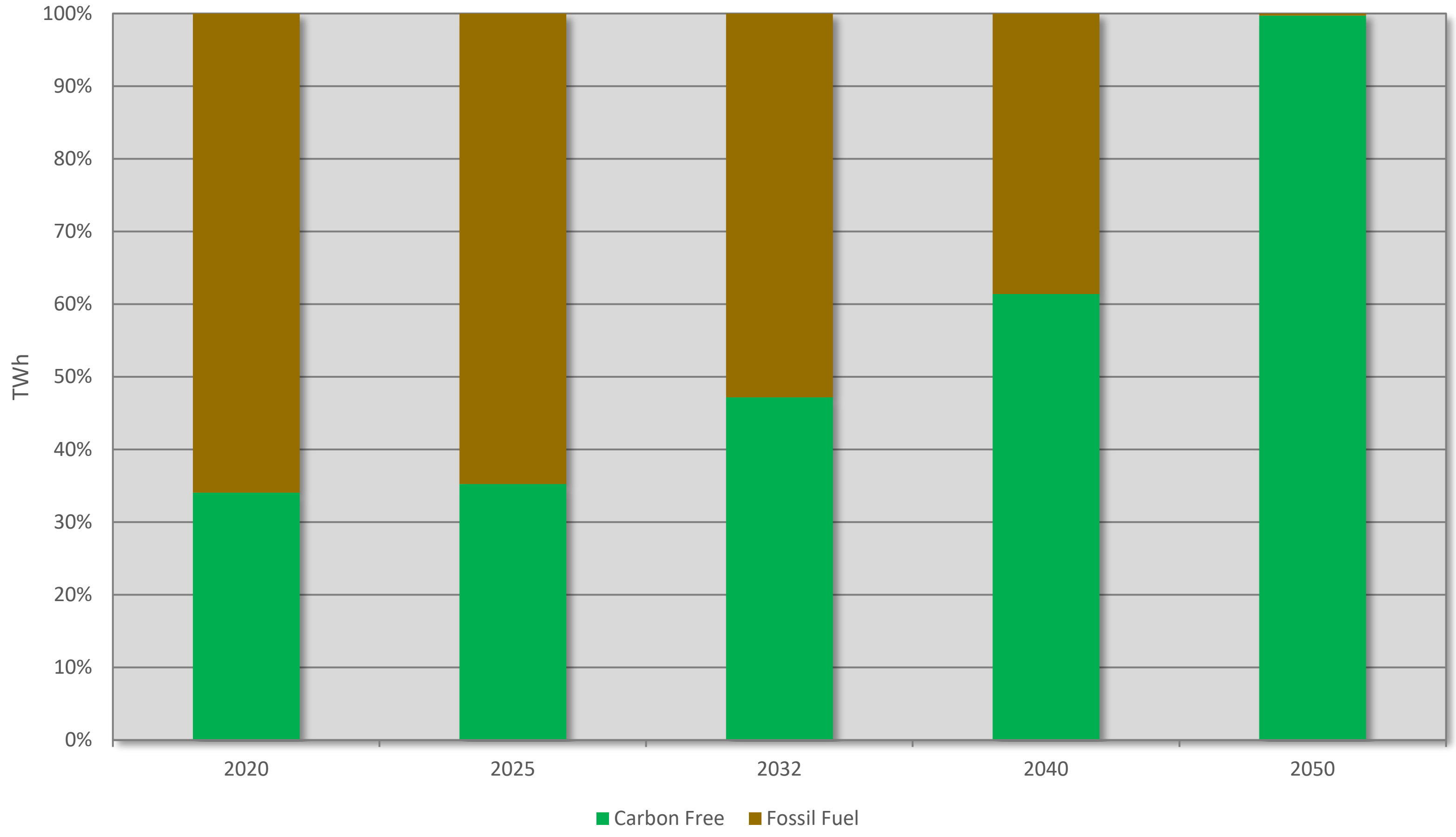


What Electricity Looks Like under 95% Decarbonization by 2050

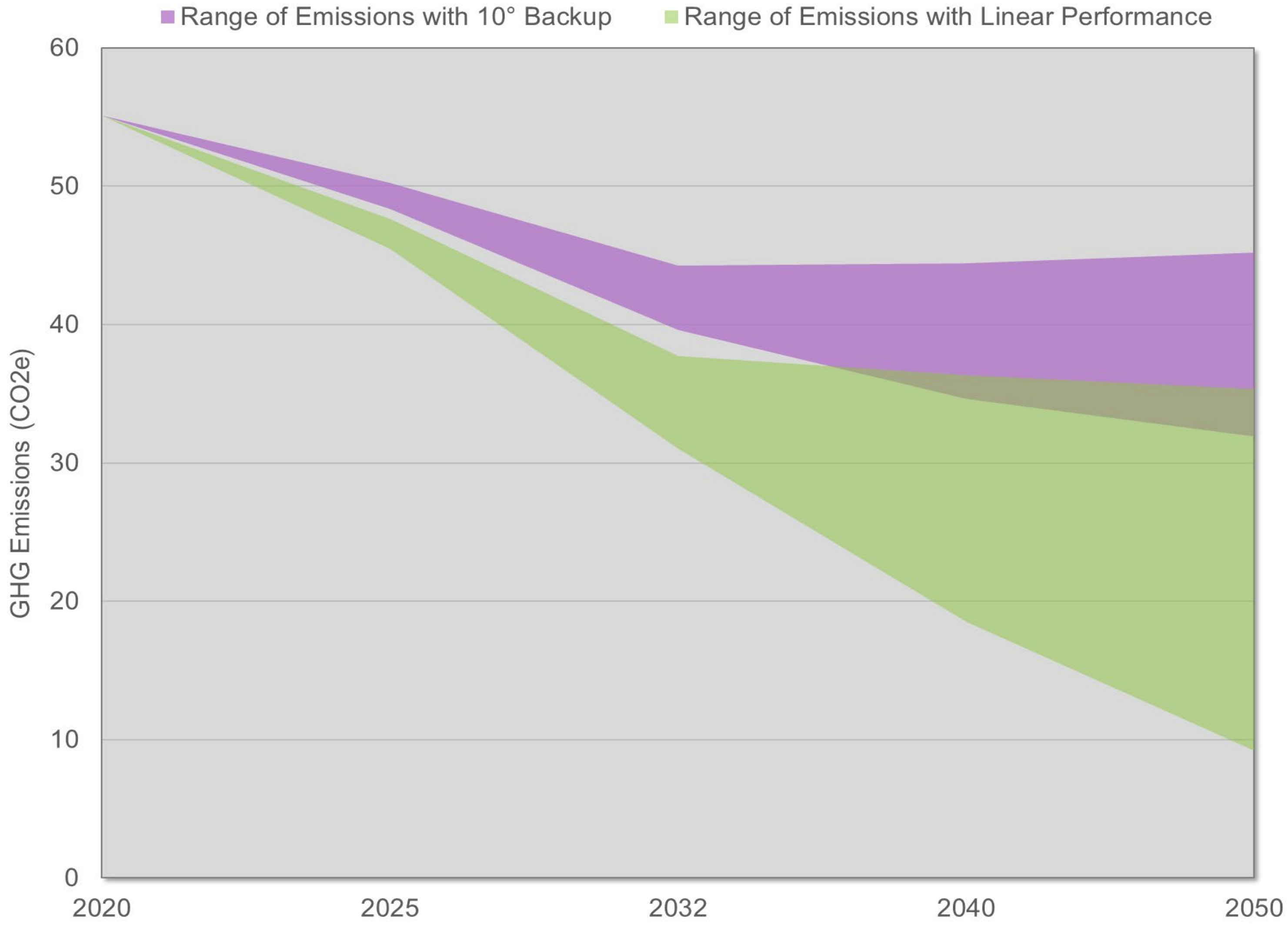
No Coal; More Wind, Solar, Nuclear and Gas with Carbon Capture



Share of Carbon Free Generation under 95% Decarbonization Policy through 2050



Range of Regional Carbon Emissions Results Across Residential Buildings Scenarios

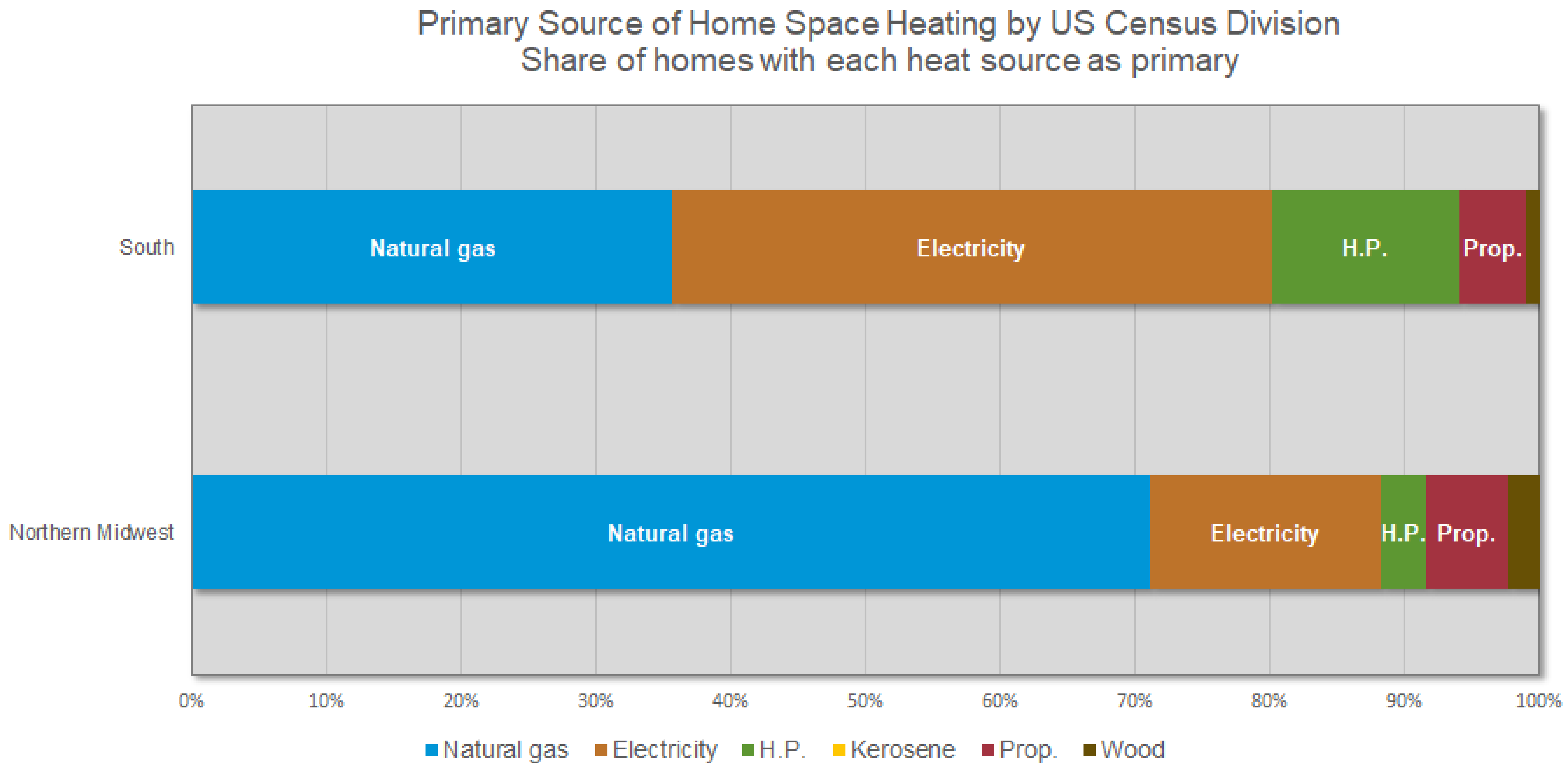


- Wide range of possible outcomes—ranging between 18% and 82% reductions in direct emissions
- When backup is needed and overcoming barriers to adoption are the two biggest factors

Heat Pump Adoption

Understanding the Conditions that Drive Deeper Adoption

Current Heat Pump Adoption Relative to Other Options

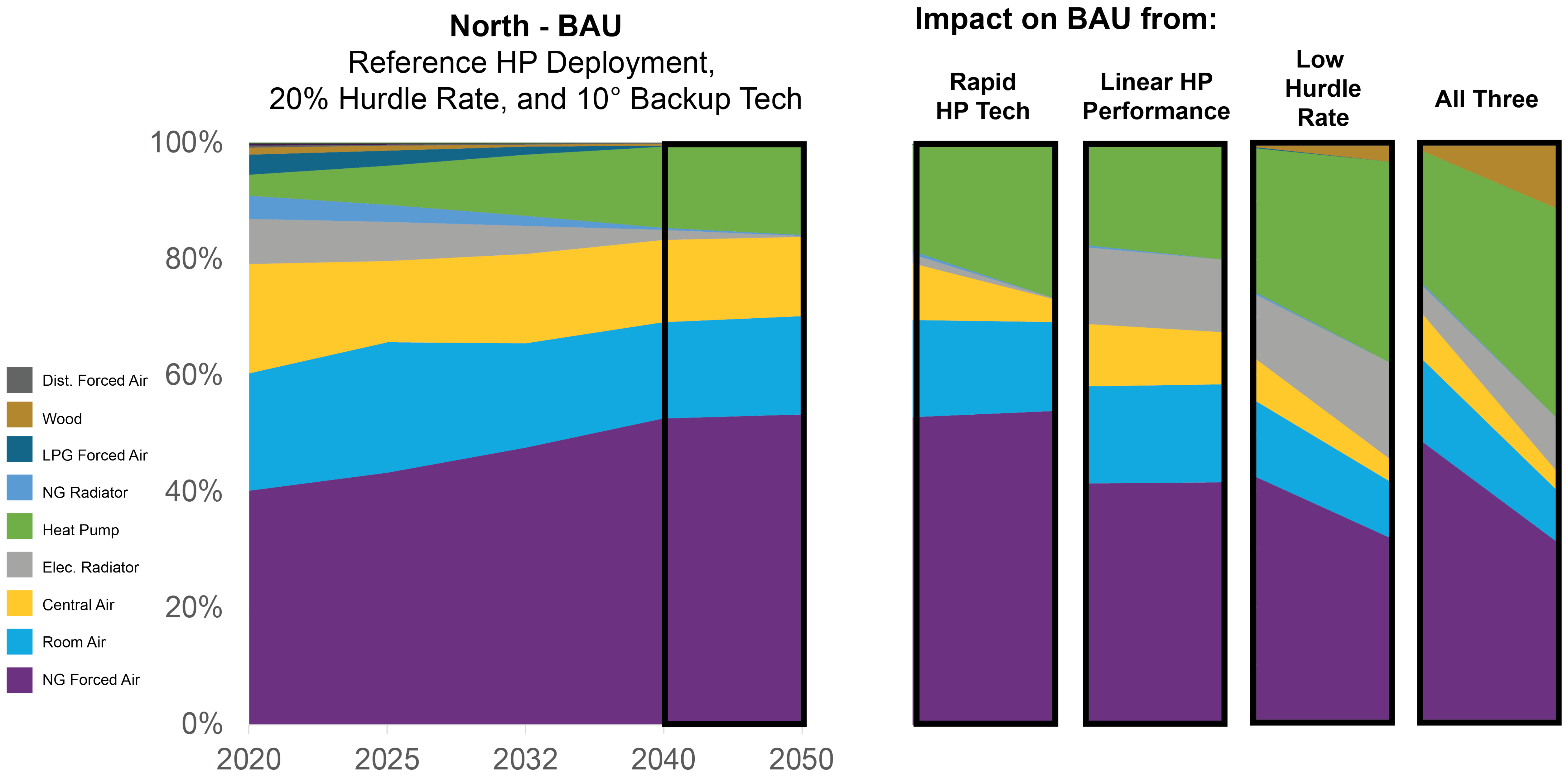


Five Key Scenarios Modeled

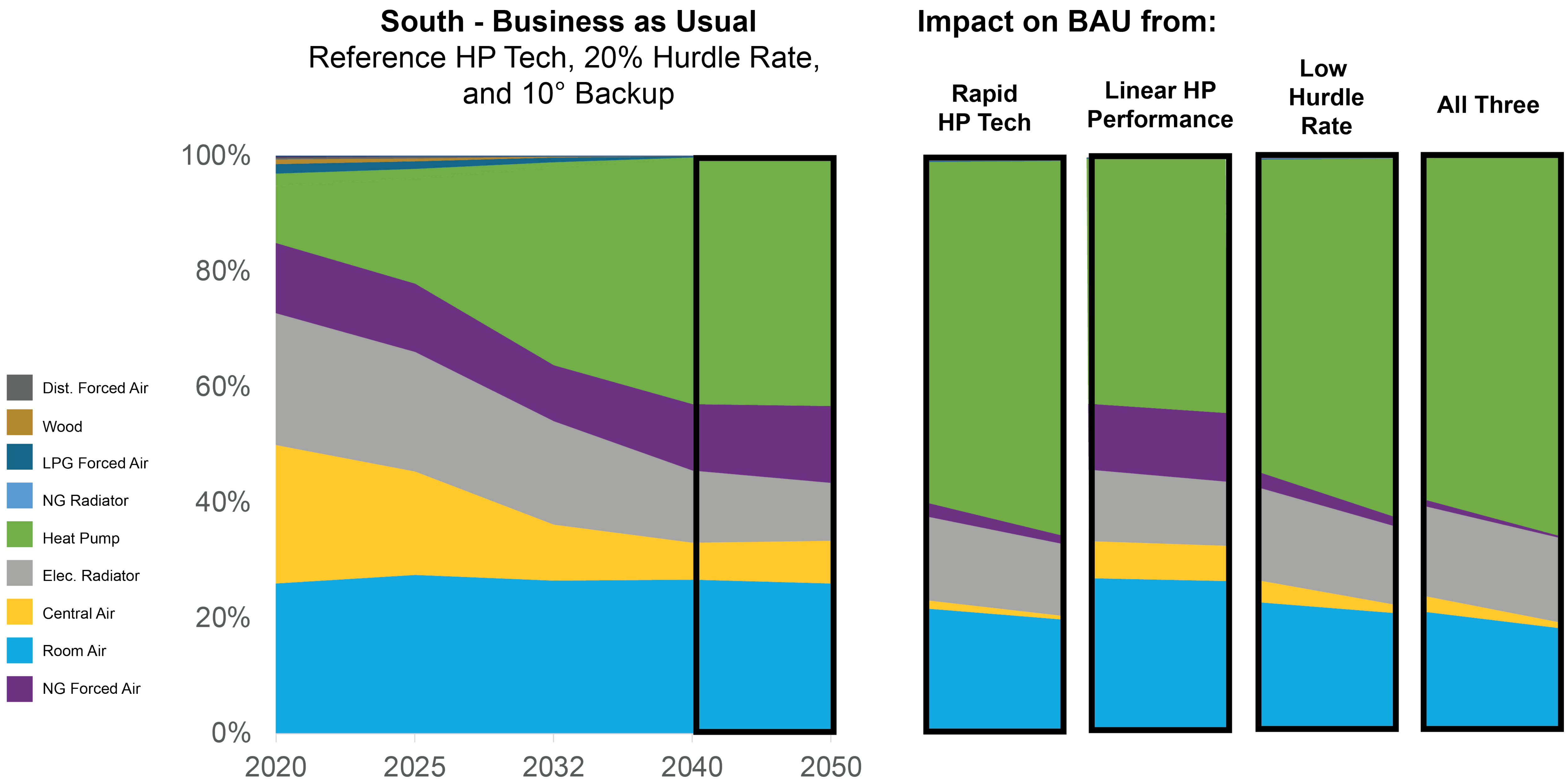
Individual levers explored

1. Business as usual (BAU)
2. With rapid heat pump technology
3. With linear backup performance
4. With reduced "hurdle rate," which is a proxy for active efforts to reduce hurdles to adoption from 20% to 7.5% "adder" on cost
5. All three – aka" All hands on deck" (e.g., rapid heat pump technology, linear HP performance, <u>and</u> reduced hurdle rate)

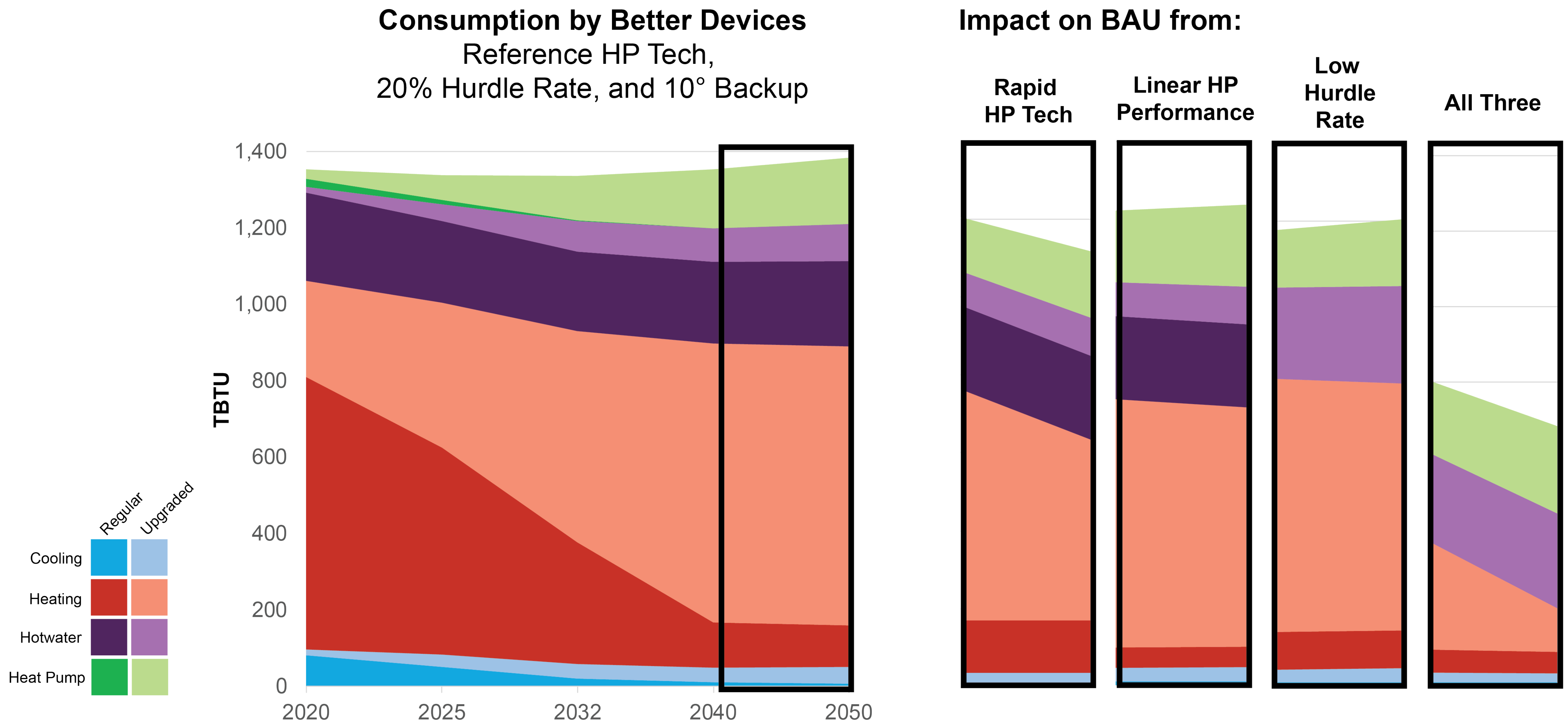
Heat Pump Penetration as a Share of Devices Across Scenarios



Heat Pump Penetration as a Share of Devices Across Scenarios



Energy Consumption by End Use and Device Efficiency

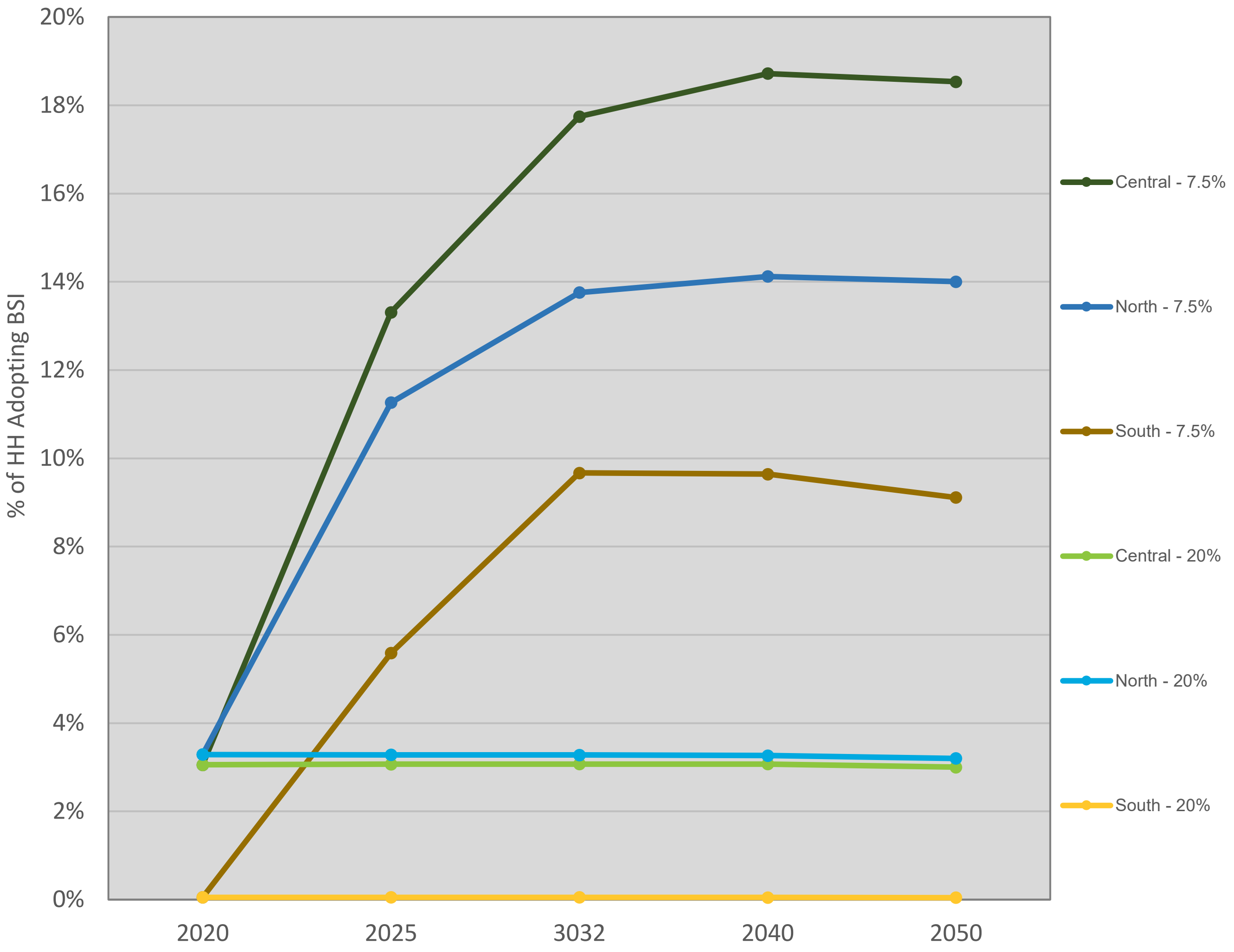


Energy Efficiency: Building Shells

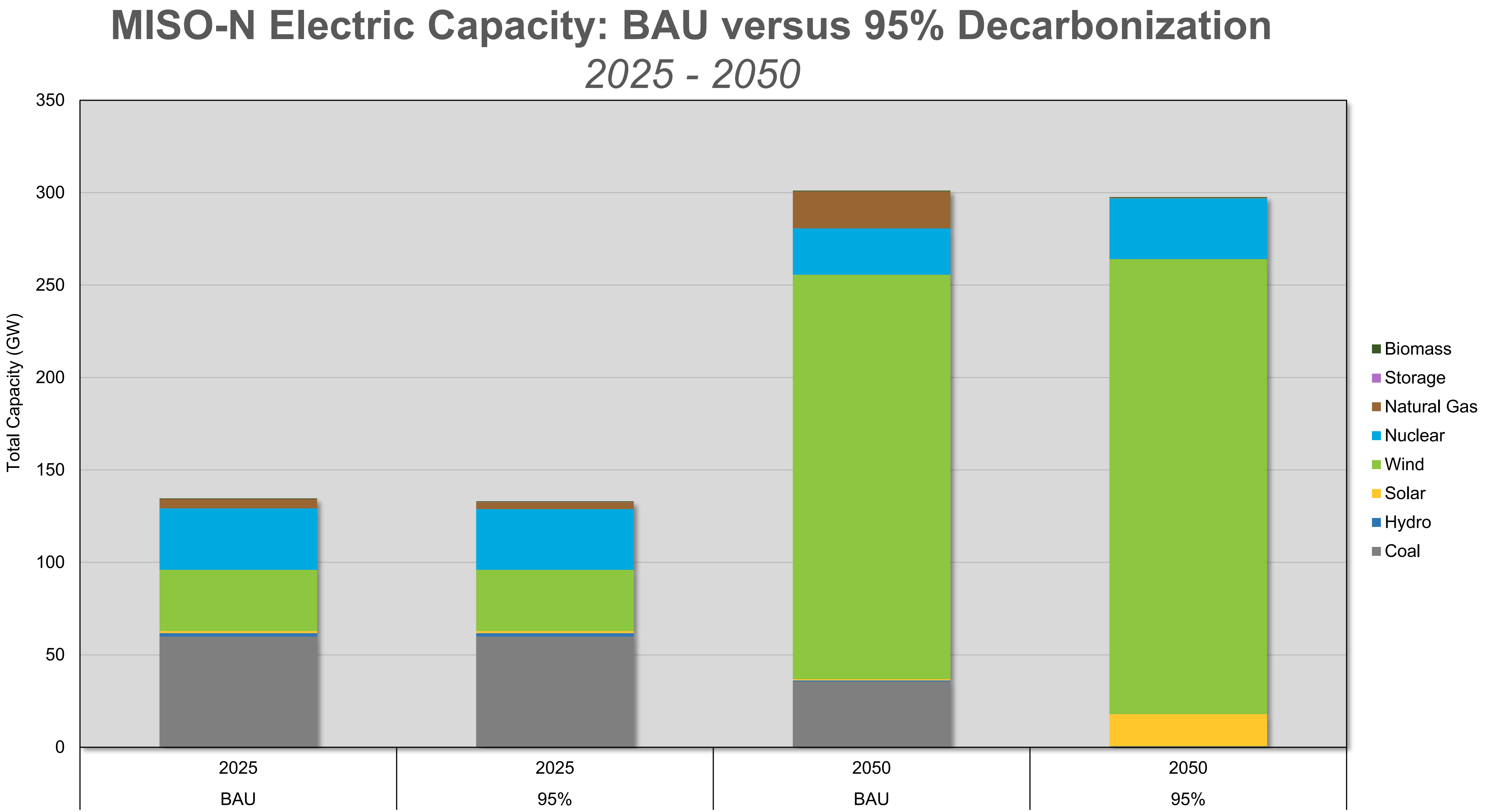
Energy Efficiency: Building Shell Improvements

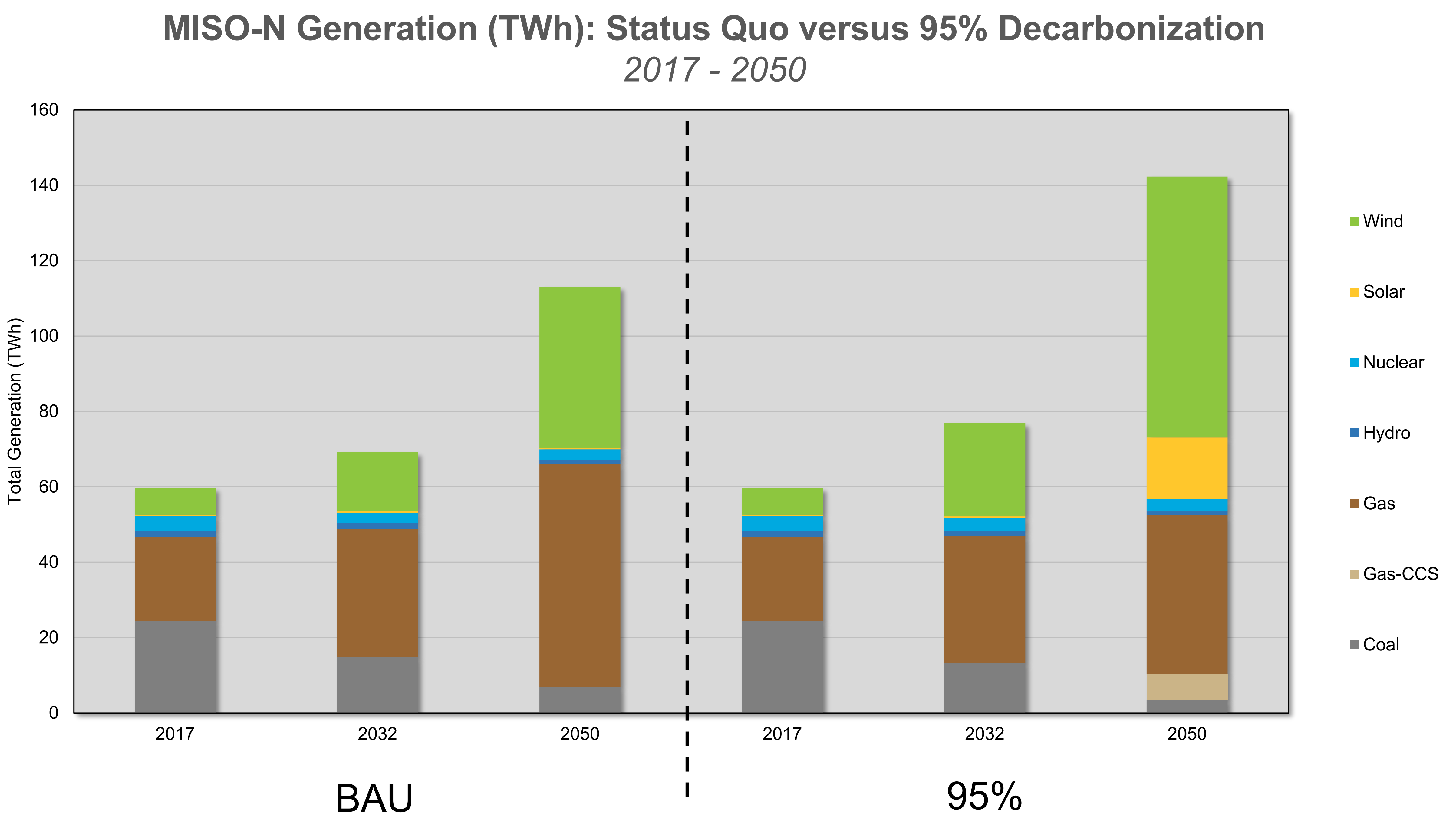
- In the modeling, between 14% and 19% of the residential buildings see building envelope improvements

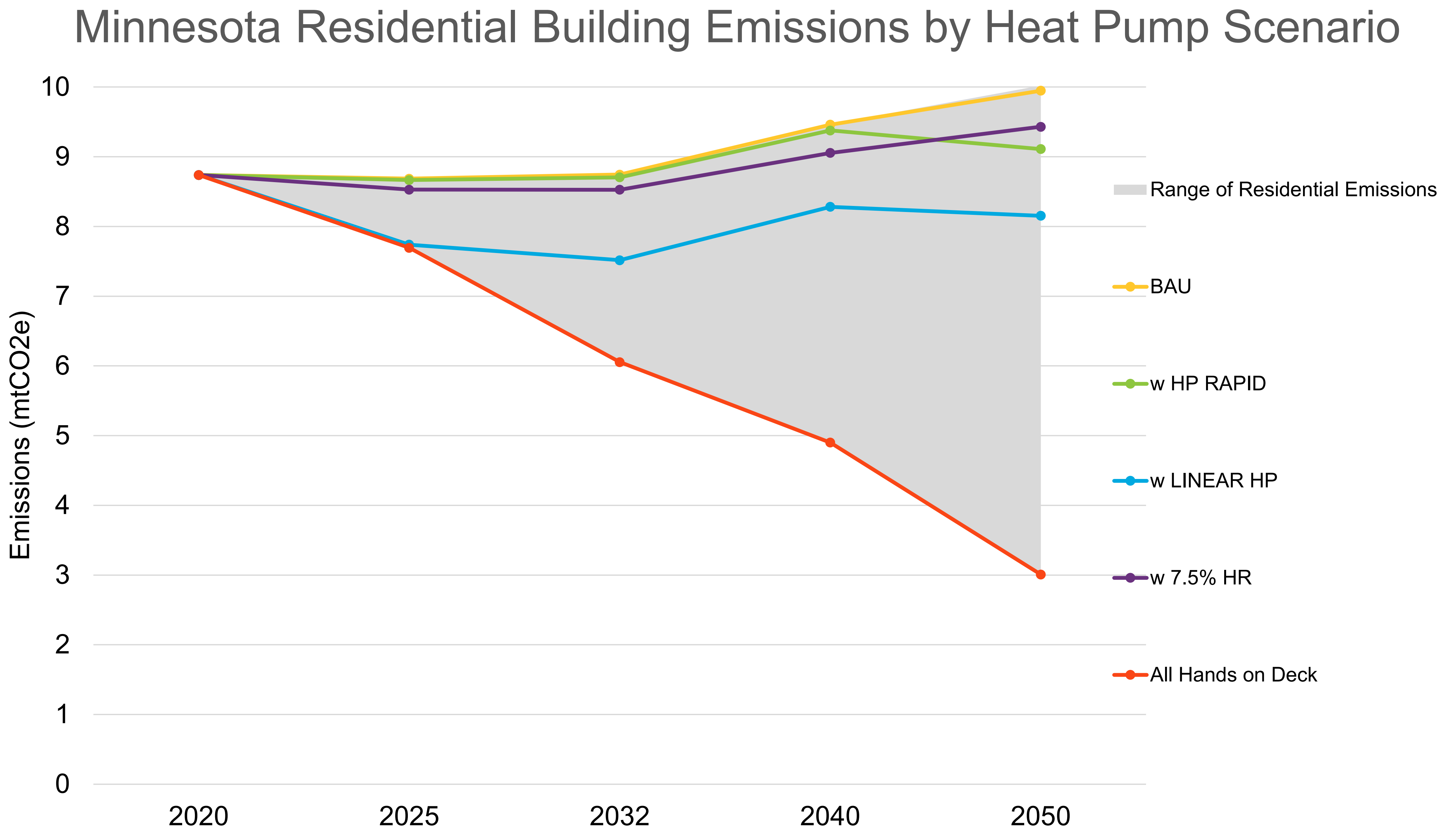
- Improvements depend on measures to reduce hurdles to the equivalent of 7.5% hurdle rate



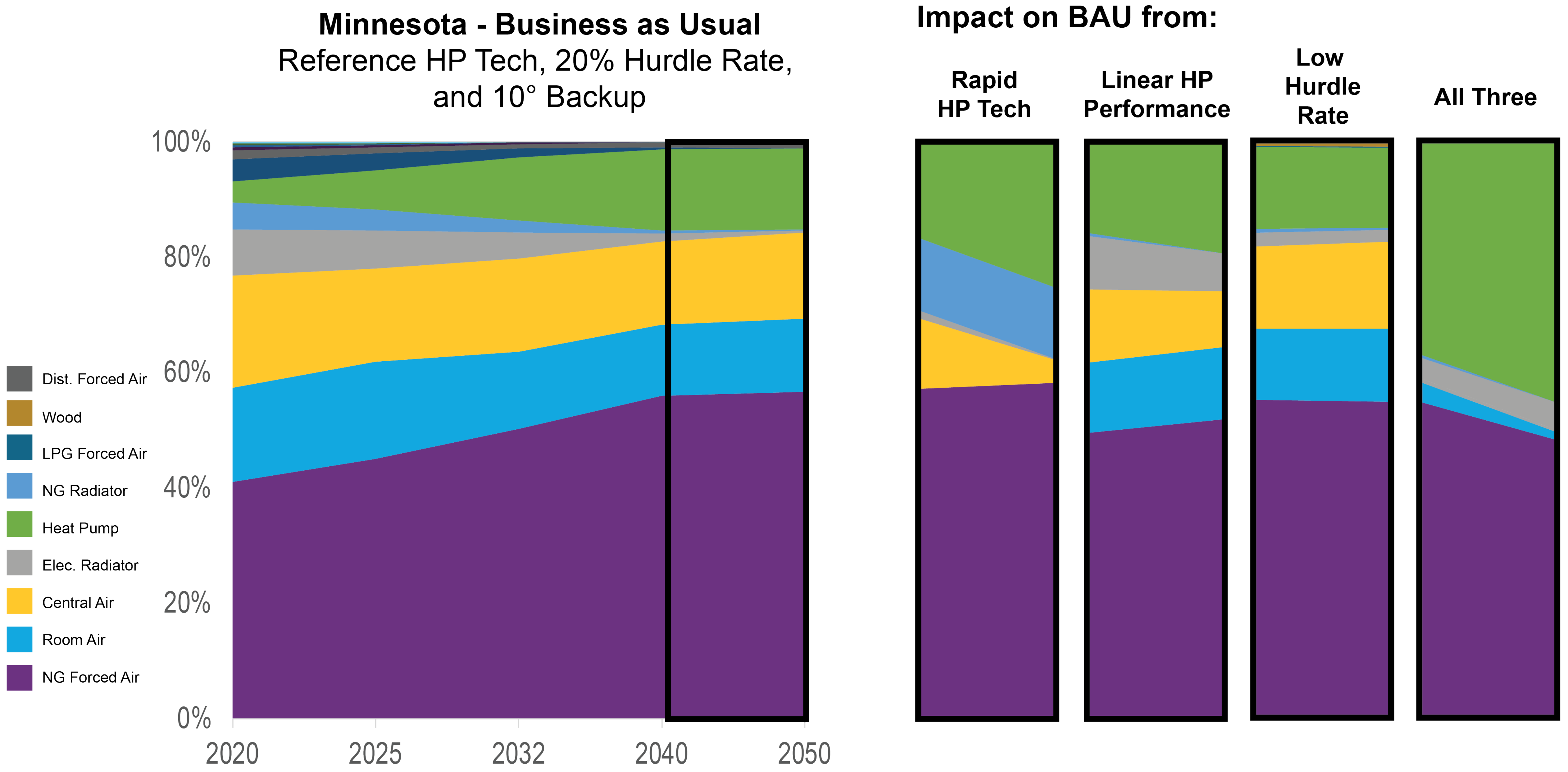
Building Roadmap: Minnesota-Specific Results


MISO-N Electric Capacity: BAU versus 95% Decarbonization
2025 - 2050
Total Capacity (GW)
350
300
250
200
150
100
50
0
2025
BAU
2025
95%
2050
BAU
2050
95%
Biomass
Storage
Natural Gas
Nuclear
Wind
Solar
Hydro
Coal


MISO-N Generation (TWh): Status Quo versus 95% Decarbonization
2017 - 2050
Total Generation (TWh)
160
140
120
100
80
60
40
20
0
2017
2032
2050
2017
2032
2050
BAU
95%
Wind
Solar
Nuclear
Hydro
Gas
Gas-CCS
Coal


Minnesota Residential Building Emissions by Heat Pump Scenario
Emissions (mtCO2e)
10
9
8
7
6
5
4
3
2
1
0
2020
2025
2032
2040
2050
Range of Residential Emissions
BAU
w HP RAPID
w LINEAR HP
w 7.5% HR
All Hands on Deck

Heat Pump Penetration as a Share of Devices Across Scenarios



Key Findings and Conclusions

- There is still action needed in the electricity sector
- Electrification is an important part of any strategy to decarbonize residential buildings
    - The southern part of the region is already ripe for more rapid adoption of heat pump technology & making it easier for building owners to switch to
    - Improvements in HP technology to make it more effective in cold climates and lower its cost is necessary would help in the northern part of the region.
- If we're being prudent, it may be wise not to count on electrification to carry the full load—

Appendix

Methodology

Reference Energy System network

Resource Supplies

80 coal types, by grade, sulfur and mercury content

Natural gas supply curves from AEO

Wind and solar potential and time profile by region from NREL

Liquid fuels supply curves from AEO

Transformation Techs

FACETS Power Sector: Existing power plants at unit level + New units built when economic

Simple representation of commercial district heat boilers

Combined heat and power options?

Demand Technologies

Commercial: 100s of furnaces, boilers, heat pumps, cooling units, light bulbs, water heaters, ventilation units, walk in coolers, etc.

Residential: 100s of furnaces, boilers, heat pumps, air conditioners, light bulbs, water heaters, etc.

Gasoline, electric, and hybrid vehicles

Other transport and industry: pass-through accounting techs

Service Demands

Transport: LDV miles traveled, other vehicles end use consumption

Commercial and Residential: Heating, Cooling, Water heating, Lighting, Cooking, Office Equipment, Ventilation, Refrigeration, Misc.

Industry electricity load curves

Building demands are for energy *services*

Commercial Demands	Residential Demands
Heating	Heating
Cooling	Cooling
Water Heating	Water Heating
Ventilation	Cooking
Cooking	Lighting
Lighting	Refrigeration
Refrigeration	Freezing
Office Equipment-PCs	Clothes Washing
Office Equipment-non-PCs	Clothes Drying
Miscellaneous	Dishwashing
	Miscellaneous

Units are BTUs of heating, cooling *delivered*, lumens of light, etc.

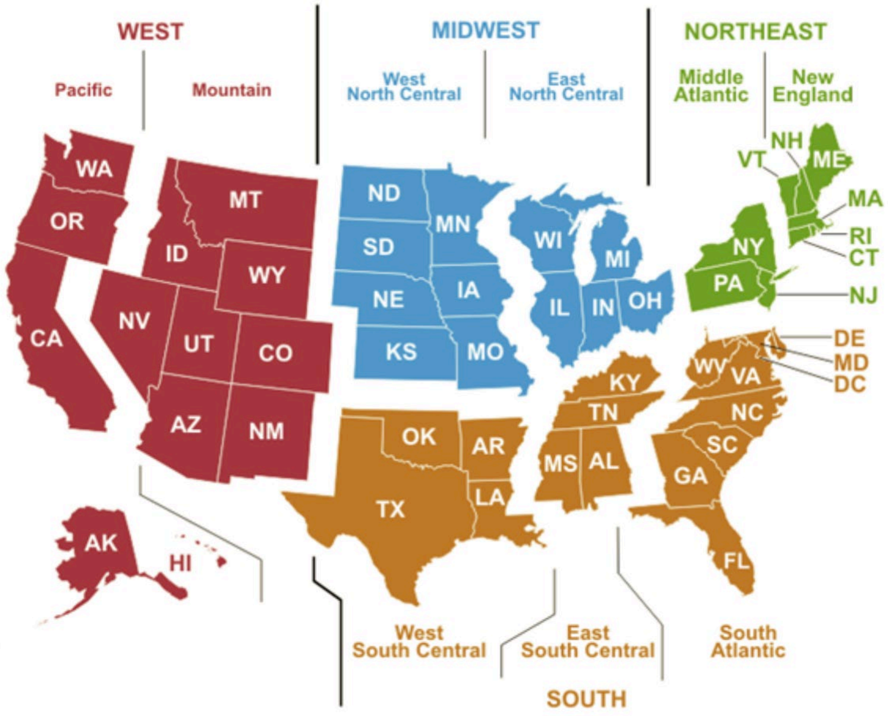
Each demand has a suite of technologies available, with different fuels, costs, and efficiency levels

Residential Heating Technologies

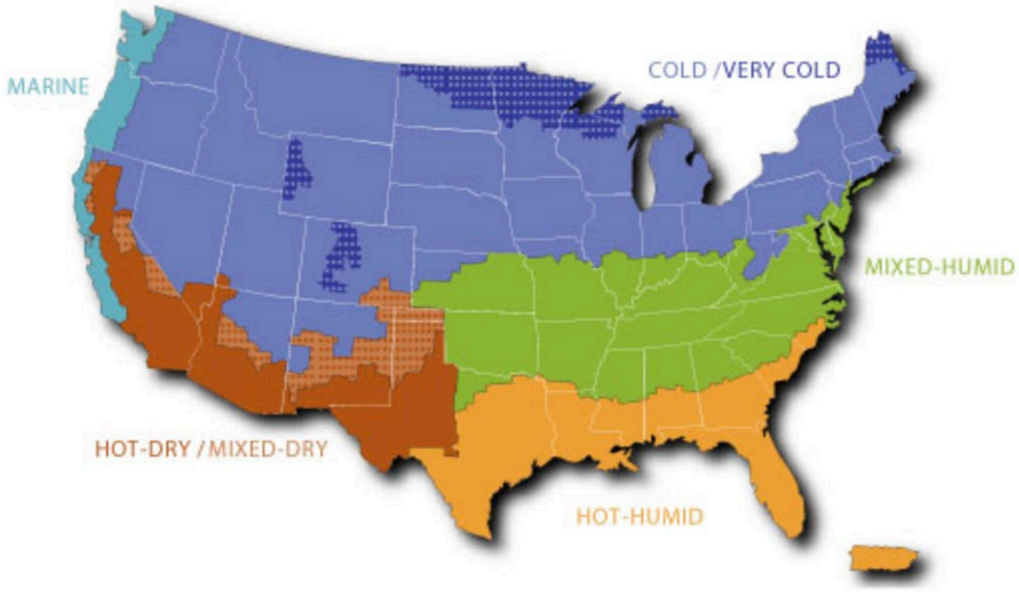
Tech Name	First Year	Efficiency	Capital Cost		Tech Name	First Year	Efficiency	Capital Cost
ELEC_RAD2	2016	0.98	1100		DIST_FA1	2016	0.83	4125
ELEC_HP1	2016	2.40	2425		DIST_FA2	2016	0.83	4125
ELEC_HP1	2023	2.58	2575		DIST_FA2	2020	0.84	4225
ELEC_HP2	2016	2.52	2550		DIST_FA3	2016	0.85	4350
ELEC_HP2	2023	2.58	2575		DIST_FA4	2018	0.97	6450
ELEC_HP3	2016	2.49	2475		DIST_RAD1	2016	0.84	9125
ELEC_HP4	2016	2.64	3050		DIST_RAD1	2021	0.86	9425
NG_FA1	2016	0.80	2050		DIST_RAD2	2016	0.84	9125
NG_FA2	2016	0.92	2610		DIST_RAD2	2021	0.86	9425
NG_FA3	2016	0.95	2740		DIST_RAD3	2016	0.87	9425
NG_FA4	2016	0.99	3040		DIST_RAD4	2016	0.90	11450
NG_RAD1	2016	0.82	7175		WOOD_HT2	2016	0.70	7050
NG_RAD1	2021	0.84	7350		WOOD_HT2	2030	0.73	7150
NG_RAD2	2016	0.82	7175		WOOD_HT2	2040	0.74	7250
NG_RAD2	2020	0.90	7875		WOOD_HT4	2016	0.76	7250
NG_RAD3	2016	0.90	7875		WOOD_HT4	2020	0.77	7250
NG_RAD4	2018	0.97	8925		WOOD_HT4	2030	0.78	7350
LPG_FA1	2016	0.80	2050		WOOD_HT4	2040	0.79	7450
LPG_FA2	2016	0.92	2610		GEO_HP1	2016	3.20	7800
LPG_FA3	2016	0.95	2740		GEO_HP2	2016	3.70	8075
LPG_FA4	2016	0.99	3040		GEO_HP3	2016	3.60	8075
					GEO_HP4	2016	4.50	8525
					NG_HP2	2016	1.30	6800

There are some data challenges…

- Unlike power plants, which individually report data to EIA every year, and vehicles, which are state registered, there are no official counts of furnaces, air conditioners, light bulbs, etc.
- We rely on EIA's Residential and Commercial Buildings Energy Consumption Surveys (RECS and CBECS)
    - Conducted every 4-5 years
    - Report results at the Census Division/climate zone level!



Building America Climate Regions — CBECS 2012



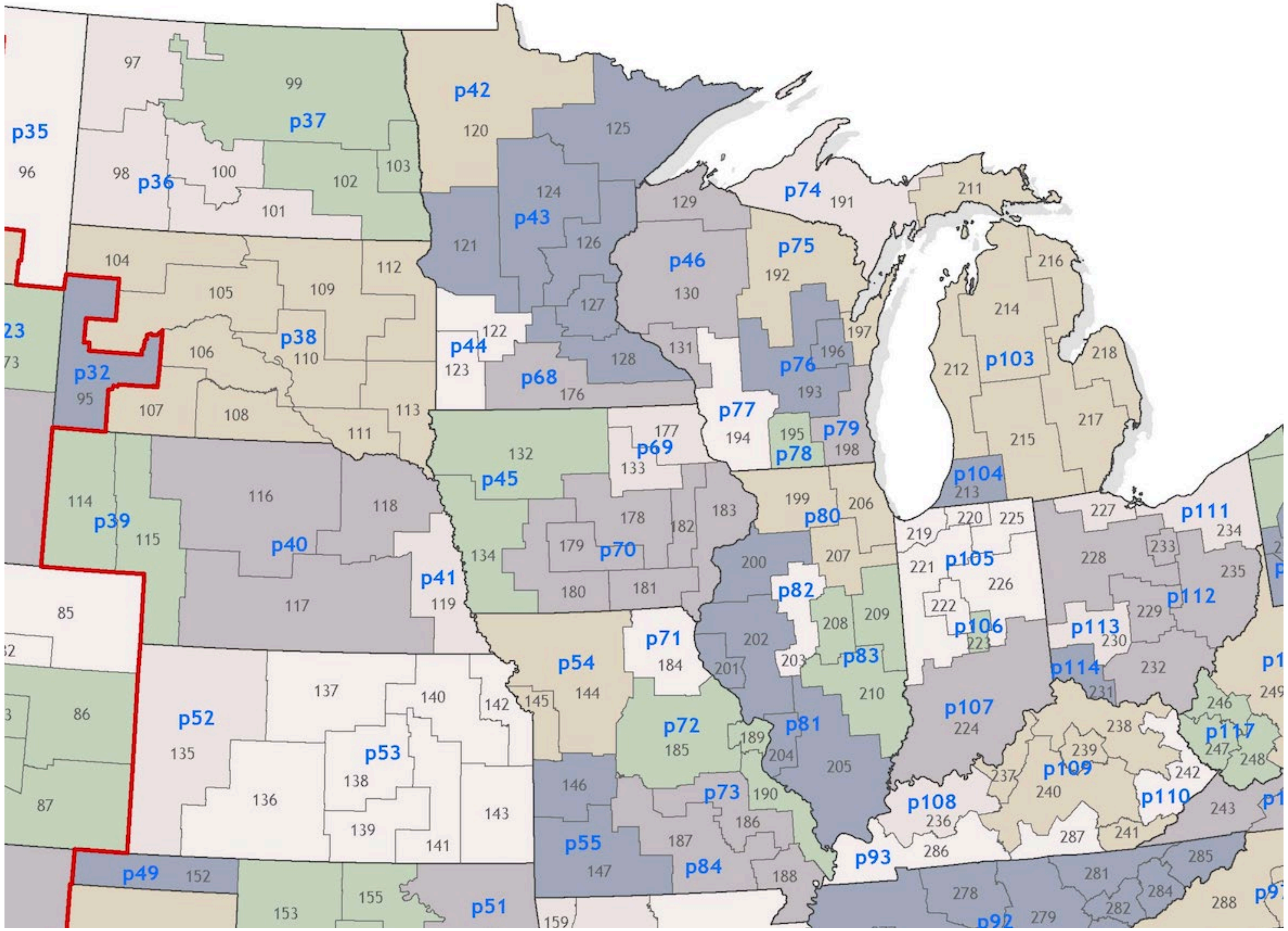
RECS and CBECS divide buildings into types

Commercial Buildings	Residential Buildings
Assembly	Single family
Education	Multi-family
Food Sales	Mobile
Food Services	
Health Care	
Lodging	
Office-large	
Office-small	
Mercantile and Service	
Warehouse	
Other	

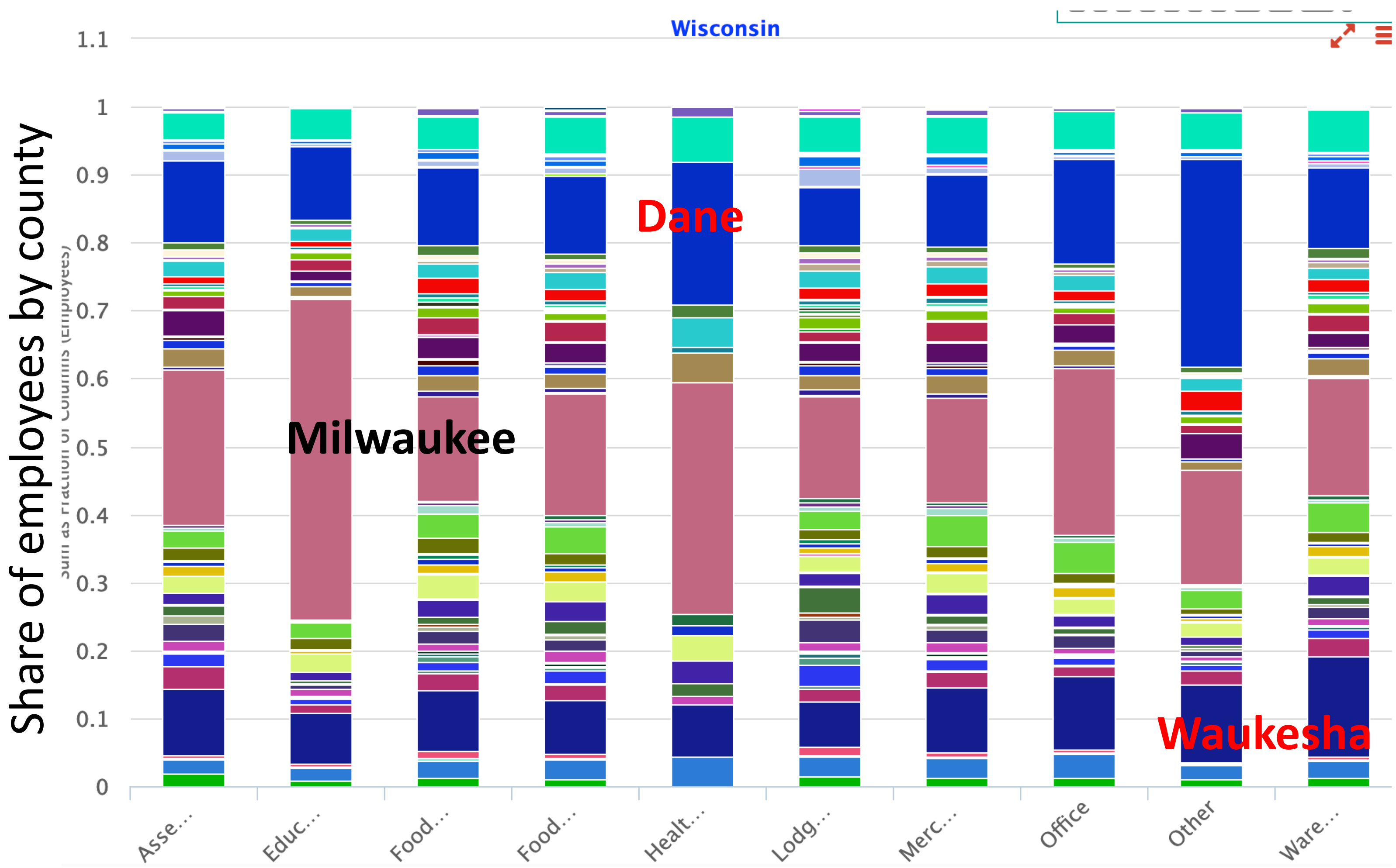
Each type has a different profile for energy using equipment and energy intensity

We use county-level Census data to downscale the building type/climate zone profiles to our model regions

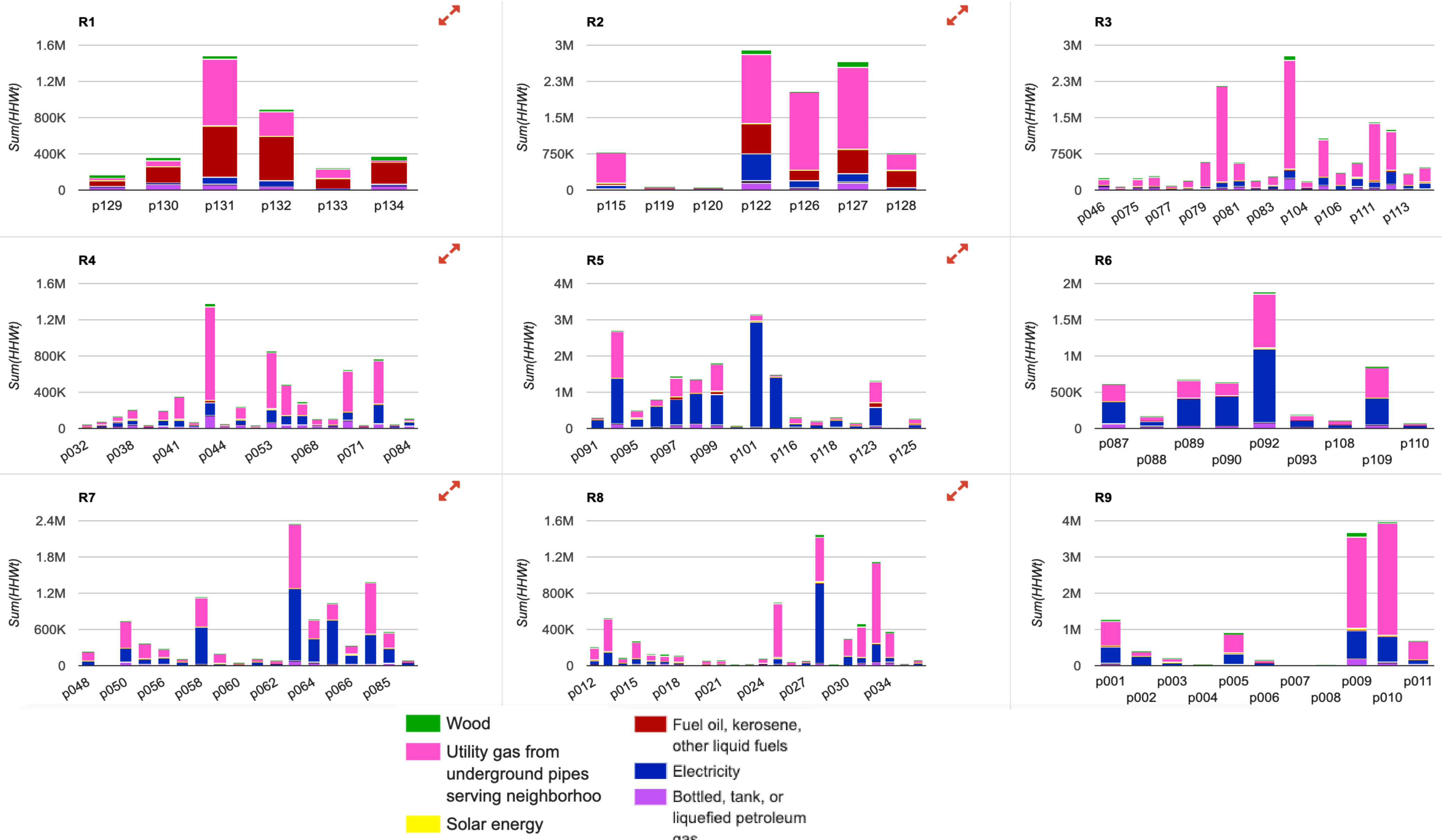
- Commercial: County Business Pattern data on establishments in each building type industry by size
- Residential: American Community Survey counts of households in each type by main heating fuel



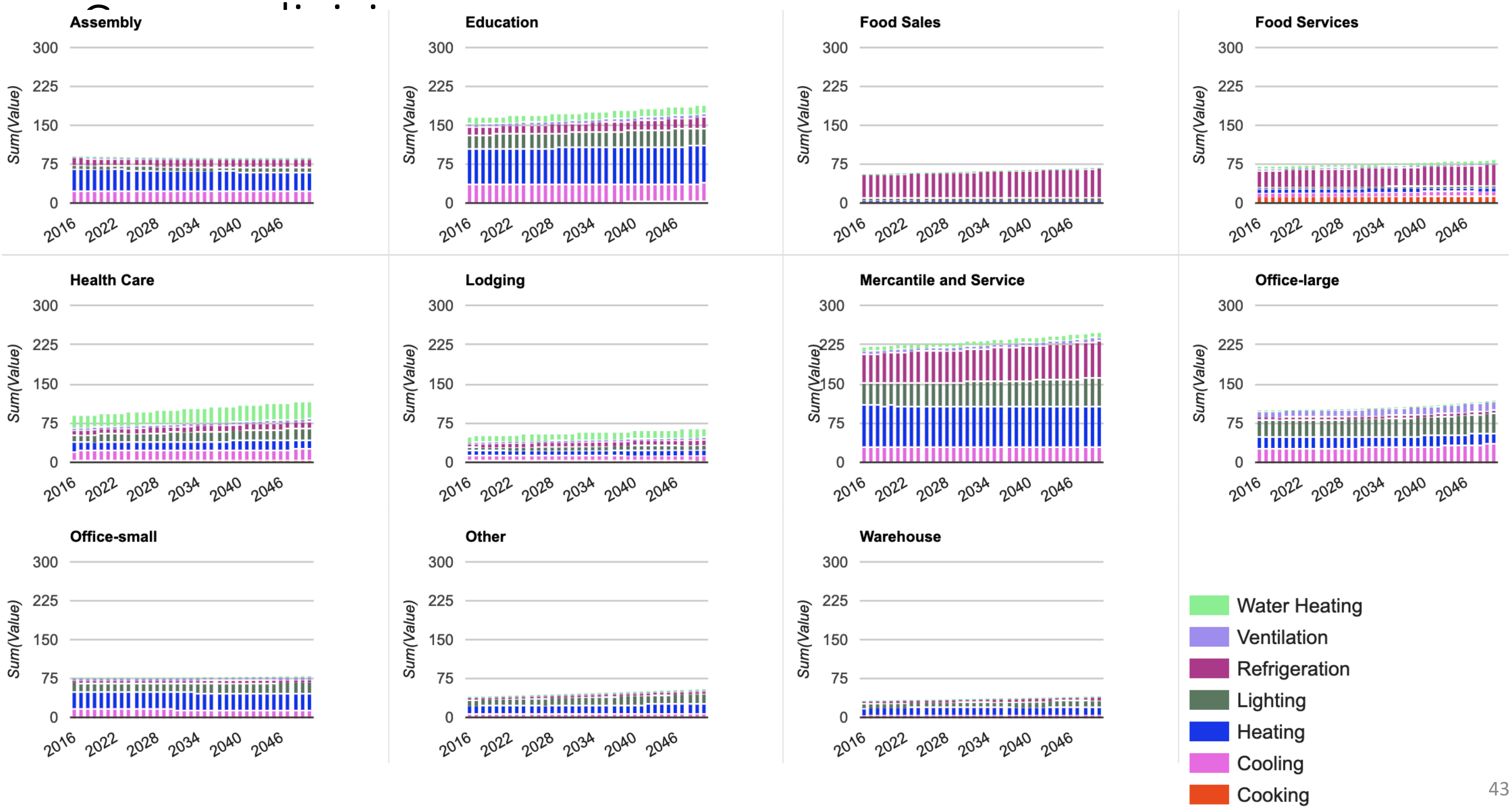
Commercial data: employees by county



Residential data: single family households by heating fuel

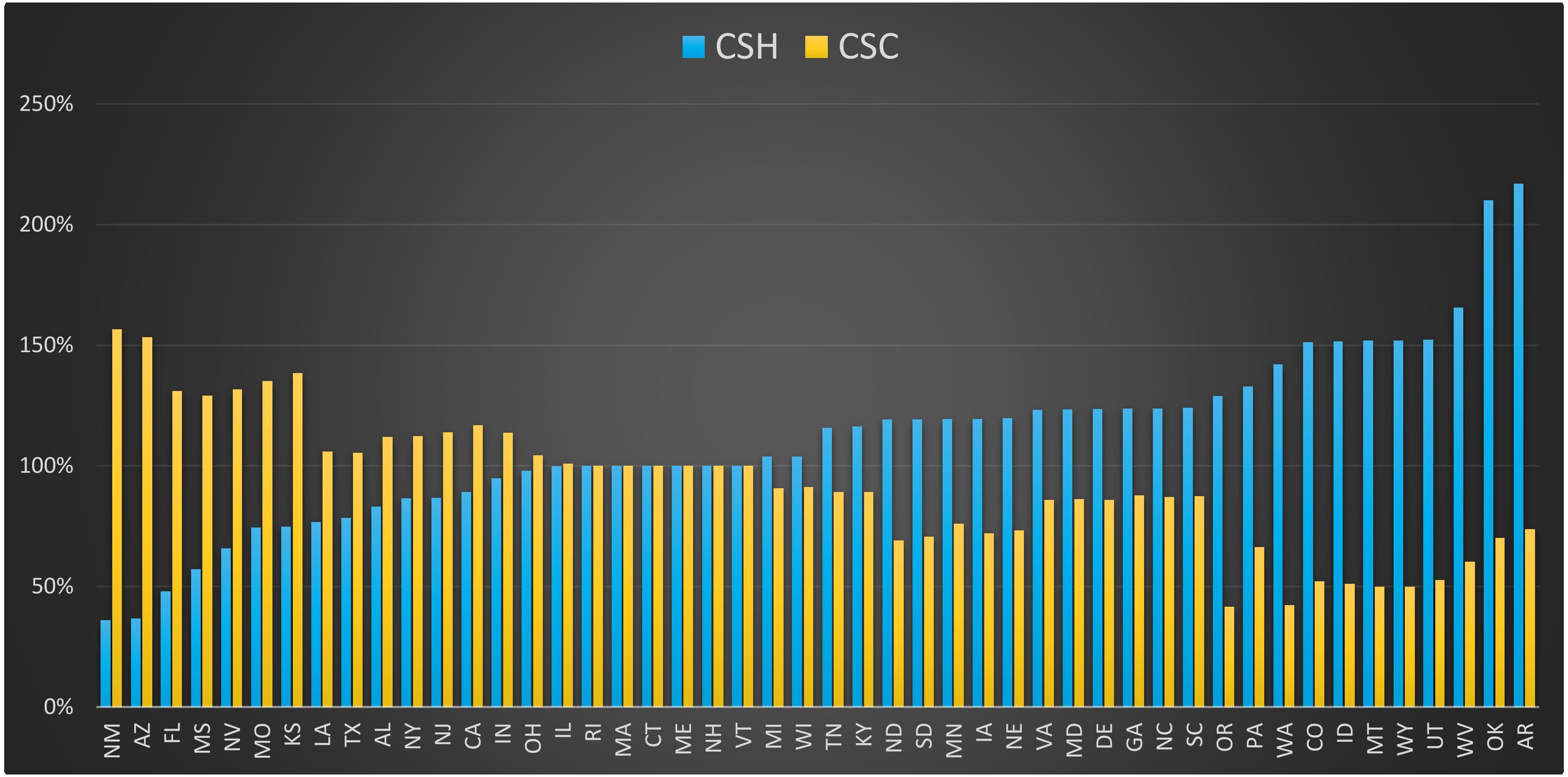


From AEO we take the total projected service demands by



We apportion the AEO demands and base year equipment to regions based on the Census data and climate zones for heating and cooling

Commercial space heating (CSH) and cooling (CSC) by state, relative to a simple share without climate zones



The technology library is available to meet demands

- Choices are modulated by
  - Constraints that limit the rate of fuel switching
  - Constraints that limit the rate technology switching
    - Can’t substitute an ice machine for a walk-in cooler, or a gas fired chiller for a window air conditioner
    - Can substitute a heat pump for a furnace, or an LED for a fluorescent, but not everyone will at once
  - “Hurdle rates”: equipment purchasers act as if they need a greater return on investment than their cost of financing

We can analyze a lot of things with this framework

- Electrification
  - Heating: location/climate-based analysis of heat pump performance and backup requirements
  - Water heating: Grid-controlled storage
- Building energy efficiency through device choice and shell improvements
- Thermal energy storage
- Distributed renewables
- Increased district heating and/or combined heat and power
- Others?

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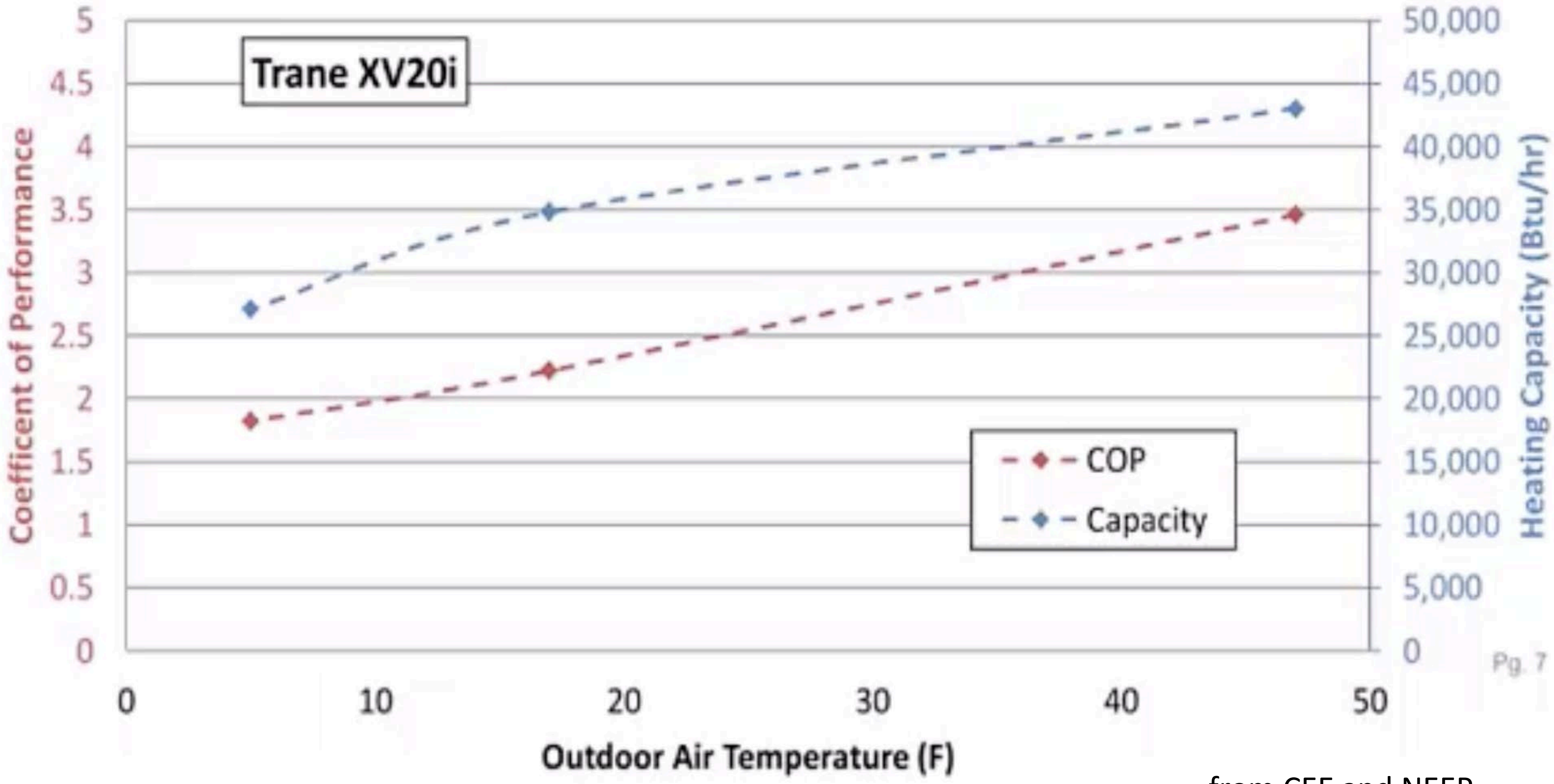
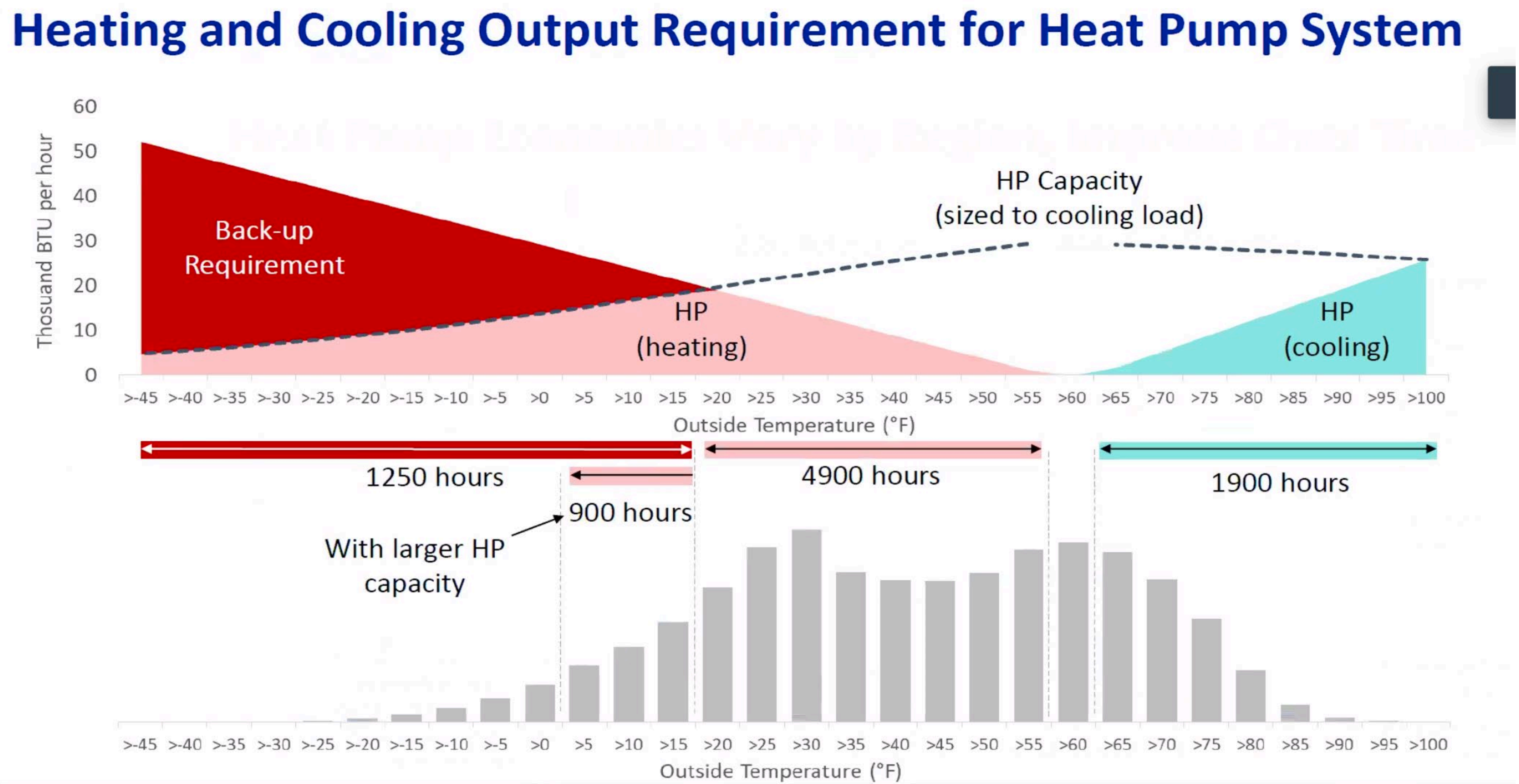
Heat pumps generally cannot serve the entire heating load

- Somewhere between 10 and -20 degrees, HP efficiencies and capacities decrease
- Backup heating devices are required, dependent on climate



from CEE and NEEP

Climate and tech characteristics will affect the capacity factor and back up needs

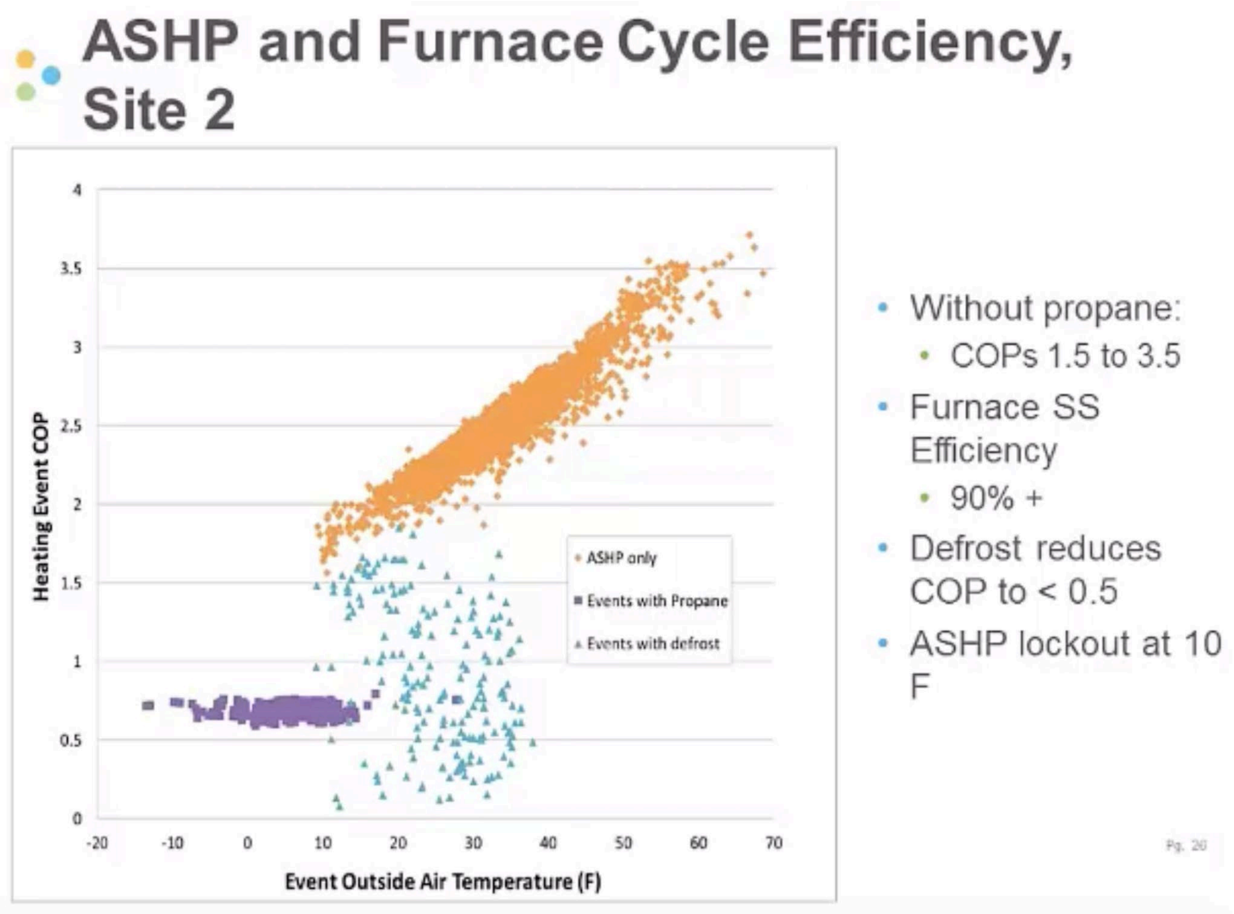


We saw this analysis from EPRI… we can do this in the model for all locations

Energy Cost Trade-offs across options (future HP technology)

	Gas Furnace + A/C	Gas-Electric HP	All-Electric HP
Electricity Price		$0.12 / KWh (example)	
Gas Price		$12 / MMbtu (example)	
Cooling (KWh/year)	600	600	590
Cooling ($/year)	$72	$72	$71
Heating (KWh/year)	0	8,000	9,200
Heating (MMbtu/year)	91	4	0
Heating ($/year)	$1,092	$960 (ele) + $48 (gas)	$1,104
Total Annual Energy	**$1,164**	**$1,008**	**$1,175**

CEE found a pretty linear relationship between temperature and efficiency for cold climate heat pumps in Minnesota



We can calculate based on typical hourly temperature for each location

- Number of hours per year below HP operating threshold
- HP capacity factor
- HP efficiency
- Secondary heating requirements

- Then the model can make the cost effectiveness calculation, based on fuel costs, capital costs, electricity price, etc. in response to all our usual uncertainty variables and decarbonization ambition

Water heating

- RAP estimates each water heater can serve as storage for about 2 KW of wind/solar
- We can model water heater daily load timing as price-optimized, like we did for EVs
- Heat pump and resistance technologies are available

Building EE

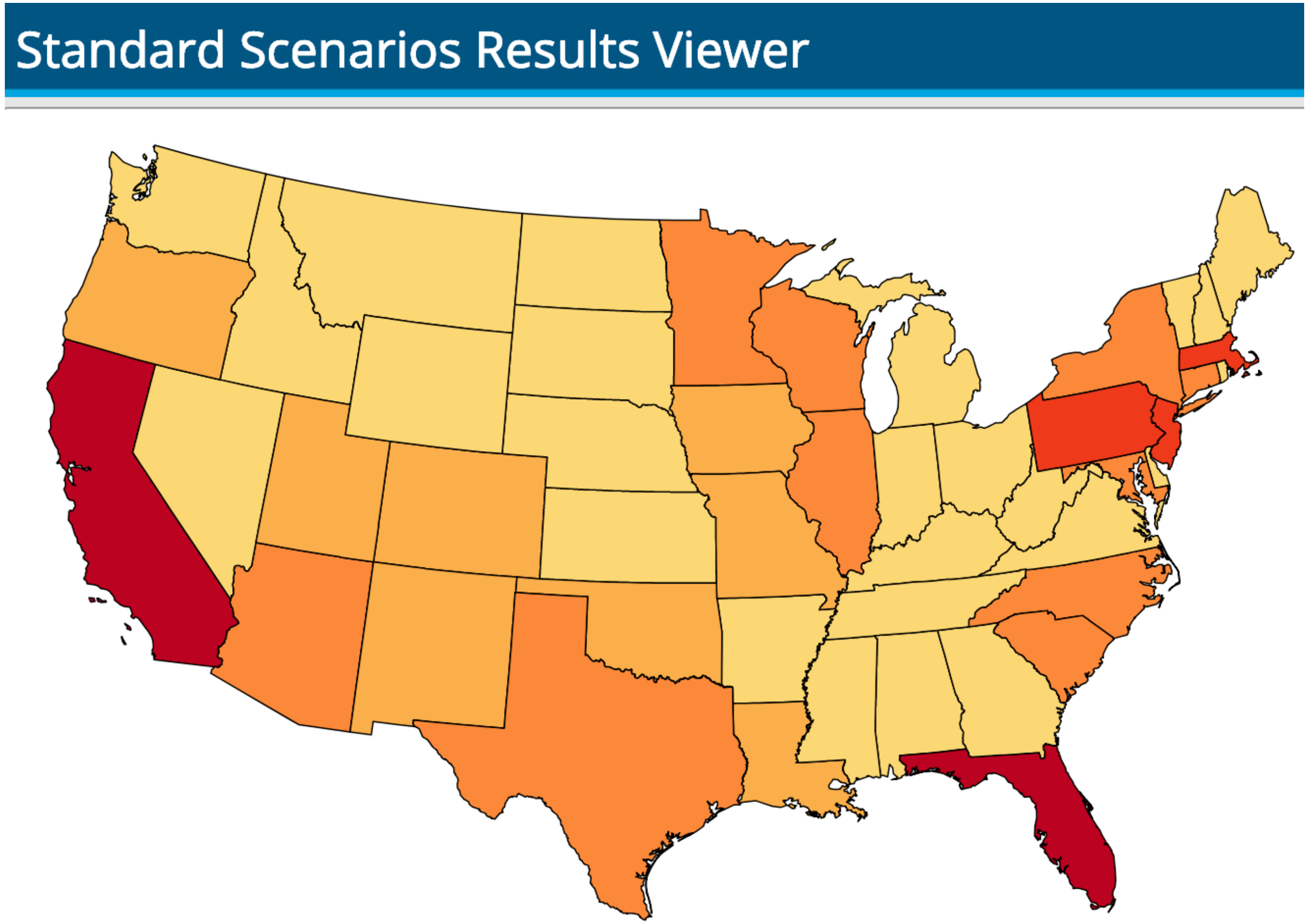
- We model EE at the device level for the modeled demands
- Plus shell improvement investments, for residential
- Industrial EE will remain in our per-kwh cost/supply curves

Thermal storage for commercial cooling

- We have costs and a method for calculating potential for ice storage and chilled water systems to substitute for some commercial cooling requirements
- RAP estimates that these techs can shift 90% of peak cooling loads
- This is a flexible load strategy, not an energy saving strategy

Distributed PV scenarios are from NREL

- NREL has a detailed model of distributed PV competitiveness
- State-level results are available for scenarios similar to our power sector scenarios (gas price/RE cost variations)



District heating and/or combined heat and power

- We have base year and BAU district heat and CHP projections from AEO
- We could model increasing penetration… but it would be good to have some data on cost/potential

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Opportunities and Challenges for Air Source Heat Pumps in a Cold Climate

Joshua Quinnell, Center for Energy and Environment

Alex Haynor, Center for Energy and Environment

Center for Energy and Environment

Cold Climate
Air Source Heat Pumps

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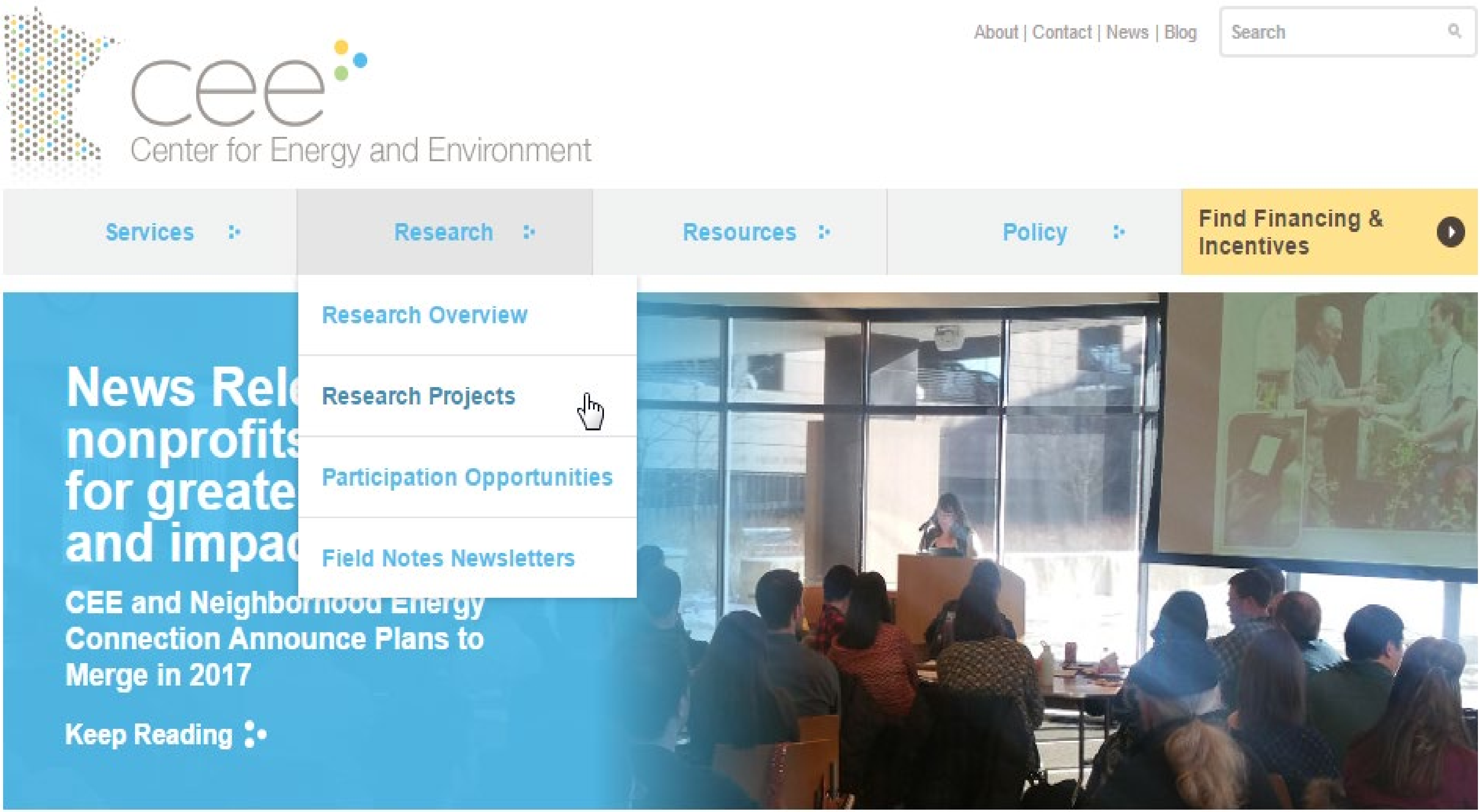
On our website: www.mncee.org/heat_pumps

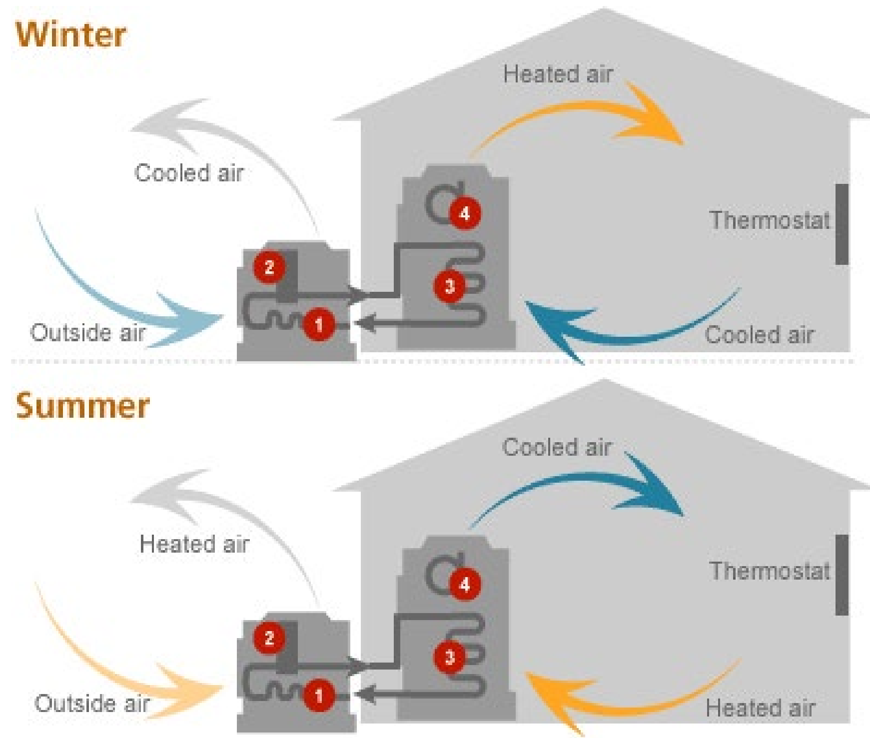


Overview

1. Basics on cold climate air source heat pumps
2. CEE's technology research
3. Potential and emissions
4. Q & A

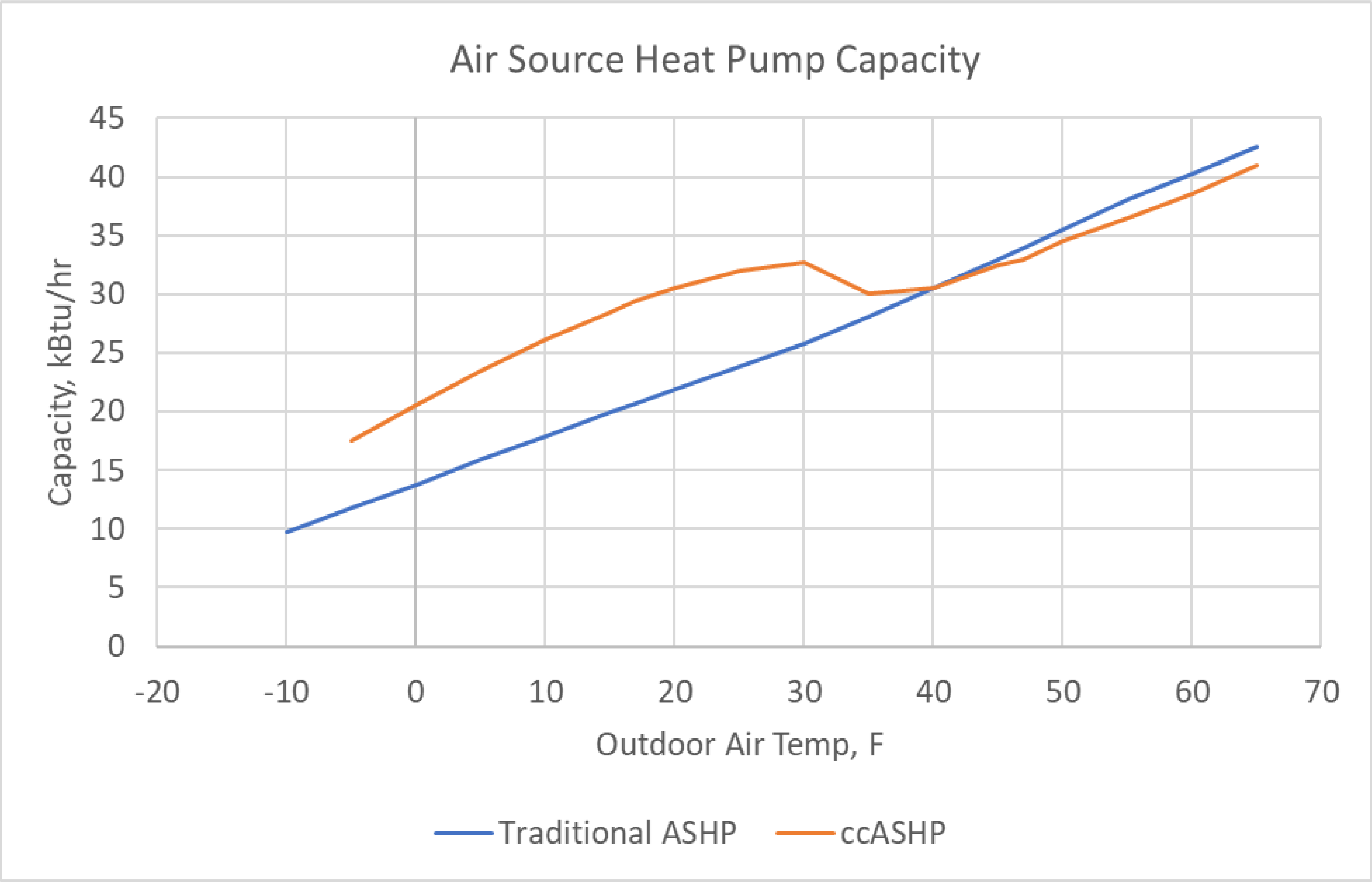
Cold Climate Air-Source Heat Pump

- 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
- Potential to deliver energy and peak saving & reduce reliance on delivered fuels.

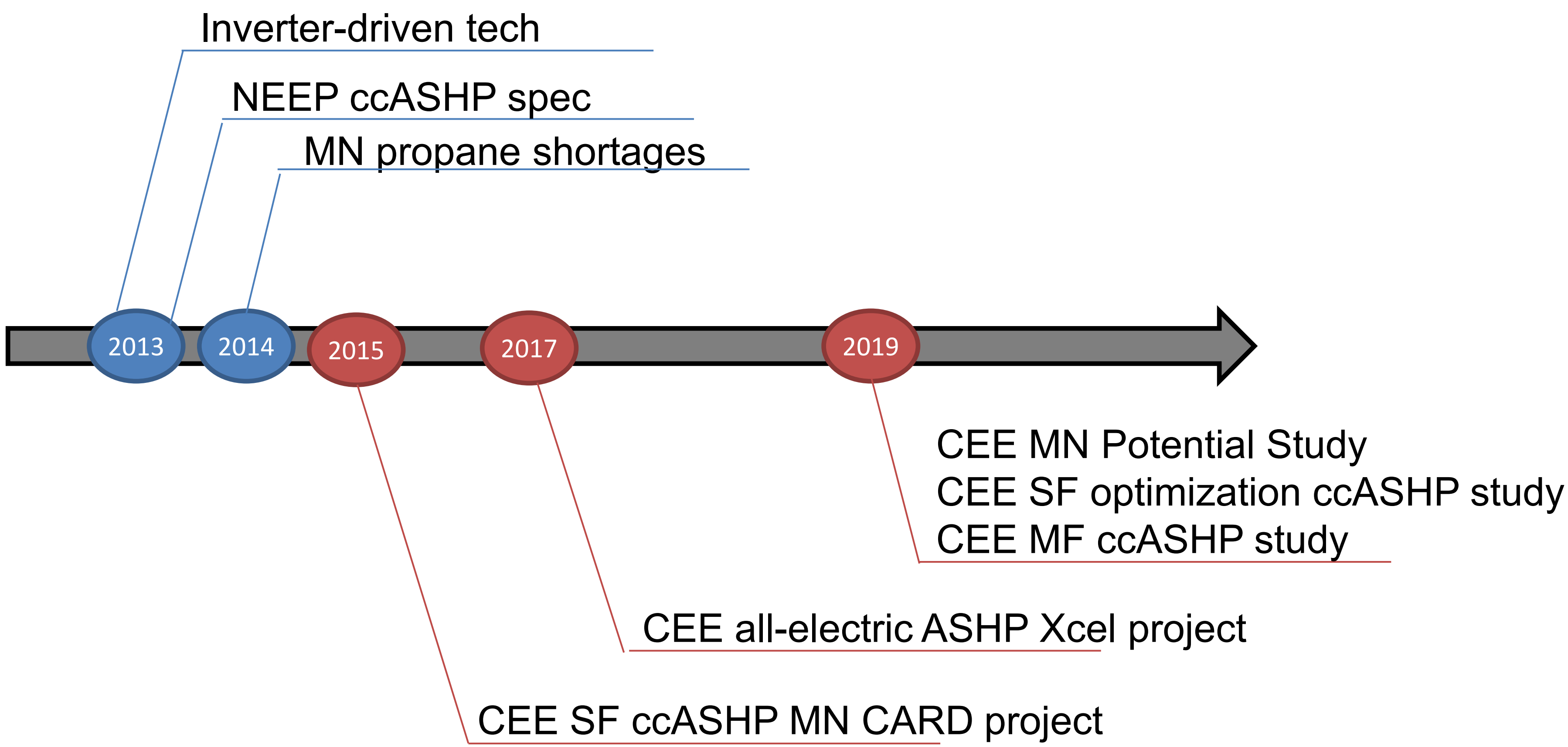


Really… in Minnesota?

- 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 -20F
- CEE has documented systems delivering heat as cold as -25 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

ccASHP Development & CEE Research Timeline



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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

Minnesota's Conservation Applied Research & Development Fund (CARD)

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*

Additional support from: Great River Energy, Electric Power Research Institute, Xcel Energy

Research Findings

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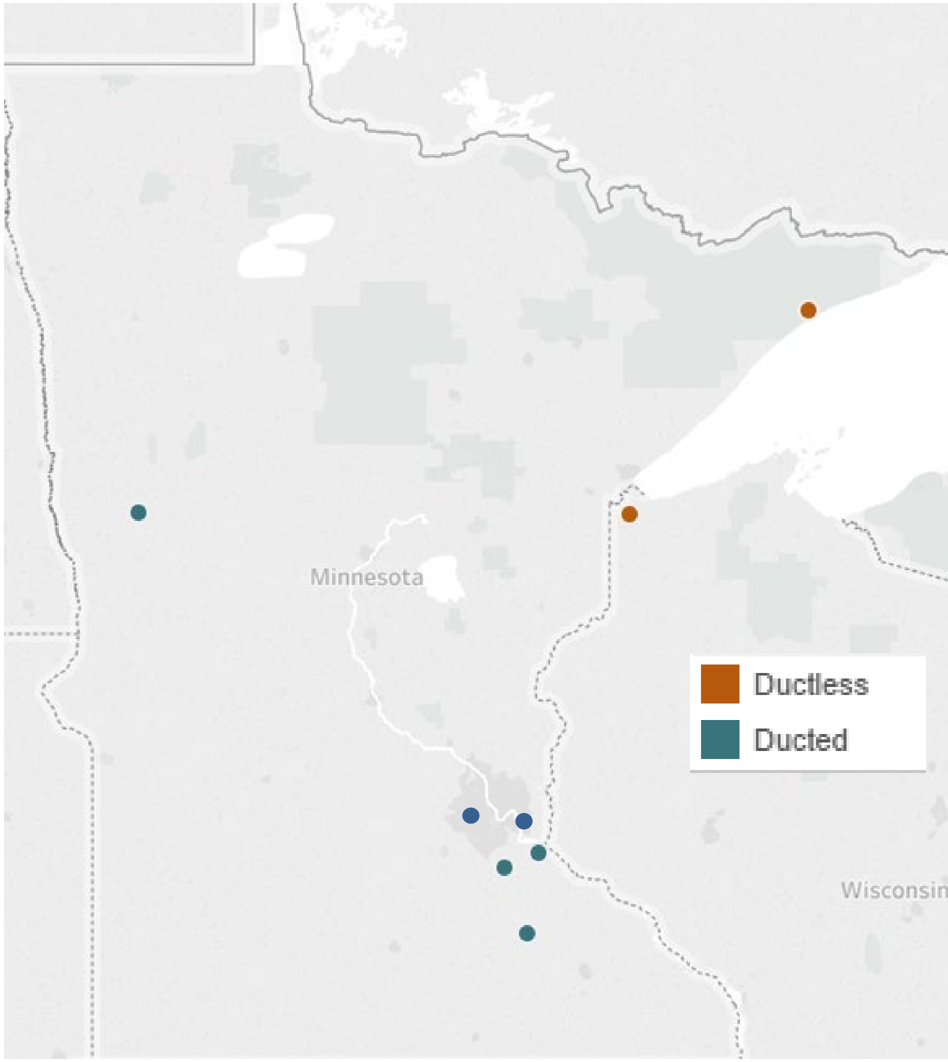
Overview of Completed Research

Field studies

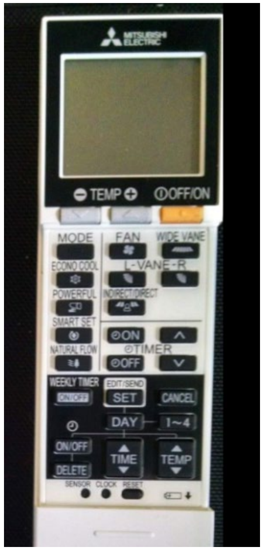
- 8 ccASHP in a variety of MN residences
  - 6 ducted whole house system
  - 2 ductless mini-split systems
- Monitor installed field performance of ASHP & backup
- Each site had detailed data collection
- Installs in climate zones 6 & 7



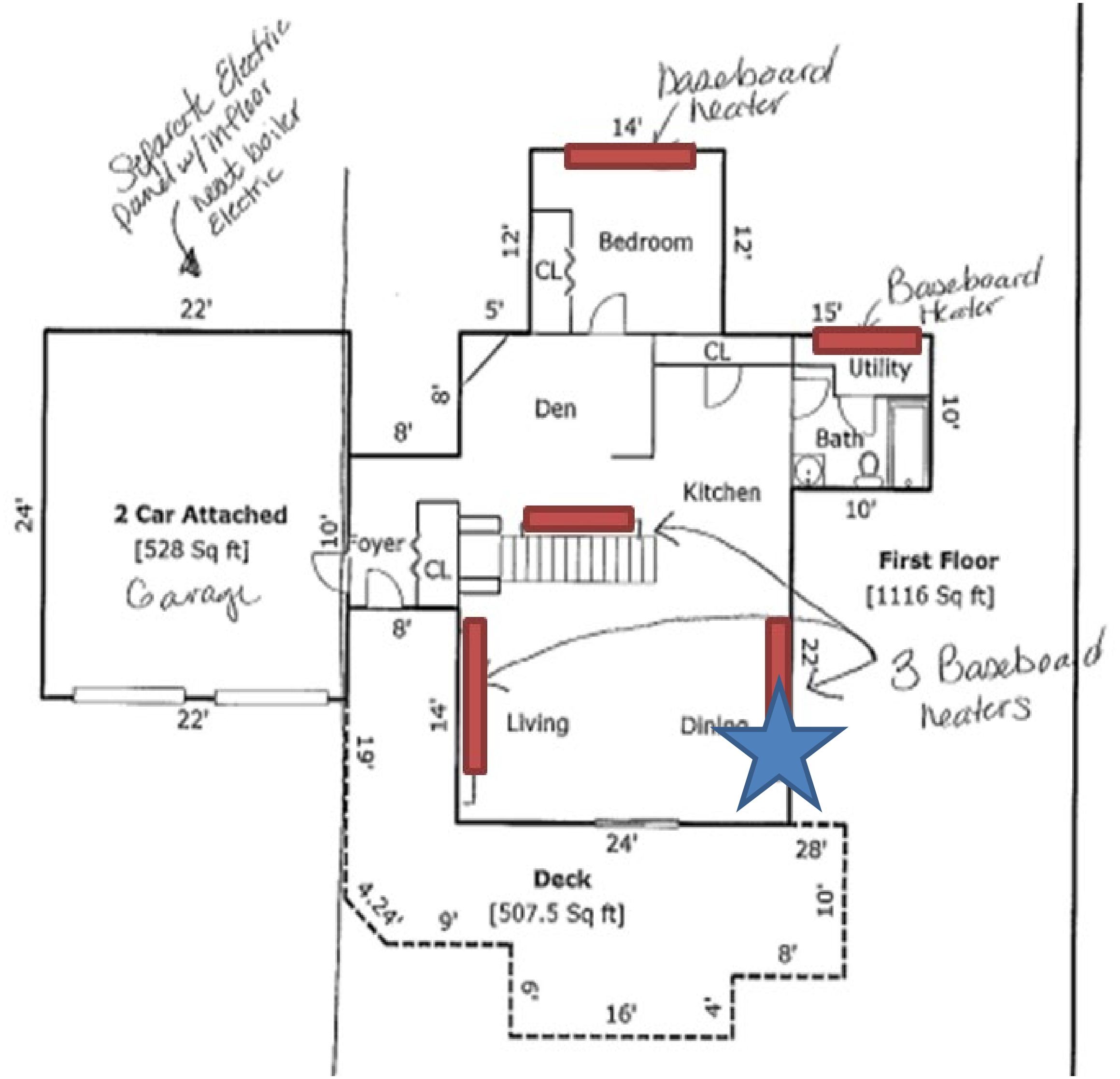
Ducted Whole House Installation, Flex Fuel

Ducted Whole House Installation, All-Electric

Ductless / Mini-Split Installation



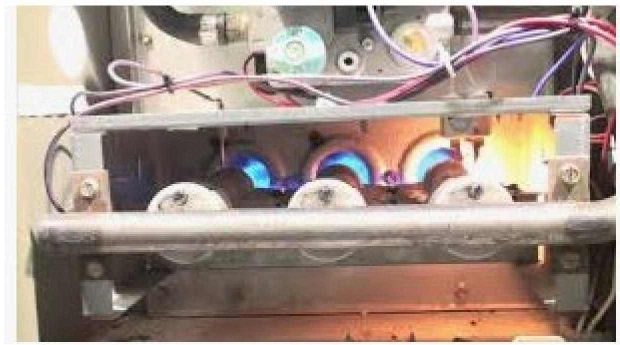
Ductless: Install Location



Installation Considerations

Control and Operation

Integration with backup

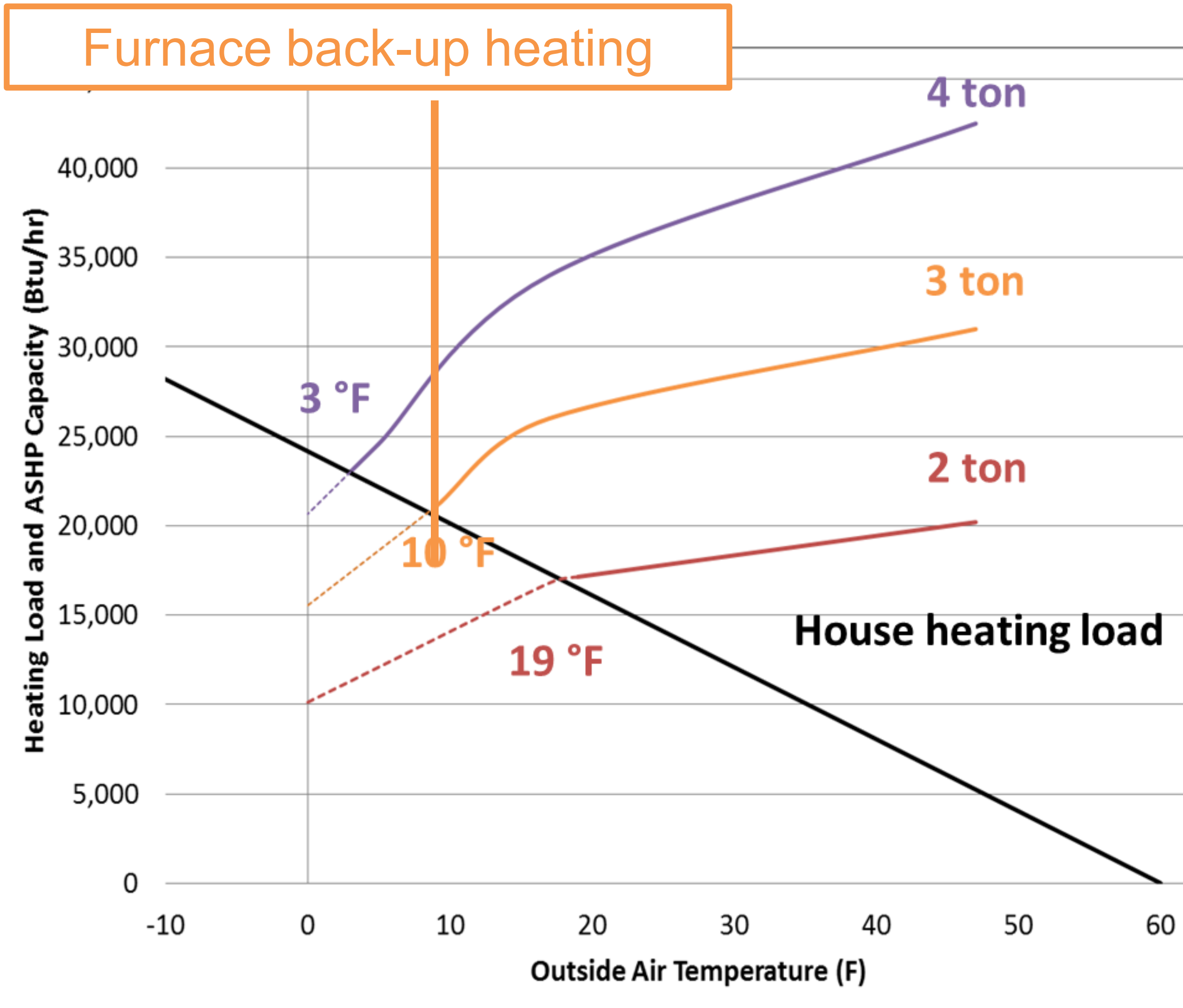


Sizing

Impact of System Choice

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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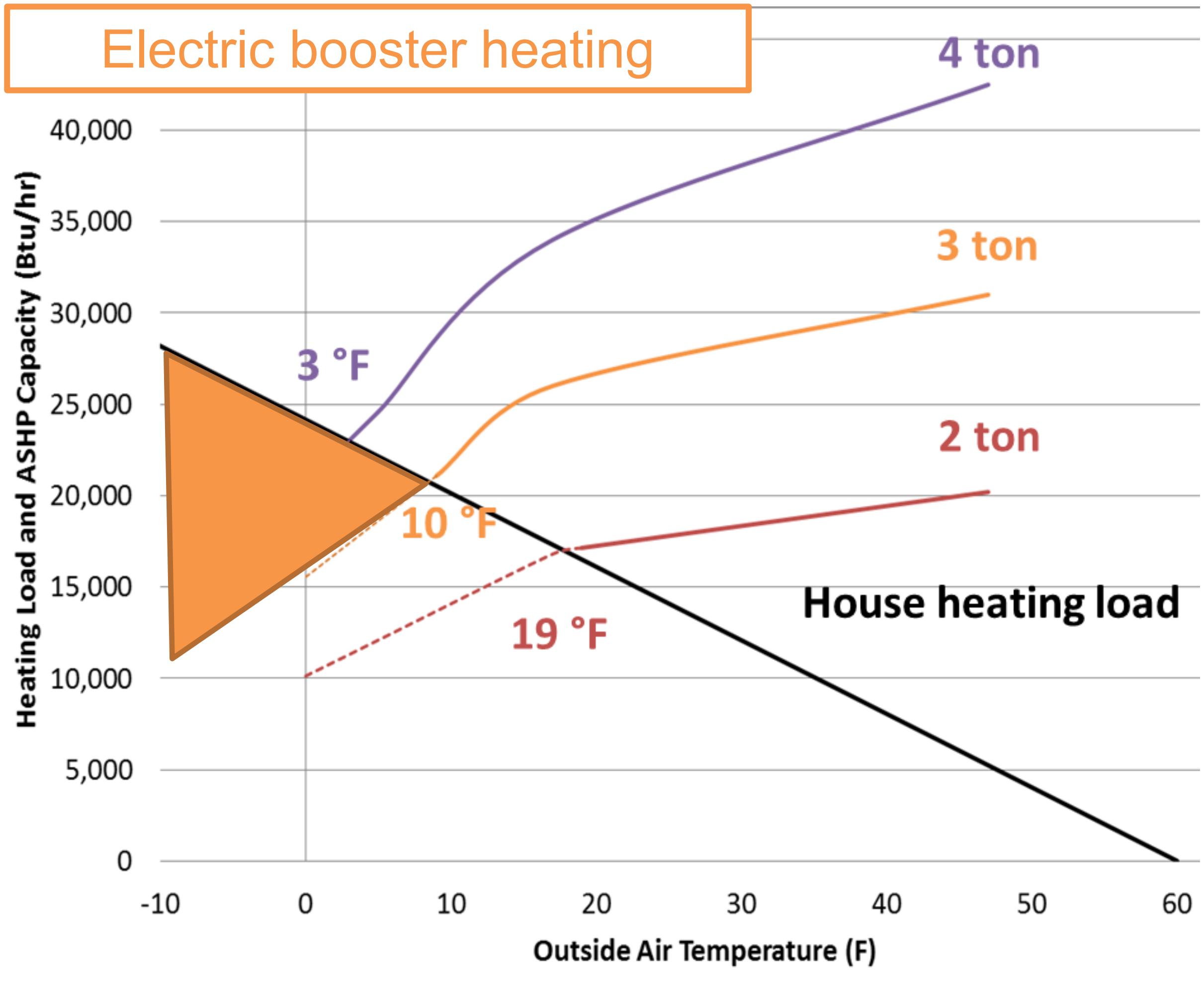
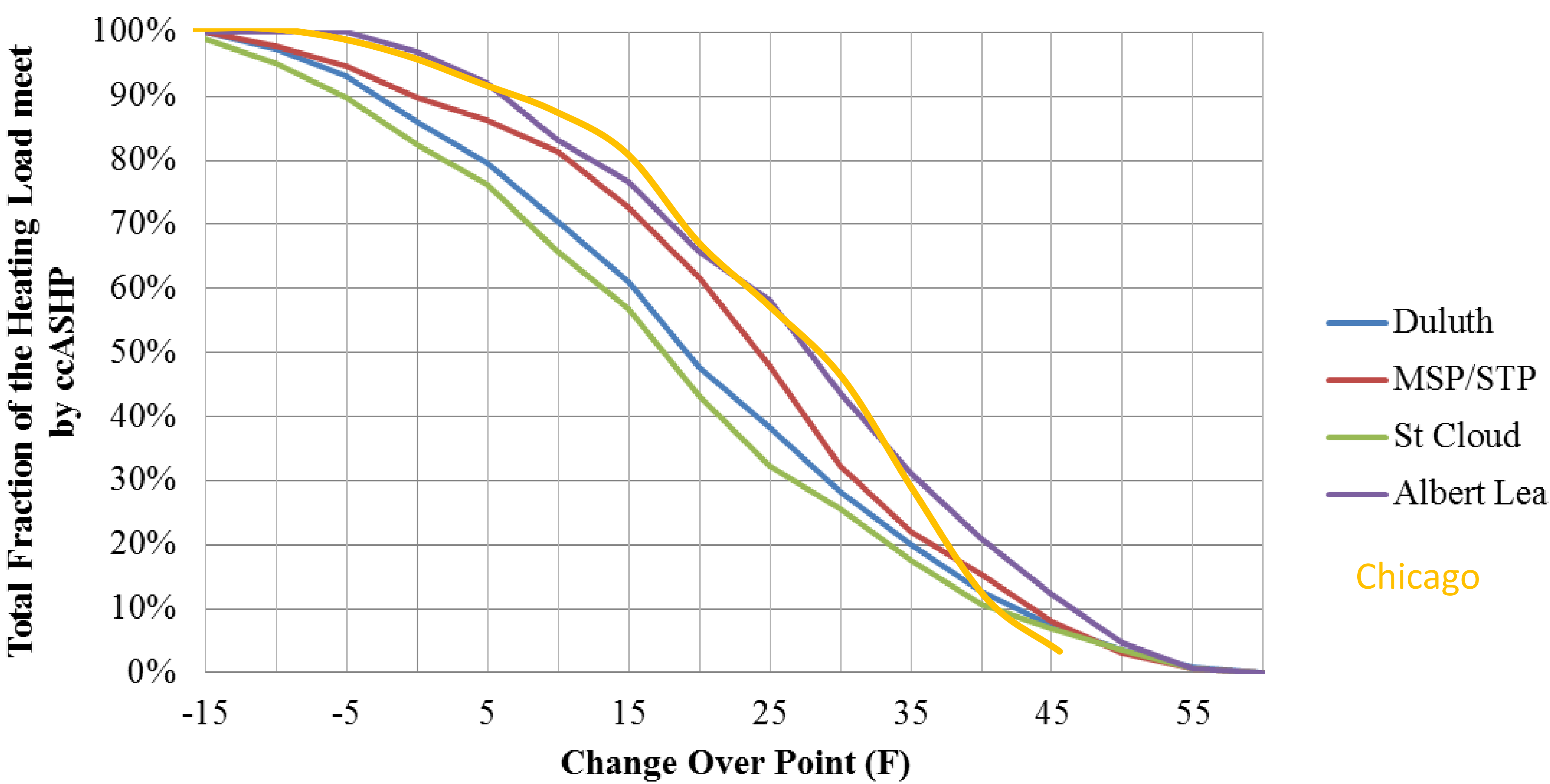


Impact of Change-Over Set Point



Time for Some Heat Pump Data!

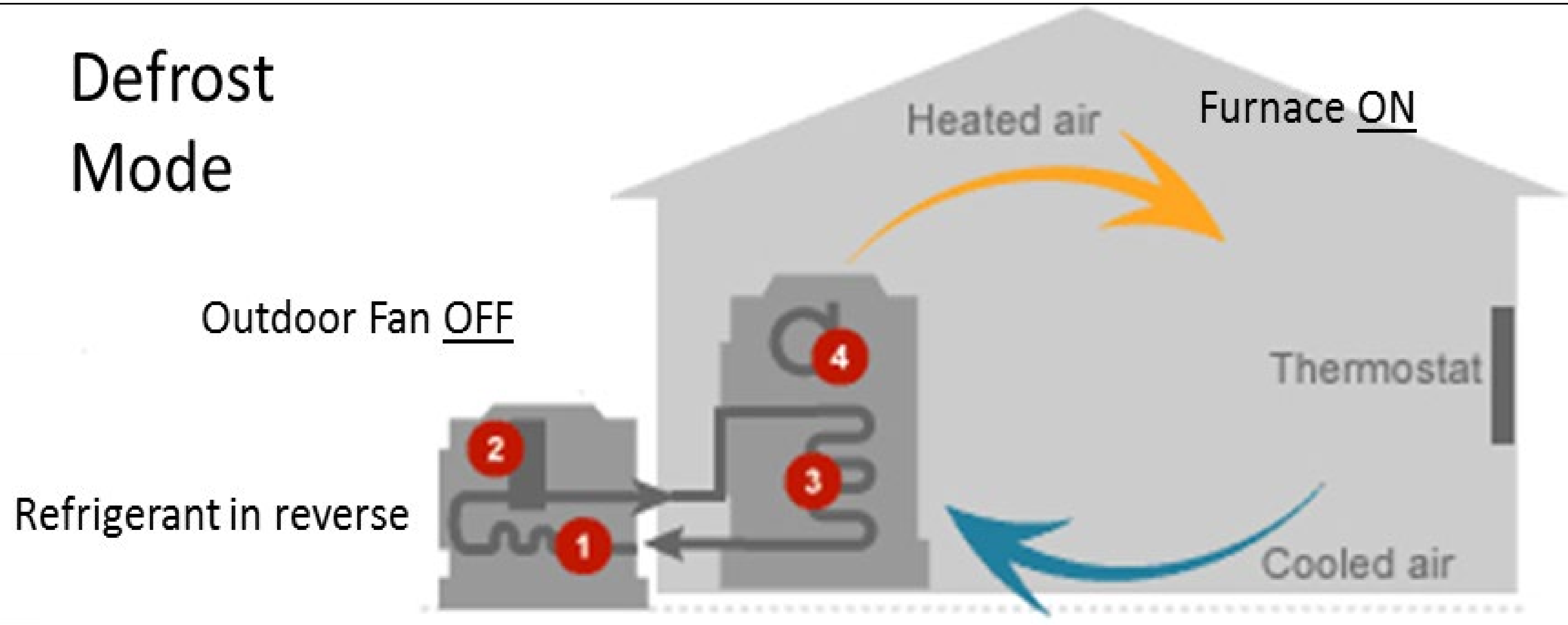
- To-date we've monitored 8 different installs
- Collected over 16 months of data on each
- Approximately 20 measurements per site
- One second collection interval
- LOTS of data!

Modes of System Operation

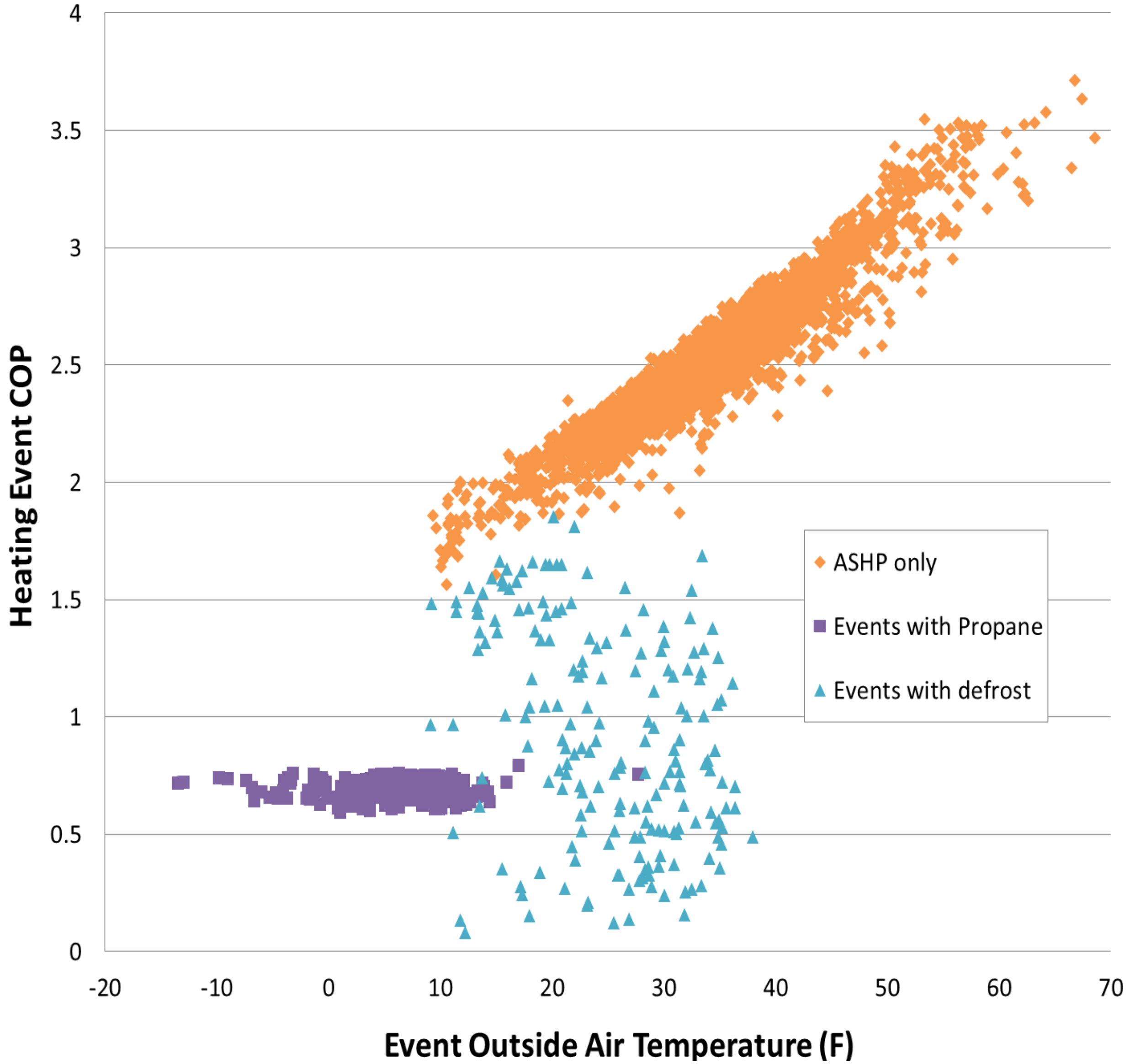
Heating system has 3 modes of operation

- ASHP heating
- Back up heating
- Defrost

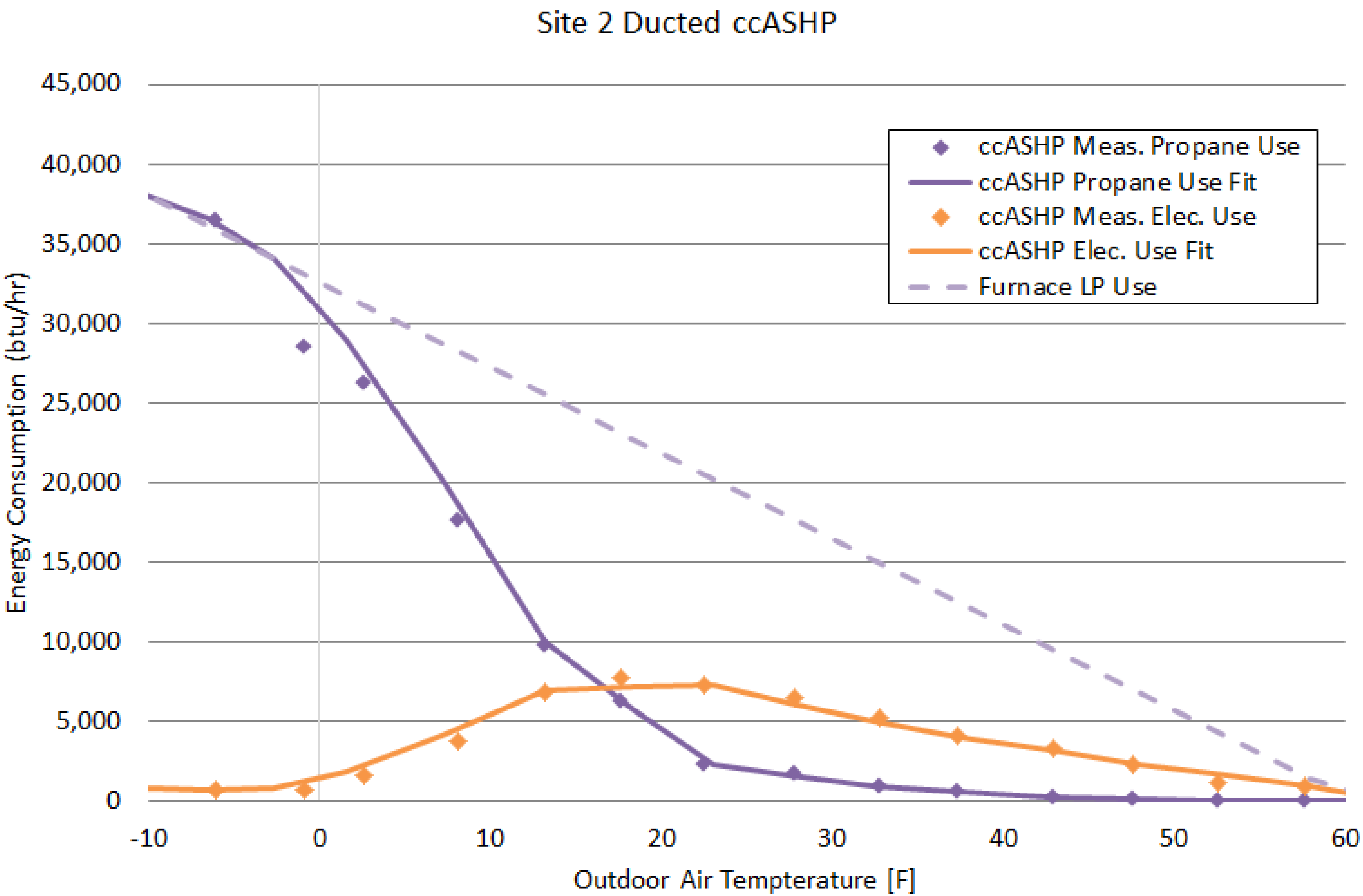
Defrost Mode



Heating cycle COP of a Flex Fuel System



Energy Use Vs OAT Models



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 from the Research

- ccASHP have a significant potential to save energy and reduce emissions

- Savings are dependent on quality system design and installations which includes
  - Baseline/backup fuel type
  - Existing heating system
  - House characteristics
  - Controls

- Our research continuing on guides, training, and controls

RESIDENTIAL SPACE HEATING ELECTRIFICATION

Decarbonizing Minnesota's Natural Gas End Uses

Josh Quinnell, Jenny Edwards,
Rabi Vandergon, Lindsay Beavers

June 12, 2020

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Ongoing Efforts

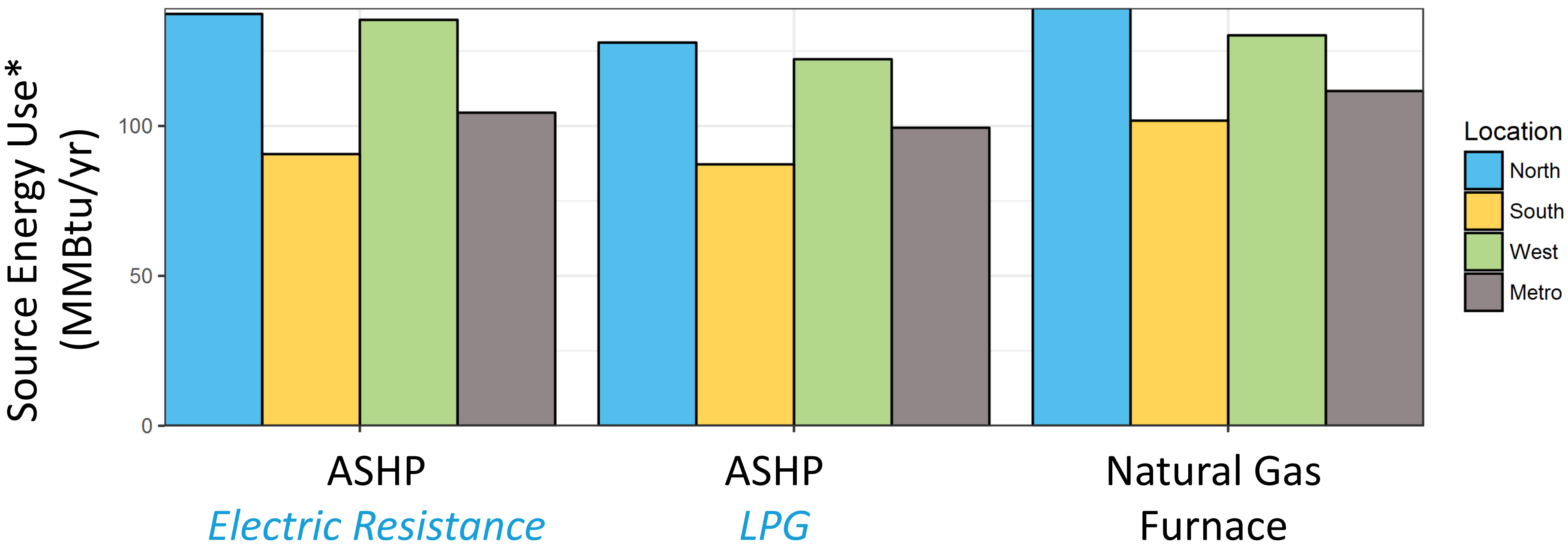
- Beneficial Electrification (2018+)
  - Studying the what, how, and why of cold climate electrification
  - Supported by McKnight Foundation
- High Performance Envelope Upgrades (2019-2020)
  - Supported by MN Dept. of Commerce CARD
- Electrification Roadmap (2020+)
  - Identify electrification opportunities and develop strategies to optimize and accelerate space heating electrification
- Other market transformation initiatives & ongoing fieldwork
  - Working with manufacturers and utilities to accelerate ccASHP adoption

Defining “Beneficial”

Electrification is beneficial if it can provide:

1. A net reduction in source energy use
2. A net reduction in lifetime carbon emissions
3. A net reduction in fuel-neutral customer energy costs, and
4. A neutral or net reduction in coincident electricity demand

Source Energy Use: Current Grid



*US DOE. 2016. "Accounting Methodology for Source Energy of Non-Combustible Renewable Generation." DOE/EE-1488.

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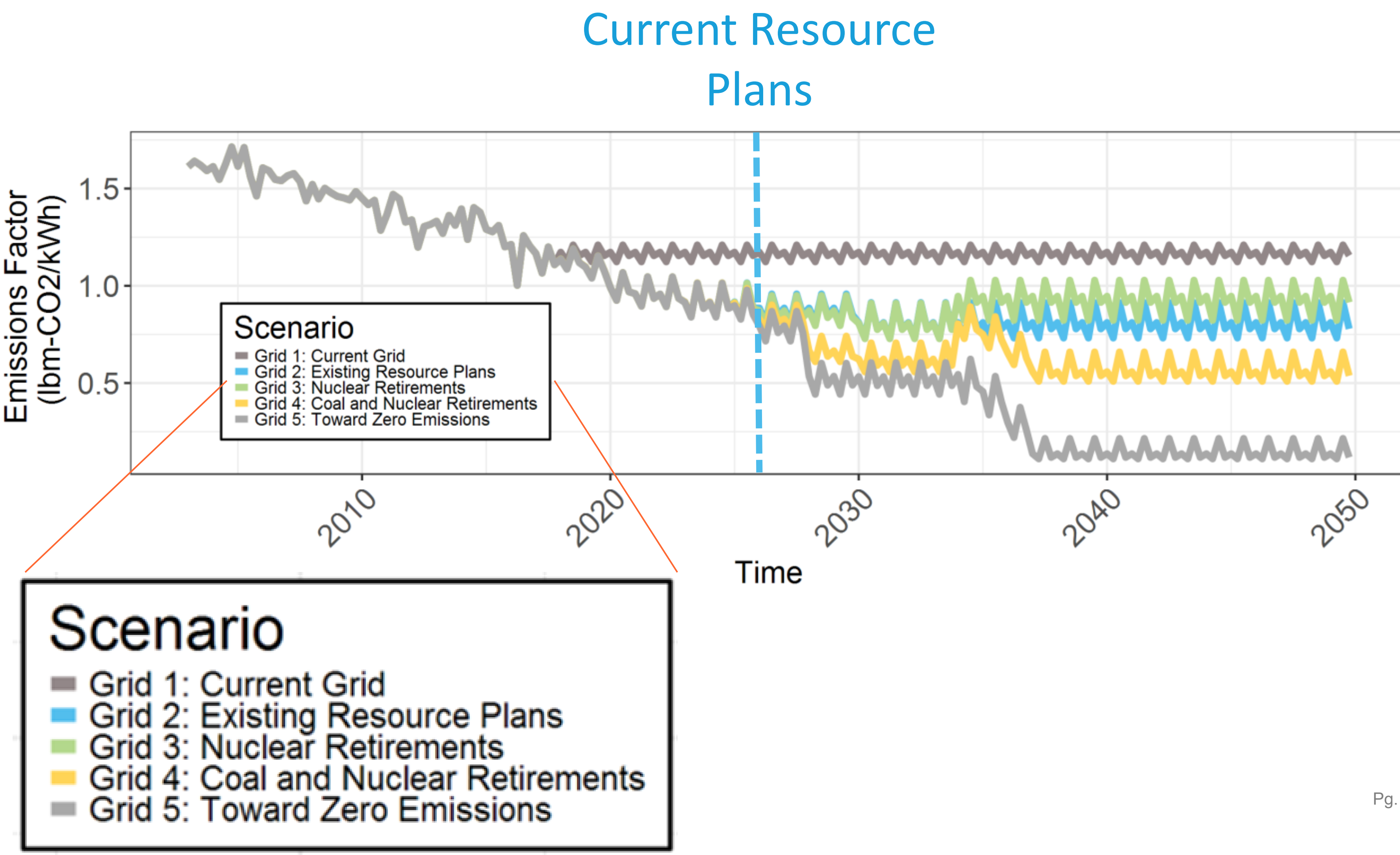
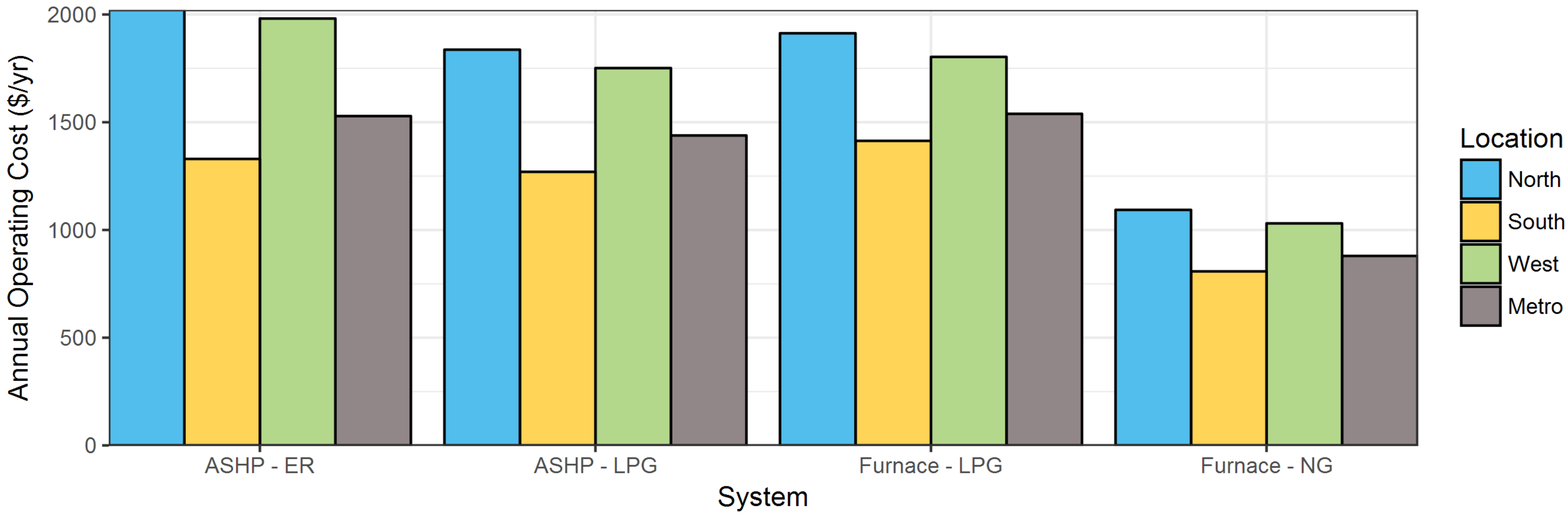
Grid Emission Scenarios



Operating Costs



Operating costs are nearly double natural gas

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ASHP Electrification Considerations

✓A net reduction in lifetime carbon emissions - **YES**

✓A net reduction in source energy use - **YES**

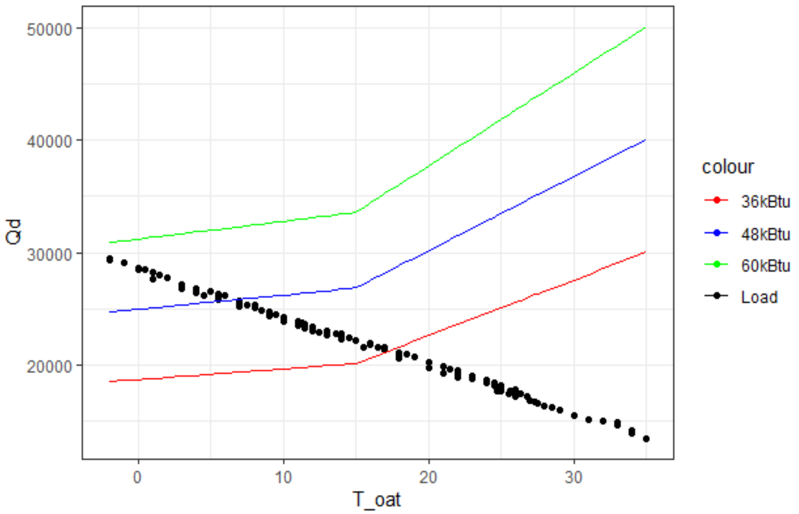
✓A net reduction in fuel-neutral customer energy costs?- **NO**

✓A neutral or net reduction in coincident electricity demand – **OK FOR NOW**

Capacity

- Furnaces have fixed capacity ~ 40 – 120 kBTU/hr
- Heat pumps have variable capacity ~ 12 – 60 kBTU/hr

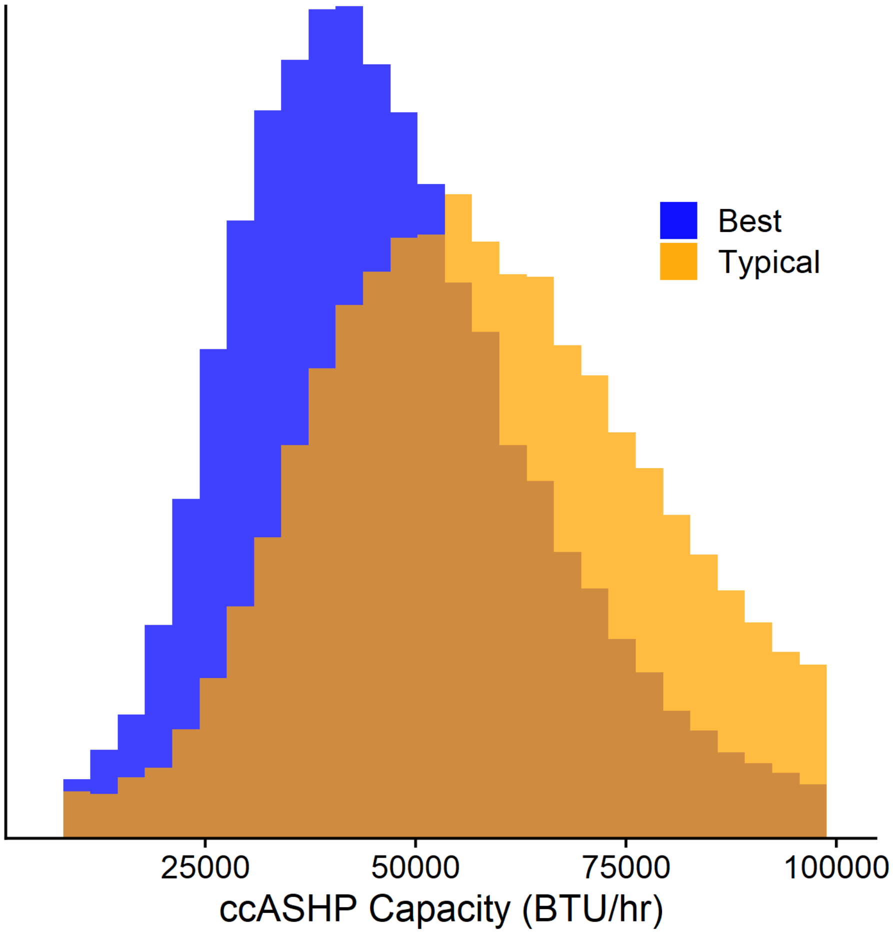
- Heat pumps lose capacity as outside temperatures fall
  - Older models rapidly lose capacity below 47 °F
  - Best units today maintain 80% design capacity at -12 °F
  - Typical unit may be 60-70% at -12°F or 0% - doesn't run
  - Currently, backup should be expected in most cases



Design Load

- “Best” ccASHP
  - 1/5 of homes need largest systems on market
  - 1/4 of homes have too large a load
- “Typical” ccASHP
  - 1/2 of homes have too large a load
- Larger ASHP?
- Lower heating loads?
- Backup heat?

	MN Housing Stock	
ccASHP Size	**Best ccASHP**	**Typical ccASHP**
<24 kBtu	10%	5%
24 - 36 kBtu	21%	8%
36 - 48 kBtu	26%	17%
48 - 60 kBtu	20%	20%
60+ kBtu	23%	49%



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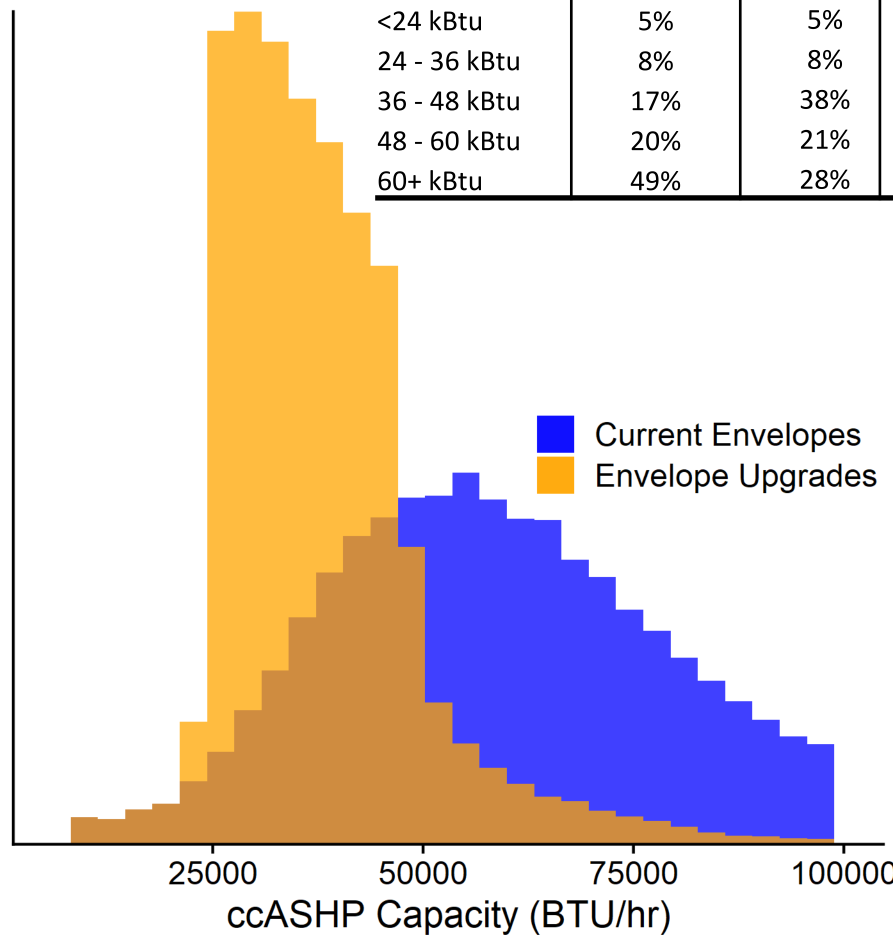
Changing Design Load

- Weatherization Efforts
  - Open up 20% more homes to ccASHP
  - Insufficient for 28%
  - Changes backup optimization
- High performance envelopes
  - Bring 88% of housing stock below 4 ton nameplate capacity
  - No backup?

ccASHP Size	MN Housing Stock Existing Envelopes	20% Savings	50% Savings
<24 kBtu	5%	5%	5%
24 - 36 kBtu	8%	8%	46%
36 - 48 kBtu	17%	38%	37%
48 - 60 kBtu	20%	21%	7%
60+ kBtu	49%	28%	5%



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Main Barriers

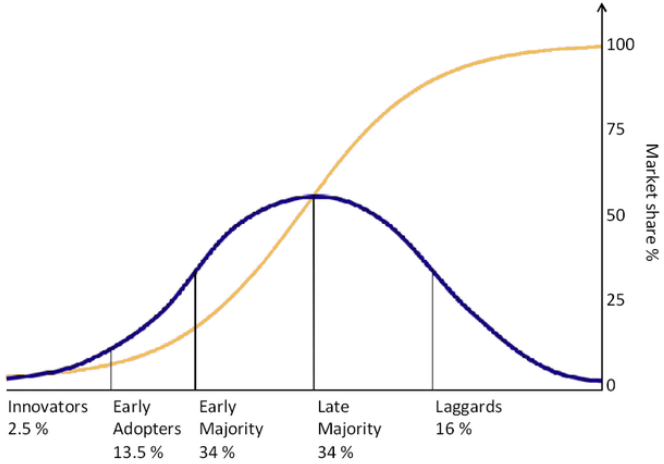
- Costs
  - ccASHP are about twice the cost of gas furnace/AC combo
  - ccASHP are twice as expensive to operate as gas furnaces
    - Electricity costs forecasted increase faster than natural gas costs
- Loads
  - Much existing construction can't be served by today's ccASHPs
  - Existing weatherization efforts are insufficient to prepare existing building stock

Electrification Roadmap: Space Heating

Today:1-2% ASHP Penetration

- Challenges
  - High load housing stock
  - High operating costs
  - Scale barriers
    - Workforce
    - Technological familiarity
    - Capital cost?

"High" ASHP penetration in 30 years?



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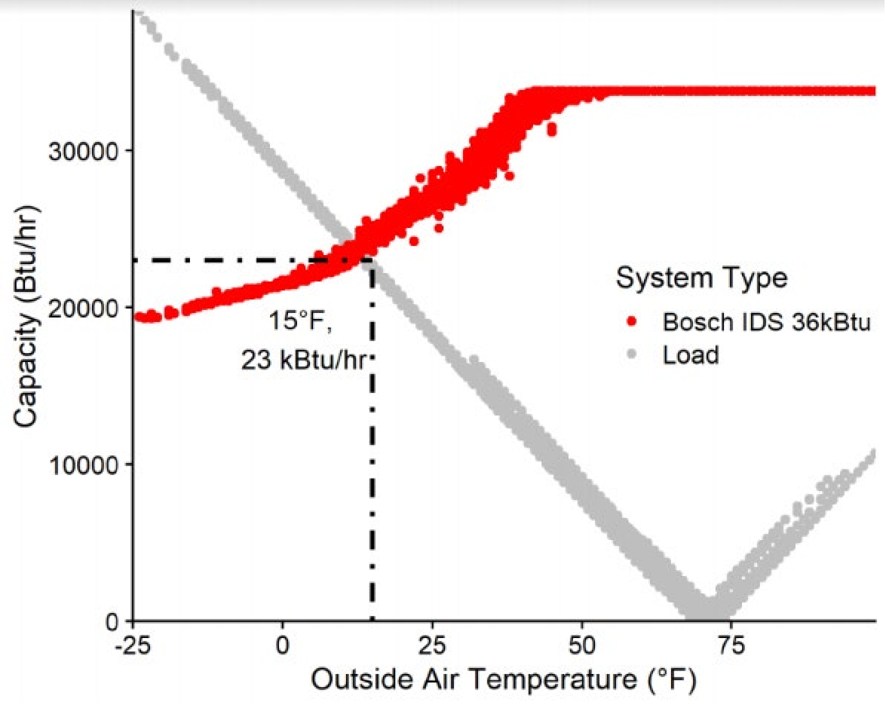
Strategies

- Aggressively pursue cost-effective installations
  - LPG / Electric resistance heating
- ASHP as A/C replacement in NG markets
  - Regular ASHP for warm weather load (cost effective)
  - ccASHP to take “more” heating load (cost neutral)
  - ccASHP to take maximum heating load (capacity limit)
- Envelope upgrades
  - Cost effective traditional measures, e.g. air sealing, insulation (~20% load reduction)
  - High performance envelopes
    - Are there opportunities for Deep Envelope Retrofits (50 – 70% load reduction)?
    - How does the cost-effectiveness calculus change when electrification goals are included (high cost ASHP vs high cost retrofits?)

ASHP and Natural Gas Systems

- ccASHP as an central air conditioner replacement
  - ASHP heats home above 15 °F, furnace below 15 °F



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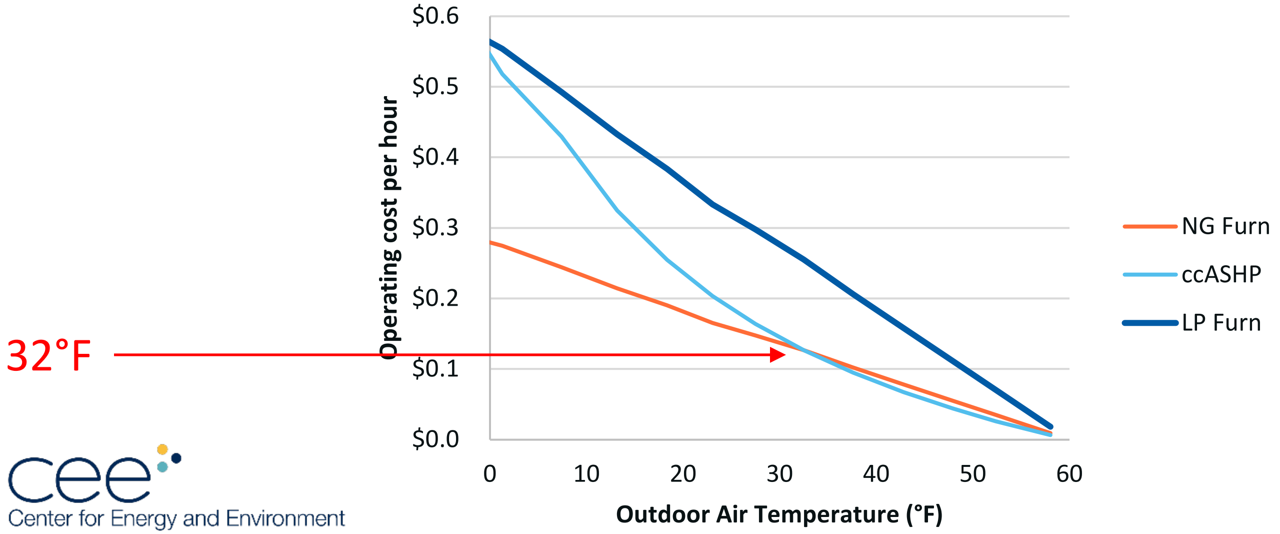
ASHP and Natural Gas Systems

- ccASHP as an central air conditioner replacement
  - ASHP heats home only above 15 °F (capacity limit)

	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



High Performance Envelope Upgrades

- Barriers
  - High capital cost
  - One-off, detail-oriented, and invasive projects
  - Invisible
- Opportunities
  - Siding Replacement ~ 2% stock/yr
  - Windows/Roofing ~ 5/6% stock/yr
  - Remodeling ~ $350 billion/yr
  - Incorporating operating costs into market valuation
- Streamline design work & focus on integrating measures at low incremental cost to non-energy projects
  - Exterior insulation
  - Upgraded windows
  - Advanced air sealing

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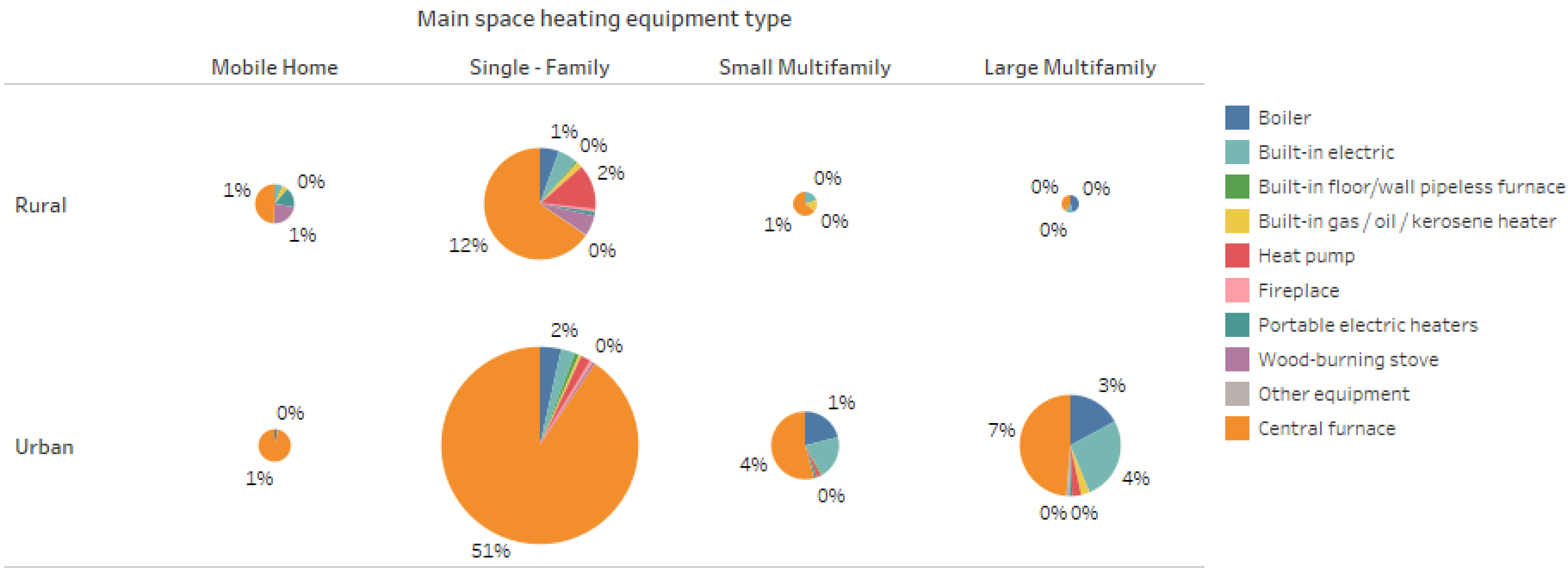
What are the market opportunities?



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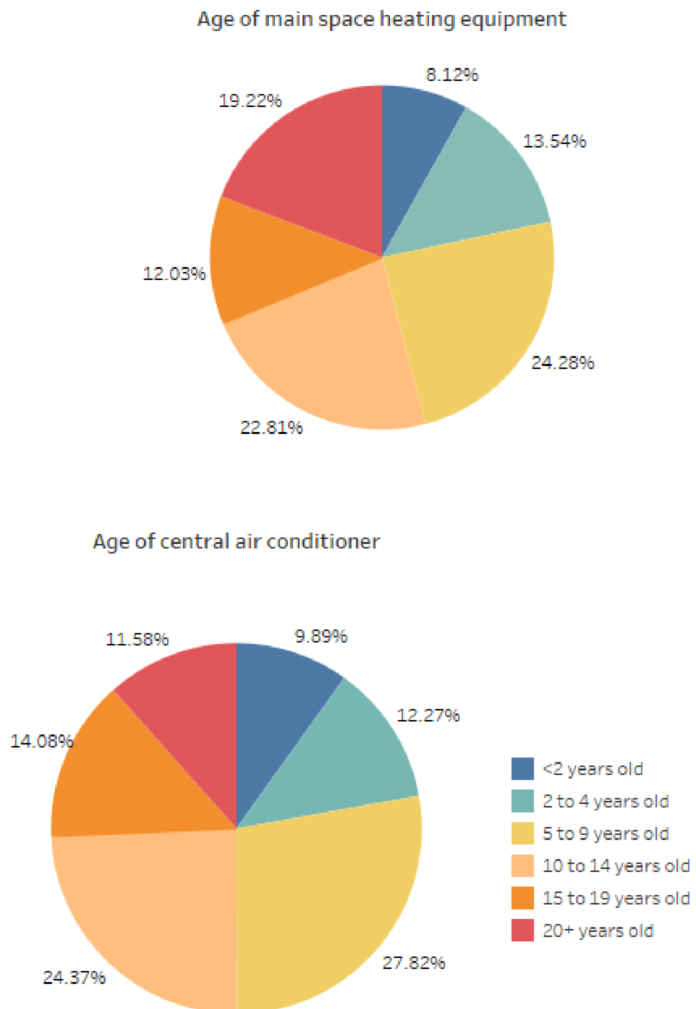
When are the timing opportunities?



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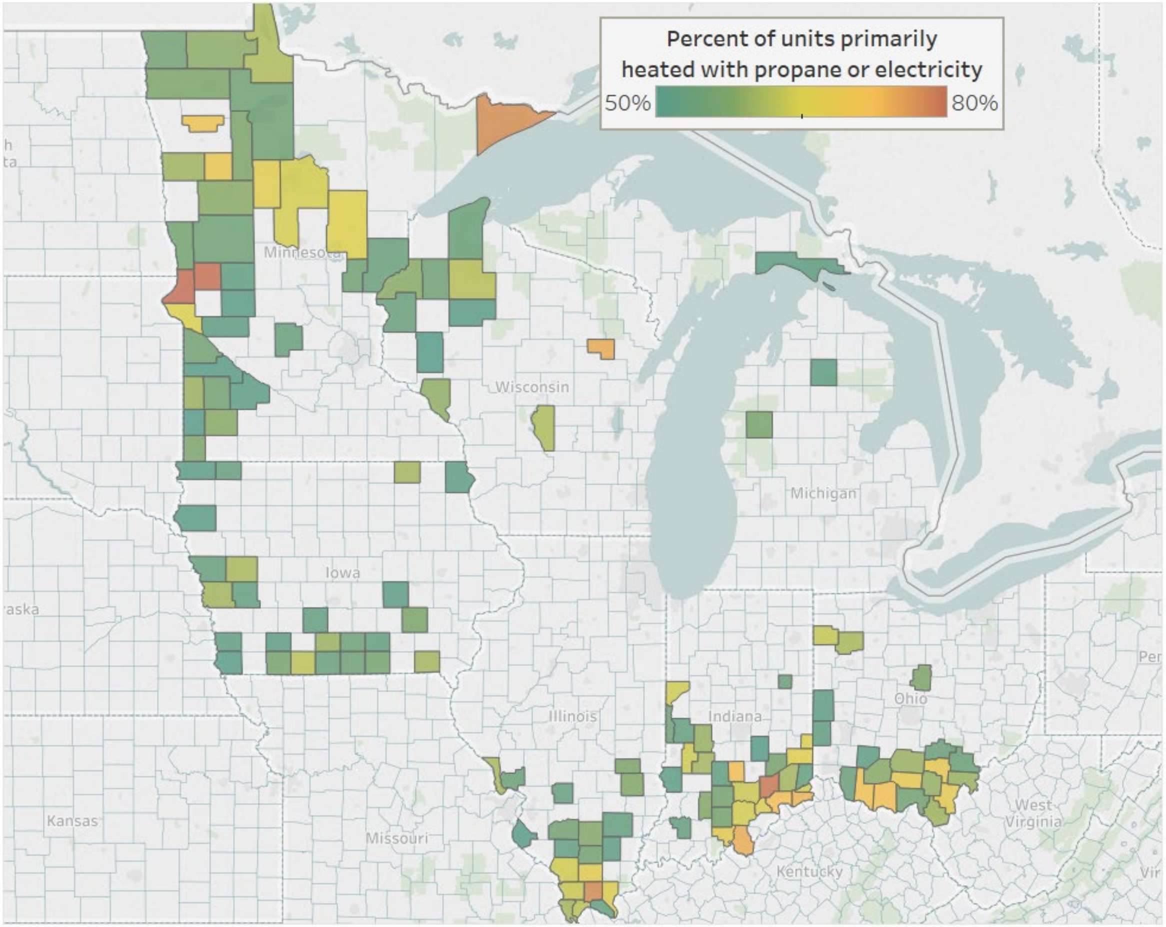
Where are the economic opportunities?



Additional Research Questions

- What is the scale of winter peak demand changes across the region, and what are effective strategies to manage that peak? Similarly, what are cooling savings and peak demand reductions from summer air conditioning?

- What are equity considerations around the cost distribution of a wholescale transformation, such as stranded gas assets?

- What type of workforce transformation initiatives are needed to reach scale?

Conclusion

- Recognize & work within current equipment & market limitations
  - Equipment cost/specifications
  - Weather/Housing stock
- Avoid the barriers we can't overcome in favor of those we can – chase the low hanging fruit
  - Replace ER/LPG heat
  - Emphasize working with NG systems, not displacing them
- Multidisciplinary problem that needs collaboration
  - High performance envelopes, market transformation, & roadmap efforts

THANK you

Josh Quinnell

jquinnell@mncee.org | 612.244.2437

Agenda

9:00 Welcome and Introductions

9:15 Discussion on Factors to Evaluate Decarbonization Options

9:45 Presentation and Q&A: Midcontinent Power Sector Collaborative

11:00 BREAK

11:15 Presentation and Q&A: Opportunities and Challenges for Air Source Heat Pumps in a Cold Climate

<u>12:00 LUNCH</u>

12:45 Discussion of Opportunities and Challenges for Air Source Heat Pumps in a Cold Climate

1:30 Discussion of Electrification

2:30 ADJOURN

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Opportunities and Challenges for Air Source Heat Pumps in a Cold Climate

Joshua Quinnell, Center for Energy and Environment

Alex Haynor, Center for Energy and Environment

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Discussion on Electrification

Virtual Breakouts 15 mins (4-5 people per room):

- What conclusions are you drawing about this technology?
- What are your remaining questions?
- What do you think are the key challenges and opportunities?

Full Group Discussion

- Build a list of collective conclusions, remaining questions, challenges, and opportunities.
- Ask and answer any clarifying questions around what different breakout groups discussed.
- Refine the collective list to identify the TOP conclusions, questions, challenges, and opportunities.

Decarbonizing Minnesota’s Natural Gas End Uses

Meeting 7 – Exploring Technologies Part II

June 12th, 2020

Via Zoom

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