ENVELOPE UPGRADES ESSENTIAL FOR COLD CLIMATE ELECTRIFICATION?

Josh Quinnell

Sr Research Engineer | 612.244.2437 jquinnell@mncee.org



Decarbonizing the Building Sector

- Amazing attention nationally and in cold climates like Minnesota
 - Near term retirements of all major coal plants
 - Largest utility 85% carbon free by 2030
 - Electric appliances installed today may have order of magnitude reduction in emissions in their lifetime
- Space heating loads loom above all other building loads in CZ 6+
 - Space heating is 60% to 80% of the site energy in 1.6 million MN SF homes
 - ccASHPs are great and will save us 50%+ site energy
 - More important than all other building electrification measures combined by 2X +



Old homes of MN: 73% of homes built before 1990

Climate Zones 6 & 7





Northwest (Thief River Falls)

- ~ 120K (69%)
- -22 °F / 9700

Northeast (Duluth)

- ~200K (67%)
- -17 °F / 9000

Southwest (Worthington)

- ~160K (79%)
- -11 °F / 7700

Southeast (Minneapolis – St. Paul Metro)

- ~1.1M (74%)
- -11 °F / 8400

MN Single Family Loads (<1990)</p>

- 25% less the 3-ton
- Median load of ~44 kBtu (~4-ton)
- 75% less the 5-ton





ASHPs for Cold Climate Heating Loads

3 & 5 Ton ccASHPs

Reference – Mid Tier

- Strong performance
- Medium-high capacity maintenance

Capacity Champ – High End

- Strong performance
- Best capacity maintenance
- Fictional trans critical CO₂ Future Potential
 - Very High Performance
 - 90% capacity maintenance at -25 °F





Problem?

- Current systems cannot meet design loads
- High-End 5-Ton
 - Meets design load in 41% of homes built before 1990
- Other ccASHPs meet load on small fraction of older homes
- Future widgets may save the day?





Auxiliary Electric Power

No problem electric resistance is cheap!

Supplement low ASHP capacity

Rarely need it, anyway

Can supply 3 – 15 kW of *auxiliary resistance heating* depending on the ccASHP and existing home





Peak Load

- Today best case 8.7 kW median peak
 - ~2-4X typical CAC cooling peak?
- tCO₂ ~6 kW?
- Still undersized for peak conditions
 - Cold snaps
 - Polar vortices

Annual coldest periods:

Region	1 hr	8 hr	1 day
Northwest	6%	2%	-4%
Northeast	3%	0%	-8%
Southwest	11%	8%	-4%
Southeast	17%	12%	9%





Intermission - Recap

- ccASHPs bring promise of decarbonizing biggest building end use
- The majority of MN building stock will need *substantial auxiliary* or *very substantial backup* electric resistance even with todays best and biggest residential heat pump
- Even fictional high-capacity, high-performance heat pumps will drive unprecedented winter system peaks
- Not accounting for true peak 1h, 8h, 1day, or polar vortex type weather



It's Always Been About the Envelope

- Aggressive weatherization
 - Higher standards
 - Larger scale efforts
- High Performance Envelope Upgrades
 - Continuous exterior insulation
 - Recladding, change of occupancy, flipping
 - Window upgrades
 - Replacements & New





Aggressive Weatherization Savings



Center for Energy and Environment



Pg. 1

Envelope Improvements Show Results





One More Step

- Continuous Exterior Insulation
- U = 0.32 Windows
- Majority of building stock can be electrified with today's reference ccASHPs
- Savings further improved as tight buildings enable energy recovery
- Peak loads reduced to ~2.8 kW to 4.6 kW





Some Notes About Costs

Upgrade	Cost \$	Inc Cost \$	(40 yr) \$	
Furnace w/ CAC	\$6 <i>,</i> 000	-		
Reference 3-Ton	\$8 <i>,</i> 000	\$2,000	\$5,000	
Reference 5-Ton	\$10,000	\$4,000	\$10,000	
Capacity Champ 3-Ton	\$10,000	\$4,000	\$10,000	Cost effective ? In some cases
Capacity Champ 5-Ton	\$12,000	\$6,000	\$15,000	
Fictional CO ₂	\$12,000	\$6,000	\$15,000	
Aggressive weatherization	\$3 <i>,</i> 900	\$3,900	\$3,900	Cost effective across 1.1m building stock
+R-10 CEI	\$8,900	\$8,900	\$8,900	Almost cost effective
+ U=0.32 Windows	\$16,100	-	\$21,600	Cost effective ? In some cases





- ccASHPs are the second most important cold climate building decarbonization measure
- Upgrading existing building envelopes (~70% of existing MN single family homes) is the most important step & *much is cost effective today*
- Dual fuel applications with natural gas and existing efficiency opportunities are an amazing opportunity
- They will buy (1) product lifetime (<16 years) to develop cheap magical widgets or sort out envelopes and manage peak load





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