

Air Source Heat Pumps in Minnesota

Low Cost Hybrid Heating in a Cold Climate

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CERTS Conference | St. Cloud, MN

February 21, 2013

GREAT RIVER ENERGY®

A Touchstone Energy® Cooperative

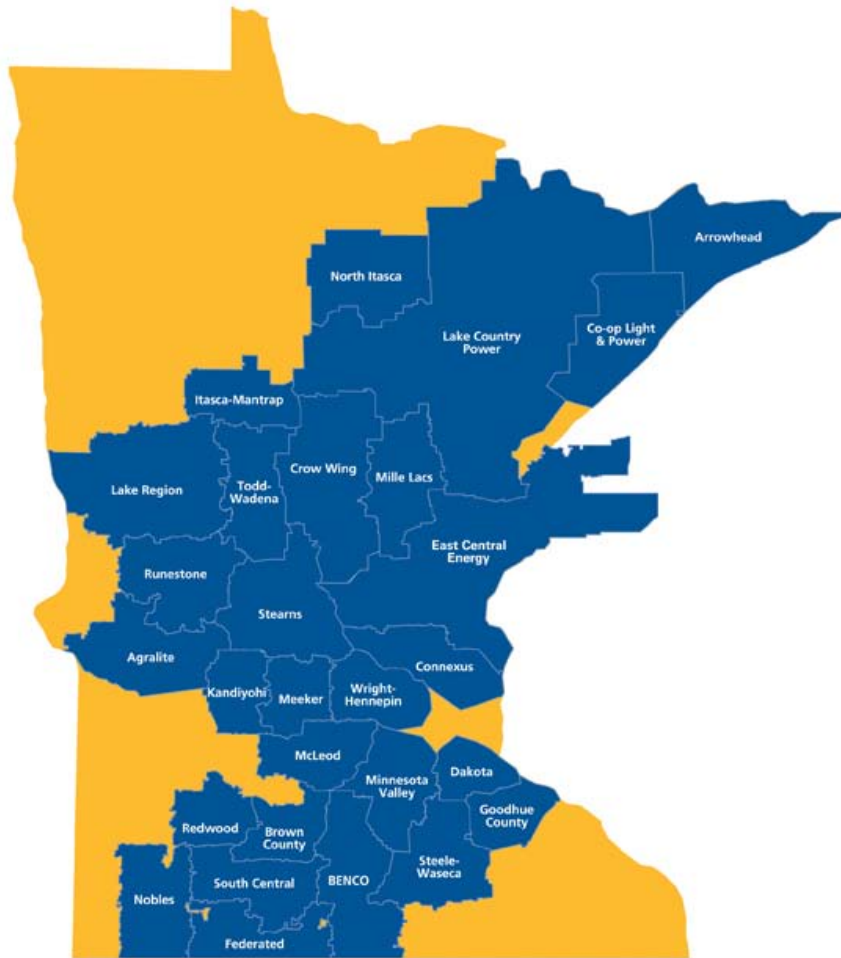


Agenda

- Overview of Air Source Heat Pump Technologies
 - History, General
- Comparison of Operating Costs to Other Space Heating Technologies
 - Electricity, Natural Gas and Delivered Fuels
- Cold Climate Performance
 - Do ASHP Technologies work in Minnesota?
- Electric system compatibility of ASHPs
- Future Technology Developments
 - Will the performance of ASHPs improve over time?



Great River Energy



- Not for profit generation & transmission cooperative providing wholesale electricity to 28 distribution cooperatives in Minnesota and into Wisconsin.
- Second largest utility in Minnesota, our member cooperatives distribute electricity to families, farms and businesses serving almost 1.7 million people.



Successful Portfolio of EE Programs

- Residential & Commercial Lighting
- Energy Efficient Appliances
- Commercial & Industrial Efficiency Programs
- Quality Installed Air Conditioning Systems
- Quality Installed Air Source Heat Pump Systems
- Ground Source Heat Pumps
- Agricultural Programs
- Heat Pump Water Heating
- Electric Thermal Storage Water & Space Heating
- Load Management Programs



Heat Pumps Generate Significant Energy Savings

Program	Energy Savings (kWh)	Percent of Total Energy Savings
Residential Lighting	29,638,551	19.8%
Comm. Lighting	20,134,718	13.4%
GSHPs	17,724,829	11.8%
Appliances	15,284,509	10.2%
ASHPs	5,978,073	4.0%
Air Conditioning	1,630,582	1.1%
Load Management	804,584	0.5%
Total	91,195,846	60.8%

- Heat Pump Technologies account for nearly 15% of our annual energy savings achievements.
- These savings are largely based on energy savings over electric resistance heating.



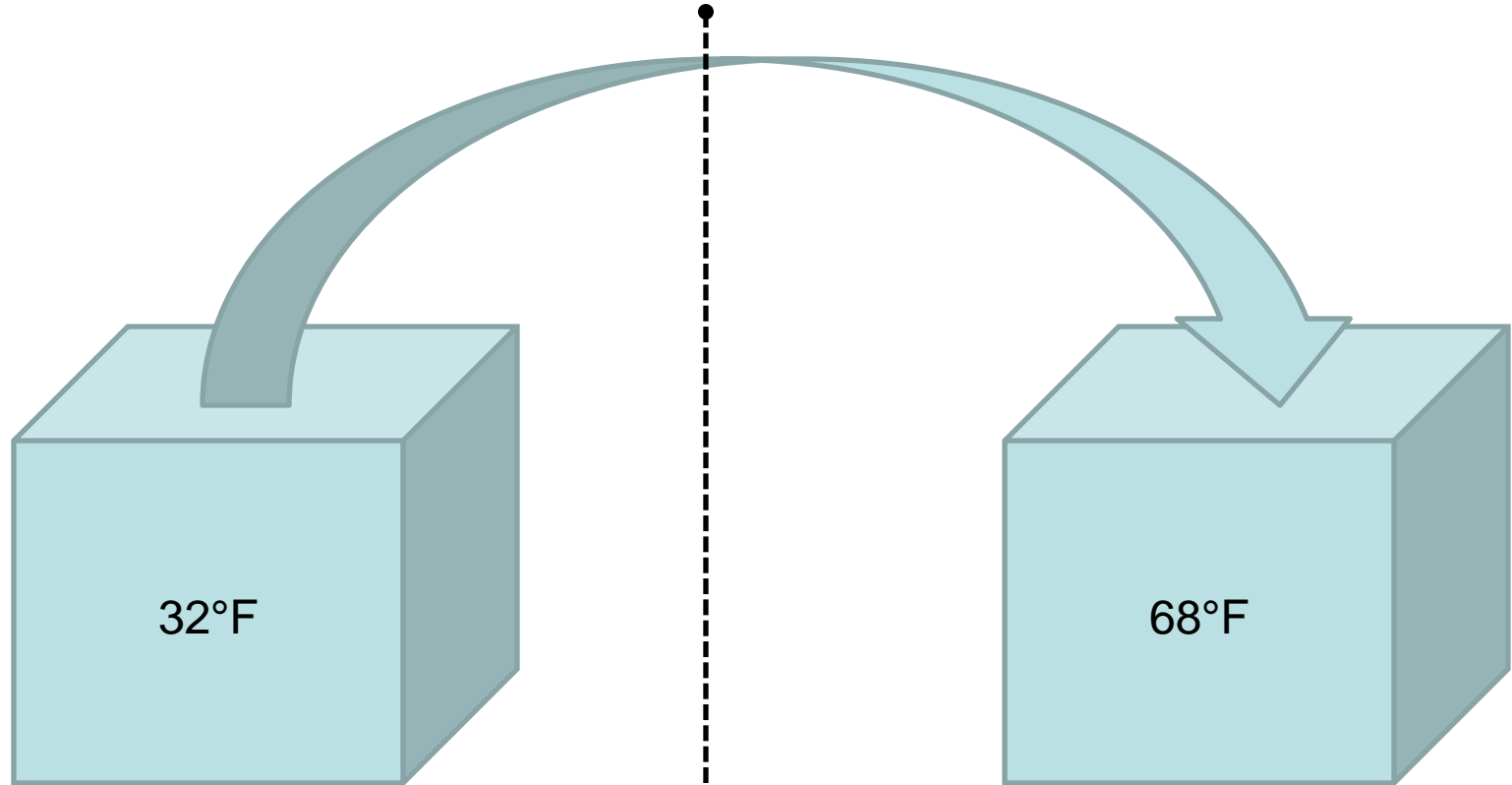
How many of you have an air source heat pump?



- Air conditioners
- Refrigerators
- Freezers
- Dehumidifiers



How does an ASHP “Pump” Heat?



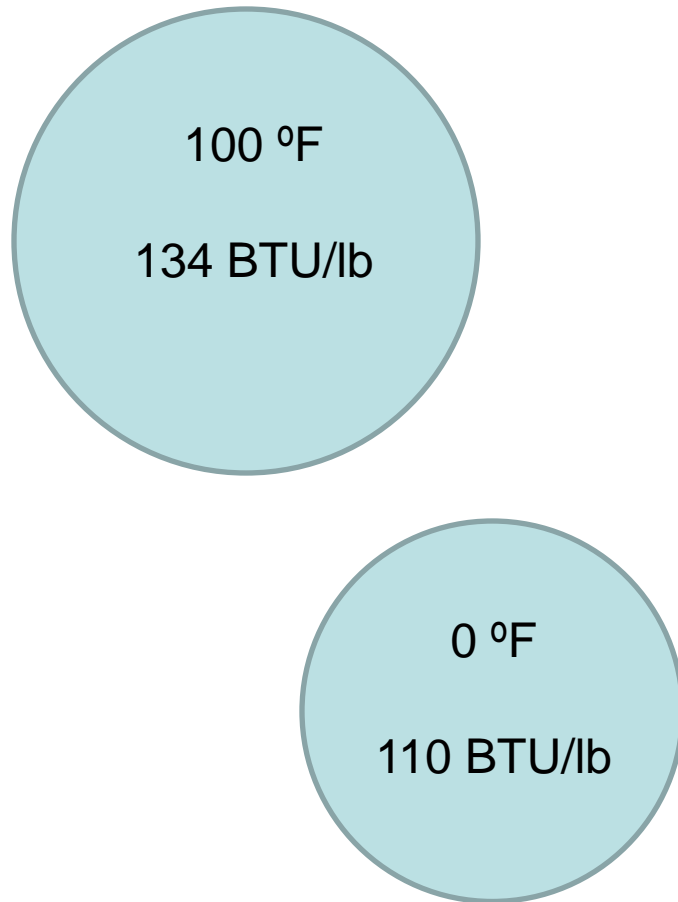
Heat Pumps are Analogous to Pumps



- Pumps move fluids from one place to another, they do not create the fluid.
- Pumps are incredibly efficient at doing this, but we refer to their ability to do work in terms of capacity and efficiency.



There is Heat in “Cold” Air

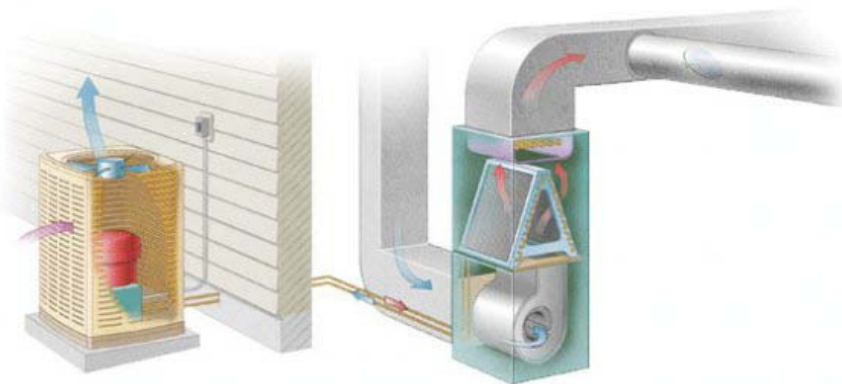


- At 0°F one pound of dry air contains approximately 110 BTUs.
- At 100°F one pound of dry air contains approximately 134 BTUs.
- At -460°F one pound of dry air contains 0 BTUs

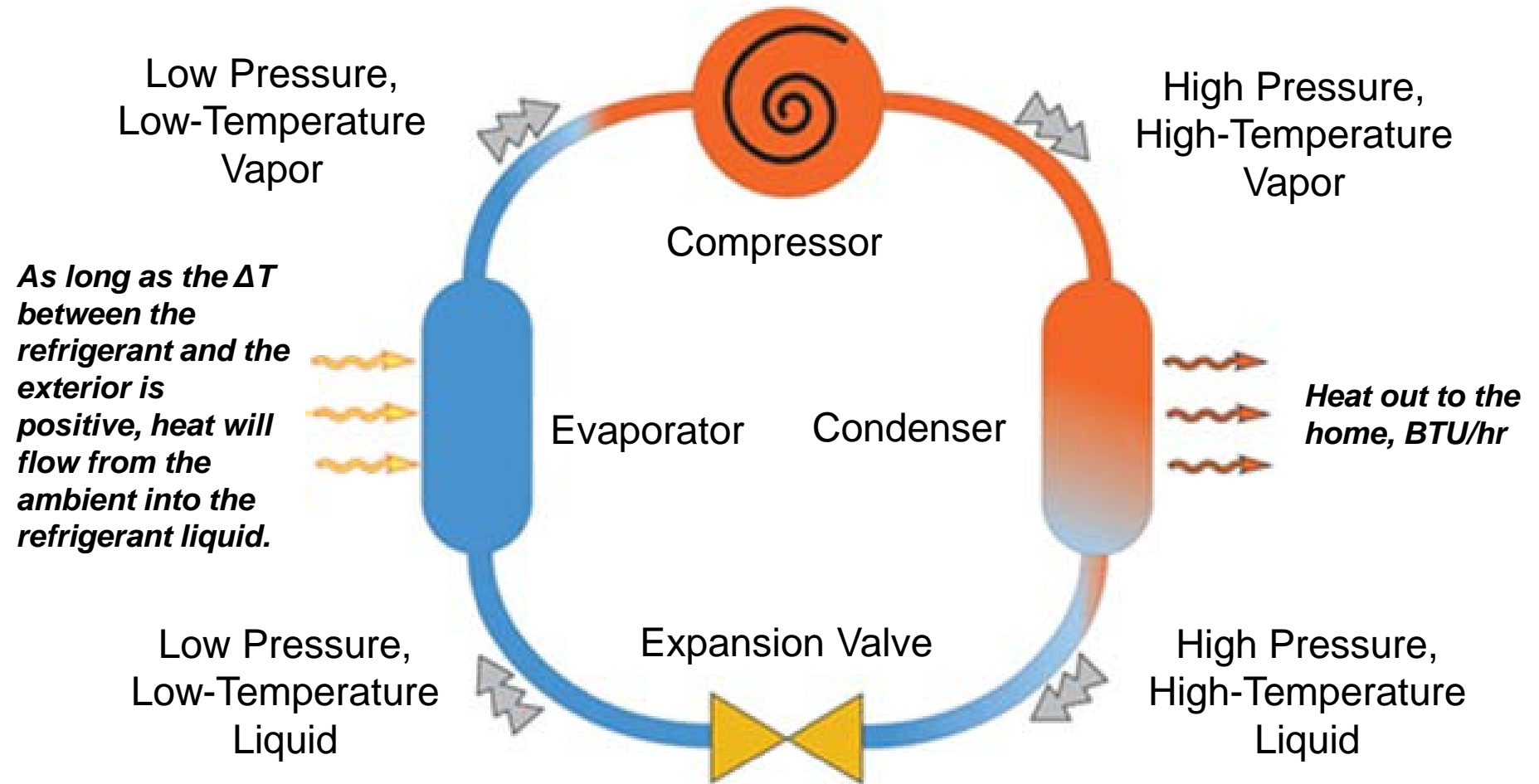


Heat & Heat Pumps

- Heat flows naturally from higher to lower temperatures.
- A heat pump does not generate heating or cooling energy.
- Heat pumps move heat from lower to higher temperatures, using a small amount of high quality drive energy.
- This is enabled by the vapor compression cycle.



Vapor Compression Cycle



Bin Temperature Data

Duluth, MN

Bin	Total Hours
90 95	6.7
85 90	28.6
80 85	86.6
75 80	237.7
70 75	317.3
65 70	494.4
60 65	717
55 60	660
50 55	709.4
45 50	612.5
40 45	531.3
35 40	628.3
30 35	783.1
25 30	635.5
20 25	568.3
15 20	411.6
10 15	351.3
5 10	279.6
0 5	216.1
-5 0	172.3
-10 -5	136.5
-15 -10	84.6
-20 -15	55.5
-25 -20	25.2
-30 -25	9.6
-35 -30	1.8
-40 -35	0.1

79% of all heating hours occur when ambient conditions are above 15°F

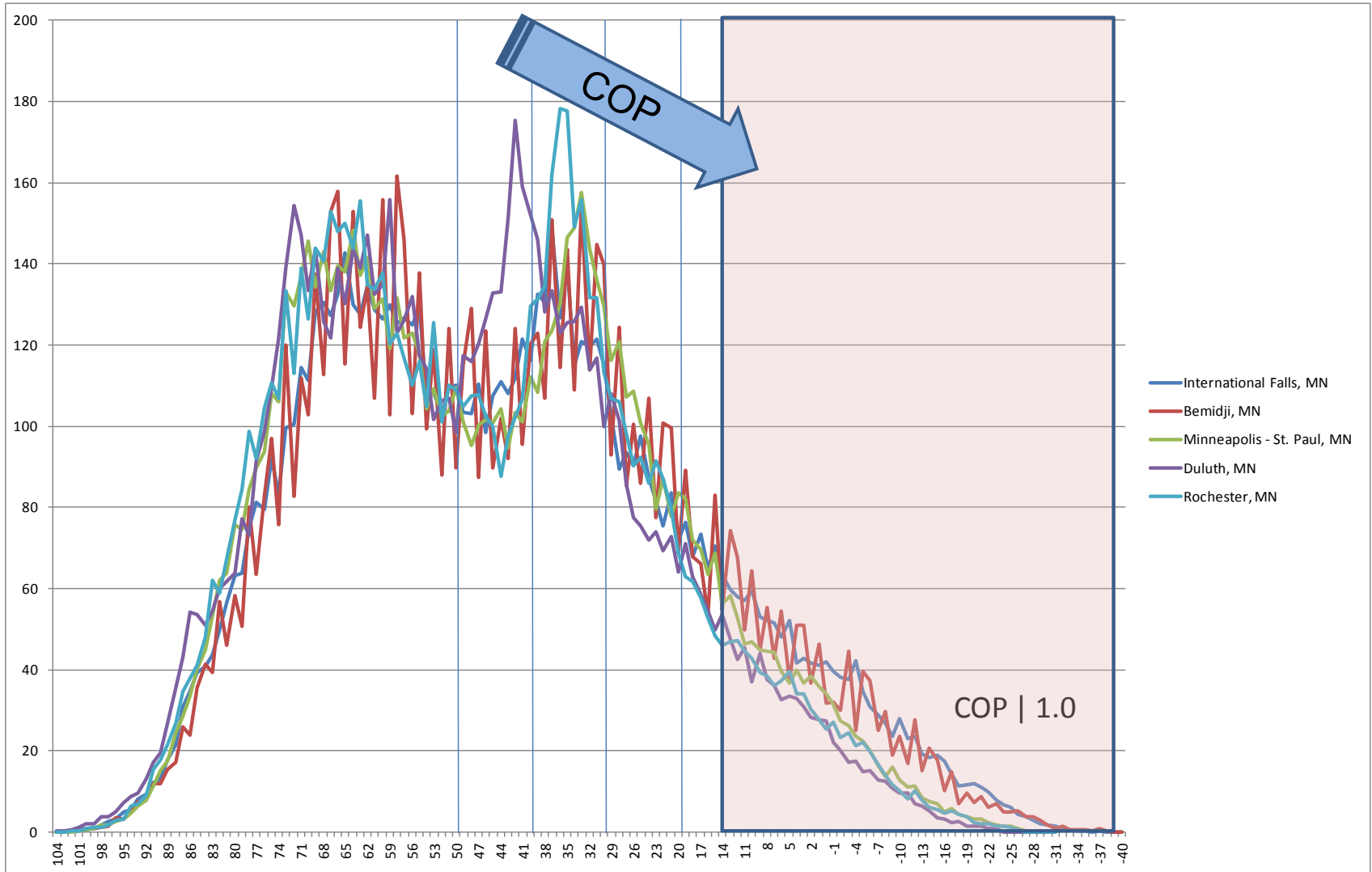
Rochester, MN

Bin	Total Hours
95 100	4.3
90 95	21.3
85 90	90.8
80 85	223.8
75 80	386.4
70 75	547.9
65 70	663.1
60 65	750.4
55 60	649.6
50 55	572.8
45 50	532.4
40 45	495.6
35 40	604.1
30 35	822.9
25 30	589.8
20 25	458.4
15 20	360.1
10 15	251.8
5 10	212.3
0 5	181.1
-5 0	133.9
-10 -5	104.3
-15 -10	54.5
-20 -15	29.4
-25 -20	15
-30 -25	4.5
-35 -30	0.2

81% of all heating hours occur when ambient conditions are above 15°F

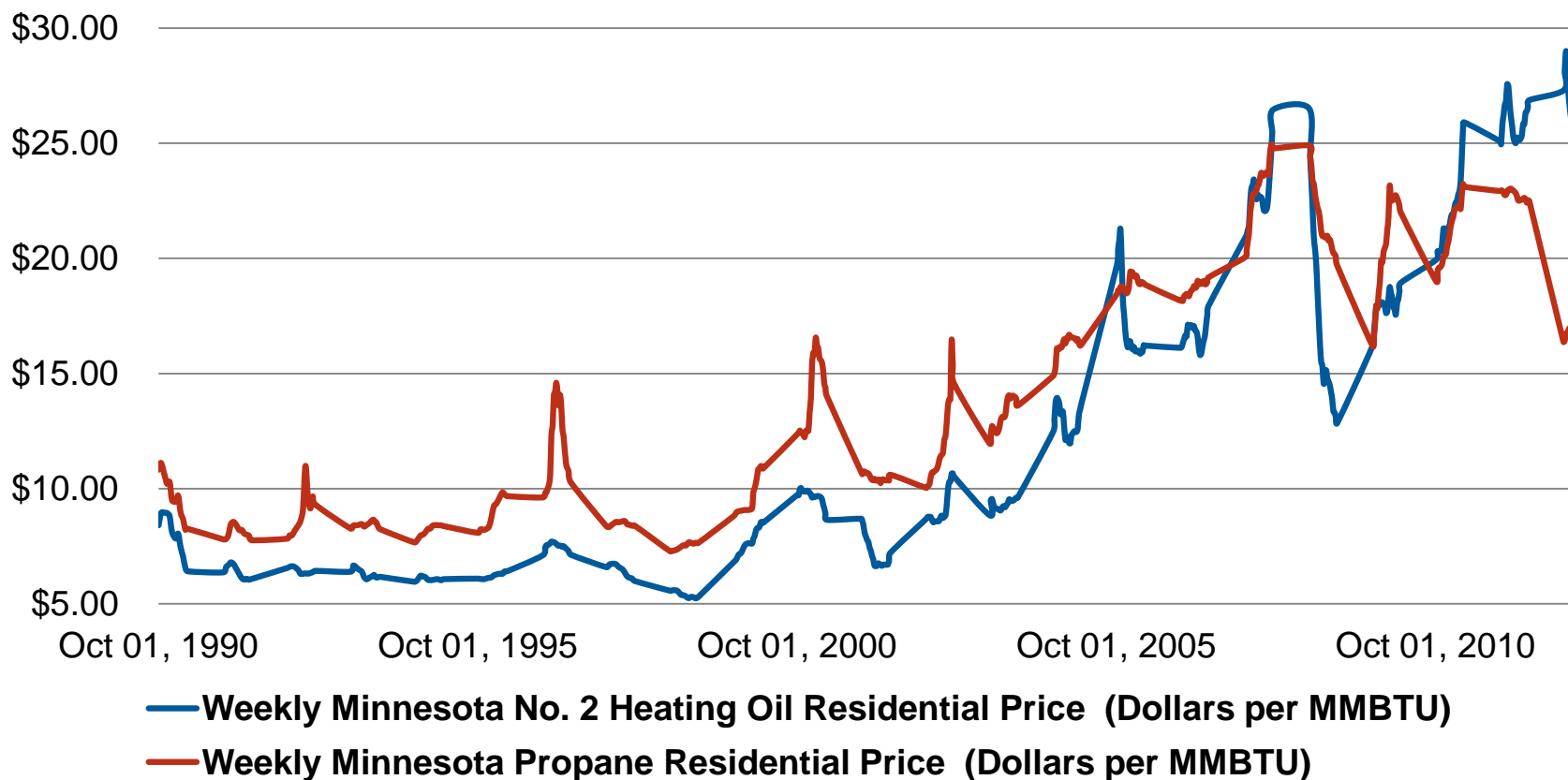


System Performance will Decrease with the Outdoor Temperature



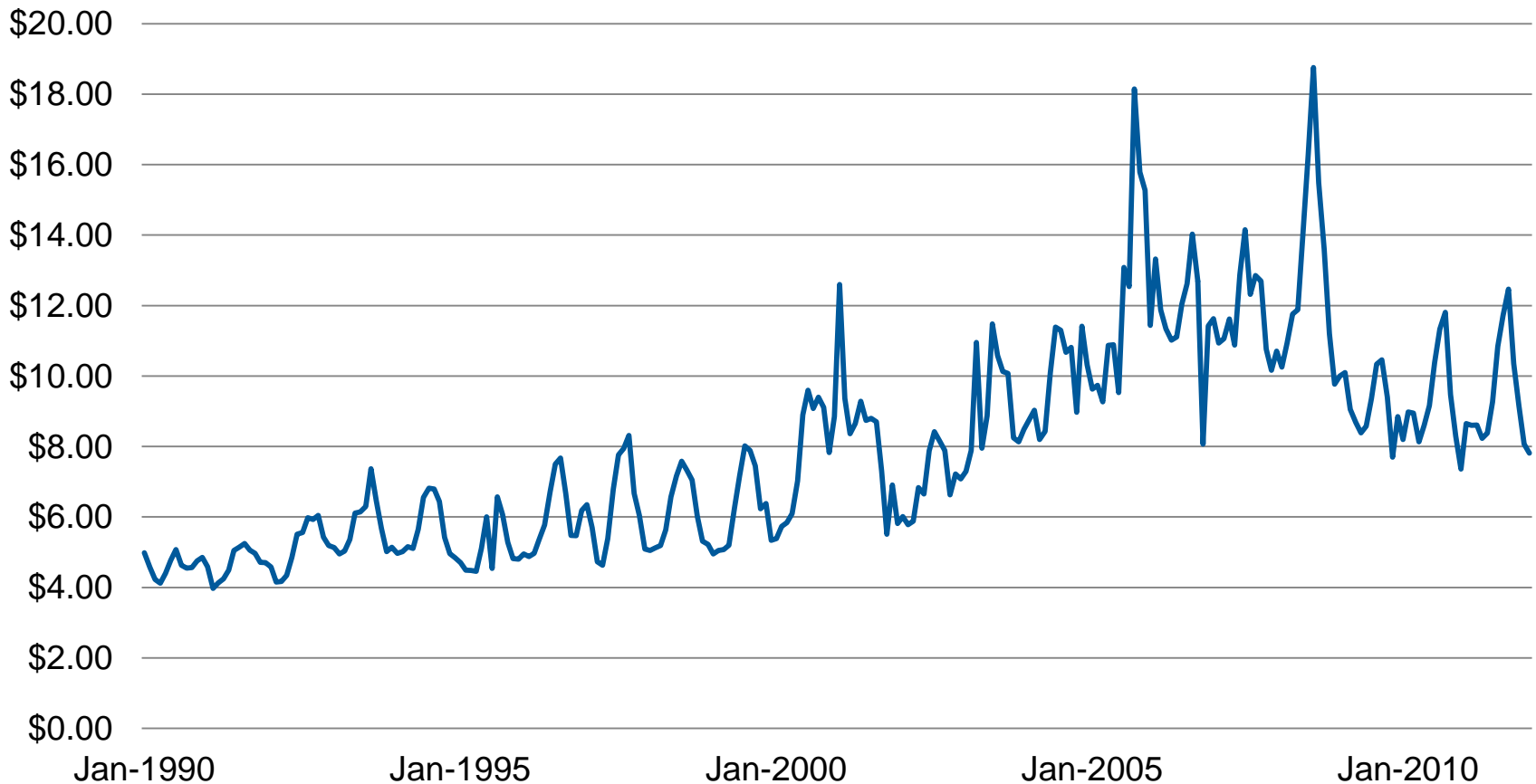
Price Variability of Delivered Fuels

Minnesota Fuel Oil & Propane Residential Price (\$/Million BTUs)



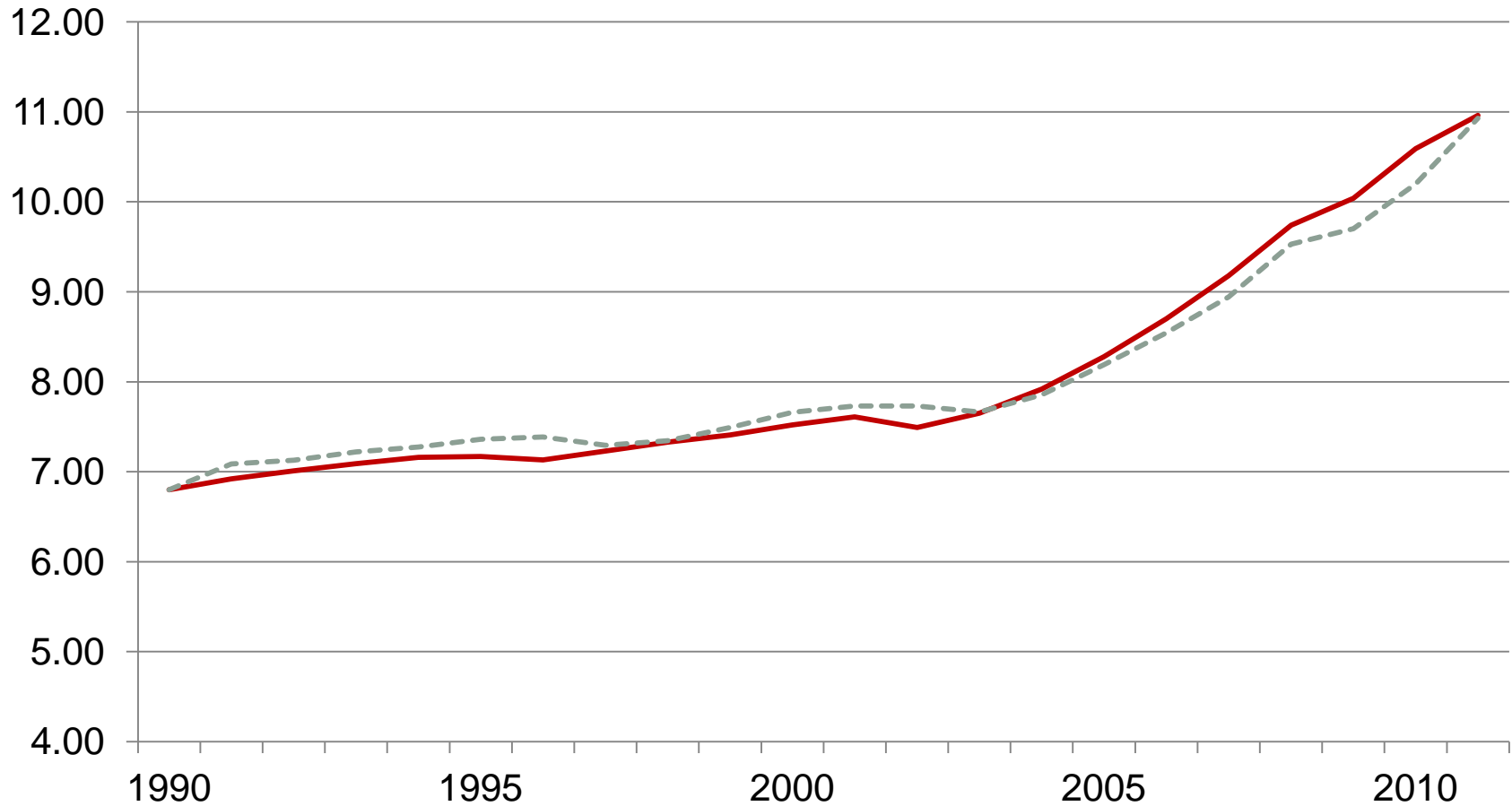
Price Variability of Natural Gas

Minnesota Price of Natural Gas Delivered to Residential Consumers (\$/Million BTUs)



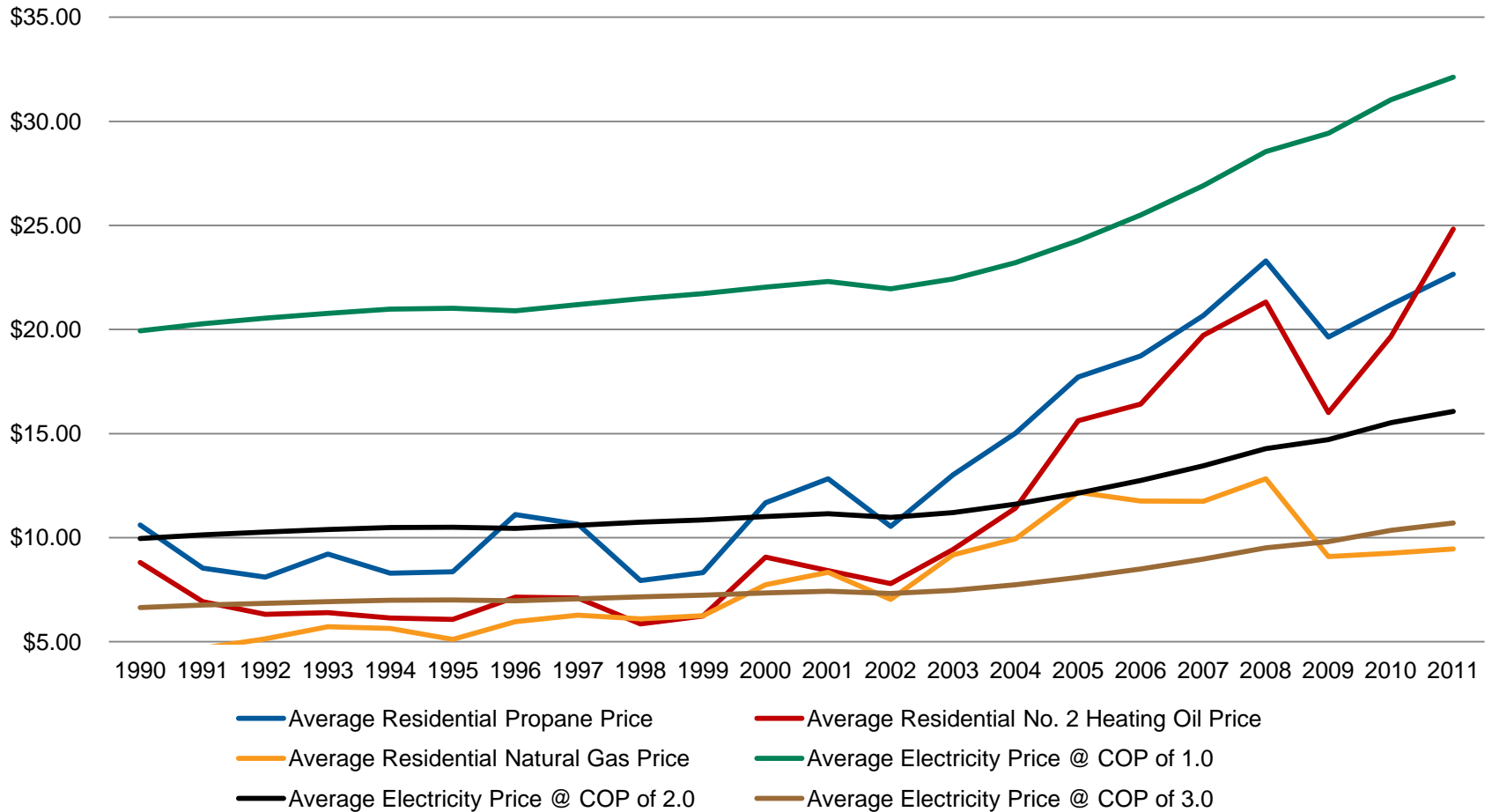
Price Variability of Electricity

Residential Price (Cents per kilowatthour)



Fuel Price Comparison

Fuel Price Comparison (\$/MMBTU)



Dual Fuel Electric Rates

- Dual Fuel Rates are Offered by many utilities.
- Example | Mille Lacs Electric Cooperative
 - Dual Fuel rate of 5.5¢ per kWh (3412 BTU/kWh)
 - Comparable to:
 - \$1.48 per gallon of propane (91,500 BTU/Gallon)
 - \$1.61 per therm of natural gas (100,000 BTU/therm)
 - \$2.24 per gallon of fuel oil (138,700 BTU/Gallon)
 - These prices reflect 100% efficiency



Comparing Fuel Options using an “Assumed” Home

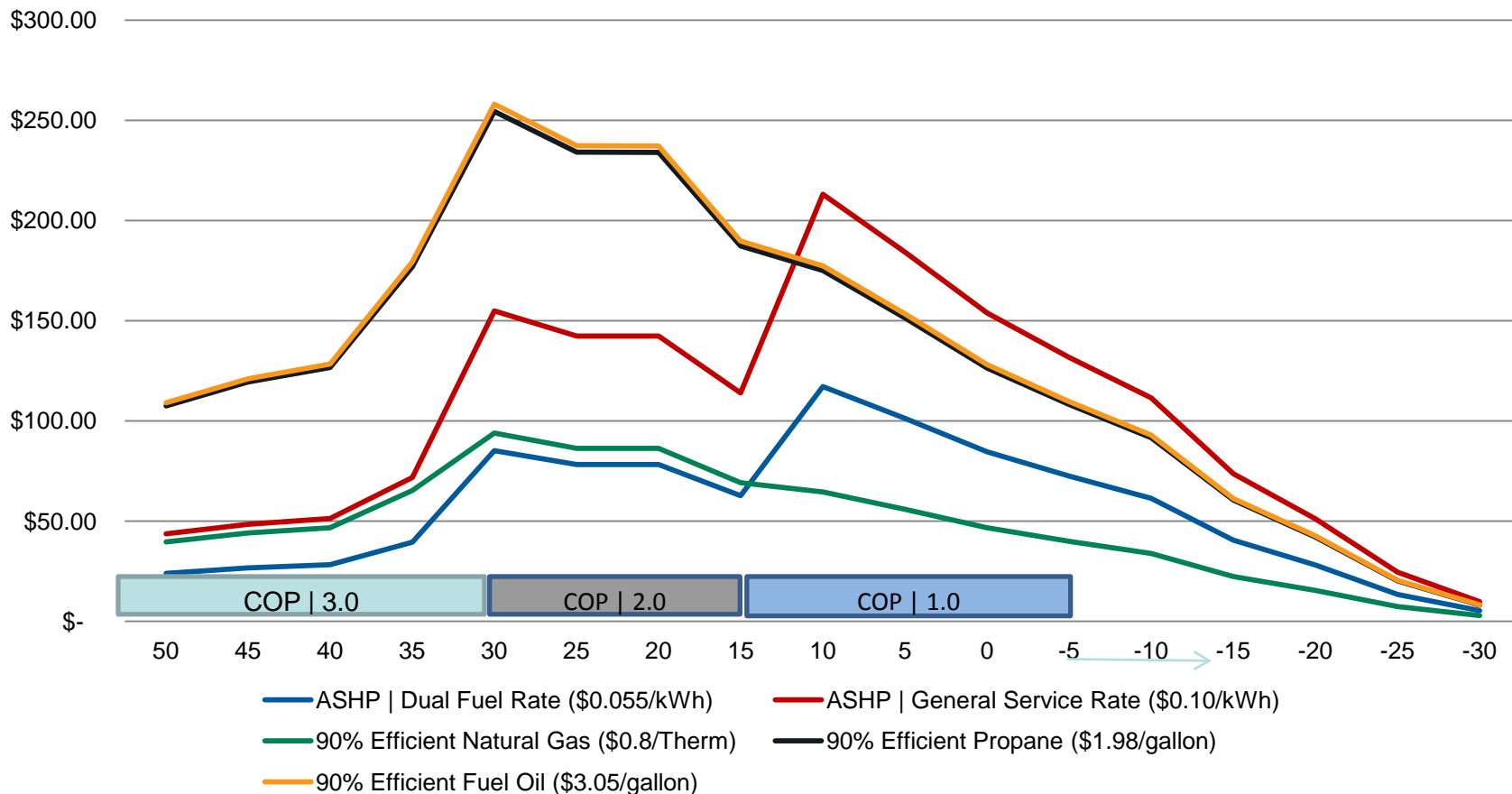


- 3,000 Square Foot
- 3 ton heat load | -30°F
- Generalized heat loss
R 8.3 | U 0.12
- Temperature Bin Data
Duluth, MN
- Setpoint | 70°F



Heating Cost Profile

Duluth, MN Temperature Bins
70°F Set Point Temperature



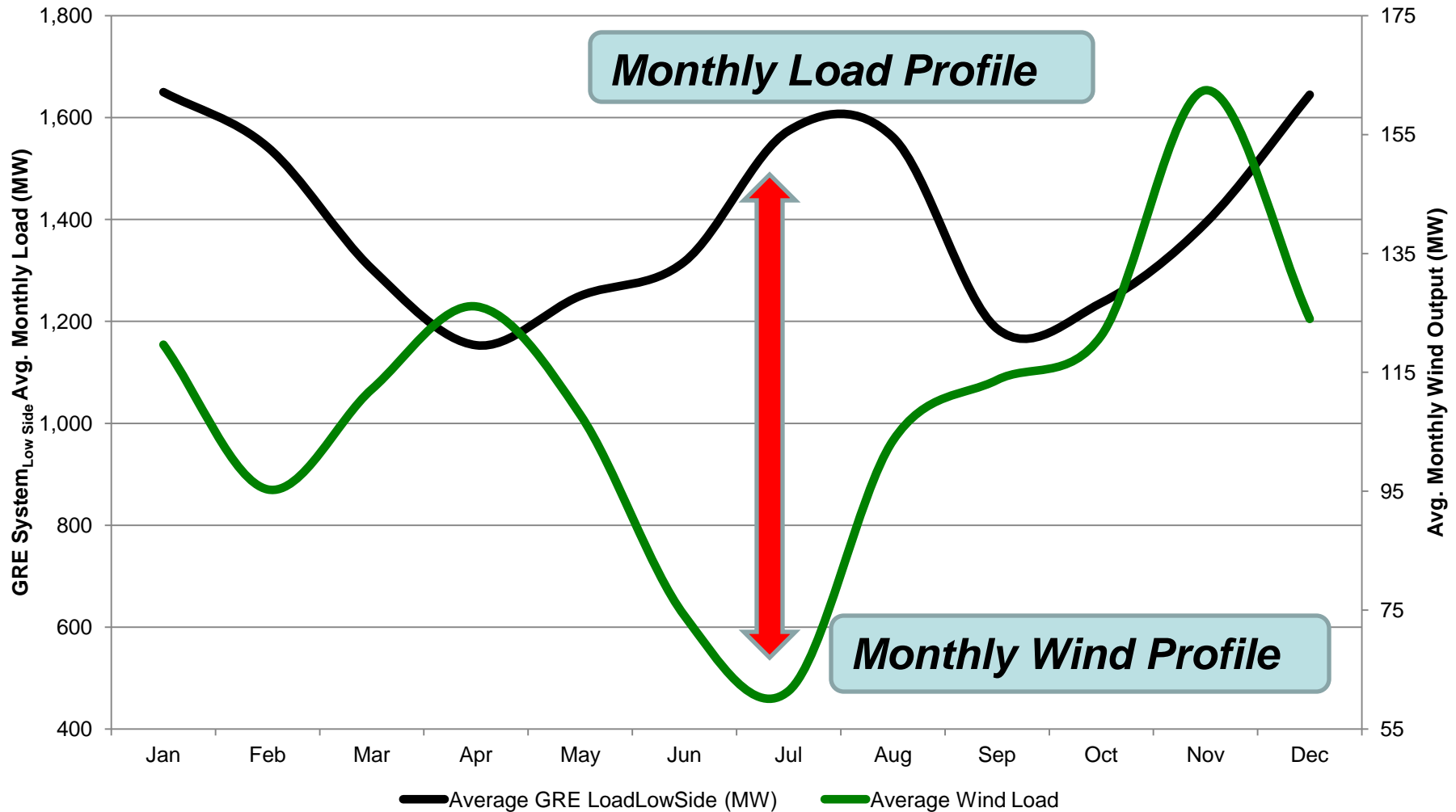
Annual Heating Costs

- ASHP
 - Dual Fuel Rate (\$0.055/kWh) - \$950
 - General Service Rate (\$0.10/kWh) - \$1,725
- 90% Efficient Natural Gas (\$0.80/therm) | \$821
- 90% Efficient Propane (\$2.07/gallon) | \$2,225
- 90% Efficient Fuel Oil (\$3.58/gallon) | \$2,255



System Compatibility of ASHPs

Wind output compared to load



ASHP COP Improves Total System Efficiency



40% System Efficiency

COP = 3.0

=

120% End Use Efficiency

Other ASHP Applications

- Ductless Mini-Splits
 - High SEER Values, retrofit applications
- Variable Refrigerant Flow Systems
 - Emerging in the US, efficient heating in cold climates, ambient conditions, very efficient commercial retrofit application
- ASHP tied to supplemental ETS Heating
 - Minnesota Division of Energy Resources
<http://mn.gov/commerce/energy/images/CIP-AirSource-Pump-Report.pdf>



The Future is Bright for ASHPs

- Technologies will continue to develop that improve the cold climate performance of ASHPs
 - Multi-stage compression, variable refrigerant flows, new refrigerants (CO₂) will all improve the overall performance and efficiency of ASHPs.
- ASHPs are complementary to our changing energy systems that include more renewables
- Improvements in Heat Pump Water Heater technologies are naturally transferable to ASHPs



Thank you!

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