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HEAT 2019
HEATING & ENERGIZING AMERICA TRADE SHOW

The Economics & Environmental Performance of Biodiesel vs. Electric Heat Pumps

Today's Presenters:

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NATIONAL BIODIESEL® BOARD

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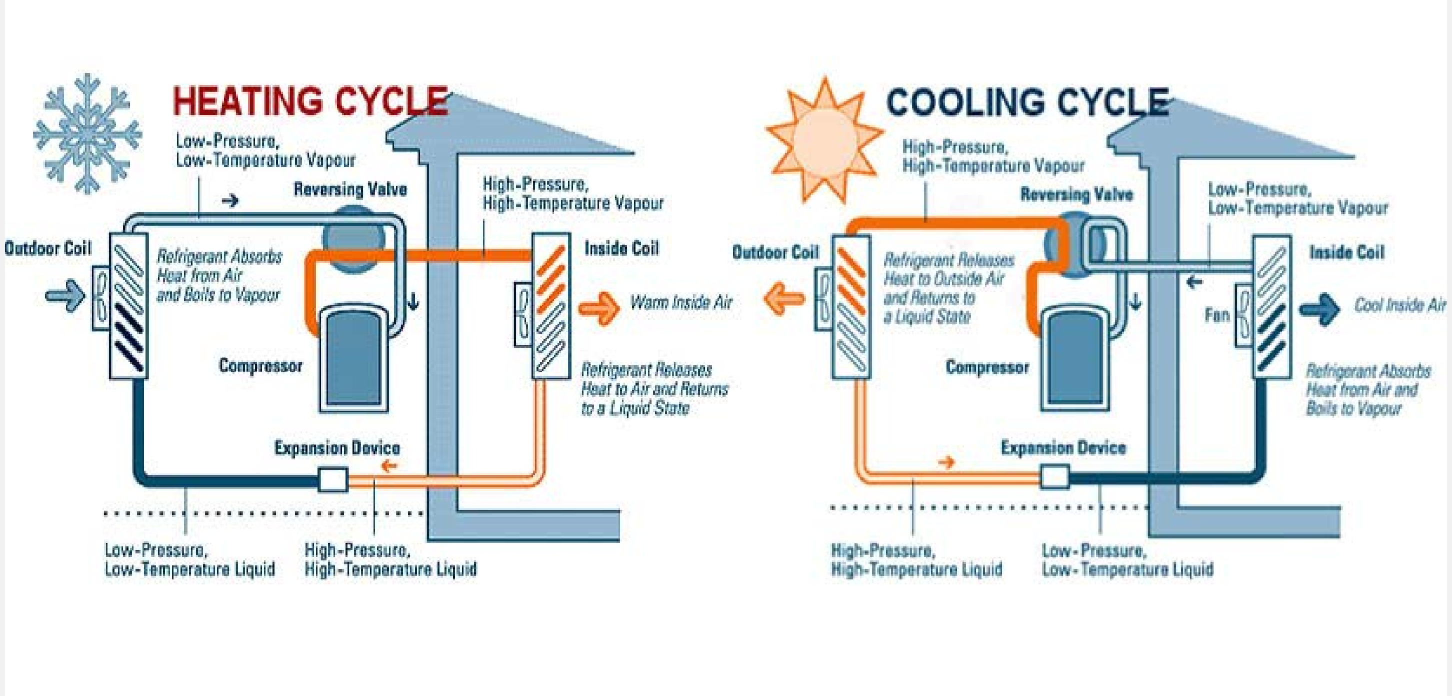
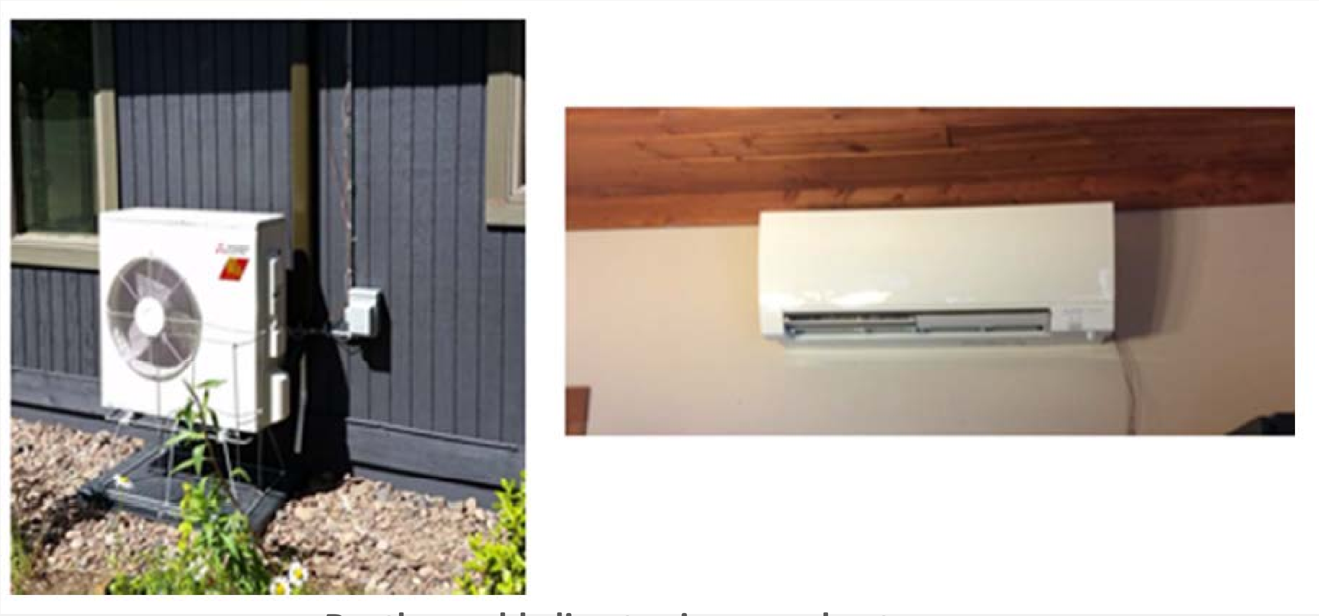
Heat Pump Cycle



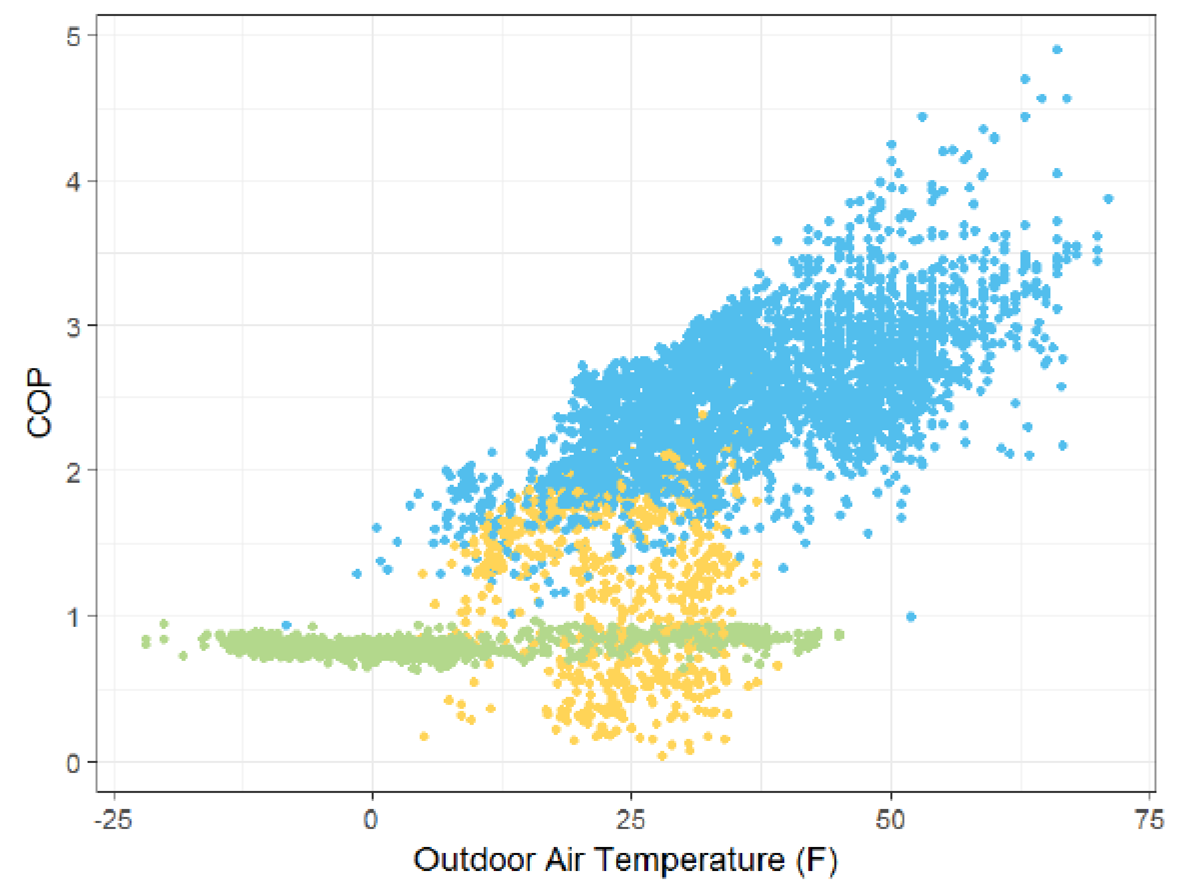
Heat Pump Types

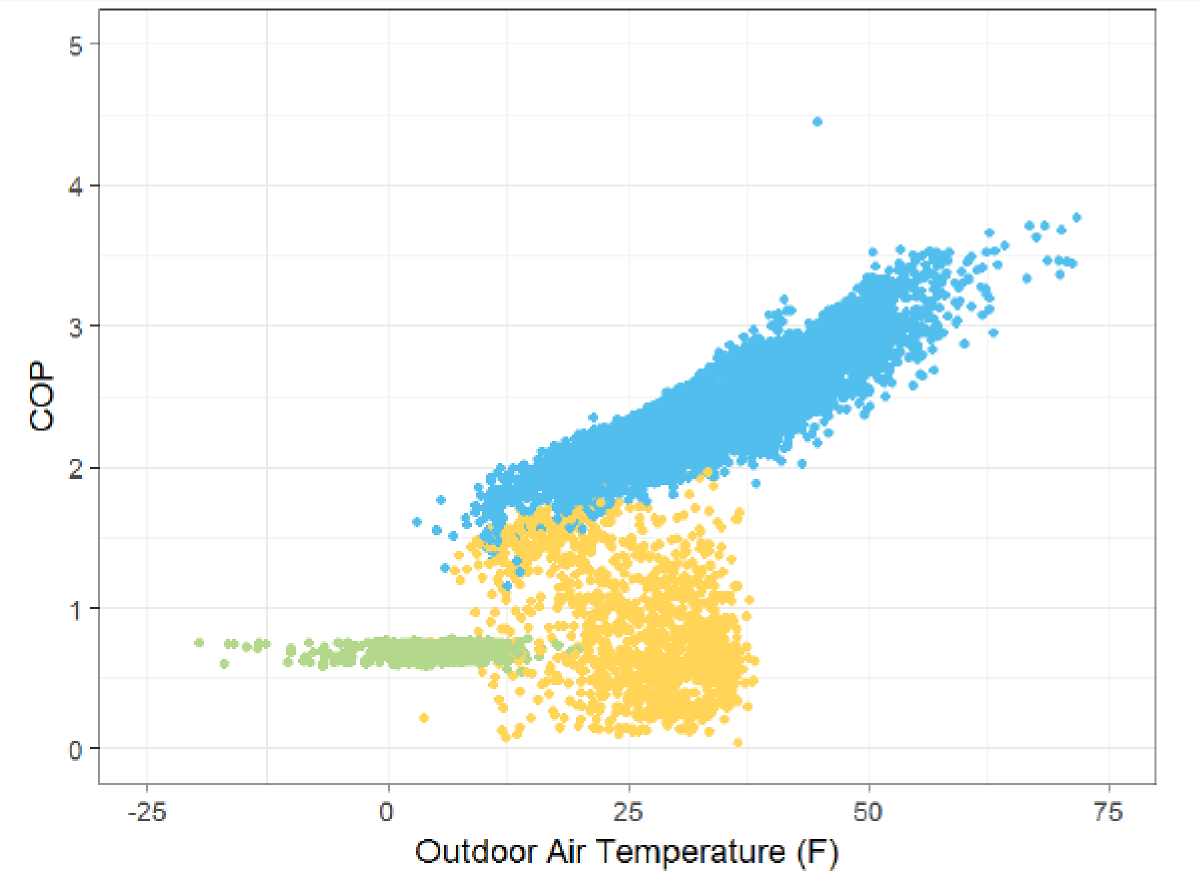
Whole home ducted cold-climate air source heat pump



Ductless cold-climate air source heat pump

Cold Climate Heat Pump Field Test Performance



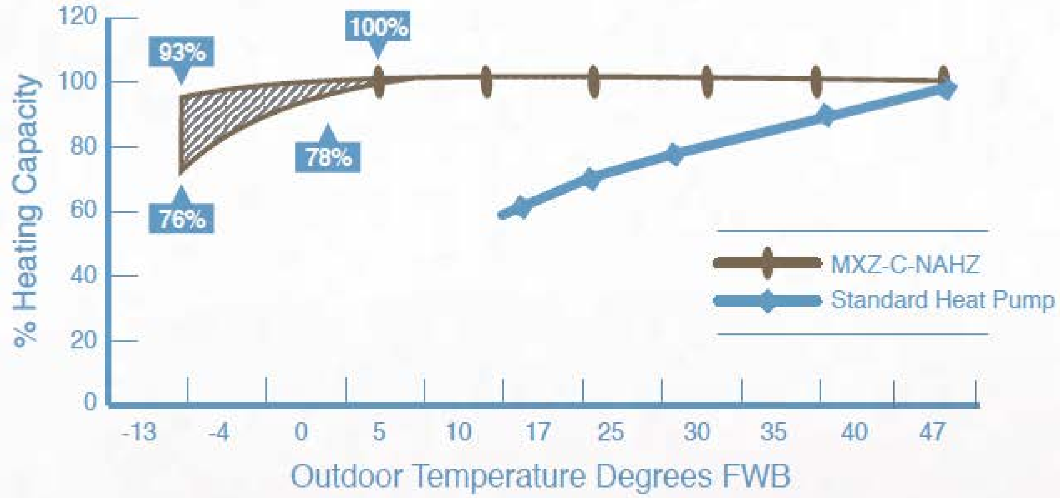


Source: Cold Climate Air Source Heat Pump Field Study, Minnesota Department of Commerce, Division of Energy Resources, 11/1/2017

New Claims

H2i® TECHNOLOGY

H2i MXZ HEATING CAPACITY AT LOW TEMPERATURES*



* *Includes correction for defrost.*

NOTE: *Low ambient temperature conditions may require base pan heater (MSZ-GE and MSZ-FE 1:1 systems)*

HEATING even when it's minus 13 degrees F outdoor ambient, producing up to 100% heating capacity at 5 degrees F.

YEAR-ROUND COMFORT in extreme climates without the need for energy-consuming indoor supplemental heating devices in many cases.

HOT-START TECHNOLOGY provides warmth from the start, reducing drafts.

MINIMAL MAINTENANCE thanks to easily accessible filters, little or no ductwork to clean, and simple wiring between the indoor and outdoor units.

Electric Conversion Heat Pump Transition Cost Estimates are Wrong

The DRAFT New Jersey Energy Master Plan states: “…the most significant expenditures will be the one-time capital cost of installing the electric heating system, which costs an average of $4,000-$7,000 for a typical residence.” (p.71)

Source for the NJ EMP is an ACEEE Study

The basis for these installed costs is an ACEEE Study which states: “These cost estimates assume that a house has adequate electric service to install a heat pump. For houses that have central air-conditioning, this will generally be the case. But for some old houses without central air-conditioning, upgrading the electric service will be needed. For cold-climate ducted heat pumps, we estimated installed costs at 30% more than a SEER 16 ducted heat pump, based on a suggestion from a major manufacturer that plans to soon introduce a ducted cold-climate heat pump to the US market. For ductless heat pumps, costs come from an ACEEE analysis of a Massachusetts database of installed costs for this equipment. We looked at homes installing two or more multi-head heat pumps, finding an average cost of $7,065 per heat pump. The sample size was 496 homes, nearly all of which purchased two multi-head heat pumps (just six homes installed three).”

Disclaimer

The industry needs to strengthen the economic transition case from oil heated furnaces, hot water boilers and steam boilers to biodiesel and advanced biofuels. NORA and NBB are working on the fuel side of the equations. We need your help to create a series of fact based case studies using real customers to show the actual economic impact to completely electrify different types of homes as each case is unique regarding the home design, potential electric offerings, and customer socioeconomic situation. The following estimates are based on actual heating transition projects or extrapolated from them.

YOUR ACTUAL CASE STUDIES ARE CRITICAL TO THIS EFFORT MOVING FORWARD. PLEASE CONTACT JOHN HUBER FOR CASE STUDY REQUIREMENTS.

INSTALLATION COST OF ELECTRIC HEAT
Furnace to air-to-air heat pump

Looking at actual installations for multi split heat pumps applied to oil heated homes with a furnace we find heating cost between $13,500 (small single-story house) and $19,000 for a 1,400 ft^2 home. Note: the stated intention is to eliminate fossil fuels including backup heat and domestic hot water heat as well. Estimates are based on real projects using multi split heat pumps.

Installed Costs	Small Home and Low-Income Row House	Large Home
Heating System	$13,500 – $19,000	$20,000 - $26000
Potential Electric Upgrade	$2,000 – 3,000	$3,000 – $5,000
Heat Pump Water Heater	$3,000 - $4,000	$3,000 - $4,000
Total	$18,500 - $26,000	$26,000 - $35,000

INSTALLATION COST OF ELECTRIC HEAT
Hot Water Boiler to air-to-water heat pump

Existing hydronic boilers heat water to 180 °F, regardless of ambient conditions, and circulate it through baseboards which radiate the heat into the room providing comfort. An air to water heat pump can heat water to 140 °F at 47 °F ambient air, but, this hot water temperature falls as ambient temperature falls. Therefore, additional heat transfer surface likely will be required (extended radiant or supplemental fan coils.

Installed Costs	Small Home and Low-Income Row House	Large Home
Heating System	$13,500 - $19,000	$20,000 - $26000
Potential Electric Upgrade	$2,000 - 3,000	$3,000 - $5,000
HP Water Heater	$3,000 - $4,000	$3,000 - $4,000
Additional Radiant Heating Surface Area for 140 °F Hot Water	$3,000 - $5,000	$4,000 - $6,000
Total	$21,500 - $31,000	$30,000 - $41,000

INSTALLATION COST OF ELECTRIC HEAT
Steam Boiler to air-to-water heat pump

Residential electric heat pumps do not create steam. Steam supply pipe and the condensate return pipe can be different sizes an air to water heat pump cannot work. This means if you want to keep the comfort of a boiler you will first need to convert your steam boiler to a hydronic boiler which may entail ripping open your walls to address the piping and then closing your walls and painting them. Thus, an air-to water heat pump cannot work for most steam systems.

Installed Costs	Small Home and Low-Income Row House	Large Home
Heating System	$13,500 – $19,000	$20,000 - $26000
Potential Electric Upgrade	$2,000 – 3,000	$3,000 – $5,000
HP Water Heater	$3,000 - $4,000	$3,000 - $4,000
Conversion to hydronic system	$4,000 - $6,000	$5,000 - $7,000
Total	$22,500 - $32,000	$31,000 - $42,000

Electric Conversion Questions

- How much of the cost of electric conversion incentives will come from investor owned utility shareholders' equity as opposed to investor owned utility ratepayers' equity reflected in their monthly electric bills?
- With the increased winter demand on the system what will the cost per kWh to heat be?
- What will the cost be for back up heat when it's too cold for the heat pump to maintain the temperature I set it for?
- What will the cost be for time of day demand pricing, i.e., will it cost me 60% more for every kWh I use to heat my house, cook my food, heat my water, and dry my clothes, between 4pm-9pm , as it does in California ?

The Liquid Fuels Industry

Today biodiesel significantly reduces greenhouse gas emissions compared to heating oil. The most comprehensive, accurate and up-to-date life cycle analysis of U.S. biodiesel produced from soybean oil concludes that greenhouse gas emissions are reduced between 66 is 72% relative to U.S. average heating oil. In the future, this reduction is expected to increase through productivity, renewable farming practices and use of renewable energy in processing plants through delivering yielding biodiesel projections of net zero carbon combustion. Furthermore, advance biofuels, such as ethyl levulinate, which uses waste cellulose as its feedstock, is projected to even reduce greenhouse gas emissions when used.

Liquid Fuels Transition 2030

Transitioning from heating oil to biodiesel and then to advance biofuels does require change. The liquid fuels industry is focused on transitioning to a blend of 50% biodiesel and 50% ultra-low sulfur diesel by 2030. This will require some changes at the wholesale and retail distribution level but is not expected require any significant change for the homeowner. This is substantially different than the transition cost contemplated to electrify all homes requiring homeowners with oilheat systems to transition to electric heat pumps ostensibly with electric backup heating an electric heat pump water heater.

Liquid Fuels Transition 2040

Looking to the future, the liquid fuels industry is developing advanced biofuels that will require a modest amount of change for their customer. This change is largely focused on fuel pump materials and a cost to the consumer a few hundred dollars when this fuel is available.

The liquid fuels industry believes they can offer the citizens of New Jersey and advance biofuel by 2040 that will reduce greenhouse gas emissions lower than they will be able to purchase from the renewable electric grid of 2040 and this advance biofuel pathway will cost homeowner significantly less than a conversion to all electric home.

The Economics & Environmental Performance of Biodiesel vs. Electric Heat Pumps

Ray Albrecht, P.E

Technical Representative National Biodiesel Board

Member of ISO New England Planning Advisory Committee

Some core principles:

CO2 emissions for biodiesel can be much lower than for cold-climate heat pumps if the renewable fuel content is high enough.

Learning more about power generation is of critical importance in protecting the future of renewable liquid fuels.

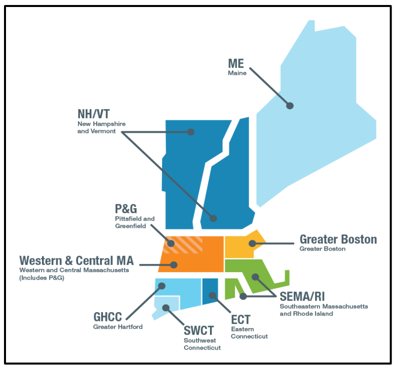
Grid loads increase significantly during cold winter weather.

Generation efficiency goes down if grid loads increase or change rapidly.

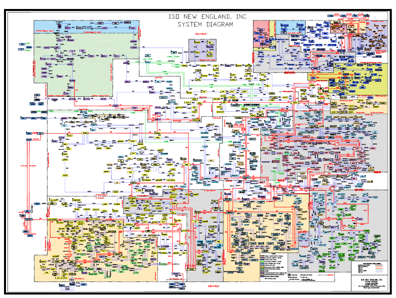
Huge impact of increased grid load on fuel consumption and cost for electricity.

Hourly analyses of grid performance can identify peak load problems that are hidden by average annual data.

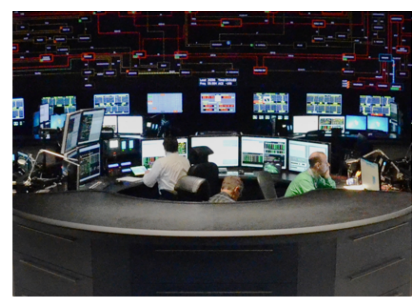
Independent System Operators regulated by FERC



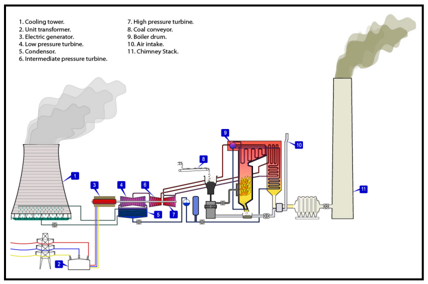
Each ISO has about 10 individual control zones for operations.



Complex grid network with central control system for dispatch and pricing of power.

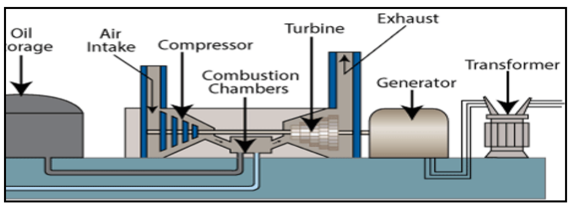


Types of Fuel-fired Power Generation Systems



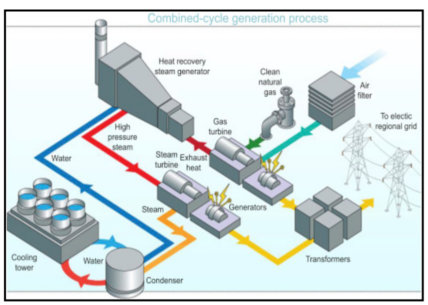
Steam cycle has about 30% steady-state efficiency with slow start capability. Old technology but still commonly used.

0.7 to 0.9 tons CO2 per MWh for Natural Gas/Oil



Combustion turbines range in steady-state efficiency from 20% (old) to 40% (new) and can ramp up relatively fast (10 minutes to 2 hours).

0.6 to 1.2 tons CO2 per MWh for Natural Gas/Oil



Combined cycle can have up to 60% max steady-state efficiency but only moderate ramp-up capability (usually 1 or 2 hours).

0.4 to 0.6 tons CO2 per MWh for Natural Gas/Oil

Energy Sources for Power Generation in New England

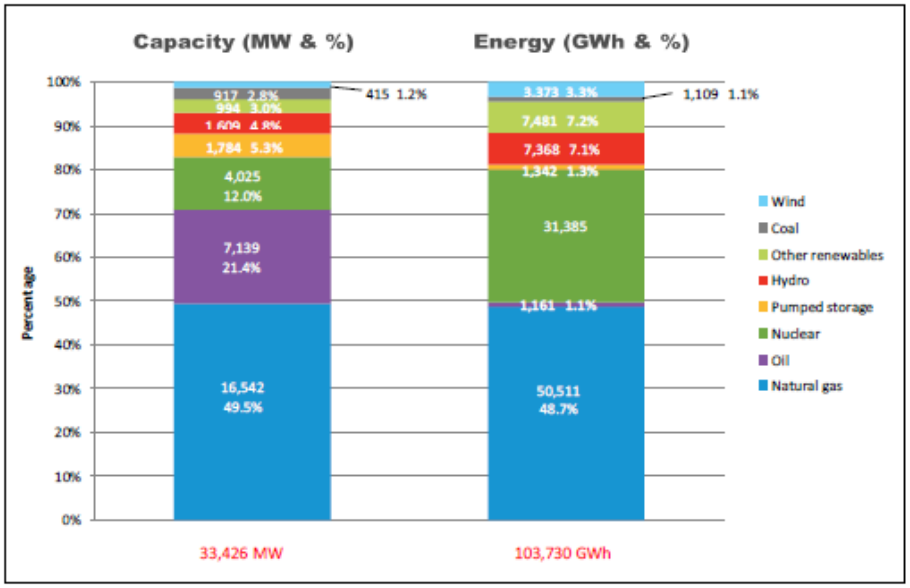
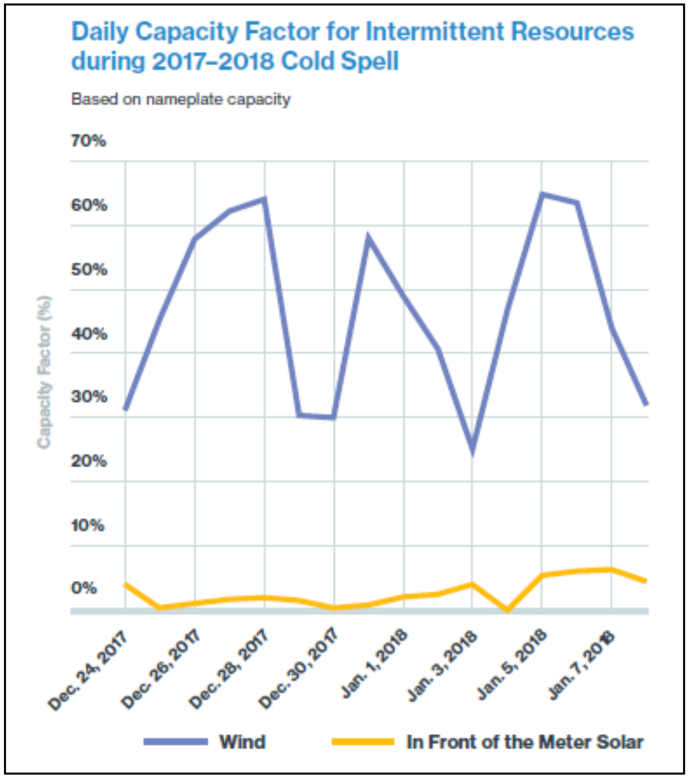


Figure 7-1: New England's generator winter seasonal claimed capability (MW, %) and annual electric energy production (GWh, %) by fuel type for 2018.

Average capacity factor of grid system about 30% but varies for each type of resource.

Natural gas is dominant fuel. Nuclear only 3300 MW capacity now due to retirement of Pilgrim station but runs 24/7 as base load. Oil-fired generation has substantial capacity but used only during severe grid peak loads. MSW and wood-fired generation significant but not growing. Solar PV and wind power growing steadily but with intermittent output.

Rapid Changes in Energy Source Mix During Winter



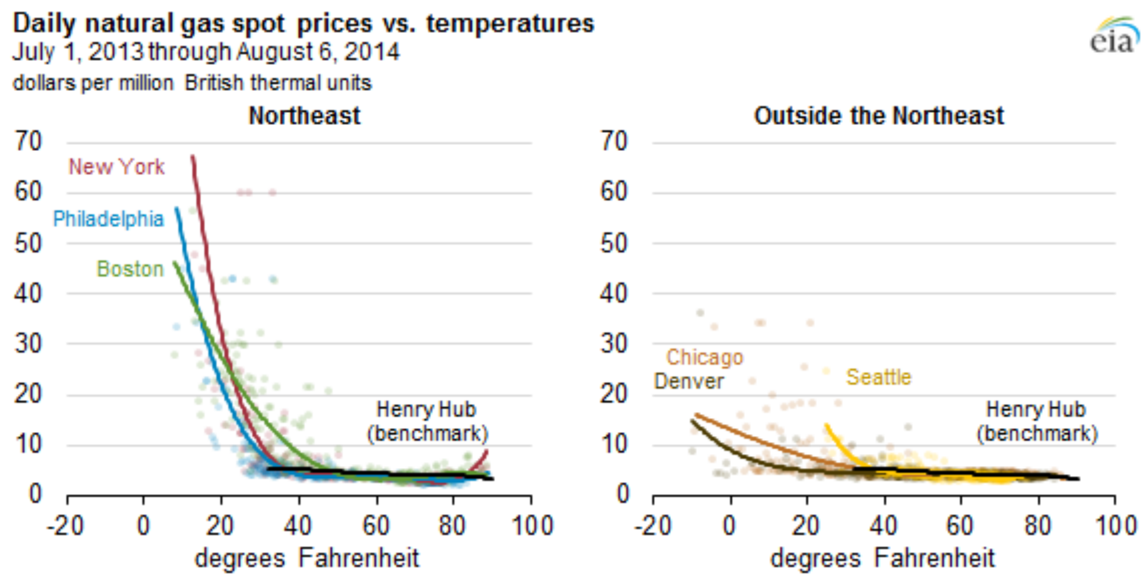
Significant variability in wind power output.

Wind power shuts downs during high wind conditions.

Loss of solar PV output due to clouds and snow.

Normal solar PV capacity factor is about 14%.

Natural Gas Spot Market Price Vs. Outdoor Temperature



Pipeline constraints limit natural gas availability in Northeast during cold weather. Spot market prices start to climb at about 30 deg F. Power plants required to purchase natural gas only in spot market not via firm price contracts.

Correlation Between Fuel Cost and Wholesale Power Cost

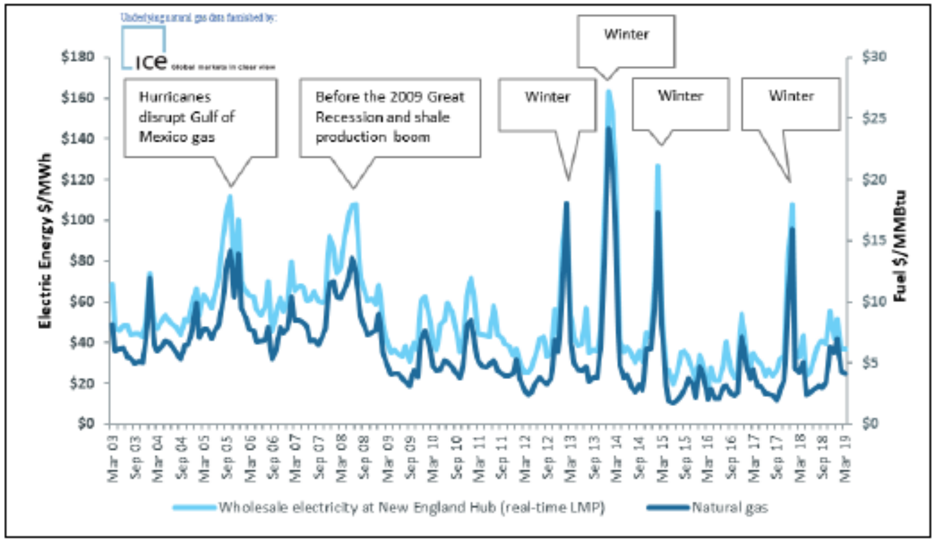


Figure 7-6: Monthly average natural gas prices and real-time Hub LMPs compared with regional natural gas prices, March 2003 to March 2019 ($/MWh; $/MMbtu).

Fuel cost represents about 80% of power generation cost.

Winter price spikes for natural gas result in higher electricity costs.

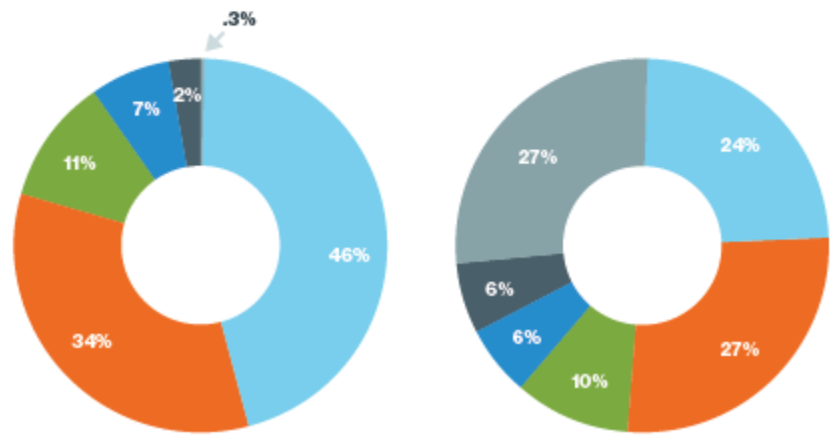
Biodiesel becomes competitive with natural gas at about $8 per MMBTU if RPS credits available and could be used as a circuit breaker for fuel cost.

Changes in Energy Source Mix for Power Generation During Cold Weather

Oil Generation is High During Extreme Winter Cold

Oil generation was 27% of the regional fuel mix during the cold spell of winter of 2017–2018 compared with 0.3% for most of the month of December.

Natural Gas
Nuclear
Renewables
Hydro
Coal
Oil

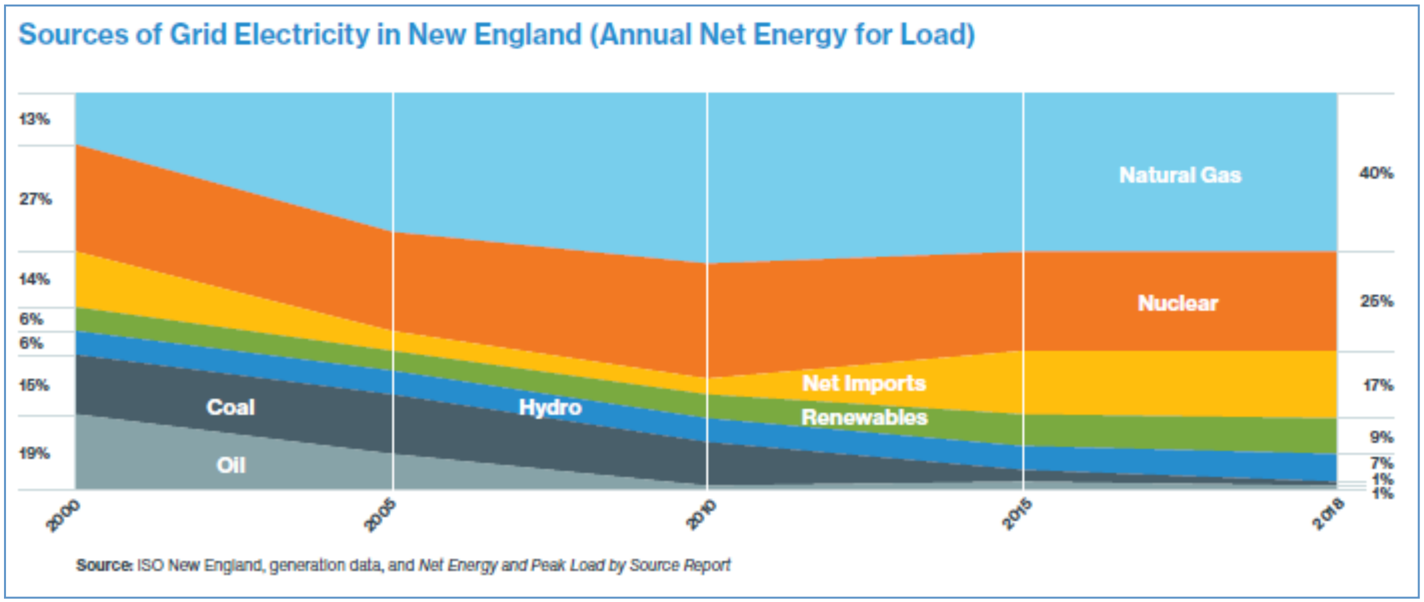


Average Fuel Mix for Most of December 2017 (Dec. 1–26, 2017)

Average Fuel Mix for Extreme Cold Spell (Dec. 26, 2017 – Jan. 9, 2018)

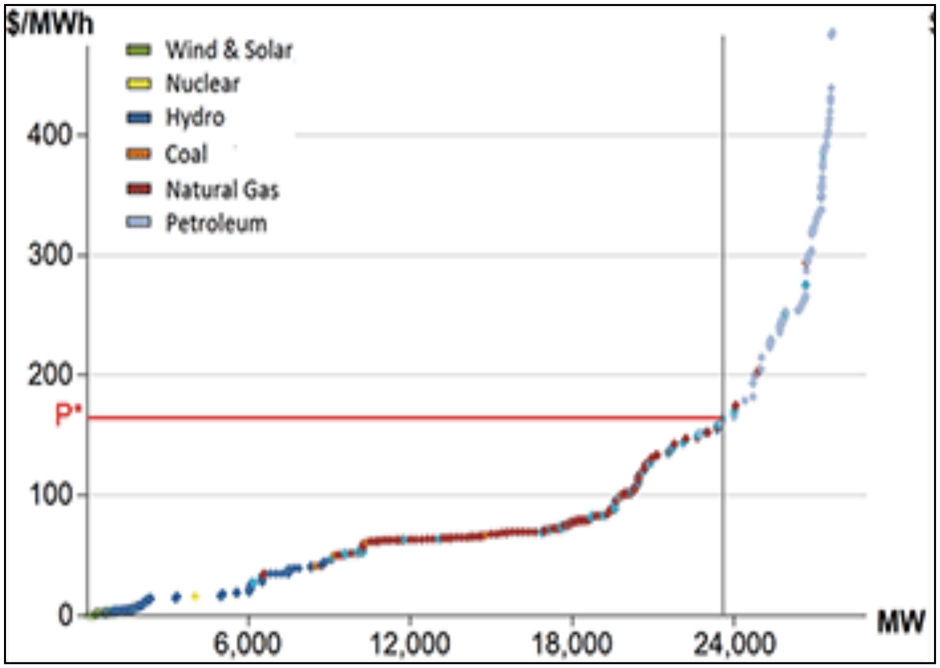
More coal and no. 6 oil for power generation during extreme cold weather.

Historical Trends of Resource Mix for Power Generation



Natural gas became dominant fuel for power generation during past 10 to 15 years due to cheap price. Coal and oil sharply decreased due to cost relative to natural gas and also emissions regulations.

ISO New England Example Graph of Wholesale Price Vs. Grid Load



Prices determined via auctions at 5 minute intervals.

All generators earn same market clearing price determined by highest successful bidder.

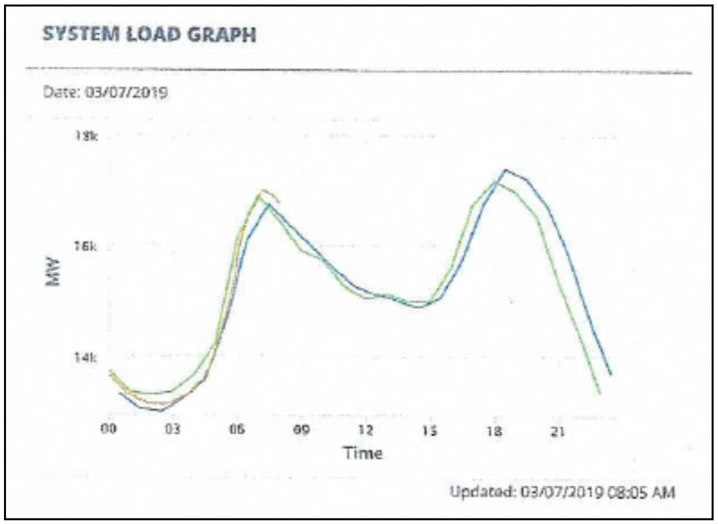
Level of curve beyond 5,000 MW depends on spot market price of natural gas.

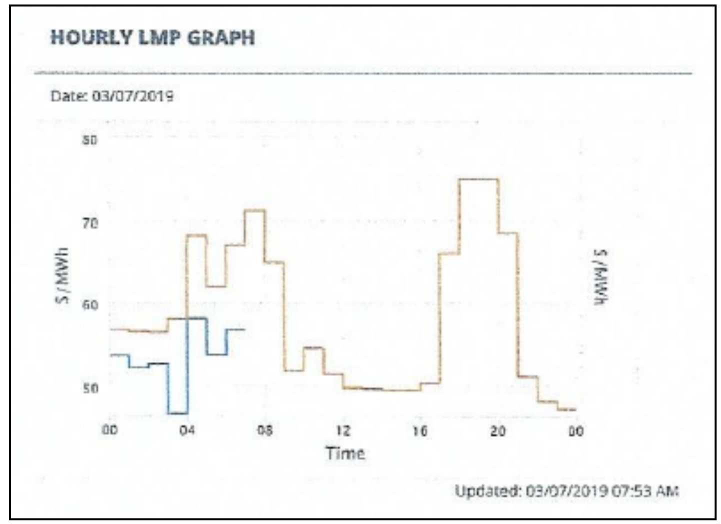
Slope of price curve becomes steeper at higher grid load due to poor efficiency of generator at margin plus short duration of extreme peaks thus greater impact of fuel consumption during start-up.

We will look at this graph again later.

ISO New England Example Hourly Load and Price Graphs

Moderate Cold Weather – February 4, 2019



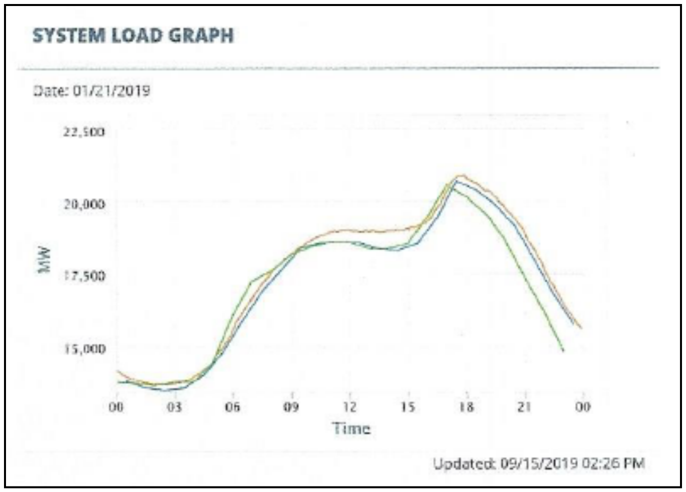


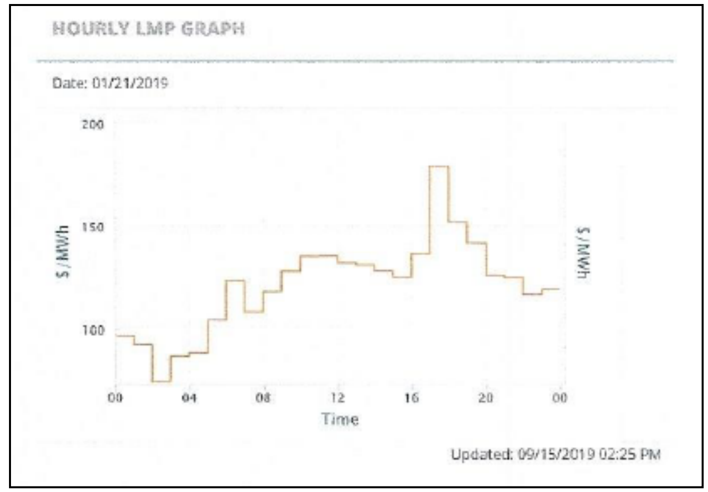
Early morning and evening peaks just under 18,000 MW. Peak pricing of just under $80 per MWh.

Existing peak loads already the result of electric heating and range from 15,000 to over 20,000 MW during the winter. Adding more heat pumps will just make things worse.

ISO New England Example Hourly Load and Price Graphs

Extreme Cold Weather – January 21, 2019

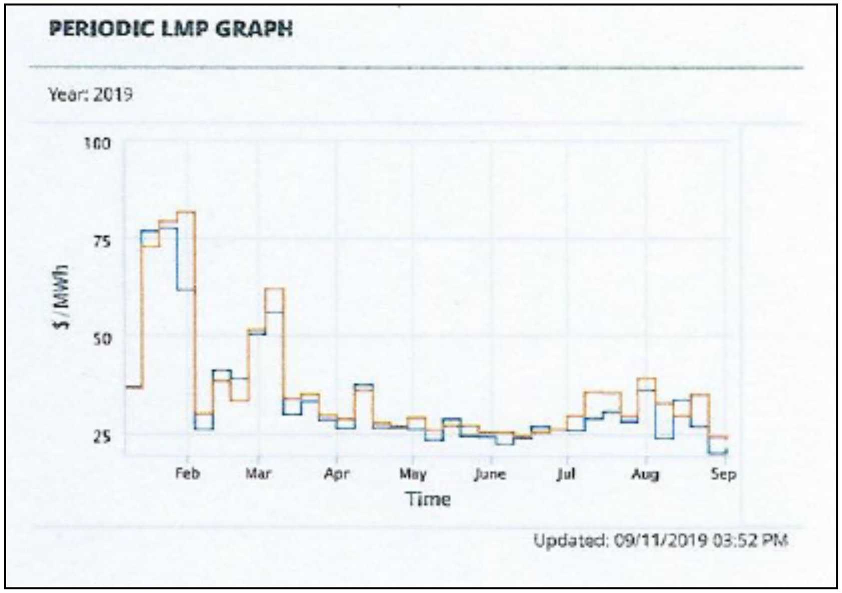




Peak evening load has climbed over 20,000 MW. Price has jumped up to almost $200 per MWh.

All residential, commercial and industrial customers pay the higher prices. Again - adding more heat pumps will just make things worse.

ISO New England Weekly Average Prices for Wholesale Power



Highest prices occur during winter months.

Cumulative sum of wholesale prices determine average supply charges on customer bills.

Peak power prices hidden from customers.

Most utility and State agency calculations of heat pump savings use average annual prices for electricity.

Winter prices for wholesale power will continue to rise with added thermal loads.

Everybody pays the higher prices.

Forecasted Growth in Solar PV in New England

Table 3-3
New England States' Annual and Cumulative PV Nameplate Capacities, 2019 to 2028 (MW_{AC})

Year	Annual Sum of States	Annual Total Capacities (MW_{AC} nameplate ratings)					
		CT	MA	ME	NH	RI	VT
Through 2018	2,883.8	464.3	1871.3	41.4	83.8	116.7	306.3
2019	463.1	68.4	292.0	7.1	12.7	51.3	31.5
2020	472.8	91.1	288.0	7.1	12.7	51.3	22.5
2021	458.0	97.5	272.0	6.7	12.0	48.5	21.3
2022	451.9	97.5	272.0	6.7	12.0	42.4	21.3
2023	426.0	71.6	272.0	6.7	12.0	42.4	21.3
2024	358.0	71.6	204.0	6.7	12.0	42.4	21.3
2025	330.0	71.6	176.0	6.7	12.0	42.4	21.3
2026	324.7	71.6	170.7	6.7	12.0	42.4	21.3
2027	291.3	43.5	165.3	6.7	12.0	42.4	21.3
2028	284.6	42.1	160.0	6.7	12.0	42.4	21.3
Total	6,744.4	1,190.9	4,143.2	109.7	205.6	564.6	530.3

Solar PV growth forecasted to average 400 MW per year but slowing down due to reduced tax credits and other incentives plus limited access to transmission or local distribution lines but subject to change.

Wind power forecasted growth much higher but speculative.

Relevant Environmental Parameters for Power Generation


ISO new england

2016 ISO New England Electric Generator Air Emissions Report

© ISO New England Inc.
System Planning

JANUARY 2018

Key environmental parameters include:

Type of fuel used

Efficiency of generation technology

CO_2 emissions

NO_x emissions

Huge quantities of average data available but marginal data difficult to extract.

Types of CO2 Data for Power Generation

Table 1-1
2015 and 2016 New England System Emissions (ktons)
and Emission Rates (lb/MWh)

Annual System Emissions						
	2015 Emissions (kTons)	2016 Emissions (kTons)	Total Emissions % Change	2015 Emission Rate (lb/MWh)	2016 Emission Rate (lb/MWh)	Emission Rate % Change
NO_X	18.86	16.26	-13.8	0.35	0.31	-11.4
SO_2	9.11	4.47	-50.9	0.17	0.08	-52.9
CO_2	40,312	37,468	-7.1	747	710	-5.0

Average bulk CO2 emissions per MWh for all generators for entire year.

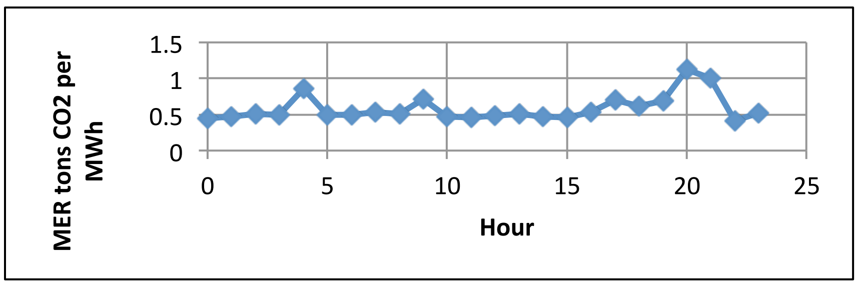
Often used by heat pump advocates.

Table 1-2
2015 and 2016 Average LMU Marginal Emission Rates (lb/MWh)

LMU Marginal Emissions						
	All LMUs			Emitting LMUs		
	2015 Annual Rate (lb/MWh)	2016 Annual Rate (lb/MWh)	Percent Change 2015 to 2016 (%)	2015 Annual Rate (lb/MWh)	2016 Annual Rate (lb/MWh)	Percent Change 2015 to 2016 (%)
NO_X	0. 28	0.21	-27.2	0.36	0.25	-29.2
SO_2	0. 33	0.16	-53.0	0.41	0.19	-53.0
CO_2	857	842	-1.7	1,036	1,007	-2.7

Average marginal CO2 emissions per MWh for entire year.

Hides winter CO2 emissions spikes.

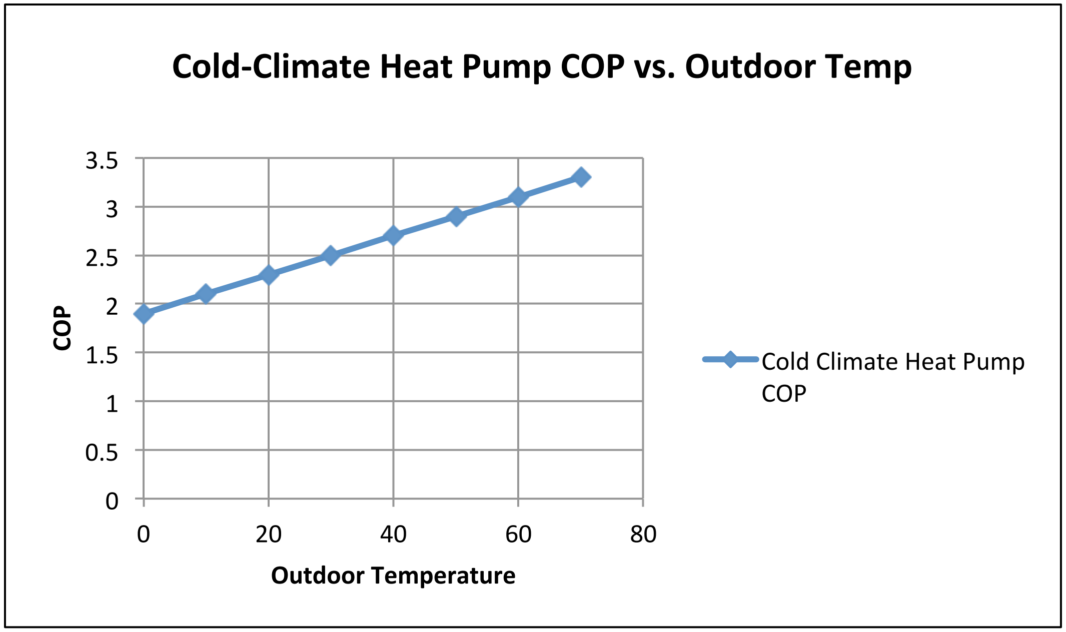


Hourly marginal CO2 emissions per MWh during winter season.

Reveals trouble spots during cold weather and morning/evening peaks.

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance

Single Family Home in Downstate New York

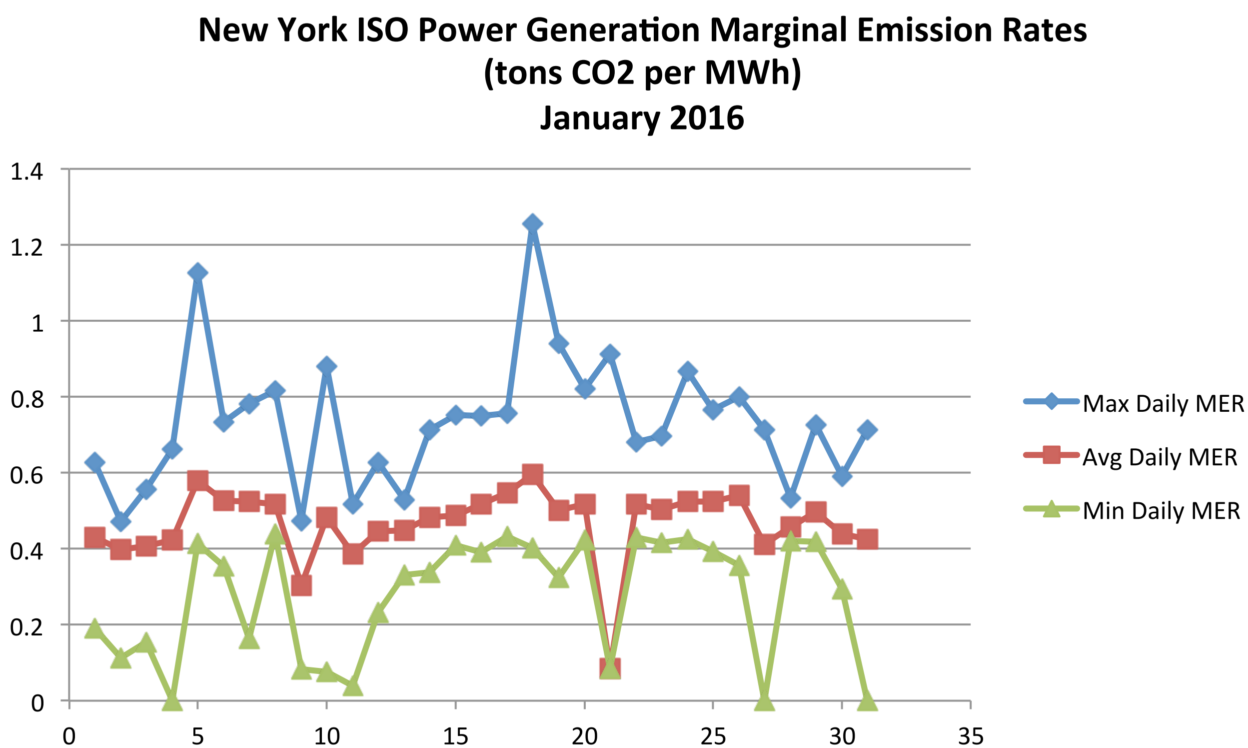


First step of analysis includes determination of heat pump COP vs. outdoor temperature.

Data above are based on multiple field testing studies not manufacturer ratings.

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance

Single Family Home in Downstate New York

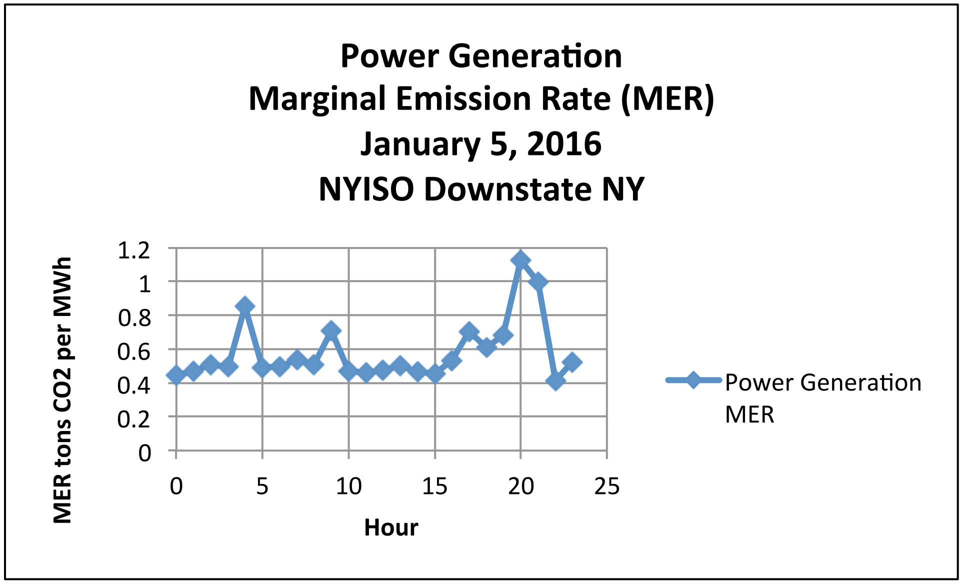


Daily MER max/average/min data for each day of January 2016 for downstate NY.

MERs range from 0 (nuclear or hydro) to over 1.2 (oil-fired) based on grid load.

New York ISO Hourly Marginal Emission Rates for Generation

Cold Winter Day



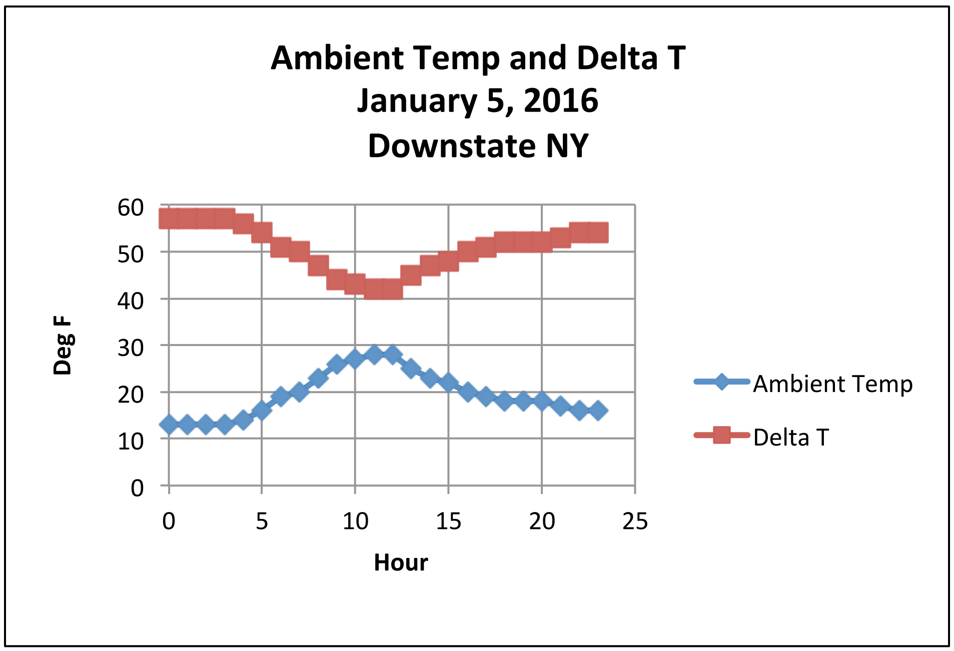
Significant peaks in MER during early morning and evening corresponding to peak grid loads.

Peak grid loads met with low efficiency combustion turbines.

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance

Single Family Home in Downstate New York

Cold Winter Day

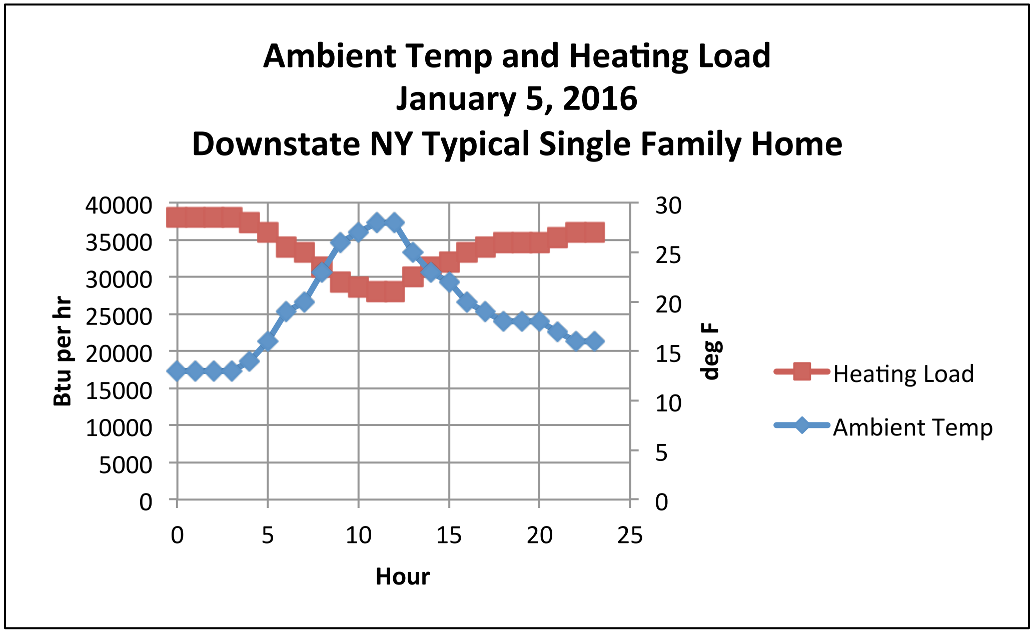


Early morning temperature of 12 deg F thus near winter design point.

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance

Single Family Home in Downstate New York

Cold Winter Day

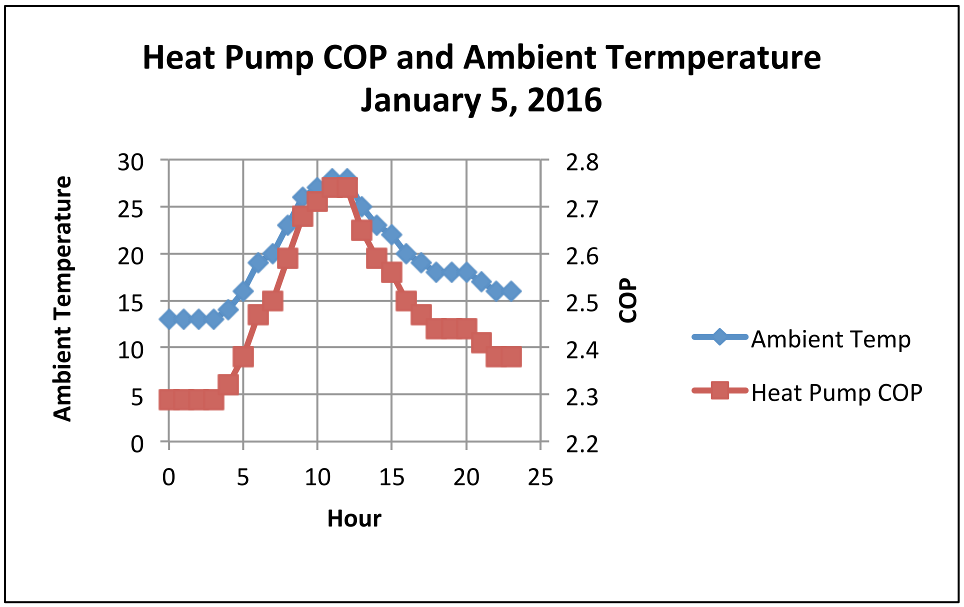


Heating load of 40,000 Btu/hr at 10 deg F design temperature.

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance

Single Family Home in Downstate New York

Cold Winter Day

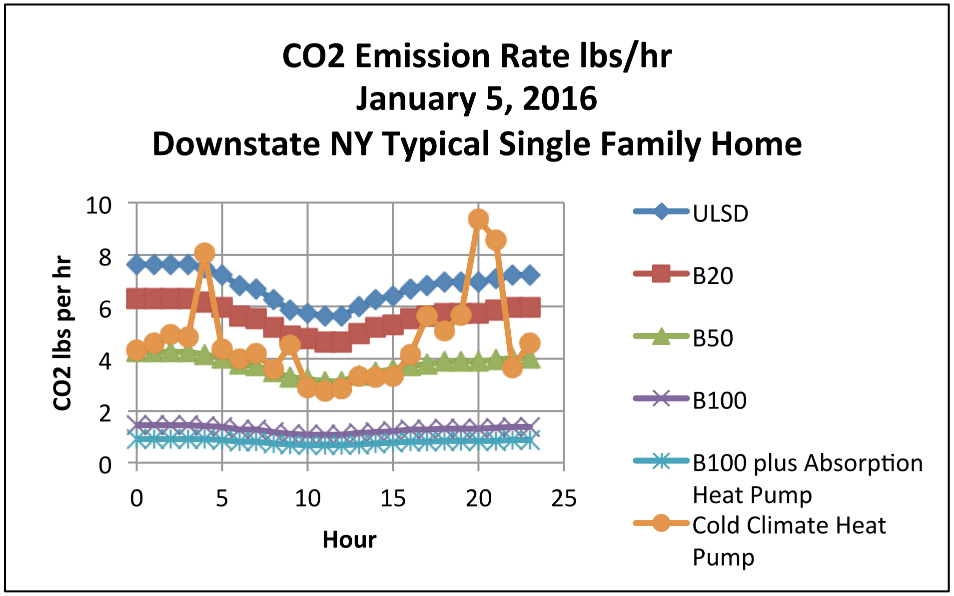


Heat Pump COP tracks outdoor temperature and ranges from 2.3 to 2.7 during the 24 hour period.

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance

Single Family Home in Downstate New York

Cold Winter Day

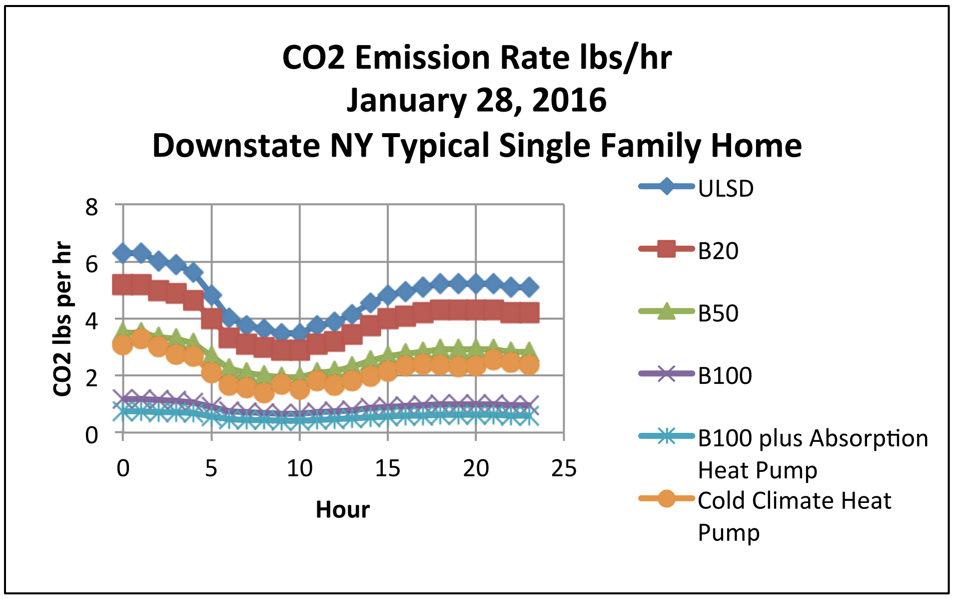


Calculations use heating load, heat pump COP and NYISO grid MER to determine CO2 emissions in lbs/hr. Heat pump has higher carbon intensity than ULSD during peak periods corresponding to MER of power generation. Approximately the same as B50 during off-peak periods. B100 the lowest carbon option.

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance

Single Family Home in Downstate New York

Moderate Winter Day

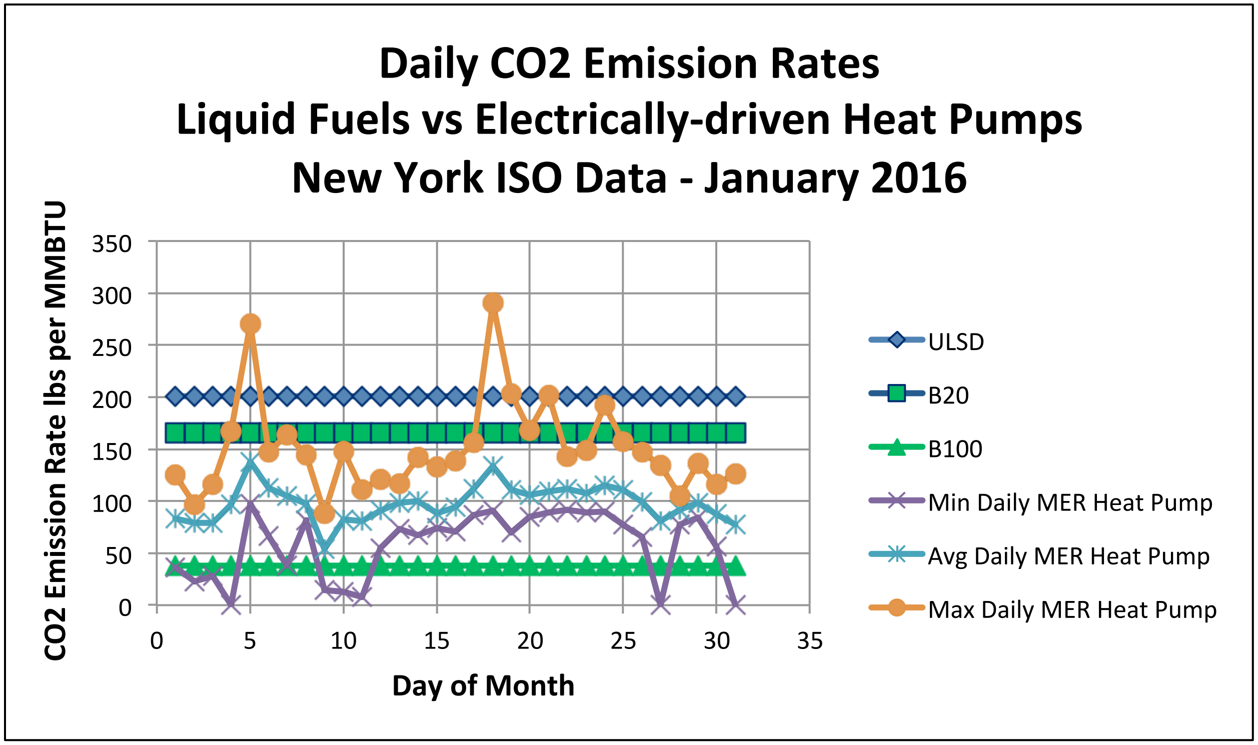


Heat pump has approximately the same carbon intensity as B50 through the 24 hour period.

B100 still lowest carbon option during moderate winter weather.

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance

Single Family Home in Downstate New York

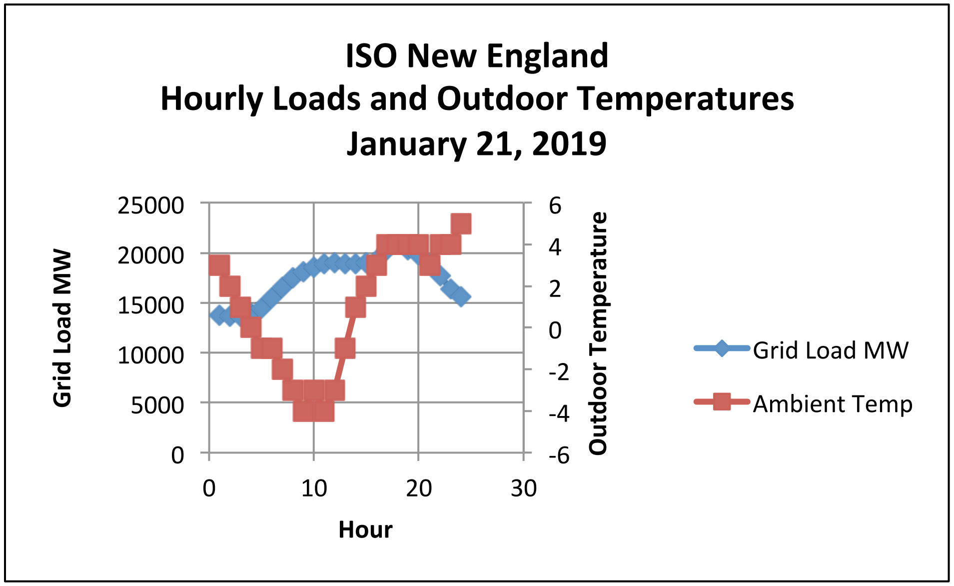


January 2016 was relatively mild with temperature distributions typical of an average winter. Heat pump achieves about 40 to 50 percent CO2 savings vs. ULSD. B100 achieves 80 percent CO2 savings vs. ULSD.

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance in New England

Single Family Home in Hartford, CT

Extreme Cold Winter Day

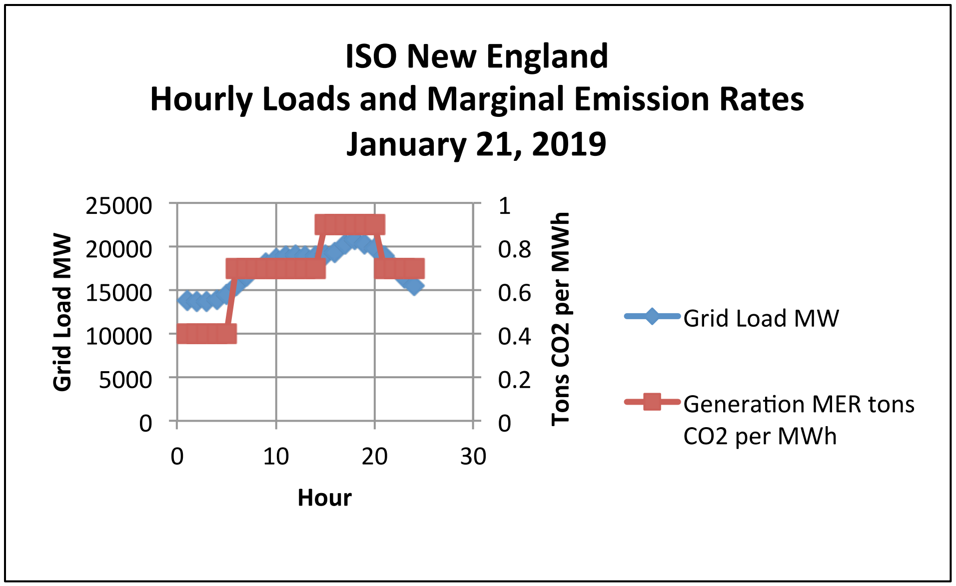


Near maximum grid load for winter season

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance

Single Family Home in Hartford, CT

Cold Winter Day



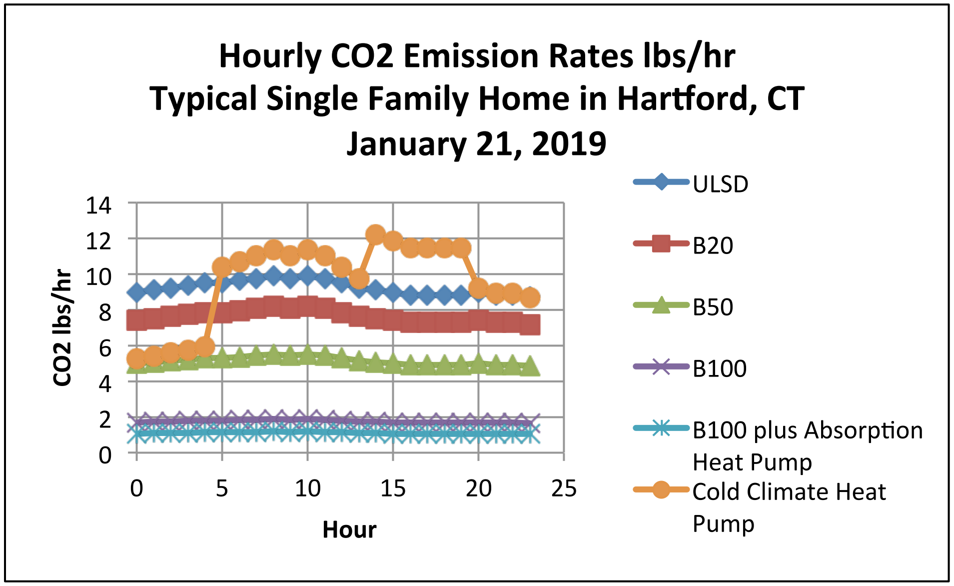
Oil-fired steam-cycle generation at margin during evening peak of about 21,000 MW.

MER shows steps from gas-fired combined cycle to gas-fired simple-cycle to oil-fired generation then back to gas-fired.

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance

Single Family Home in Hartford, CT

Cold Winter Day

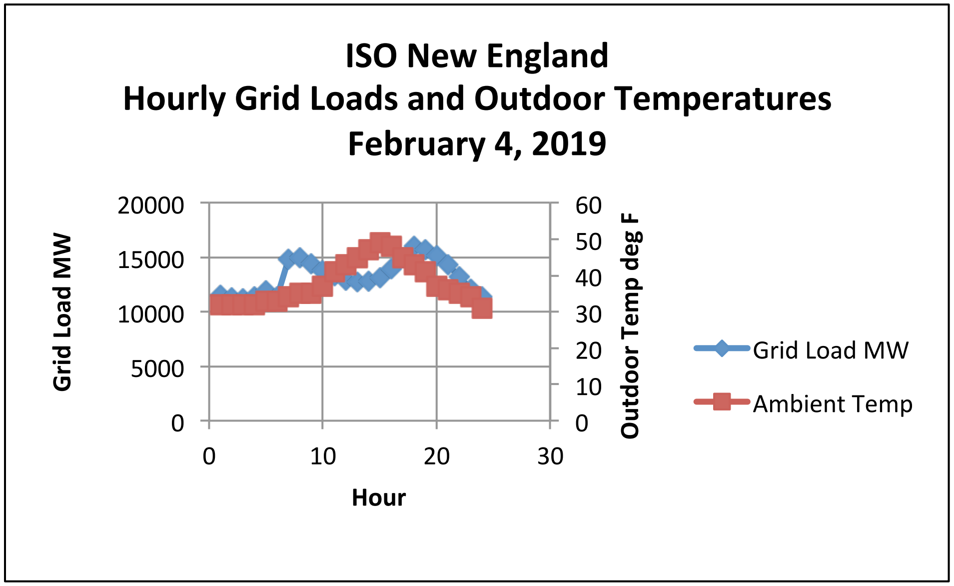


Heat pump shows higher carbon intensity than ULSD except during overnight hours due to lower COPs and higher generation MER.

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance

Single Family Home in Portland, Maine

Moderate Winter Day



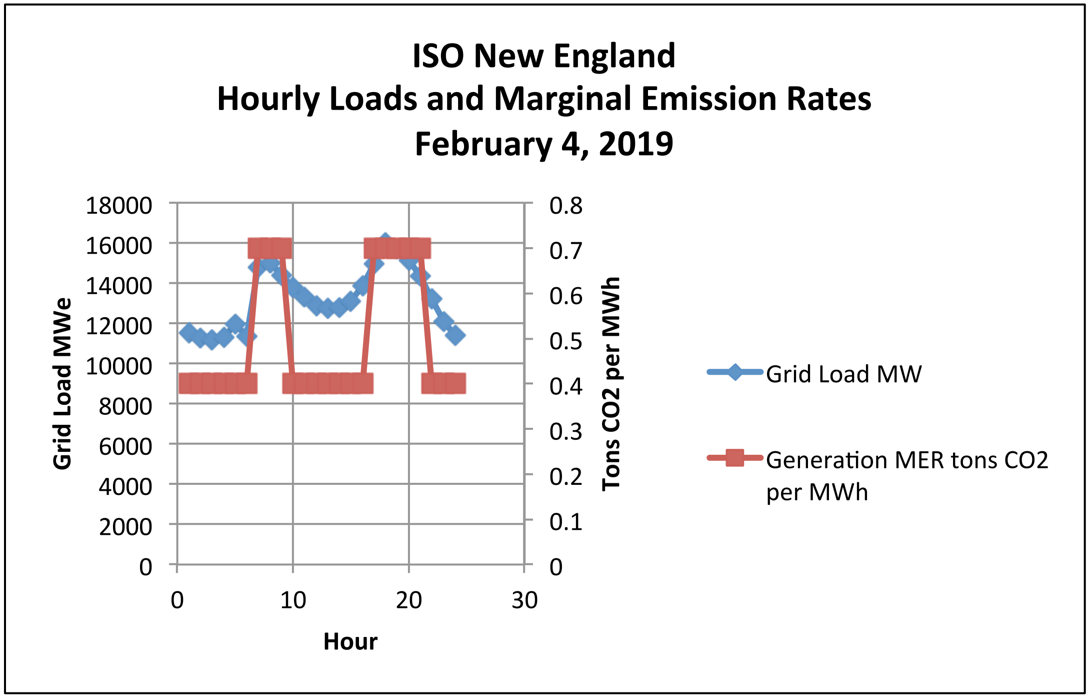
High temperature of about 50 deg F.

Peak grid load of just over 15,000 MW.

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance

Single Family Home in Portland, Maine

Moderate Winter Day



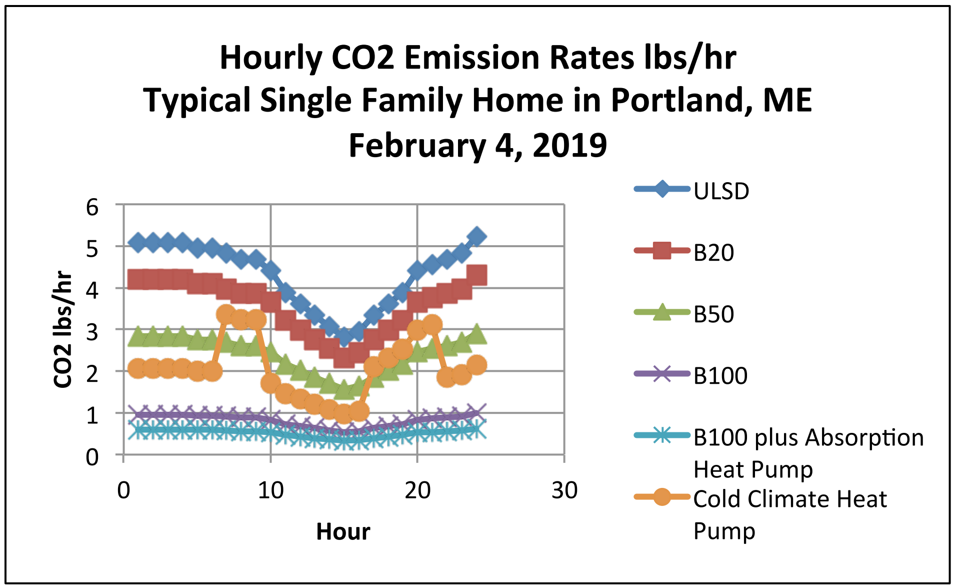
Simple-cycle generation during peak periods.

Combined-cycle generation during off-peak periods.

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance

Single Family Home in Portland, Maine

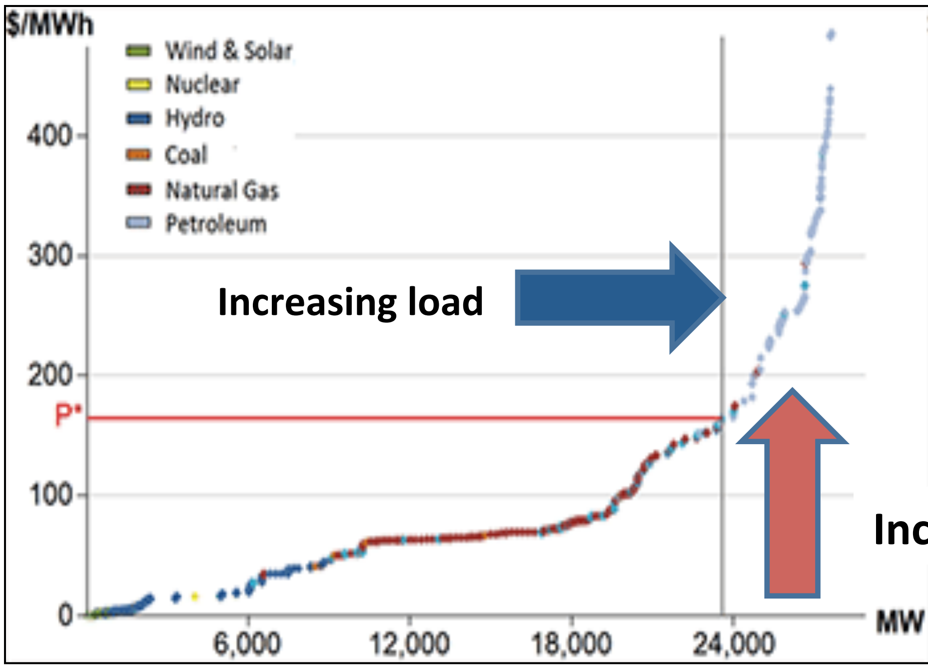
Moderate Winter Day



Heat pump carbon intensity approximately the same as B50 but with variations due to peak and off-peak power generation MERs.

B100 still the lowest carbon option vs. cold-climate heat pump.

ISO New England – Impact of Increasing Grid Load on Price



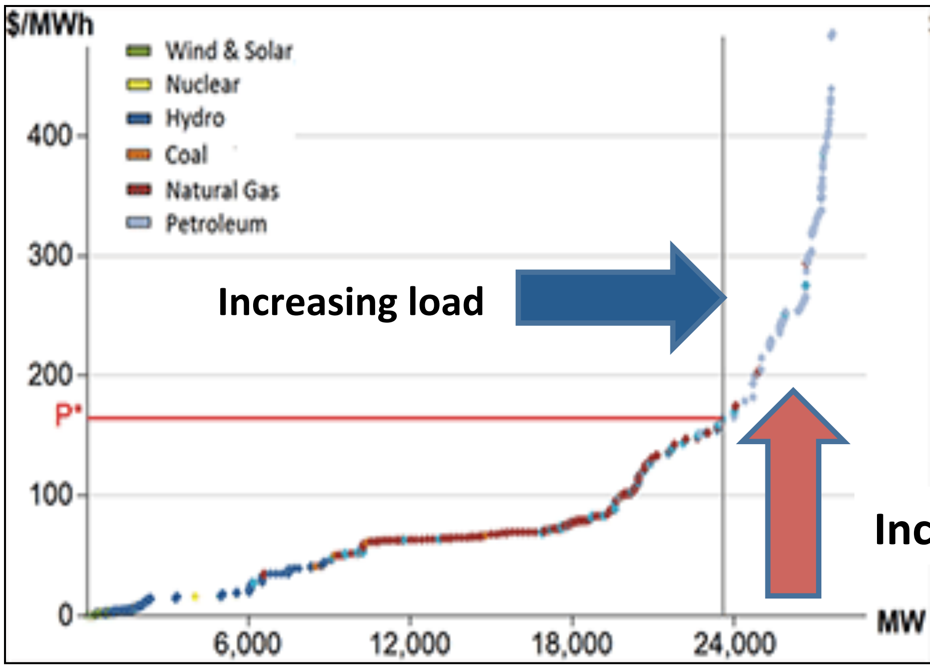
All generators earn same market clearing price determined by highest successful bidder.

A 48,000 Btu/hr cold-climate heat pump will add about 6 kW to the grid load.

1,000,000 more heat pumps in New England would add 6000 MW to the peak grid load.

An increase of 6000 MW would raise the winter peak load from 21,000 MW to 27,000 MW.

ISO New England – Impact of Increasing Grid Load on Price



A 48,000 Btu/hr cold-climate heat pump adds about 6 kW to grid load on cold winter days.

1,000,000 more residential heat pumps in New England would add 6000 MW to the peak grid load.

Wholesale power supply cost would rise from $100 per MWh to $200 per MWh approximately (or 20 cents per kWh). Cost savings to heat pump customer would disappear completely if not go negative. Resulting retail electricity cost including delivery charge would go above 30 cents per kWh for all residential, commercial and industrial customers.

Conclusions

B100 remains the lowest carbon option for heating.

B100 achieves 80% carbon savings thus double the benefit of cold-climate heat pumps.

B50 and cold-climate heat pumps have similar carbon intensity during moderate winter conditions.

Hourly marginal analysis of cold-climate heat pumps is necessary for accurate evaluation of environmental and economic performance.

Load-weighted COP of cold-climate heat pump is lower than average COP = 3 used by many heat pump advocates.

Cold-climate heat pumps show higher carbon intensity than ULSD under severe cold winter conditions but will achieve about 40% carbon savings over the entire heating season though with significant negative impact on grid operations and cost.

Q&A

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