Environmental and Economic Characteristics

Biodiesel and Cold Climate Heat Pumps

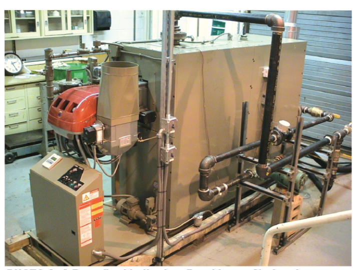


PHOTO A. A B100-fired boiler in a Brookhaven National Laboratory testing facility.

Ray Albrecht, P.E.

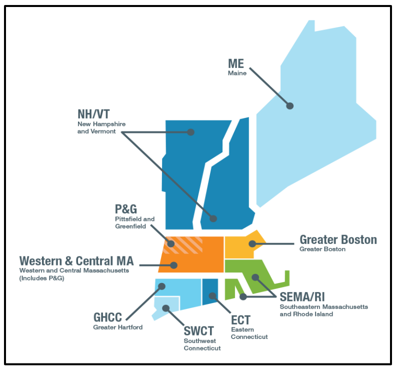
Technical Representative
National Biodiesel Board

Member of ISO New England
Planning Advisory Committee

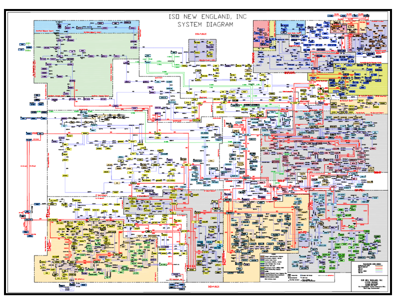
ISO new england

ISO

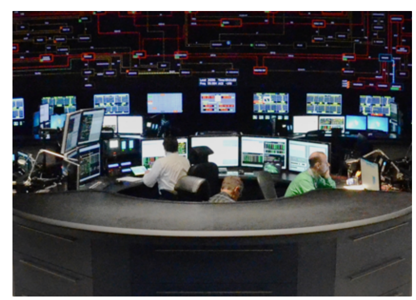
Independent System Operators regulated by FERC



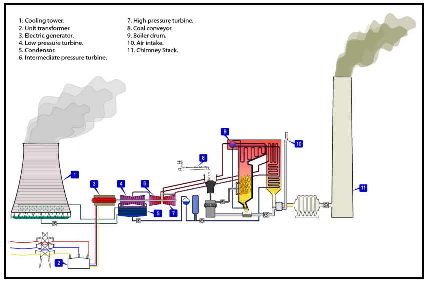
Each ISO has about 10 individual control zones for operations.



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

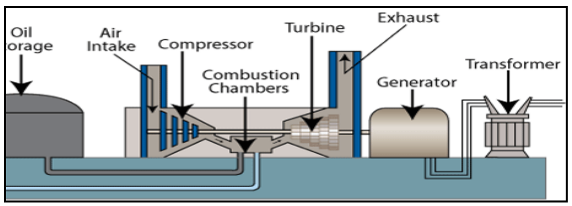


Types of Fuel-fired Power Generation Systems



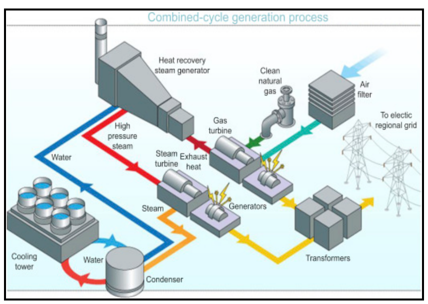
Steam cycle has about 30% steady-state efficiency with slow start capability. Old technology but still commonly used.

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



Combustion turbines range in steady-state efficiency from 20% up to 40% . Can ramp up relatively fast (10 minutes to 2 hours) but high fuel consumption and NOx emissions at start-up plus efficiency loss at less than full load.

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) and long period of high NOx emissions during start-up.

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

Energy Sources for Power Generation in New England

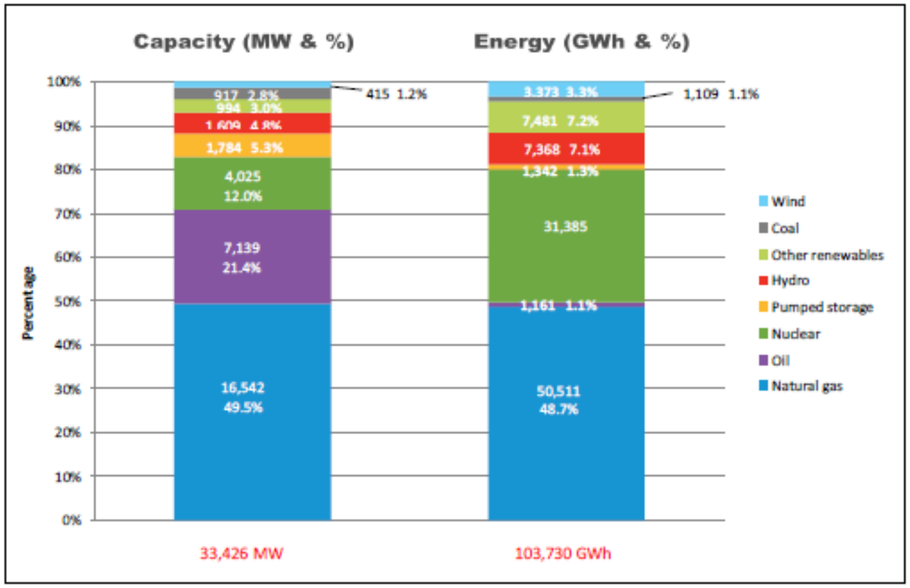
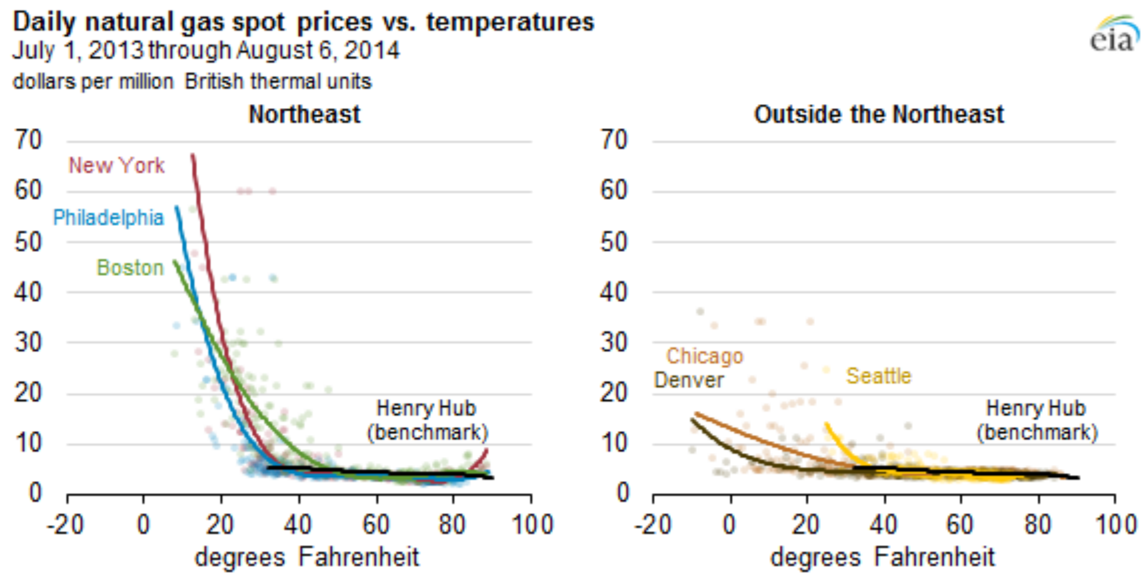


Figure 7-1: New England's generator winter seasonal claimed capability (MW, %) and annual electric energy production (GWh, %) by fuel type for 2018.

Long way to go for solar PV and wind power to displace natural gas in marginal operation.

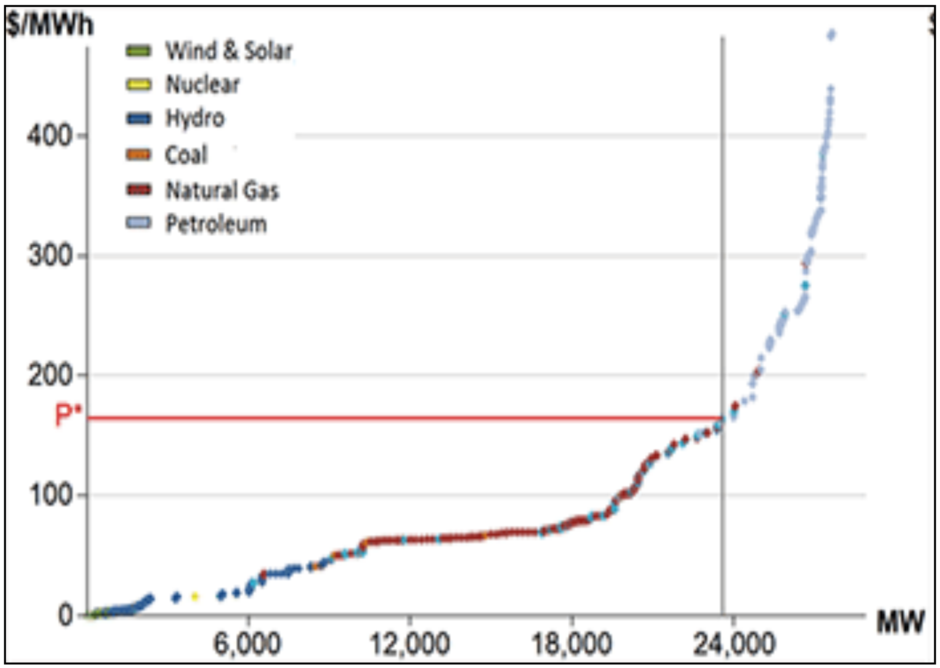
Natural gas is dominant fuel. Nuclear only 3300 MW capacity due to retirement of Pilgrim station but runs 24/7 as base load. Oil-fired generation has substantial capacity but used only during severe grid peak loads. MSW and wood-fired generation significant but not growing. Solar PV and wind power growing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

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. Fuel cost about 80% of LMP. High fuel cost = high electricity cost.

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



Prices determined via auctions at 1 hr and 5 minute intervals.

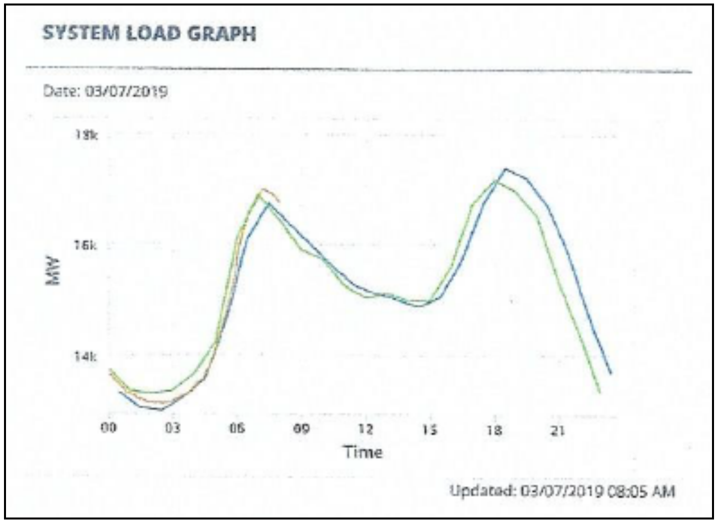
All generators earn same market clearing price determined by highest successful bidder.

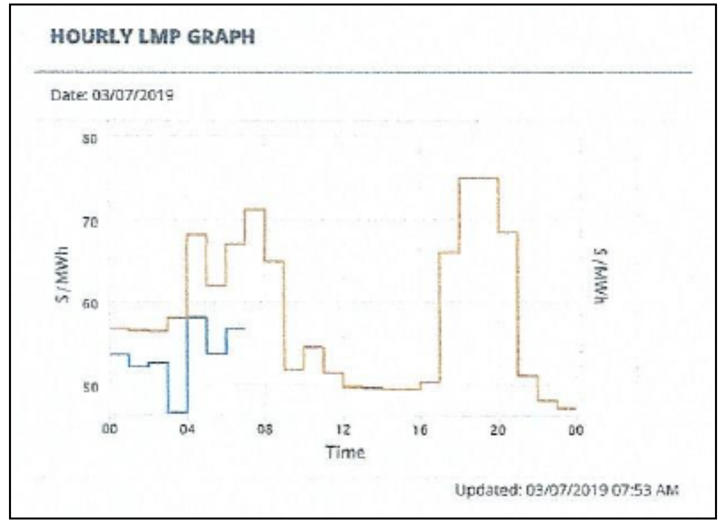
Level of curve beyond 5,000 MW depends on spot market price of natural gas.

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

ISO New England Example Hourly Load and Price Graphs

Moderate Cold Weather – February 4, 2019



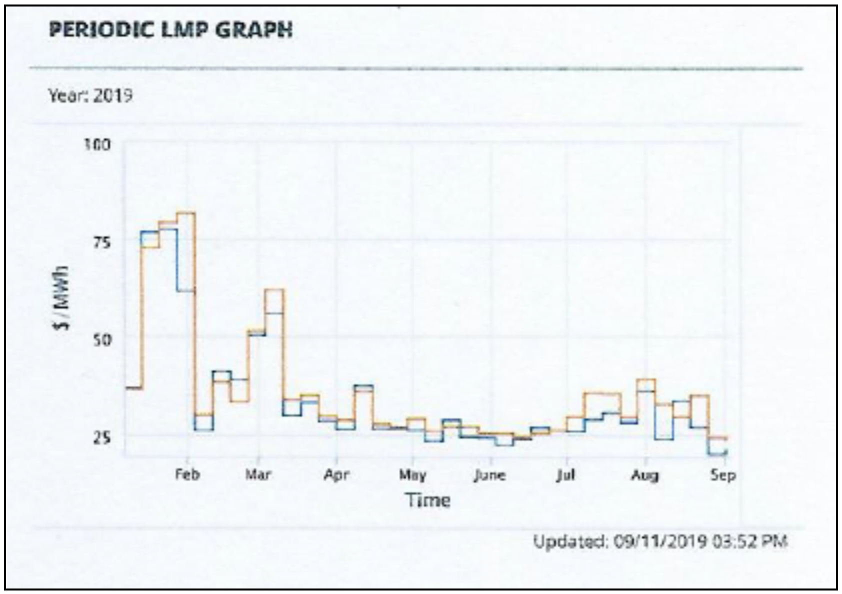


Peak grid loads = peak wholesale prices

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

Existing peak grid loads already the result of electric heating and range from 15,000 to over 20,000 MW during the winter.

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.

Many utility and State agency calculations of heat pump savings use average annual prices for electricity instead of monthly values.

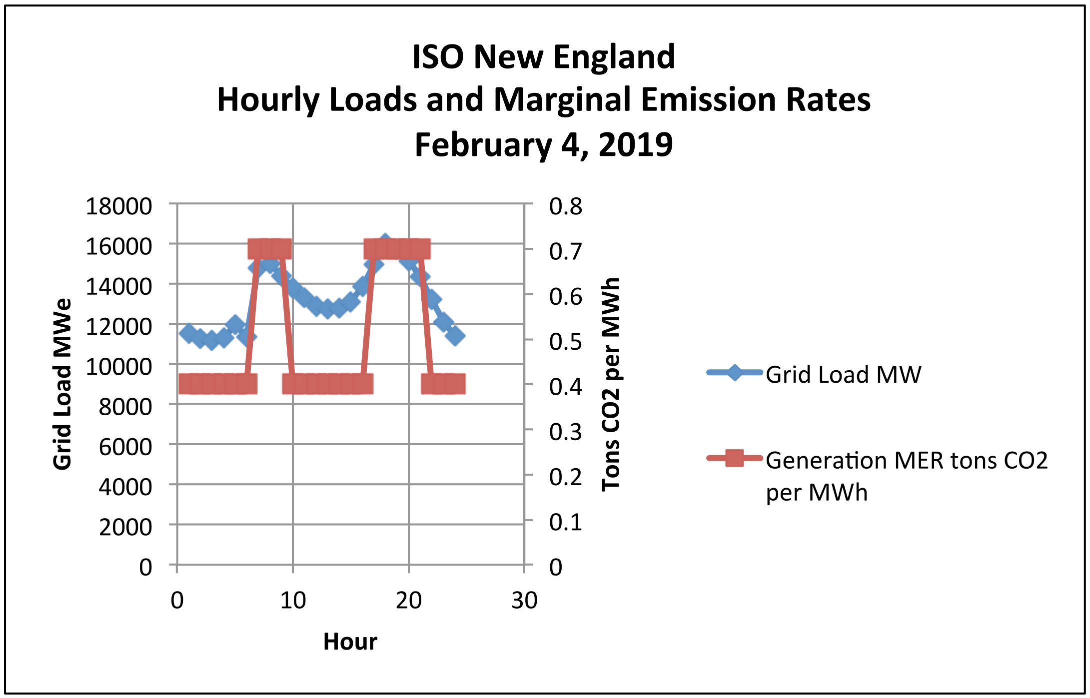
Winter prices for wholesale power will continue to rise with added thermal loads.

Everybody pays the higher prices.

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance

Single Family Home in New England

Moderate Winter Day



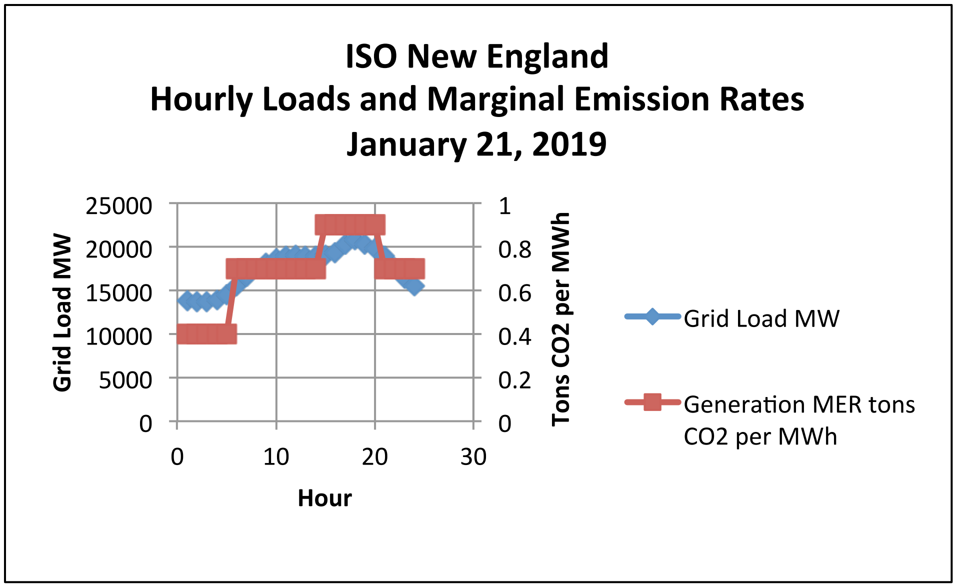
Simple-cycle generation during peak periods.

Combined-cycle generation during off-peak periods.

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance

Single Family Home in New England

Cold Winter Day

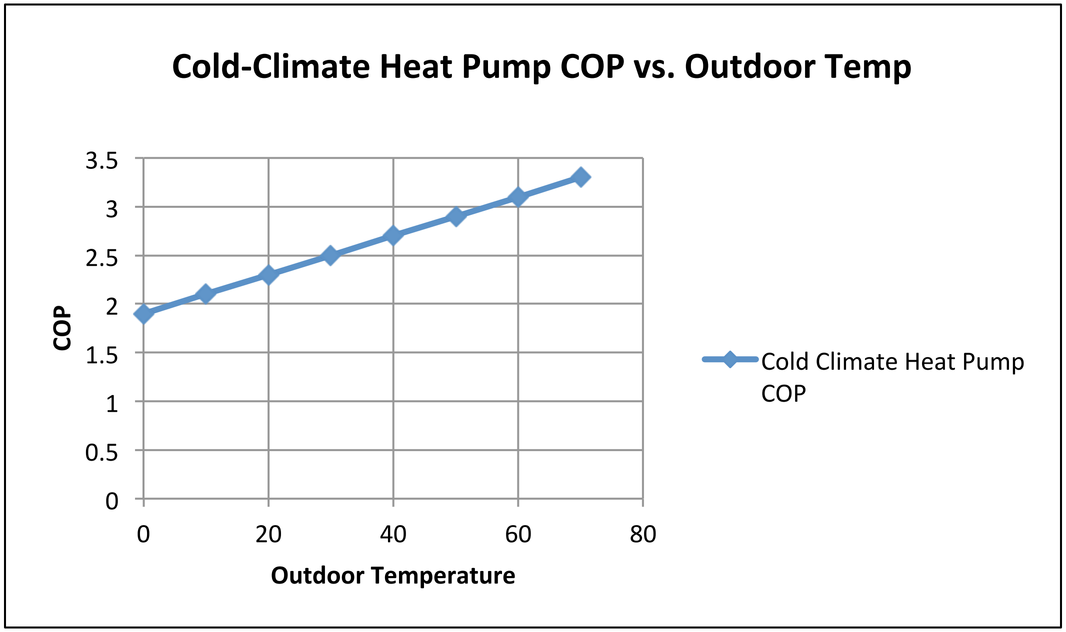


Oil-fired steam-cycle generation at margin during evening peak of about 21,000 MW.

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

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance

Single Family Home in New England



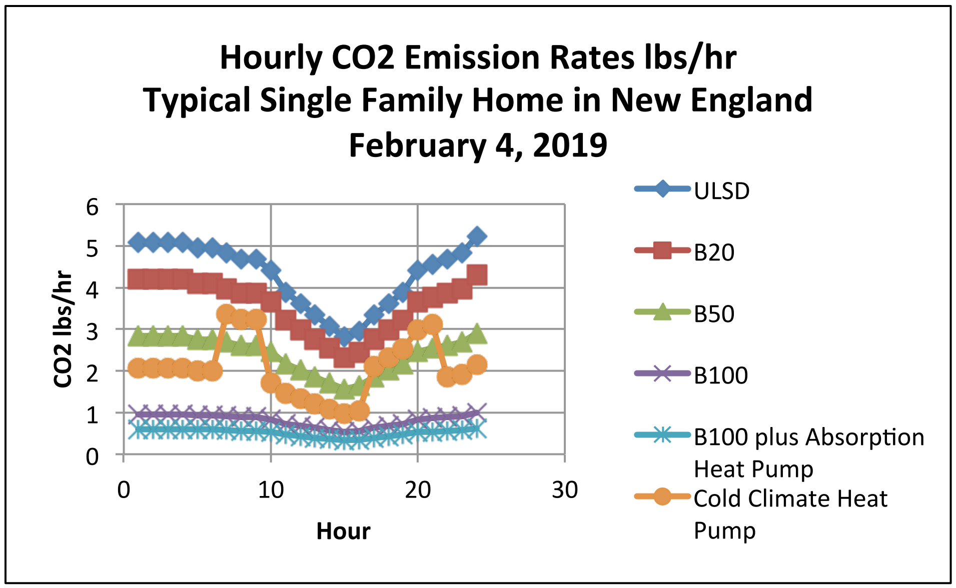
First step of analysis includes determination of heat pump COP vs. outdoor temperature.

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 New England

Moderate Winter Day



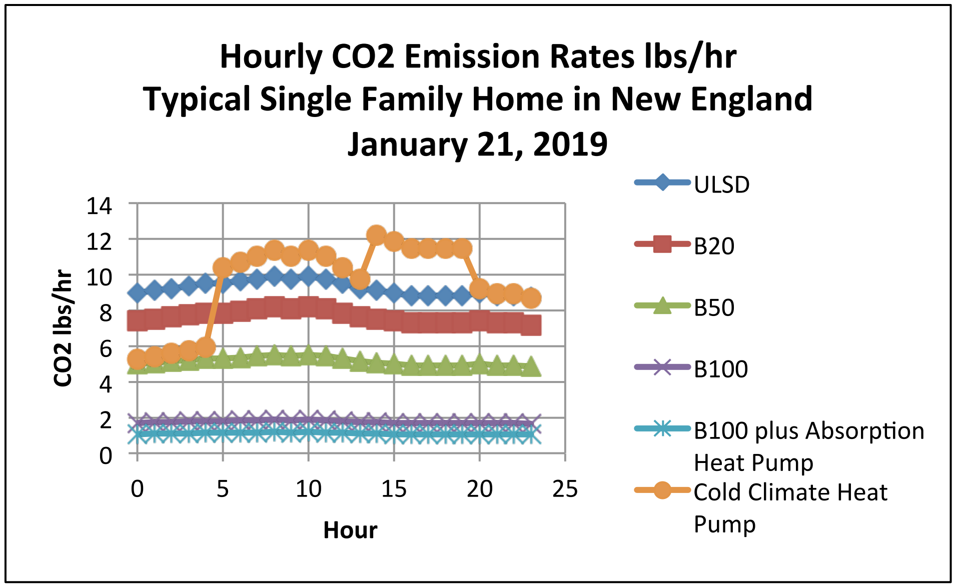
Heat pump carbon intensity approximately the same as B50 but with variations due to peak and off-peak power generation MERs.

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

Analysis of Biodiesel Vs. Cold-Climate Heat Pump Performance

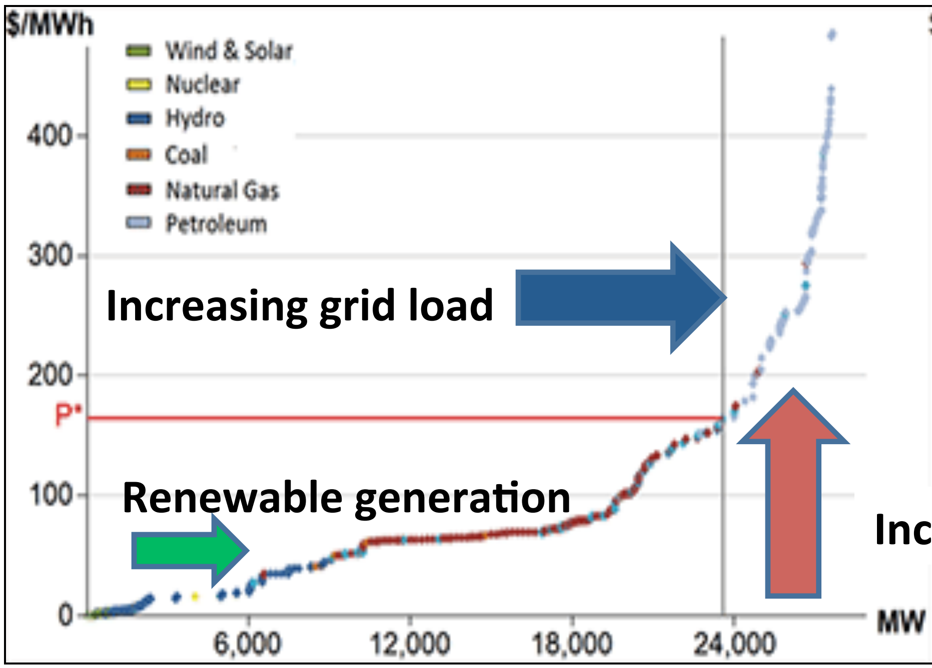
Single Family Home in New England

Cold Winter Day



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

ISO New England – Impact of Increasing Grid Load



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

5,000,000 residential heat pumps in New England would add 30,000 MW to the peak grid load.

One heat pump would consume about 10 MWh of electricity per winter or about 7 MWh during December to March.

Total offshore wind power production of 35 million MWh necessary during December to March to provide for residential heat pump operation.

27,000 MW of offshore wind nameplate capacity necessary at 45% winter capacity factor. Several times higher than MA/CT/RI offshore wind capacity goals.

Add 50% for commercial/industrial/institutional thermal loads. Problem gets worse.

Looking to the Future

CO2 Emissions (tons per year) for a Typical Single Family Home

	2020	2030	2040	2050
ULSD	8.0	8.0	8.0	8.0
B20	6.8	6.6	6.5	6.4
B50	4.8	4.6	4.4	4.0
Cold-Climate Heat Pump	5.0 ?	???	???	1.0 ?
B100	1.6	1.2	0.8	0.0

B50 and heat pumps competitive during next ten to fifteen years .

Cold-climate heat pump CO2 emissions dependent on hourly grid Marginal Emission Rates plus achievement of high levels of new renewable generation capacity.

Biodiesel-fired Boilers and Electric Heat Pumps
Typical NOx Emission Factors lbs per MMBTU Delivered Heat

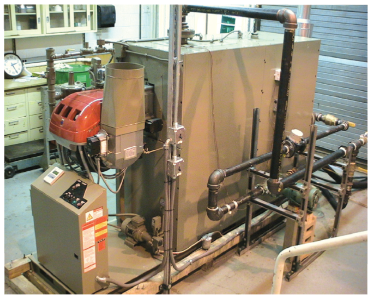


PHOTO A. A B100-fired boiler in a Brookhaven National Laboratory testing facility.

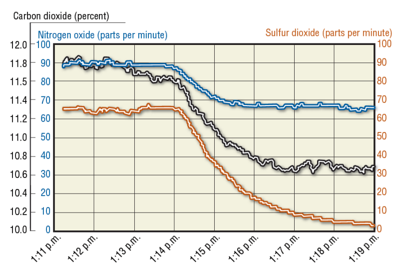


FIGURE 3. Emissions that occurred during the transition from No. 2 heating oil to B100.

	Steady-state	4 hr Peak Load
Combined Cycle w/SCR and OC (5 ppm @ 15% O2)	0.02 lb per MMBTU	0.15 lb per MMBTU
Combustion Turbine w/SCR and OC (5 ppm @ 15% O2)	0.03 lb per MMBTU	0.25 lb per MMBTU
B20 – B100 Boiler (<100 ppm @ 3% O2)	0.10 lb per MMBTU	<u>0.10 lb per MMBTU</u>
Combustion Turbine w/DLN or H2O (30 ppm @ 15% O2)	0.16 lb per MMBTU	0.25 lb per MMBTU
Steam Cycle Gas/Oil (200 ppm @ 3% O2)	0.25 lb per MMBTU	0.30 lb per MMBTU
Combustion Turbine w/o emissions control (150 ppm @ 15% O2)	0.80 lb per MMBTU	1.00 lb per MMBTU

Conclusions

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

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

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

B100 remains the lowest carbon option for heating.

Thermal load-weighted ISO New England grid Marginal Emission Rates during winter are significantly higher than figures used by many policymakers for analysis of heat pump carbon savings.

Heat pump operation during winter peak periods can result in higher total NOx emissions than individual fuel-fired heating systems. One 350 MW combined-cycle unit (e.g., GE Series 7 HA Frame with HRSG) could heat 60,000 homes but would emit NOx equal to about 120,000 natural gas/Bioheat-fired home heating systems during 2 hr start-up period. Widely dispersed low-level area sources become Major point source re: USEPA Title 5 Clean Air Act emissions standards. Possible environmental justice concerns due to high local emissions in low-income neighborhoods adjacent to power plants.

Biodiesel - protecting our environment for future generations

Ray Albrecht, P.E.

NBB Technical Representative for Northeast US region

Member of ISO New England Planning Advisory Committee

rayalbrechtpe@gmail.com

(315) 382-6044 cell

Supplemental Slides

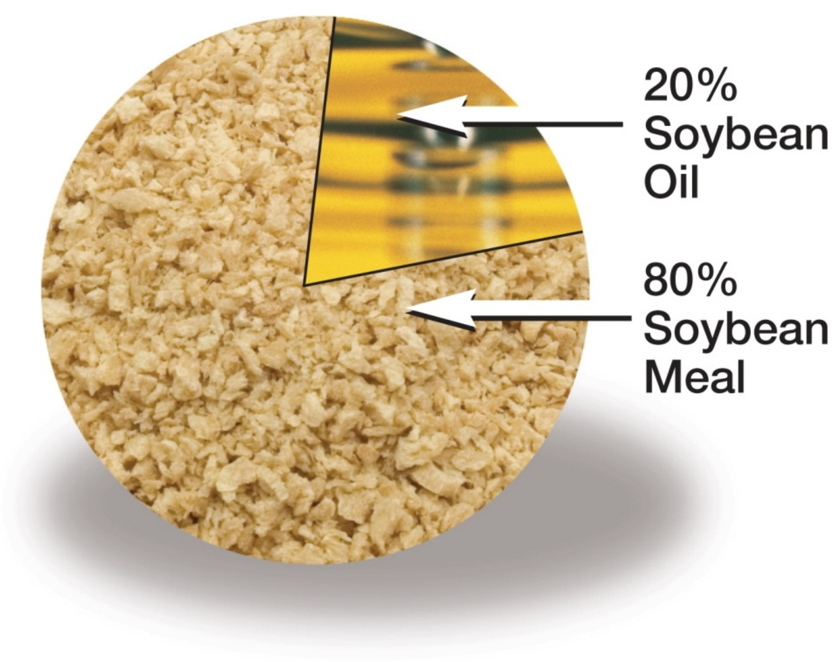
Biodiesel Feedstocks for the Northeast

- Recycled cooking oil
- Brown grease
- Soybean oil and Canola
- Pennycress and other winter cover crops gaining interest in agriculture
- Utilize existing wastes
- Improve market value for under-utilized co-products and byproducts
- Diversity helps sustainability

Co-products of Food Production

- Protein meal for livestock feed is the driver for soybean production and pricing

- Better utilization of the oil co-product can reduce the price of the protein meal.



What is biodiesel?

Biodiesel is a renewable fuel, derived from natural oils, such as soybean oil, which meets the specifications of ASTM D 6751.

Biodiesel is <u>not</u> raw vegetable oil.

Biodiesel contains about 10 - 12 % oxygen in chemical structure.

Biodiesel has ultra-low sulfur and nitrogen contents.

Biodiesel can be blended with petroleum-based heating oil and used with little or no equipment modification.

BIODIESEL®
America's Advanced Biofuel

Fuel Specifications – ASTM Standard D6751

TABLE 1 Detailed Requirements for Biodiesel (B100) Blend Stocks

Property	Test Method[A]	Grade No. 1-B S15	Grade No. 1-B S500	Grade No. 2-B S15	Grade No. 2-B S500
Sulfur,[B] % mass (ppm), max	D5453	0.0015 (15)	0.05 (500)	0.0015 (15)	0.05 (500)
Cold soak filterability, seconds, max	D7501	200	200	360[C]	360[C]
Monoglyceride content, % mass, max	D6584	0.40	0.40	—	—
		Requirements for All Grades			
Calcium and Magnesium, combined, ppm (µg/g), max	EN 14538	5	5	5	5
Flash point (closed cup), °C, min	D93	93	93	93	93
Alcohol control					
One of the following shall be met:					
1. Methanol content, mass %, max	EN 14110	0.2	0.2	0.2	0.2
2. Flash point, °C, min	D93	130	130	130	130
Water and sediment, % volume, max	D2709	0.050	0.050	0.050	0.050
Kinematic viscosity,[D] mm²/s, 40°C	D445	1.9-6.0	1.9-6.0	1.9-6.0	1.9-6.0
Sulfated ash, % mass, max	D874	0.020	0.020	0.020	0.020
Copper strip corrosion, max	D130	No. 3	No. 3	No. 3	No. 3
Cetane number, min	D613	47	47	47	47
Cloud point,[E] °C	D2500	Report	Report	Report	Report
Carbon residue,[F] % mass, max	D4530	0.050	0.050	0.050	0.050
Acid number, mg KOH/g, max	D664	0.50	0.50	0.50	0.50
Free glycerin, % mass, max	D6584	0.020	0.020	0.020	0.020
Total glycerin, % mass, max	D6584	0.240	0.240	0.240	0.240
Phosphorus content, % mass, max	D4951	0.001	0.001	0.001	0.001
Distillation temperature, Atmospheric equivalent temperature, 90 % recovered, °C, max	D1160	360	360	360	360
Sodium and Potassium, combined, ppm (µg/g), max	EN 14538	5	5	5	5
Oxidation stability, hours, min	EN 15751	3	3	3	3

[A] The test methods indicated are the approved referee methods. Other acceptable methods are indicated in 5.1.
[B] Other sulfur limits may apply in selected areas in the United States and in other countries.
[C] B100 intended for blending into diesel fuel that is expected to give satisfactory vehicle performance at fuel temperatures at or below −12°C shall comply with a cold soak filterability limit of 200 s maximum.
[D] See X1.3.1. The 6.0 mm²/s upper viscosity limit is higher than petroleum based diesel fuel and should be taken into consideration when blending.
[E] The cloud point of biodiesel is generally higher than petroleum based diesel fuel and should be taken into consideration when blending.
[F] Carbon residue shall be run on the 100 % sample (see 5.1.12).

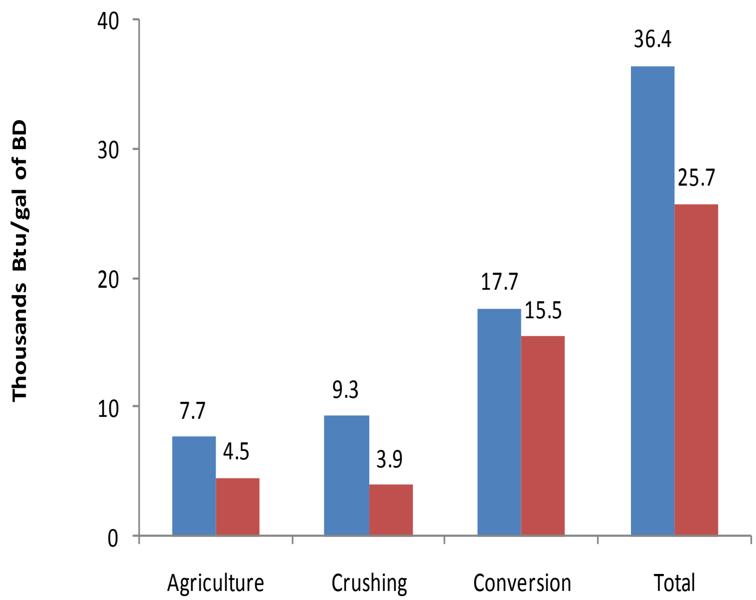
D6751 – 12

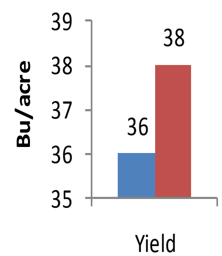
- **B100 specifications originally published in 1999**
- **23 subsequent revisions**
- **Over 20 minimum properties required for biodiesel vs 14 properties for diesel fuel**

Energy Characteristics of Biodiesel Production

Continuing Improvements in Biodiesel Production

Total Life-cycle Energy Requirements for Soy-based Biodiesel





25,000 Btu of energy input yields about 127,500 Btu output per gallon

About 80% carbon savings

Biodiesel is Advanced Biofuel

Authoring Agency	Year Published	GHG reduction compared to baseline petroleum
Argonne National Lab.	2017	66-72%
CARB	2015	50%
USDA	2012	76%
CARB	2011	12%
Argonne National Lab.	2011	73-90%
USEPA	2010	57%
Argonne National Lab.	2008	66-94%
USEPA	2008	22%
Nat. Renewable Energy Lab.	1998	78%

USEPA and CARB independently confirm LCA values for biodiesel including indirect land use change. GHG reductions will increase with further improvements in agriculture (e.g., no-till planting) also use of solar/wind power for processing and biodiesel for transport.

Argonne National Laboratory Life-cycle Analysis of Biodiesel

Bioresource Technology 251 (2018) 249–258

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Life cycle energy and greenhouse gas emission effects of biodiesel in the United States with induced land use change impacts

Rui Chen[a], Zhangcai Qin[a], Jeongwoo Han[a], Michael Wang[a,*], Farzad Taheripour[b], Wallace Tyner[b], Don O'Connor[c], James Duffield[d]

[a] Systems Assessment Group, Energy Systems Division, Argonne National Laboratory, 9700 S. Cass Avenue, Lemont, IL 60439, United States
[b] Department of Agricultural Economics, Purdue University, 403 West State Street, West Lafayette, IN 47907, United States
[c] (S&T)[2] Consultants Inc., 11657 Summit Crescent, Delta, BC V4E 2Z2, Canada
[d] Office of the Chief Economist, United States Department of Agriculture, United States

ARTICLE INFO

Keywords:
Life cycle analysis
Biodiesel
Induced land use change
Fossil energy consumption
Greenhouse gas emissions

ABSTRACT

This study conducted the updated simulations to depict a life cycle analysis (LCA) of the biodiesel production from soybeans and other feedstocks in the U.S. It addressed in details the interaction between LCA and induced land use change (ILUC) for biodiesel. Relative to the conventional petroleum diesel, soy biodiesel could achieve 76% reduction in GHG emissions without considering ILUC, or 66–72% reduction in overall GHG emissions when various ILUC cases were considered. Soy biodiesel's fossil fuel consumption rate was also 80% lower than its petroleum counterpart. Furthermore, this study examined the cause and the implication of each key parameter affecting biodiesel LCA results using a sensitivity analysis, which identified the hot spots for fossil fuel consumption and GHG emissions of biodiesel so that future efforts can be made accordingly. Finally, biodiesel produced from other feedstocks (canola oil and tallow) were also investigated to contrast with soy biodiesel and petroleum diesel.

1. Introduction

While gasoline market in the United States is expected to fall in coming decades due to vehicle efficiency gains and vehicle electrification, annual diesel consumption in transportation will increase from 7.04 to 8.45 quintillion (10^{18}) Joules by 2040 (EIA, 2016a); this is an outcome of the expansion of the freight transportation industry following the continuing economic growth. The opposing trends of these two liquids' future demand could drive many fuel producers to shift their focus from gasoline to diesel. Globally, the consumption of liquid fuels in the transportation sector alone is predicted to grow from 110.3 quintillion Joules in 2015 to 144.3 quintillion Joules in 2040 (EIA, 2016c). The globally expanding demand for transportation fuels has raised serious concerns about supply, energy independence, economic development, environmental stewardship, and human health and wellbeing. Sustainable solutions that address these issues must be explored to meet our future needs. Biomass-based alternative liquid fuels (biofuels) have received heightened interest due to positive attributes such as low life cycle greenhouse gas (GHG) emissions, renewable feedstocks, and their nontoxic and biodegradable residues. In particular, as one of the most commercially produced and consumed biofuels, biodiesel has gained significant popularity worldwide over the past two decades. Of the 5.93 billion liters of biodiesel produced in the United States in 2016, soy oil was the most abundantly used feedstock, accounting for approximately 55% of all reported feedstock inputs, followed by recycled oil/grease (~13%), distillers corn oil (~12%), animal fat (~10%), and other vegetable oils (~10%) (EIA, 2016b). These biodiesel feedstocks can also be categorized into two groups based on their free fatty acids (FFA) content: vegetable oils (such as soy oil and canola oil) that contain low FFA, and high FFA oils (such as corn oil, tallow, and grease). Different levels of FFA in biodiesel feedstocks can significantly impact the amount of energy and chemical inputs during the biodiesel conversion, and a parallel comparison of these two types of oil feedstocks can help understand differences and similarities among feedstocks for biodiesel production.

In general, the life cycle of a specific transportation fuel involves a series of stages that lead from "well" (production of the feedstock) to "wheel" (combustion of the fuel). The GHG emissions from the combustion stage of biofuels are offset by CO_2 fixation while the biomass is growing. However, the production stage of biofuels can generate relatively high GHG emissions due to the use of fossil fuels. Therefore, a life cycle analysis (LCA) of both the environmental flows and the energy

* Corresponding author.
E-mail address: mqwang@anl.gov (M. Wang).

https://doi.org/10.1016/j.biortech.2017.12.031
Received 17 October 2017; Received in revised form 10 December 2017; Accepted 11 December 2017
Available online 15 December 2017

Carbon savings of about 80% and 66-72% total GHG savings depending on feedstock and including indirect land-use change (ILUC) based on current practices.

BIOHEAT®

B100-fired Boilers – Opportunity for 100% Renewable Heating

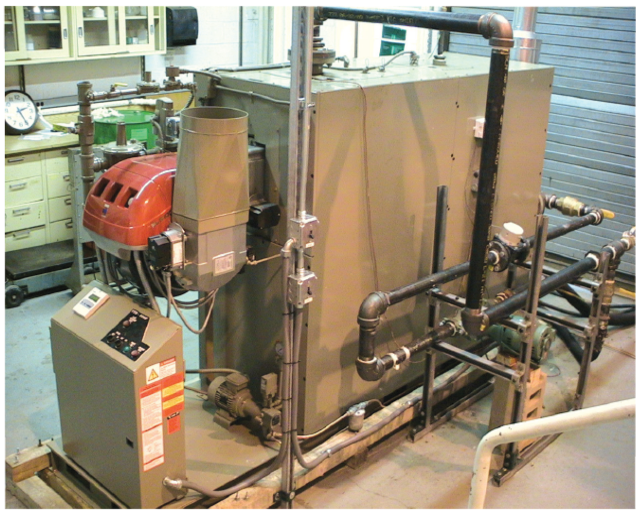
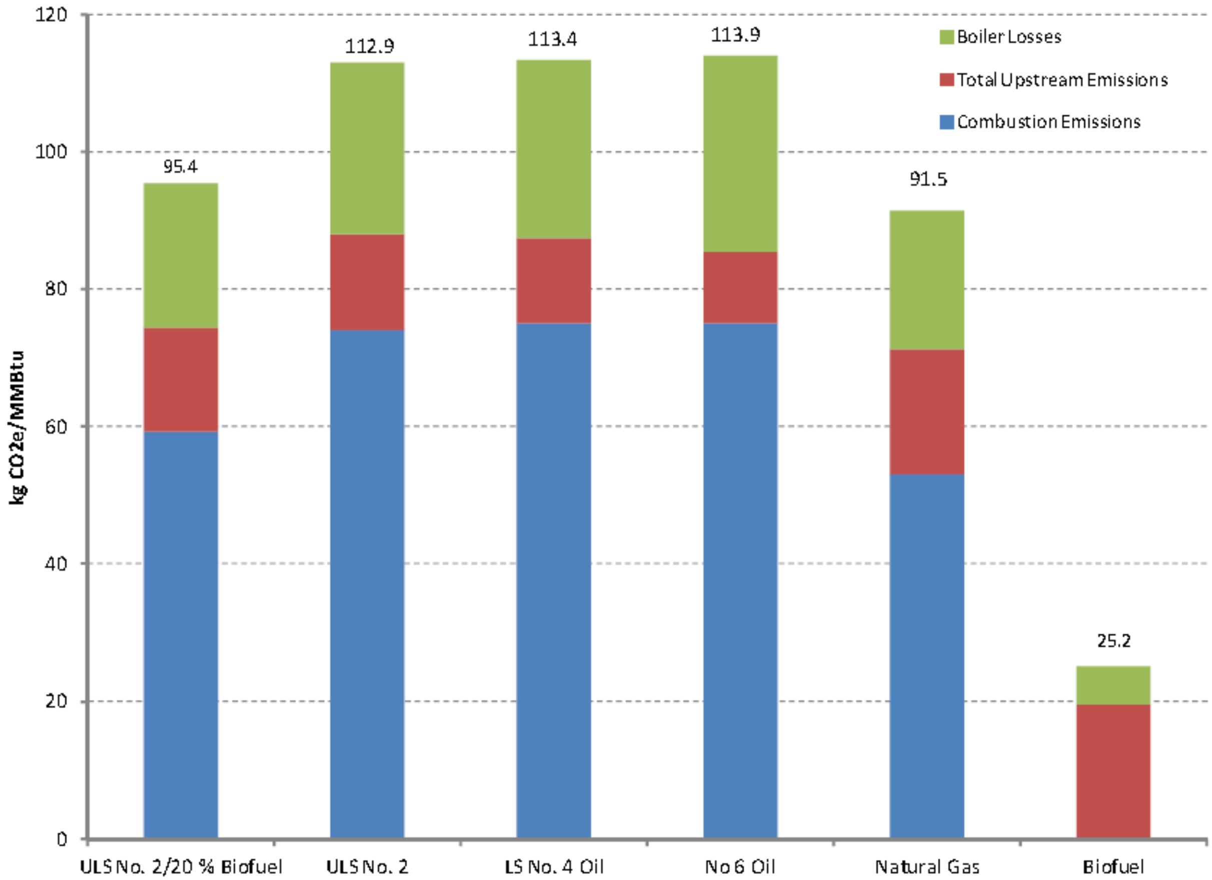


PHOTO A. A B100-fired boiler in a Brookhaven National Laboratory testing facility.

B20 blend is a drop-in fuel for residential and commercial boilers

B100 can be implemented through basic technical modifications

Exhibit 5-11: Summary Life-Cycle GHG Emissions Comparison for Residential and Commercial Boilers in New York City (kg CO_2e/MMBtu)



Source: ICF Analysis.

Biodiesel – Pathway to a Sustainable Energy Future

Providence Resolution

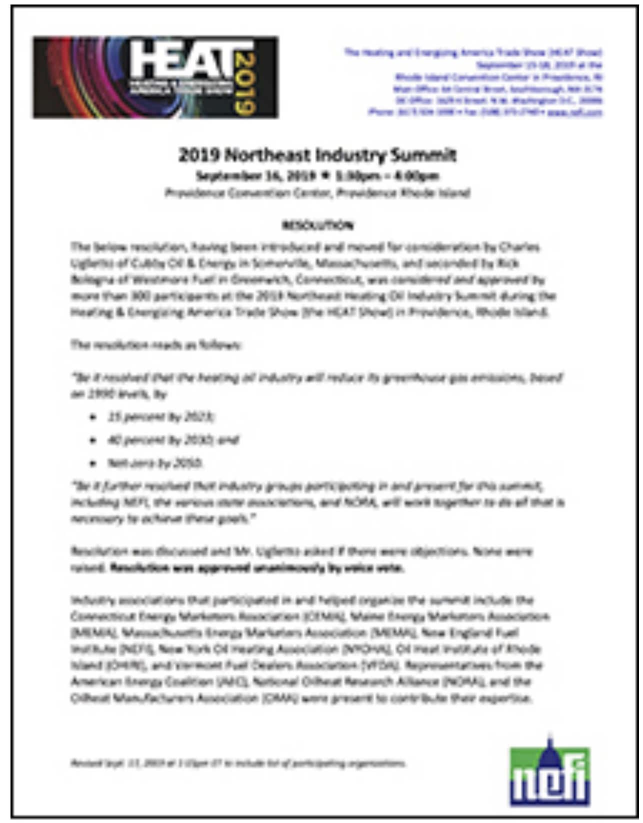
September 2019

Industry Commitment to Renewable Fuel

Transition to B20 by 2023 will achieve 15% GHG savings

B50 by 2030 will achieve 40% GHG savings

Carbon-neutral by 2050 will achieve greater than 80% GHG savings



2019 Northeast Industry Summit

September 16, 2019 ★ 1:30pm – 4:00pm

Providence Convention Center, Providence Rhode Island

RESOLUTION

The below resolution, having been introduced and moved for consideration by Charles Uglietto of Cubby Oil & Energy in Somerville, Massachusetts, and seconded by Rick Bologna of Westmore Fuel in Greenwich, Connecticut, was considered and approved by more than 300 participants at the 2019 Northeast Heating Oil Industry Summit during the Heating & Energizing America Trade Show (the HEAT Show) in Providence, Rhode Island.

The resolution reads as follows:

"Be it resolved that the heating oil industry will reduce its greenhouse gas emissions, based on 1990 levels, by

- *15 percent by 2023;*
- *40 percent by 2030; and*
- *Net-zero by 2050.*

"Be it further resolved that industry groups participating in and present for this summit, including NEFI, the various state associations, and NORA, will work together to do all that is necessary to achieve these goals."

Resolution was discussed and Mr. Uglietto asked if there were objections. None were raised. **Resolution was approved unanimously by voice vote.**

Industry associations that participated in and helped organize the summit include the Connecticut Energy Marketers Association (CEMA), Maine Energy Marketers Association (MEMA), Massachusetts Energy Marketers Association (MEMA), New England Fuel Institute (NEFI), New York Oil Heating Association (NYOHA), Oil Heat Institute of Rhode Island (OHIRI), and Vermont Fuel Dealers Association (VFDA). Representatives from the American Energy Coalition (AEC), National Oilheat Research Alliance (NORA), and the Oilheat Manufacturers Association (OMA) were present to contribute their expertise.

GE Power – Emissions Test Results for Biodiesel

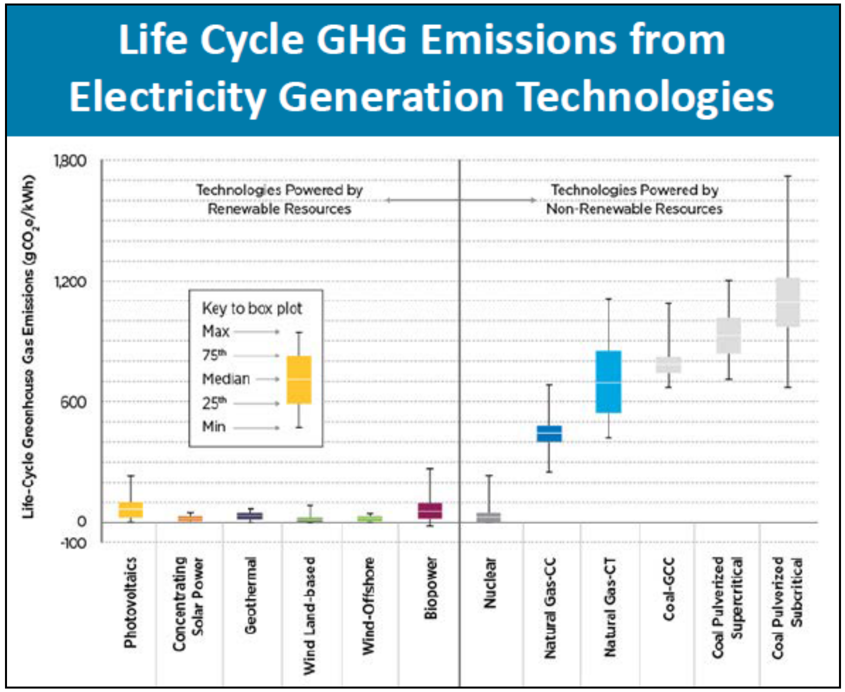
Blends with Oil and Co-firing with Natural Gas

Table 5: Field Test emission results.

Fuel	% GT Load	W/F w/w	NOx* (mg/Nm^3)	O_2* (% vol)	CO* (mg/Nm^3)	CO_2* (% vol)	VOC* (mg/Nm^3)	Bacharach No.
NG	100	0	247	15.4	< 1	3.26	1	0
DO	100	0	367	15.5	< 1	4.05	1	2.5
RME	100	0	360	15.3	< 1	4.33	1	0 to 1
DO	100	0.30	198	15.2	< 1	4.20	1	2.5
RME	100	0.43	161	15.1	1	4.51	-	0
20% RME / 80% NG	100	0	250	15.3	< 1	3.49	3	0
20% RME / 80% NG	100	0.5	105	15	1	3.67	3	0
50% RME / 50% NG	100	0	294	15.4	< 1	3.74	2	0
70% RME / 30% NG	100	0	325	15.4	< 1	3.92	1	0
70% RME / 30% NG	100	0.46	135	15.1	1	4.12	2	0
RME	75	0	247	16.1	1	3.38	2	0.5
RME	75	0.24	178	16.6	1	3.37	2	0
RME	50	0	166	17.6	5	2.65	3	0
50% RME / 50% DO	100	0	367	15.1	< 1	4.38	1.6	-

Lowest Nox levels achieved by co-firing with natural gas and biodiesel/water emulsion

Perspectives on Renewable Power Generation



Biodiesel-fired power generation in same general range of carbon intensity as other renewable energy sources