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FutureFuel – biodiesel and advanced biofuels for residential heating

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Why the Heating Oil Industry must change

The heating oil industry is facing a new challenge that must be addressed. State and local governments in oil heat regions are developing policies to achieve long-term reductions in greenhouse gas emissions (GHG). These policies include the elimination of heating with oil. One very popular approach to achieve this is converting building heating to electric cold climate heat pumps, powered by the future renewable electric grid (wind, water and solar with battery storage). If the heating oil industry is to remain part of the heating market of the future, it must develop advanced biofuel solutions now, and transition to the "renewable liquid fuels" industry.

Here is a sampling of some of the *Beneficial Electrification*[1] policies impacting the industry today:

In April of 2018, New York's Governor Cuomo announced[2] a *New Energy Efficiency Target to Cut Greenhouse Gas Emissions and Combat Climate Change*. The announcement stated: *"The New York State Energy Research & Development Authority (NYSERDA) and the New York State Department of Public Service are proposing innovative strategies and tools to achieve the target, including energy benchmarking to measure progress, accelerated building codes with implementation support from the Clean Energy Fund, and investment in heat pumps*[3] *to deliver low carbon solutions for heating and cooling."*

In September 2014, New York City committed itself to its *Roadmap 80 x 50*[4], which states "Nearly all of the city's existing buildings will need to undergo deep energy retrofits that holistically address heating, cooling and the building envelope. Many will **need to replace fossil fuel-based heat or hot water systems with renewable sources or energy efficient electric technologies** to tap into a cleaner future electric grid. Retrofits to buildings will improve the quality of housing, and the energy efficiency gained help keep homes affordable over the long-term."

Vermont's *2016 Comprehensive Energy Plan*[5] established new planning goals to reduce GHG emissions from its energy use. These goals are:

- 40% reduction below GHG levels in 1990 by 2030
- 80% to 95% reduction below 1990 levels by 2050

Massachusetts *Clean Energy and Climate Plan for 2020*[6], updated in 2015 states: "Developing a Mature Market for Renewable Thermal Technologies—continued and **accelerated renewable thermal installations are required to electrify the buildings sector's heating and cooling loads**, and utilize Massachusetts' clean electric supply."

The result of these policies has led to state and local incentives to switch fuel from oil heating systems to cold climate electric heat pumps, or to a lesser extent, natural gas furnaces and boilers.

Renewable Fuels

National Oilheat Research Alliance (NORA) research demonstrates that high biodiesel blends (greater than 20%) are operating very well in the field although most oil burners are rated by the manufacturer to burn a maximum of 5%. Biodiesel is the only renewable fuel available now in sufficient quantities to make a difference in the market. Currently, it is common for biodiesel to be blended into home heating oil and it is becoming increasingly difficult to find homes heating with oil which have no biodiesel.

Renewable diesel[7] (RD) is a low carbon biofuel that could offer solutions in the future. However, RD costs significantly more than biodiesel in today's market. RD's price is currently driven by the California transportation market. It is clear that RD capacity will be easily absorbed by the transportation market for the foreseeable future and may not be available for home heating. Also, RD has no ASTM specification and production processes are not the same. RD fuels have not been fully evaluated for compatibility with elastomers commonly used in fuel systems.

NORA continues to research other biofuels that may have potential for the future.

What About Beneficial Electrification?

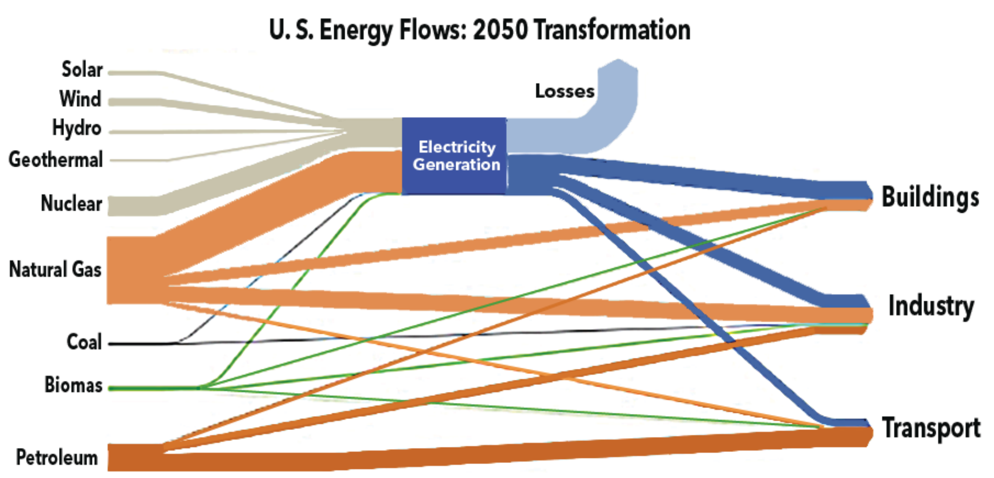
Since New York, New England and other state policy makers are actively pursuing *Beneficial Electrification*, let's examine this approach. There are a number of flaws in this policy-driven movement that affects the heating oil industry and all other energy providers:

- Policy-driven electrification would increase average residential household costs largely because intermittent renewables and batteries would substantially increase the electric infrastructure. A vastly oversized grid and a dramatic increase in production will be necessary to ensure that the electric operating system does not collapse during a sustained freeze and when heat pump efficiency is low or fails to provide heat.
- Despite the desire to move to renewably-fueled electric power plants, the electric grid in 2050 will not be 100% renewable. It will likely require natural gas combined cycle combustion turbines (CCCTs) operating, at the margin, to fulfill the increased demand of millions of households currently using natural gas or heating oil. In fact, the Electric Power Research Institute's (EPRI) *April 2018 National Grid Assessment* predicts in its *Transformation Model* that the final delivered energy from the electric grid will account for only 47% of the total delivered energy needs.
- Switching residential heating (oil and natural gas) to electric heat pumps would only result in GHG emissions reduction by 1% to 1.5%.

So why is this happening? Proponents of *Beneficial Electrification* include environmental organizations driving an easily understood agenda, electric utilities that directly benefit and government entities that react to constituencies—and all need to demonstrate success.

Policy-driven electrification

Policy-driven electrification, through switching residential heating to electric heat pumps, would increase the average residential household energy-related costs by approximately 38% to 46%[8], resulting in an increase to the average affected residential household of between $750 and $910 per year[9]. Widespread residential electrification will lead to increases in peak electric demand that could shift the U.S. electric grid from summer peaking to winter



This Sankey diagram shows EPRI's model results for its most aggressive carbon reduction scenario (Transformation) in 2050. Most notable is large dependence on nuclear and natural gas power generation and significant requirements for fossil fuel combustion in buildings and industry.

Switching from residential heating fuel to electric heat pumps would only result in a GHG emissions reduction of 1% to 1.5%

peaking in every region of the country. This would result in the need for new investments in the electric grid including generation capacity, transmission capacity and distribution capacity.

The U.S. Energy Information Administration (EIA) projects that by 2035, the sum of natural gas, propane and fuel oil used in the residential sector will account for less than 6% of total GHG emissions. Reductions from policy-driven residential electrification would reduce GHG emissions by 1 to 1.5% of U.S. GHG emissions in 2035. The potential reduction in emissions from the residential sector is partially offset by an increase in emissions from the power generation sector; even in a case where all incremental generating capacity is renewable[10].

Where is the heating oil industry today?

The heating oil industry today is moving away from traditional oil-based fuels to biofuels with NORA exploring the transition from B5-B20 to a 1/3 Biodiesel—1/3 Advanced Biofuel[11] and 1/3 ULSD by 2035. The advanced biofuel under consideration yields negative carbon due to avoided carbon emissions. As a result, this fuel would yield carbon-free combustion for heating.

The U.S. Department of Energy is supporting the development of thermal heat pump technology that will be more efficient, provide more comfortable heating and cost less. Additionally, it would make the electric grid less vulnerable to failure and make any failure less catastrophic.

Biodiesel and advanced biofuels *must not* be ignored by policy makers when developing their carbon and methane reduction plans for the future. Renewable biofuels may provide the most cost-effective method to reduce carbon and can make other GHG reduction strategies more easy to obtain.

Pathway to Energy Efficiency

Energy efficiency is a significant factor in achieving carbon reduction. The less fuel used in generating electricity or in directly fueling appliances, the lower the carbon emissions. With carbon emissions, site efficiency (energy used in the home such as kilowatts and BTUs) must be considered in evaluating different heating fuels. More importantly for electricity, the source energy and impact of demand fluctuations on efficiency, grid reliability and total carbon emissions must be considered when comparing heating energy sources.

Boilers: current typical fossil-fueled residential boilers are 82% to 86% efficient. This is largely because existing hydronic systems were designed for high temperatures. New hydronically-heated homes can use condensing boilers at 96% efficiency.

Furnaces: all homes can take advantage of higher cost modern condensing furnaces at 96% efficiency.

Electric Heat Pumps: an electric heat pump with a site-based coefficient of performance (COP) of 3.2[12] for heating has a source-based COP of 1.09[13], when operating at design conditions. A recent U. S. Department of Energy field test report[14] shows actual performance during winter testing: a cold climate heat pump in Vermont had a seasonal site heating COP of 2.3 (source COP of 0.78). This same heat pump in Vermont had a site COP of 1.0 (source COP of 0.34) at 0°F ambient. Note: delivered electricity is a mere 34% efficient when measured from fuel to the power plant—to electricity delivered to the electric socket in a home.

Thermal Heat Pumps: an exciting new technology in late stage development is the air-sourced thermally-driven heat pump. This technology would deliver a site-based COP of 1.4[12] for heating, with a source-based COP of 1.2. The thermal heat pump also has a site COP of 1.0 (source COP of 0.90) at 0°F ambient. This means that the thermal heat pump is more source-based efficient versus the electric heat pump (~30% at 47°F and 120% at 0°F). Thermal heat pumps, when fully developed, can be integrated with existing and new home furnaces and boilers. Their coefficient of performance and delivered air temperature would not drop precipitously during cold weather like electric heat pumps.

What is COP

The coefficient of performance or COP of a heat pump is a ratio of heating or cooling energy provided vs. energy input required. Higher COPs equate to lower operating costs. The COP may exceed one, because, instead of just converting electric energy to heat (which, if 100% efficient, would be a COP of one), the system draws additional heat from the outside air.

	2018	2025	2030	2035		
	ULSD	B20	B40	B100	ULSD40, B50 & EL10	1/3 ULSD, 1/3 B100 & 1/3 EL
Standard Boiler, 14 SEER Minisplit AC	0%	14%	29%	71%	95%	95%
Condensing Boiler, 14 SEER Minisplit AC	14%	26%	39%	74%	95%	95%
Heating only LF-AHP and 14 SEER Minisplit	35%	43%	54%	78%	93%	93%
14 SEER Minisplit Heat Pump with Boiler Back-up	25%	34%	46%	70%	85%	85%
18 SEER 5 RT Cold Climate Heat pump with Boiler Backup	57%	59%	64%	66%	69%	69%

Table 1: Percent Reduction in CO_{2e} Annual Emissions from Heating and Cooling a Single-Family Home (Hydronic-Cold Air)

	2018	**2025**	**2030**	**2035**		
	ULSD	B20	B40	B100	ULSD40, B50 & EL10	1/3 ULSD, 1/3 B100 & 1/3 EL
Non-Condensing Furnace, 14 SEER Central AC	0%	14%	28%	72%	83%	87%
Condensing Furnace, 14 SEER Central AC	14%	26%	38%	75%	84%	88%
Heating only LF-AHP and 14 SEER Central AC	38%	47%	55%	81%	87%	89%
14 SEER Electric Heat Pump with Resistance Back-up	28%	28%	28%	41%	28%	28%
18 SEER 5 RT Cold Climate Heat pump with Resistance Backup	58%	58%	58%	66%	58%	58%

Table 2: Percent Reduction in CO_{2e} Annual Emissions from Heating and Cooling a Single-Family Home (Hot-Cold Air)

Pathway to Low Carbon Fuels

Based on a peer-reviewed site energy performance and emissions study[15], **Tables 1** and **2** show that moving from non-condensing appliances to condensing appliances, and finally to thermal heat pump technologies, significantly reduces carbon emissions. Furthermore, shifting to low carbon fuel blends dramatically reduces greenhouse gas emissions.

Looking forward to NORA's 2035 goal, **Tables 1** and **2** show that in the case of radiant heating and forced-air home heating and cooling systems, all three liquid fuels-based heating technologies, coupled with three specific fuel scenarios, reduce carbon emissions more than cold climate electric heat pumps using electricity from low emissions, advanced natural gas central station and combined cycle combustion turbine production. The yellow highlights indicate liquid fuel pathways to no-carbon combustion. Note, the remaining carbon emissions for liquid fuel pathways in the last two columns are from the electric grid (marginal natural gas central station combined cycle combustion turbine electricity production) for cooling and ancillary equipment. Zero net carbon is from combustion. ICM

1. "Beneficial Electrification" assumes that all or most home heating energy will be supplied by an electric grid that is exclusively powered by renewables and batteries coupled with cold climate electric heat pumps.
2. https://www.governor.ny.gov/news/governor-cuomo-announces-new-energy-efficiency-target-cut-greenhouse-gas-emissions-and-combat
3. This refers to electric heat pumps.
4. https://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/
5. https://outside.vermont.gov/sov/webservices/Shared%20 Documents/2016CEP_Final.pdf
6. https://www.mass.gov/service-details/clean-energy-and-climate-plan-for-2020
7. Renewable diesel (RD) is not a fossil fuel. Instead, it is made of nonpetroleum renewable resources such as natural fats, vegetable oils, and greases. RD is a "drop-in" diesel substitute. It can be produced in the same facilities as conventional diesel; transported, stored and dispensed in the same existing network; and combusted in the same engines.
8. https://www.aga.org/research/reports/implications-of-policy-driven-residential-electrification/
9. ibid.
10. ibid.
11. There are several pathways moving toward advanced biofuels, two of which are listed. 1) Biofine Technology, LLC. Has developed a cellulosic biodiesel for use in residential heating, and 2) Synthetic Genomics, Inc. (SGI) and ExxonMobil have developed a strain of algae able to convert carbon into a record amount of energy-rich fat, which can then be processed into biodiesel.
12. Standard rated conditions of 47°F outdoor temperature and 70°F indoor temperature.
13. Site efficiency 3.2 COP x 34% efficient electric grid = source efficiency of 1.09.
14. Field Performance of Inverter-Driven Heat Pumps in Cold Climates James Williamson and Robb Aldrich Consortium of Advanced Residential Buildings, US DOE, August 2015
15. "Energy, Cost and CO2e Analyses of Reversible, Hybrid and Heating- Only LF-AHP in the Northeast", Christopher Keinath, PhD, Thomas Butcher, PhD and Michael Garrabrant, PE, ASHRAE, June 2018 with updated energy prices.

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