futurefuel

Richard Sweetser

NORA Sr. Advisor on Research

Technical Workshop

September 24-25, 2018

understanding the viability of advanced biofuels and combustion technologies to deliver zero net carbon combustion in the future

and

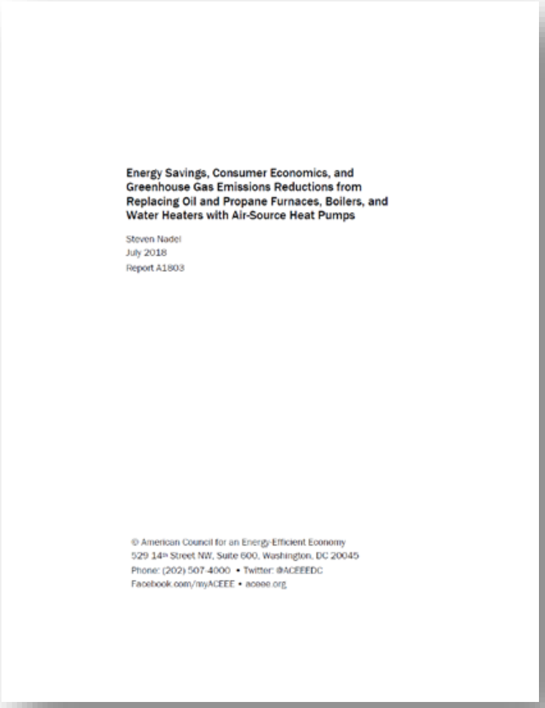
examining advanced biofuels as an alternative to electric heat pumps and other fossil fuel combustion in tomorrow's homes

ACEEE July 2018 Report

Energy Savings, Consumer Economics, and Greenhouse Gas Emissions Reductions from Replacing Oil and Propane Furnaces, Boilers, and Water Heaters with Air-Source Heat Pumps

recommends

"… programs to promote high-efficiency heat pumps to replace less-efficient oil and electric systems ... Such efforts can build on successful programs in the Northeast and Northwest. In addition, programs to promote heat pumps in new construction deserve attention."



Energy Savings, Consumer Economics, and Greenhouse Gas Emissions Reductions from Replacing Oil and Propane Furnaces, Boilers, and Water Heaters with Air-Source Heat Pumps

Steven Nadel
July 2018
Report A1803

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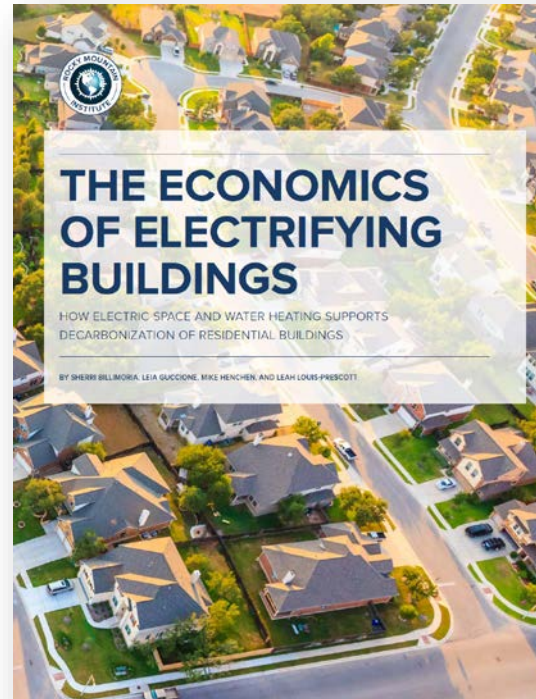
Rocky Mountain Institute's "RMI's" June 2018 Brochure

<u>The Economics of Electrifying Buildings</u>

concludes:

"Prioritize rapid electrification of buildings currently using propane and heating oil in space and water heating. Although these represent less than 10% of US households, they account for more than 20% of space and water heating emissions. Electrification is very cost-effective for propane customers, and has a comparable cost to heating oil depending on local pricing."



nationalgrid’s June 2018 Brochure

<u>80 x50 Pathway</u>

states:

“A transformation of the heat sector, by doubling the rate of efficiency retrofits and converting nearly all of the region’s 5 million oil-heated buildings to electric heat pumps or natural gas” …“Additional incentives for heat electrification and green gas production will be important.” …“Beyond 2030, the heat sector will require sustained efficiency investment and conversion to heat pumps, the steady decarbonization of natural gas supply (through renewable natural gas, hydrogen, and synthetic fuels), and conversion of many natural gas homes to hybrid natural gas-heat pump configuration”.

Clean Energy, Efficiency, and Electrification: National Grid's Northeast 80x50 Pathway

This paper presents National Grid's integrated blueprint for New York and New England to reduce greenhouse gas emissions deeply below 1990 levels while supporting economic growth and maintaining affordability and customer choice. Our approach combines several mutually-reinforcing strategies that together provide a clear pathway to significant emissions reductions and signal a paradigm shift in the way we all relate to energy. National Grid is keen to achieve greater collaboration within the Northeast on this pressing and critical issue.

EXECUTIVE SUMMARY

Climate change threatens our quality of life and the livability of planet earth. To reduce the risk that global temperature increases more than 2 degrees Celsius above pre-industrial levels, greenhouse gas (GHG) emissions in developed countries must fall by approximately 80% below 1990 levels by 2050 ("80x50"). Commitments to reduce GHG emissions by this level are in place across the Northeast U.S., spanning New York and all New England states. Similar targets are in place in the European Union, the United Kingdom, and in other U.S. states such as California, Oregon, and Washington.

The Northeast has emerged as a leader in achieving these targets, with the electric sector leading the way. 2015 emissions from power generation were nearly 50% below 1990 levels, driven mainly by energy efficiency, conversion from coal and oil-based generation to natural gas, and deployment of renewable electricity. The most recent data (2015) shows that the Northeast has achieved a 16% economy-wide GHG reduction below 1990 levels. Emissions in 2015 related to heating (for space and water heat in homes and businesses as well as industrial heat processes) were roughly 12% below 1990 levels driven by energy efficiency and oil-to-gas conversions. Reducing transportation emissions has proven more difficult, with emissions still at 1990 levels (or even higher) across the region.

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Recent Fuel-Switching Studies

	Does not evaluate biodiesel	Does not evaluate advanced biofuels	Does not evaluate thermal liquid-fueled heat pumps	Does not cost grid upgrades required for 80% renewables	Does not evaluate low ambient comfort
ACEEE's July 2018 report	●	●	●	●	●
RMI's - The Economics of Electrifying Buildings	●	●	●	●	●
nationalgrid's 80 x50 Pathway brochure	●	●	●	●	●

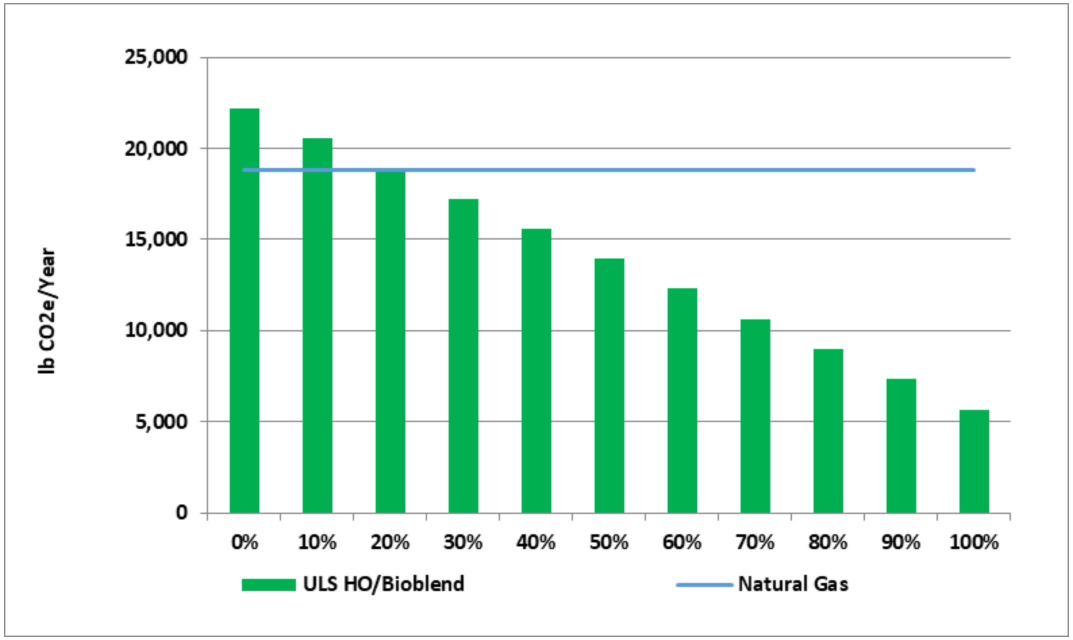
Let's examine natural gas and electricity positions a bit further:

Natural gas has been declared the bridge fuel, by some, to an all renewable future. Renewable gas is touted as the future for natural gas, but it has limits.

The electric power sector is widely expected to be the linchpin of efforts to reduce greenhouse gas (GHG) emissions. Most studies exploring climate stabilization pathways envision a decline in global anthropogenic GHGs of 50-90% below current levels by 2050 . To reach these goals, the power sector would need to cut emissions nearly to zero, while expanding to electrify (and consequently decarbonize) portions of the transportation, heating, and industrial sectors.

Comparing Liquid Biofuels with Natural Gas

For Boston, the GHG emissions of a typical replacement residential oil boiler using a B20 blend are equivalent to the emissions from a typical replacement natural gas boiler based on 100-year atmospheric lifetime calculations without considering induced land use change impacts. Blends up to B100 have been used in the field today, with B20 blend being quite typical.



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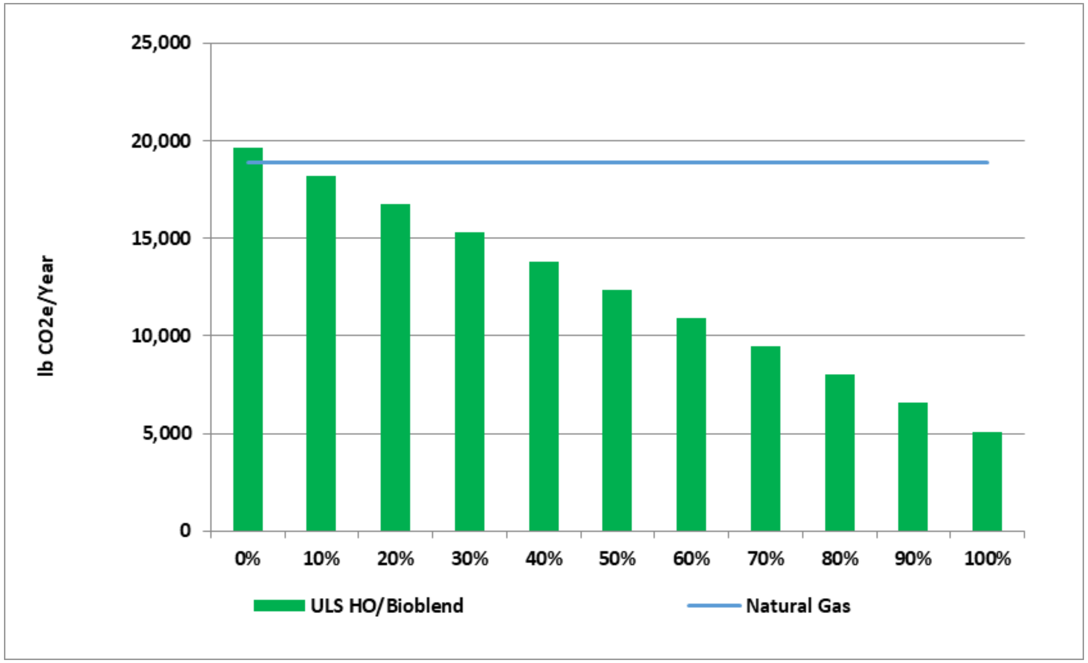
Comparing Liquid Biofuels with Natural Gas

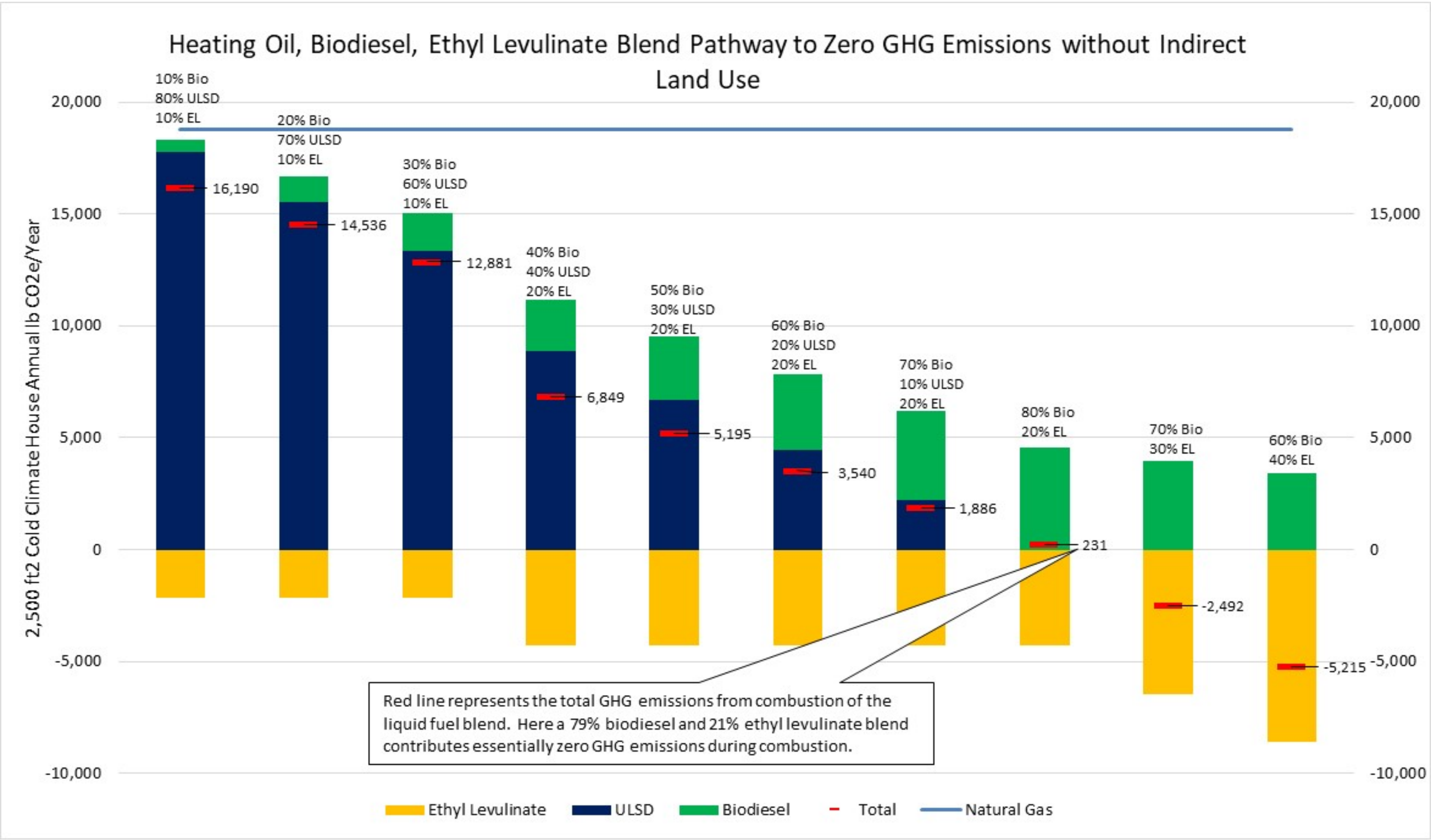
For Boston, the GHG emissions of a typical replacement residential oil boiler using a B7 blend of heating oil are equivalent to the emissions from a typical replacement natural gas boiler based on 20-year atmospheric lifetime calculations without considering induced land use change impacts.



Comparing Liquid Biofuels with Natural Gas

The graph in the next slide shows a blend of just 10% biodiesel, 10% ethyl levulinate and 80% ULSD has lower annual GHG emissions than natural gas. The graph shows that increasing biodiesel and ethyl levulinate blend content significantly improves GHG emission compared to natural gas. In fact, because of the feedstock used, production techniques and multiple usable products, ethyl levulinate actually enables the potential for reduction of GHG beyond a neutral point – a blend of 79% soybean-based biodiesel and 21% ethyl levulinate contributes zero total fuel cycle GHG emissions, based on using the 100-year atmospheric lifetime global warming potential (GWP) factors with carbon feedback.

Comparing Liquid Biofuels with Natural Gas



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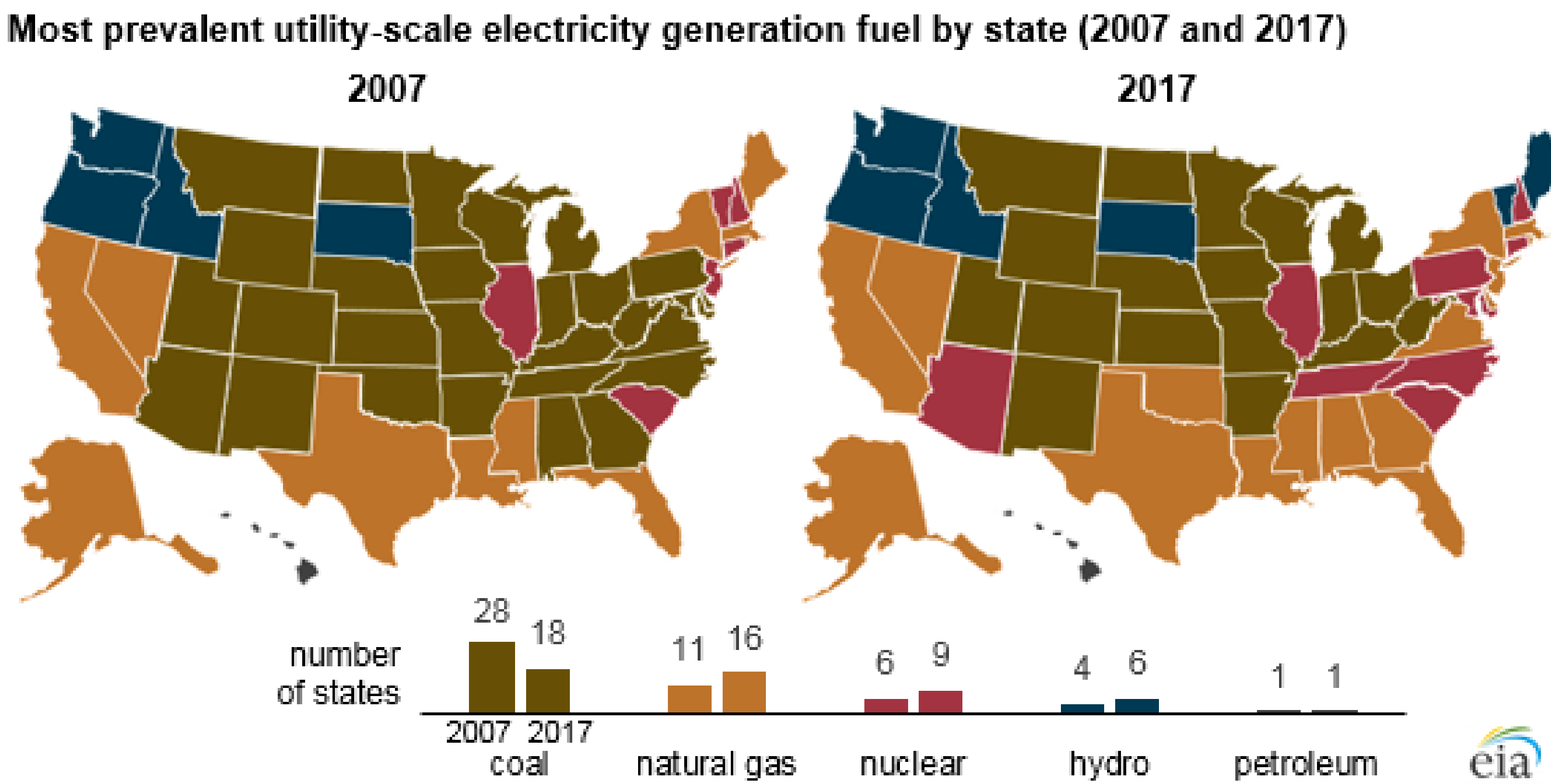
Beneficial Electrification

Meaning: Eventually all energy is delivered by a renewably supplied (solar, wind, hydro and batteries) electric grid.

Favored by the environmental community: which advocates no more development of fossil fuel infrastructure and fuel switching.

However, policy-driven electrification would increase the average residential household cost – 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 when demand is high and heat pump efficiency is low or fails to provide heat.

Coal is the most-used electricity generation source in 18 states; natural gas in 16



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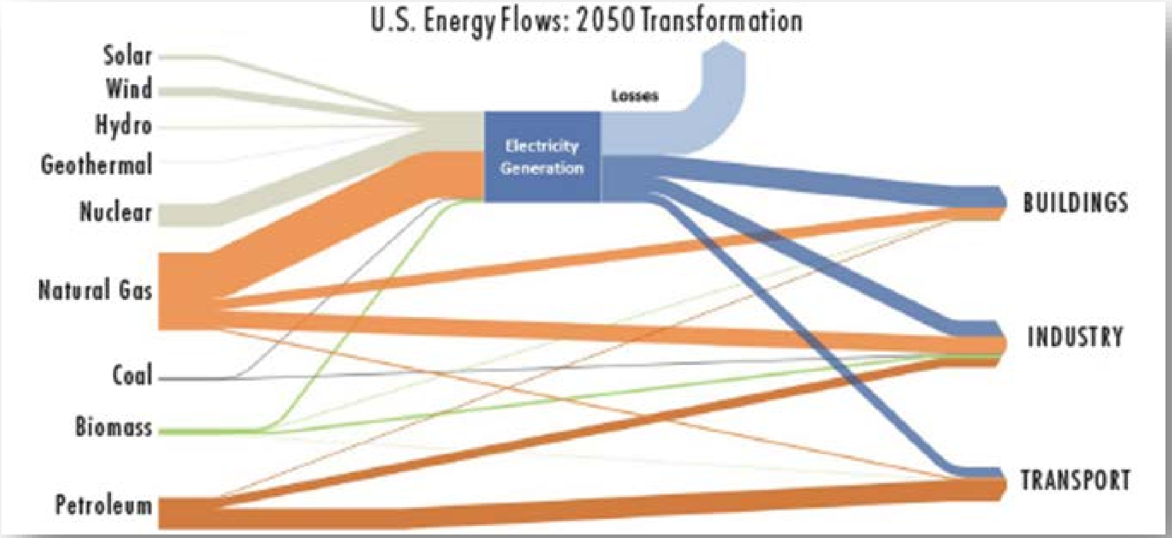
Electric Power Research Institute's April 2018 National Grid Assessment

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 EPRI predicts, in its Transformation Model, that the final delivered energy from the electric grid will account for only 47% of the total delivered energy needed by end-users.



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Decarbonized Power Systems

Decarbonized power systems dominated by variable renewables such as wind and solar energy are physically larger, requiring much greater total installed capacity.

a. A scenario for decarbonizing the European power system by 2050 - total installed capacity in this scenario is 4.2-times larger than the peak demand.

b. 100% renewable electricity scenario for Australia features total capacity roughly 3-times the peak demand in the system.

c. Another study concludes that total installed capacity is 3.5 to 5.5 times larger for wind and solar-dominated power systems than more balanced systems.

d. Total U.S. generating capacity is projected to be roughly 2-times today's installed capacity in a set of 80% renewable electricity scenarios.

Greater required installed capacity and the lower energy-density of wind and solar resources also significantly increase the land use consequences of power systems dominated by variable renewable resources.

Cost of Policy-Driven Electrification

Policy-driven electrification would increase the average residential household energy-related costs (amortized appliance and electric system upgrade costs and utility bill payments) of affected households by between $750 and $910 per year, or about 38 percent to 46 percent.

Widespread residential electrification will lead to increases in peak electric demand and could shift the U.S. electric grid from summer peaking to winter peaking in every region of the country, resulting in the need for new investments in the electric grid including generation capacity, transmission capacity, and distribution capacity.

Cost Impacts from Electrification Policies

The direct costs to consumers of policy-driven electrification include:

1. The incremental costs for new or replacement electric heating and hot water equipment relative to the natural gas or other direct fuel alternative.
2. Costs of upgrading or renovating existing home HVAC and electrical systems.
3. Difference in energy costs (utility bills) between the electricity options and the natural gas and other direct fuel options.

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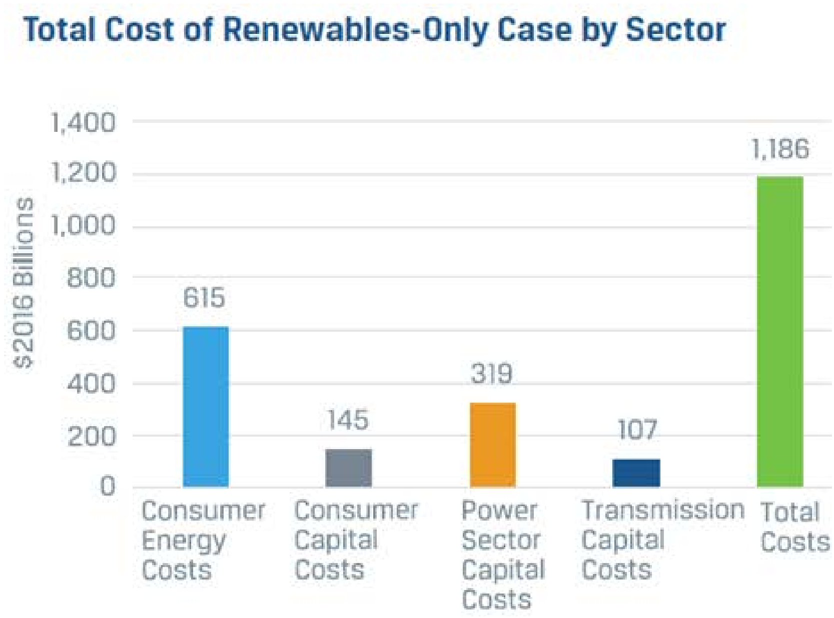
Cost Impacts from Electrification Policies

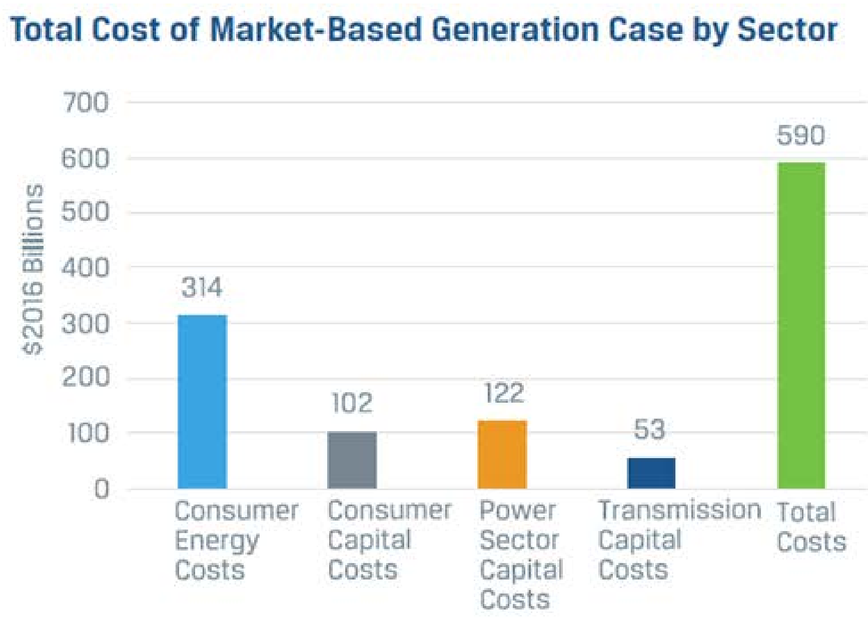
Power Generation Costs: The capital cost of new electric generating capacity needed to supply the increased electricity demand.

Transmission Costs: The cost of new electric transmission infrastructure required to serve the increased load and generation.

The latter two costs are often neglected by most studies that promote the concept of beneficial electrification. The reason generally stated is that electric heat pump high efficiency and future energy efficiency programs will essentially reduce electric demand. Note the cost of these future energy efficiency programs is never calculated. Therefore, additional electric capacity (generation, transmission and distribution capacity) "fuel-switching" for a fossil fuel to electricity must be added.

Electric Grid: Renewables-Only Case and Market-Based Generation Case





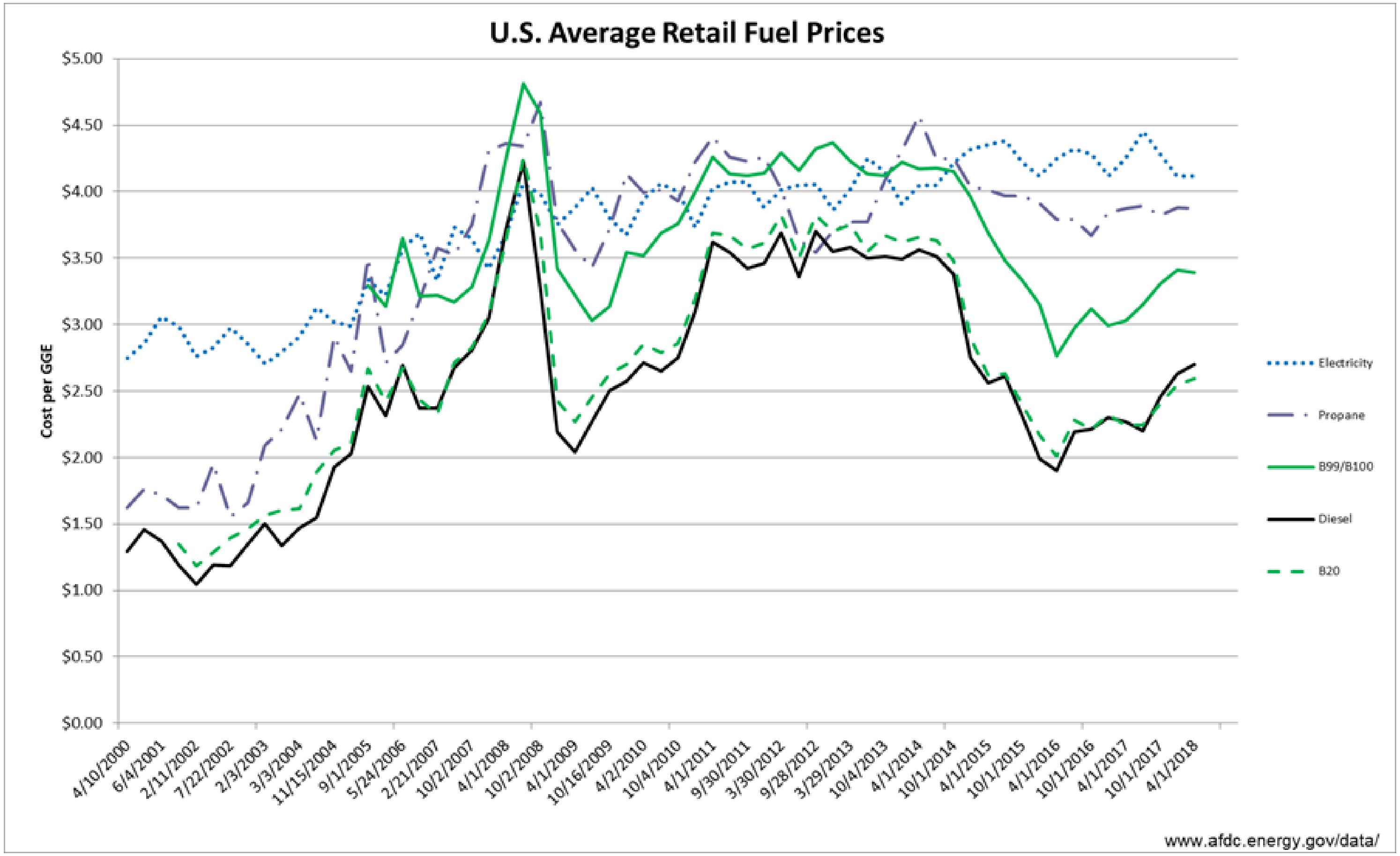
Source: "*Implications of Policy-Driven Residential Electrification*", An American Gas Association Study prepared by ICF, July 2018

Annual Per Household Total Costs of Electrification Policies (Real 2016 $)

Region	Renewables-Only Case		Market-Based Generation Case	
	Cumulative Change In Costs Per Converted Household	Annualized Change In Costs Per Converted Household	Cumulative Change In Costs Per Converted Household	Annualized Change In Costs Per Converted Household
East Coast	18,440	1,240	16,550	1,110
Midwest	25,920	1,740	Policy Not Implemented	
New York	58,580	3,930	57,770	3,880
New England	41,210	2,770	35,340	2,370
Plains	29,120	1,950	Policy Not Implemented	
Rockies	25,060	1,680	Policy Not Implemented	
South	7,820	520	650	40
Texas	1,970	130	740	50
West	5,880	390	5,140	340
Total U.S.	**21,140**	**1,420**	**15,830**	**1,060**

Source: "*Implications of Policy-Driven Residential Electrification*", An American Gas Association Study prepared by ICF, July 2018

National Equivalent Fuel/Energy Price – EIA 2018



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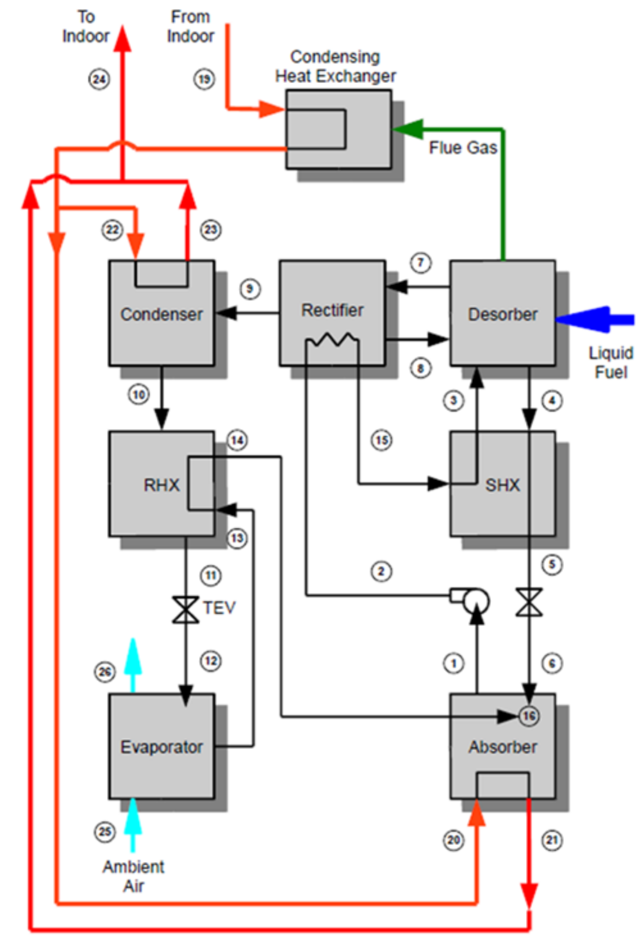
Thermal Heat Pump (THP)

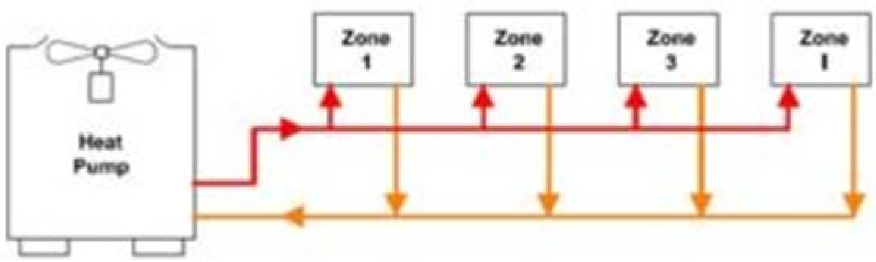
Thermal Heat Pumps: an exciting new technology, in late stage development, is the air-sourced thermally-driven heat pump. This technology would, in today's world, deliver heating at a source coefficient of performance (COP) of about 1.3. Thermal heat pumps, when fully developed can be integrated with existing and new home furnaces and boilers. And their coefficient of performance and delivered air temperature would not drop precipitously during cold weather like electric heat pumps.

Thermal Heat Pump

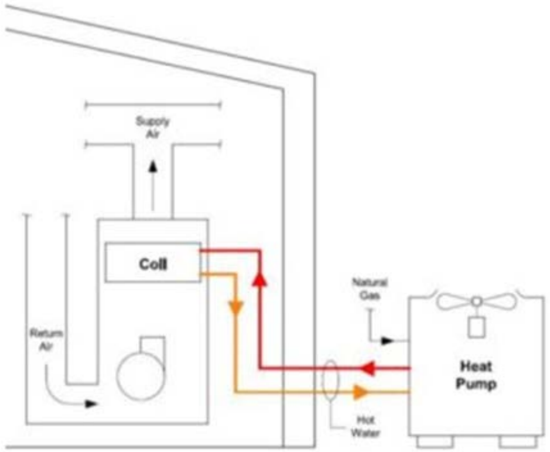
In heating mode, thermal energy (at a relatively low temperature) from outside ambient air enters the heat pump through the evaporator coil, and is raised to a higher useful temperature using the thermodynamic leverage of heat from combustion. Energy from both the colder outdoor air and a liquid fuel is combined and delivered to the heating. Thus, the total useful energy is greater than the fuel energy alone, resulting in a net fuel-input efficiency greater than 100% - breaking the so-called “100% barrier”. In addition, because approximately 35% of the delivered heat energy comes from the outdoor air, the THP is a partially renewable energy technology, and is recognized as such in some regulatory systems.



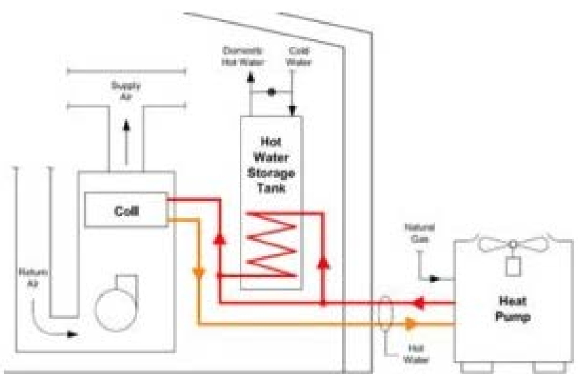
Thermal Heat Pump Applications (THP)



Boiler



Furnace



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Economic Comparison THP v CCEHP

Baseline Heating / Cooling System	Radiator Based Boiler, 14 SEER Minisplit AC			Forced Air System with Condensing Furnace, 14 SEER Central AC			
Replacement Technology	Hybrid THP/14 SEER AC	Heating only THP and 14 SEER AC	18SEER- 12 HSPF CCEHP with Boiler backup	Hybrid THP/14 SEER AC	Heating only THP and 14 SEER AC	18SEER- 12 HSPF CCEHP with Furnace backup	18SEER- 12 HSPF CCEHP with Resistance backup
Location	**Payback Period, Years**						
Portland, ME	0.8	3.6	8.6	4.7	4.8	9.5	5
Hartford, CT	0.7	3.4	9.8	4.3	4.4	12	7.6
NYC, NY	0.9	3.9	Never	5	5.1	Never[15]	Never[15]
Albany, NY	0.6	2.9	7.8	3.8	3.8	9.3	5.2
Concord, NH	0.7	3.3	14	4.2	4.3	20.9	Never[15]
Burlington, VT	0.6	3	15.5	3.9	3.9	Never[15]	Never[15]
Worcester, MA	0.7	3.2	10	4.1	4.1	13	7.3
Location	**15 Year Total Cost, USD**						
Portland, ME	$33,625	$35,575	$36,728	$31,250	$31,300	$31,833	$28,876
Hartford, CT	$36,889	$38,839	$42,729	$34,435	$34,485	$38,063	$36,433
NYC, NY	$37,240	$39,190	$49,964	$35,061	$35,111	$45,703	$42,441
Albany, NY	$39,081	$41,031	$43,119	$36,444	$36,494	$38,444	$36,231
Concord, NH	$39,365	$41,315	$49,640	$36,710	$36,760	$44,585	$46,941
Burlington, VT	$43,153	$45,103	$55,576	$40,244	$40,294	$50,106	$56,924
Worcester, MA	$37,405	$39,355	$44,226	$34,913	$34,963	$39,809	$37,087

Source: "Energy, Cost and CO2e Savings Analyses of Reversible, Hybrid and Heating-Only Liquid Fuel Fired Absorption Heat Pumps in the Northeastern United States", ASHRAE Summer Meeting, Christopher Keinath, PhD, Thomas Butcher, PhD, Michael Garrabrant, PE, June 2018

Our Basis

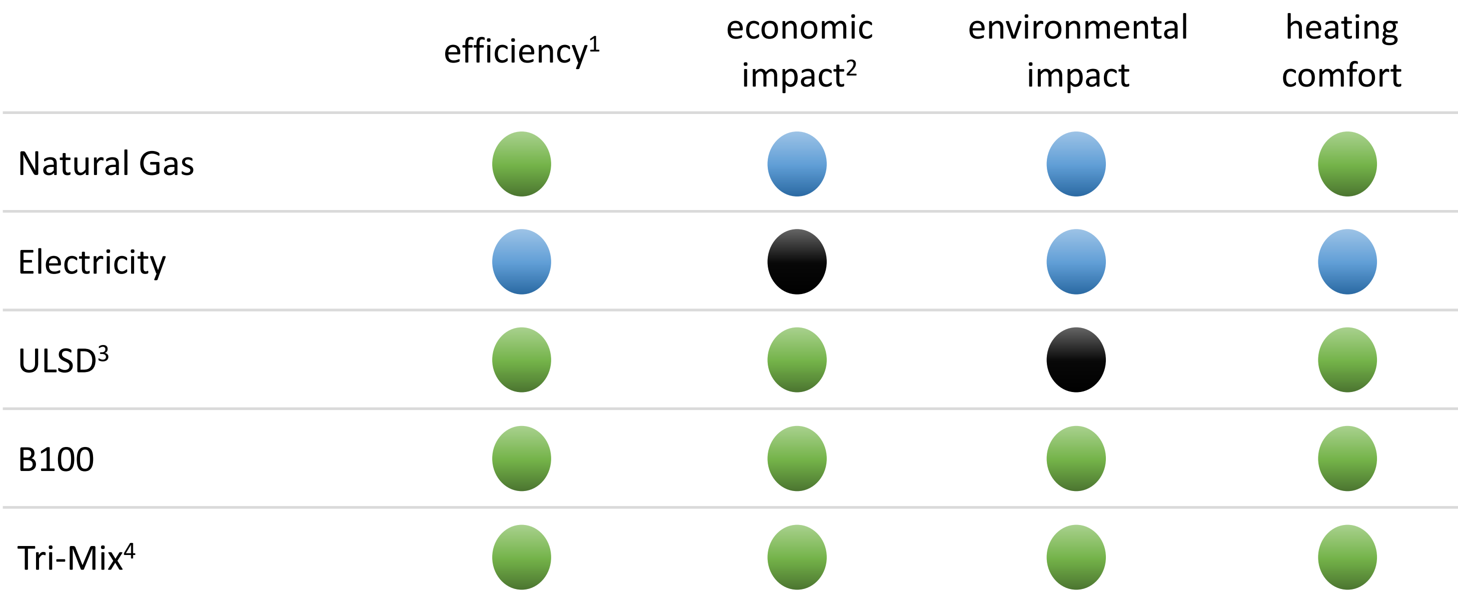
1. "Analysis of Fuel Cycle Energy Use and Greenhouse Gas Emissions from Residential Heating Boilers", Bruce Hedman, Entropy Research LLC, June 2018
2. "Energy, Cost and CO2e Savings Analyses of Reversible, Hybrid and Heating-Only Liquid Fuel Fired Absorption Heat Pumps in the Northeastern United States", ASHRAE Summer Meeting, Christopher Keinath, PhD, Thomas Butcher, PhD, Michael Garrabrant, PE, June 2018
3. "Implications of Policy-Driven Residential Electrification", American Gas Association Study, prepared by ICF, July 2018
4. "Comparison of Ethyl Levulinate with Gasoline and Diesel: Well to Wheels Analysis", Harnoor Dhaliwal and Lise Laurin, EarthShift, June 2009
5. "U. S. National Electrification Assessment", Electric Power Research Institute, April 2018

Pathway to Low Carbon Fuels

"Several reduced carbon liquid fuels in the field and under development would offer an almost drop-in replacement for heating oil, overcoming the significant cost and practical issues of replacing an entire heating system, as well as, upgrading expensive energy delivery networks. There is also a well-developed and competent network of supply, installer and servicing businesses already in place who could continue to support consumers at little or no additional cost."

Dr. Thomas Butcher, Brookhaven National Laboratory

Residential Energy Supply and Usage Trajectories Impact Attributes



[1] Electric heat-pump source-based COP of 1.09, thermal heat pump source-based COP of 1.3

[2] Economic impact refers to the cost of transitioning from a home with one energy source to another e.g. from liquid-fueled furnace to electric heat pump including any infrastructure costs to support the transition e.g. transmission and distribution capacity upgrades or battery storage for internment renewable power sources.

[3] ULSD - < 15 ppm sulfur diesel

[4] 1/3 ULSD, 1/3 B100 and 1/3 Ethyl Levulinate

Pathway to Low Carbon Fuels

Boiler and furnace-based home heating and cooling systems, all three liquid fuels-based heating technologies coupled with three specific fuel approaches [100% biodiesel and ultra-low sulfur diesel (ULSD), biodiesel and one advanced biofuel (ethyl levulinate)] reduce carbon emissions greater than cold climate electric heat pumps using electricity from low emissions advanced CCCTs.

Pathway to Low Carbon Fuels

The yellow cells indicate liquid fuel pathways to no carbon combustion.

	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%

Percent Reduction in CO2e 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%

Percent Reduction in CO2e Annual Emissions from Heating and Cooling a Single-Family Home (Hot-Cold Air)

Our View

The capability of the oil heating industry to innovate and meet state's decarbonization agenda has not been adequately recognized. It is not furnaces or boilers that produce carbon emissions, it's the fuel they run on. Therefore, it is premature for policy makers to consider regulating against oil heating when all liquid fuel furnaces and boilers could be run on a low carbon alternative fuel <u>before</u> 2035."