Accelerating the Pace to Fossil-Free Residential New Construction

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Abstract

Residential new construction increasingly serves as a "test bed" for expanded efforts to go beyond just energy efficiency. These efforts include fuel choice, demand response, and renewable and electric vehicle integration. Possibly the most important of these is fuel choice. As the need to address climate change becomes increasingly apparent, it will become ever more important to ensure that new home construction minimizes its carbon footprint. The best way to do this is to promote the use of fossil fuel-free heating and hot water. New building codes have substantially lowered the heating load of homes built today compared to those built in 2006, narrowing the gap between a home built to code and a high-performance home. This has created opportunities for fossil-free homes with a much lower impact on first costs. This paper will discuss ongoing efforts in multiple jurisdictions in the Northeast to influence fuel choice in new home construction. Some are addressing the issue of fuel choice directly through activities like the inclusion of all-electric new home packages in new construction efficiency programs. Related factors include increased interest by policymakers in zero energy new homes and stretch codes. While fossil fuel-free construction is not predicated for zero energy and stretch code homes, it is often the most cost-effective outcome. The paper examines the economics and carbon impacts of fuel choice in new home construction and concludes with a set of program and policy recommendations, including how efforts to promote fossil fuel-free homes can support the advancement of zero energy building codes.

Introduction

Heating and hot water fuel choice in residential new construction in the Northeast has historically been a decision made by the developer, builder or new homeowner, with limited recent efforts by policy makers or efficiency program administrators to influence the decision of what fuels to use. These parties have focused primarily on increasing the efficiency of new home construction, not on what fuel is to be used for space and water heating. However, the growing focus on greenhouse gas emissions by policymakers in many states makes fuel choice a potentially important opportunity to minimize the future greenhouse impacts of new home construction.

Beyond energy efficiency, efforts to minimize new home greenhouse gas impacts can be best supported by the use of fossil-free alternatives to meet the needs of the space and water heating end use. For many builders and homeowners, the most viable fossil-free alternative is electricity from renewable sources. In some locations, biomass may be a viable option, depending on the carbon impacts of the fuel, but it is not included in the scope of this paper. For all-electric homes, the emission benefits will vary based on the local electric mix, but will generally increase over time in all parts of the US as the deployment of renewables increases[1] (Acadia Center 2012, 6).

Using New England as an illustrative example, this paper looks at the costs and benefits of moving residential new construction off of fossil fuels.

Policy Context

The New England states have been early leaders on climate policy. Adopted in 2001, the New England Governors' and Eastern Canadian Premiers' Climate Change Action Plan (NEGECP 2017) set regional 2010, 2020, and 2050 emission reduction targets for the New England states – Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont – as well as for the Eastern Canadian provinces. These targets are not legally binding, but they do represent the collective goals for the region. The New England states subsequently adopted emission reduction targets, either binding state statutes or voluntary goals. Nearly all New England states aim to make further reductions by 2020 and significant reductions by 2050, in line with science-based recommendations (IPCC 2014).

Role of Strategic Electrification in Meeting Greenhouse Gas Goals

Thanks to advances in technology, heat pumps have become a new tool for emissions reductions in buildings in northern climates, extending potential emissions reductions well beyond what can be achieved with efficiency alone. Heat pumps are far more efficient than traditional electric resistance heating and, with today's electric generation mix, provide immediate emissions reductions compared to heating with fossil fuels.[2] As generation grows cleaner, emissions from heat pumps will continue to decline (Acadia Center 2012, 6). Installing electric heat pumps today creates a "renewable-ready" infrastructure that will take advantage of a cleaner grid as additional renewables continue to come on line.

Characterization of Regional Residential New Construction Market

For the purposes of this analysis, state-level permit data is used as a proxy for residential new construction activity. Table 1 summarizes preliminary permit data for New England by number of units. In 2017, an estimated 32,721 units were permitted in the six New England states (Census Bureau 2018). The very large majority of these (93%) are single family dwellings.

[1] The general decrease in electric emissions rates due to increased renewable deployment could temporarily be interrupted in some jurisdictions due to nuclear plant retirements.

[2] Typically, two to three times as efficient for air-source and three to four times for ground-source heat pumps over a New England winter, relative to conventional electric resistance heat. (BSC 2018)

Table 1. 2017 Preliminary residential new construction permits

	Total	1 Unit	2 Units	3 and 4 Units
Connecticut	2,799	2,664	86	49
Maine	4,011	3,901	86	24
Massachusetts	8,511	7,766	472	273
New Hampshire	2,828	2,597	164	67
Rhode Island	1,061	997	46	18
Vermont	1,203	1,122	40	41
New England Total	20,413	19,047	894	472

Source: United States Census Bureau 2018.

Fuel choice in new homes in New England has increasingly shifted away from fuel oil to natural gas and propane. This is likely due to several factors including lower first costs for gas and propane furnaces, low natural gas fuel prices, and customer preference. Several recent residential new construction baseline studies document the dominance of pipeline and bottled gas in new construction throughout New England (Table 2). For example, in Massachusetts the penetration of new homes using fuel oil as the primary heating fuel declined from 13% in 2011 to 2% in 2015, while 94% of homes used gas as their primary heating fuel (NMR 2016a, 49). In Connecticut, no homes heated with fuel oil were observed during the most recent new construction baseline study (NMR 2017b, 72). Similar results were found in Vermont's most recent new construction baseline Study (NMR 2017a, 45) where only one oil heated home was reported. This declining trend of oil heat in new homes has been underway since Vermont's first baseline study in 1995 that found 60% of homes with oil heat, 2002 with 45%, 2008 with 34%, 2011 with 9%, and 2015 with only 4% of new homes with oil heat (NMR 2017a, A-5).

With gas — both pipeline and bottled — dominating primary heating fuel penetration, the percentage of homes using electricity as their primary heating fuel is fairly small, ranging from 3% in Massachusetts (NMR 2016a, 49) to 11% Vermont (NMR 2017a, 45).

Table 2. Residential new construction primary heating fuel penetration

State (Year of Construction)	Natural Gas	Propane	Electric	Oil	Pellet	Wood
Massachusetts (2015-2016)	67%	27%	2%	2%	1%	1%
Connecticut (2014-2015)	48%	45%	8%	-	-	-
Rhode Island (2014-2016)	45%	42%	7%	6%	-	-
Vermont (2015-2016)	23%	39%	11%	3%	6%	17%

Sources: NMR 2016a, NMR 2017a, NMR 2017b, NMR 2018.

Table 3 shows the predominance of forced air heating systems, mostly furnaces. Of the electrically heated homes, almost all employed some form of heat pump.

Table 3: Primary heating system type penetrations

State (year of construction)	Furnace	Hyro-air	Combi appliance	Boiler	Electric baseboard	Ductless minisplit heat pump	Ground source heat pump	Ducted air source heat pump	Stove
Massachusetts (2015)	88%	5%	2%	2%	-	-	1%	2%	1%
Connecticut (2014-2015)	73%	13%	4%	3%	2%	4%	1%	1%	-
Rhode Island (2014-2016)	70%	8%	6%	9%	-	-	5%	2%	-
Vermont (2015-2016)	19%	-	16%	33%	-	3%	6%	3%	21%

Sources: NMR 2016a, NMR 2017a, NMR 2017a, NMR 2018.

Code Evolution, Low Load Homes and Fuel Choice

Where jurisdictions adopt long-term strategic electrification goals, the most likely building sector to be impacted first will be residential new construction. The incremental costs for an efficient electric heat system will be lower in new construction than in a retrofit situation and distribution and control systems can also be more easily optimized in new construction. As energy codes are updated every three years or so in many jurisdictions, there are indications that they are progressing towards zero energy at some point over the next decades. California has been the most aggressive state, establishing 2020 as that target, while at least a half dozen other states have also incorporated some form of zero energy goals (Architecture2030 2018). Along the way, these codes have substantially lowered the heating loads of homes built today compared to those built just ten years ago. Studies have shown that compliance rates with the more stringent codes have been maintained or even increased (NMR 2016b). New homes built to the 2015 International Energy Conservation Code (IECC) are about 30% more efficient than a new home built in 2006, as shown in Figure 1 below. All New England states except New Hampshire and Maine have adopted IECC 2012 or later as a statewide base code, and update to the latest version on a regular basis.

These increasingly stringent codes contribute to narrowing the gap in New England between a home built to code and a high-performance home. This has created opportunities for fossil-free homes with a much lower impact on first costs, because the cost of cold climate heat pumps increases more rapidly with heating load (i.e. multiple units are needed) than with fossil systems, where the marginal cost of a larger furnace or boiler is relatively small.

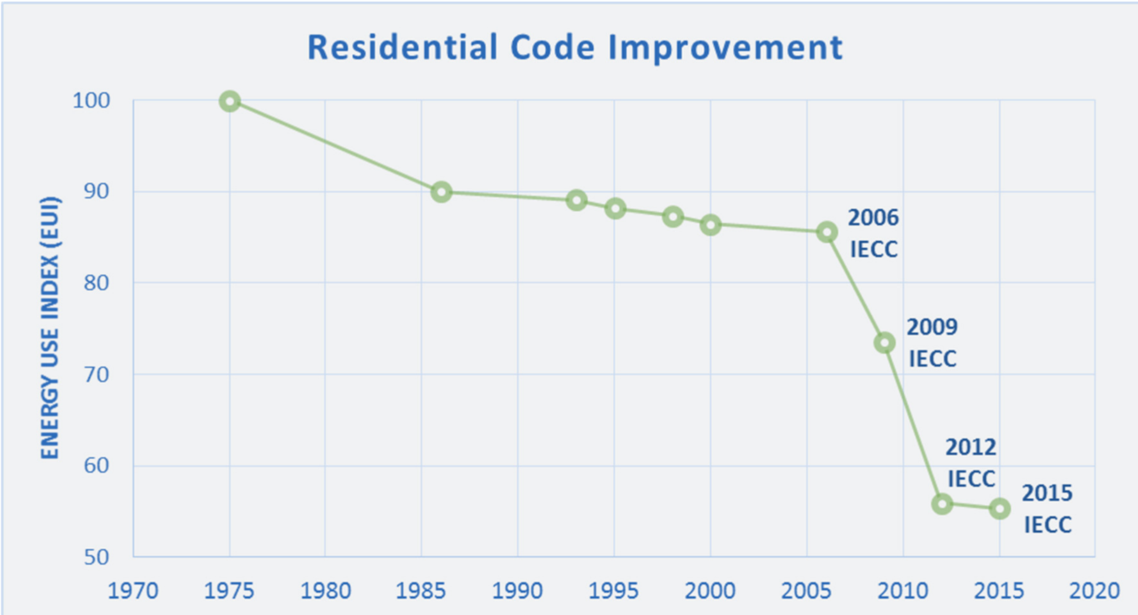

Figure 1: Residential energy code efficiency improvements over time, *Source: A*dapted from BCAP 2016.

Additionally, states in the Northeast have been developing and implementing "stretch codes" that establish a second energy code tier at a more stringent level than the statewide base code, providing a group of even higher performing homes. These homes are tight, insulated with high R-values throughout, and have high-performing windows, mechanicals, lights and appliances (NMR 2016b). Currently, Massachusetts, Rhode Island, and Vermont have adopted some level of stretch code that seek to advance the energy performance of new homes at a higher level than the base building energy code. The stretch codes provide a good opportunity to address heating system alternatives to fossil fuels. These stretch codes have often served as the de facto next energy code generation.

Some jurisdictions (RI) establish the stretch code as an aspirational building standard, while others (MA and VT) allow cities and towns to adopt the stretch code instead of the base code to meet certain statewide environmental standards and/or in exchange for receiving incentives from the state.

With building loads decreasing and the need for larger heating systems decreasing with them, there arise increasing opportunities to heat buildings with smaller heating systems, such as ductless and ducted cold-climate heat pumps that are powered by electricity. Advances in air-source heat pump technology that allow operation without backup heat in cold climates and increasingly efficient heat pump water heaters, mean that new homes in northern climates can operate comfortably and efficiently using just electricity as their sole fuel source.

In fact, the market may be moving toward electrification on its own. In areas in the Northeast where inexpensive natural gas is not available, we are seeing shifts away from heating oil and toward electricity in new home construction. In recent new construction baseline studies summarized above in Tables 2 and 3, less than 10% of new homes are installing oil systems and a small, but increasing number are installing electric systems (primarily air-source and ground-source heat pumps). Compare this to existing homes of which more than 50% heat with oil and with new homes that were installing oil at a rate of about 40% throughout New England less than 15 years ago.

Regional Efforts to Influence Fuel Choice in Residential New Construction

While there have been discussions and proposals in several New England states regarding residential new construction fuel choice, no specific policies or programs are yet in place to either influence or to mandate residential new construction fuel choice.

In Connecticut, the state's utilities committed in their 2018 Conservation and Load Management Plan Update to:

> explore the development of a fully-electric package for the Residential New Construction ("RNC") program. The Companies' intent behind developing this fully-electric package is to provide a path for builders and/or potential homeowners to build an all-electric residential home that avoids the use of fossil fuels altogether…. The Companies' fully-electric package may provide support for the following measures: building envelope measures, thermal energy-efficiency measures, air-source or geothermal heat pumps, increased use of biofuels, biomass heating systems, support for electric vehicle or related infrastructure, and on-site renewable energy production and storage. (Eversource Energy 2017, 14-15)

In Rhode Island, through the Public Utilities Commission "Power Sector Transformation" on-going rate case, discussions are underway that consider a move to increasingly electrify the building and transportation sectors. As part of this effort, an all-electric tier has been considered for National Grid's Residential New Construction (RNC) program, but it has not yet been established.

Economics of Fuel Choice in Residential New Construction

For this analysis, results from a recently completed Massachusetts and Rhode Island ductless mini-split heat pump (DMSHP) impact analysis are leveraged (Cadmus 2016). The study metered sites in both states and determined both fossil fuel savings and changes in electricity usage. The results from that study were scaled to analyze full, fossil fuel displacement in a new, efficient home using an inverter-based ducted heat pump[3]. This type of system uses the same type of outdoor unit as a DMSHP, but substitutes a central air handler for the indoor unit. Additionally, the impact study also estimated cooling savings from using a high efficiency DMSHPs versus a SEER 13 central air conditioner (CAC) and those values are incorporated into this analysis. For the furnace baseline, the Cadmus study assumed an AFUE of 90% with 15% duct losses, which was used for all systems in this analysis.

The Cadmus study presented average savings and usage values for all of the metered DMSHP units. In addition, the study examined and presented savings and usage values for the top 25% performing (based on energy savings) units. These units were more likely to be used for heating-only or for both heating and cooling purposes, rather than just for cooling only. Further, these units were more likely to be operated in a manner to maximize fossil fuel displacement. The savings and usage values from these top 25% DMSHP units are used in this analysis.

The energy costs used in this analysis are from the most recent EIA Annual Energy Outlook (EIA 2018) for New England. In addition to the fuel operating costs associated with

[3] The use of a ducted heat pump in this analysis allows for a more direct cost comparison with a natural gas or propane furnace and central air conditioner system.

using propane, an above ground tank cost of $2,000 was assumed[4], which would be avoided in an all-electric home. A 3% discount rate is used to present value all operating costs back to 2018 and an 18-year equipment measure life is assumed.

Table 4 summarizes the estimated operating, equipment, and total costs of a ducted heat pump, a gas furnace/CAC system, and a propane furnace/CAC system in a new home in Massachusetts or Rhode Island. Table 4 only includes differential costs. Items that would be required in all cases, such as wiring and electrical service, are not included. Installation labor costs are assumed to be similar for all systems. Therefore, installation costs are not needed for comparison and are excluded from the analysis.

Table 4. New construction lifetime heating and cooling system differential costs

	Fuel costs	Equipment costs[5]	Total costs
Ducted HP	$12,102	$5,000	$17,102
Propane furnace w/CAC	$15,526	$4,200	$19,726
Natural gas furnace w/CAC	$12,423	$2,200	$14,623
Natural gas furnace w/CAC including socialized costs of gas connection	$12,423	$6,500	$18,923

From this analysis, a ducted heat pump provides a lower total cost of ownership when compared to a propane furnace and central air conditioner. However, the natural gas system does appear to have a lower cost of ownership; at least from the new homeowner's perspective.

However, this customer-focused analysis does not fully account for the costs of a new natural gas hook up. Service line and meter costs have been about $4,300 for recent additions in Connecticut (State of Connecticut 2012). If these costs are added to the analysis, as they are in the last line in Table 4, then the full cost of a natural gas system exceeds that of a ducted heat pump system.

Further, if the new home is off a main pipeline, thousands of dollars in additional costs can be incurred to pay for the new gas mainline. Typically, both required service line and meter costs and any off-main connection costs are socialized across all residential customers through their rates, rather than being borne up front by the builder or homeowner when a new home is built.

Estimates of Regional Greenhouse Gas Reductions

Table 5 presents an estimate of the reduced regional greenhouse impacts associated if most of the region's 2017 natural gas and propane new homes used ducted heat pumps instead. This analysis assumes the following:

[4] Based on an internet search of providers.
[5] Based on costs from online review of equipment prices

- Marginal regional electric CO_2 emission rate of 710 lbs./MWh (ISO-NE 2018), assumed to decline at 1% per year during the study period.
- That absent intervention, 55% of new homes in the region would be heated with natural gas and 35% with propane.
- That 80% of these homes, in turn, are heated with a furnace or hydro-air system and have central air. These homes can be fully space conditioned with a ducted heat pump.

Table 5. Annual New England CO_2 new construction emissions and savings based on 2017 permit data

	Number of ducted homes	Annual CO2 emissions/ home (tons)	Annual CO2 emissions (tons)
Fossil Scenario			
Propane furnace w/CAC	5,716	3.38	19,293
Natural gas furnace w/CAC	8,982	2.92	26,243
Total Fossil	14,697		45,536
Electric Scenario			
Ducted HP	14,697	1.77	26,023
Total Electric	14,697		26,023
Emissions Reduction			19,513

If most of the homes permitted in New England in 2017 had used ducted heat pumps rather than propane or natural gas furnaces with central air conditioners, then the CO_2 emissions would have been reduced by 45%. Over time, these reductions will likely increase if the New England electric grid continues to decarbonize through increased amounts of renewable capacity; From 2007 to 2016, CO_2 emissions on a per MWh basis have declined by 22% (Figure 2). Most of the New England states have Renewable Portfolio Standards that require higher percentages of renewable generation in the future. We modeled a relatively conservative scenario where emission rates for electricity decline 1% per year in the study period.

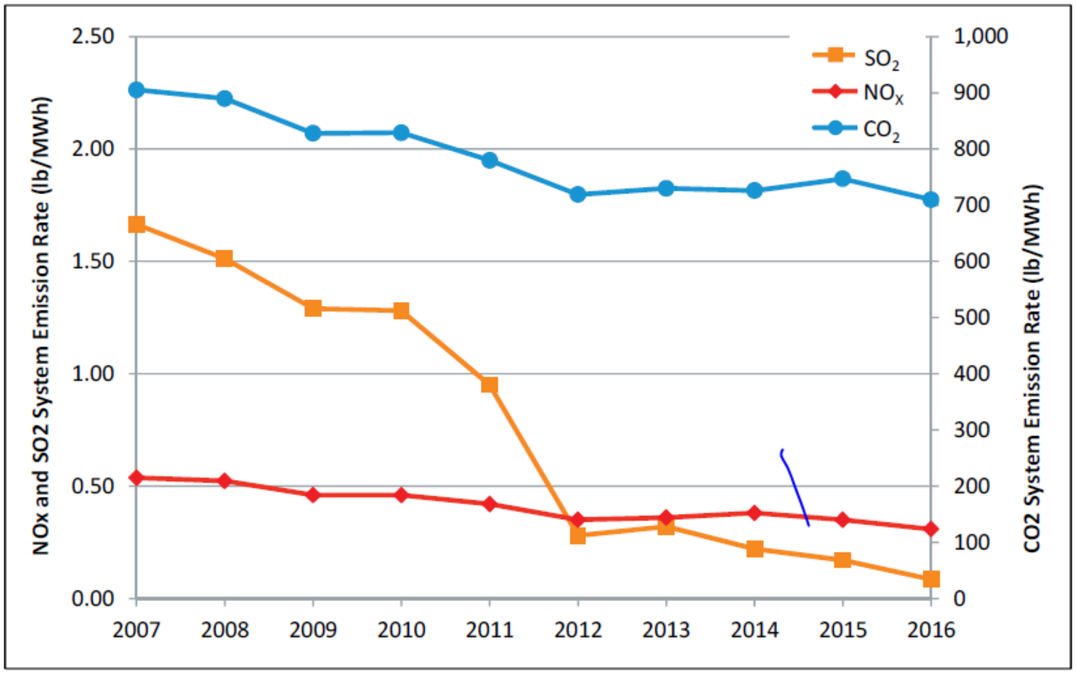

Figure 2. New England system annual average NO_X, SO_2, and CO_2 emission rates, 2007 to 2016 (lb./MWh). *Source*: ISO-NE.

Conclusions and Recommendations

Moving new home construction to being fossil free appears to be a viable option for many consumers and with significant greenhouse gas benefits. Currently, the consumer economics of heat pumps is favorable relative to propane. For natural gas, lower system first costs help drive the customer economics towards that fuel. However, not all of the costs associated with providing natural gas to a new home are addressed in this customer focused analysis. These costs can be substantial and if shouldered more fully by the builder or homeowner, could shift the economics of heating fuel choice to electricity.

Possible policy options for consideration to accelerate the move towards fossil-free new homes include:

Remove constraints that prevent efficiency program administrators from promoting fuel choice. Regulations in many states prevent the use of ratepayer funds to promote fuel choice. Such constraints are inconsistent with larger state policy objectives to mitigate greenhouse gas emissions. However, care should be taken as to how efficiency program administrators pursue and promote fuel choice and, in existing homes, fuel switching. While conversions from oil to natural gas will yield customer benefits and, possibly, some small amount of greenhouse gas reductions, such efforts will serve as an impediment to the much larger greenhouse gas reductions associated with fossil-free space and water heating systems.

Develop and offer all-electric new homes packages through residential new construction programs. Efficiency program administrators should offer financial and technical assistance to builders and homeowners to promote fossil-free new homes. Fossil-fuel free heating systems should be paired with heat pump water heaters and on-site photovoltaic solar panels to create an all-electric zero energy package.

Transition to electric-only new construction incentives to avoid committing to potentially decades more fossil fuel use by ramping down propane and natural gas program incentives in residential new construction programs over time. There is little customer or societal rationale for continued efficiency program administrator support of fossil fuels in residential new construction.

Decrease natural gas system hurdle rates. The hurdle rate refers to the timeframe in which a gas company-paid investment in infrastructure will be fully paid back through rates. Shortening this payback period to align them with public policy emissions goals will make the up-front costs of installing a new natural gas heating system include more of the actual costs.

Encourage improvements in cold climate heat pump equipment costs. Despite being similar equipment, the currently available ducted cold climate heat pumps are more than twice as expensive as conventional HVAC systems. DOE has funded research on twin compressor heat pumps that offer good cold weather performance using more traditional technology that could result in substantial cost reductions in the future (Shen 2017).

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