

Concord Residential Heating Systems

Smart Choices for Better Efficiency and
for a Reduced Carbon Footprint

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Introduction

This paper is focused on residential heating, which produces 20% of Concord's carbon dioxide emissions (CO²)¹ and should be helpful to both policy makers in Concord (e.g. Selectmen, Light Plant, etc) and to homeowners making choices on heating system upgrades and enhancements. As a topic, this is important to Concord's Comprehensive Sustainable Energy Committee (CSEC) because our goals include taking action to improve the management of energy resources and to reduce energy consumption and the carbon footprint in Concord. If we do nothing, we will gain some benefits from the improved technology as heating systems are replaced. However, there are opportunities to substantially improve our position by making informed choices as we migrate our systems to different heating system types and fuels.

Efficient Building Envelop as Prerequisite

Heating systems are sized to produce sufficient heat to replace the heat that's lost to the outside environment. A heat loss analysis is generally required to properly determine how much heat needs to be produced by a heating system. While an in-depth discussion of building envelopes and weatherization is beyond the scope of this paper, we recommend careful consideration on measures to reduce heat loss before making investments in heating system upgrades. Improvements in building envelopes through air sealing, insulation, and improved windows can yield a reduction of as much as 20-30% in heating energy consumption.

Heating Systems and Fuel Types Overview

As a heating system is expensive to install, maintain, and operate, while also impacting the environment through CO² emissions, it makes good sense to carefully evaluate the various options when considering an upgrade to your existing system. For example, at the present time, fuel types are starkly different in price. As important, your choices in heating technologies and features will have a major impact on efficiency and heating costs.

In Concord, for the most part, the types of systems in our homes can be categorized as follows:

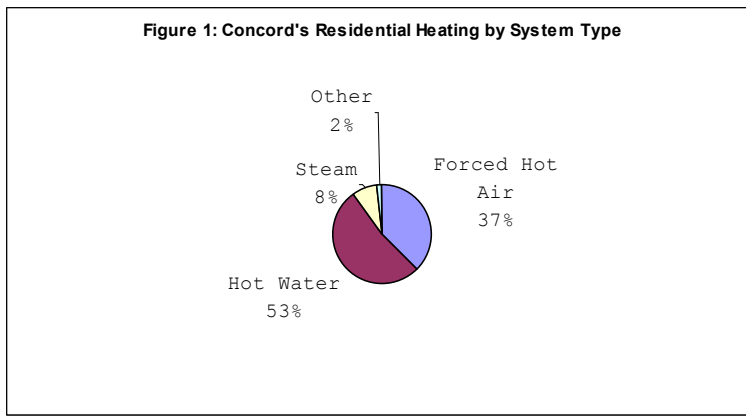
- **forced hot water** where water is heated in a boiler and pumped through various heat exchangers in the home
- **forced hot air** where cooler air is heated and pushed through ducts to the individual rooms
- **steam heat** where water is heated to steam in a boiler and cycles to individual radiators
- **numerous 'other' system types** including heat pumps which are either air sourced or ground sourced, Electric Thermal Storage (ETS), wood pellet, etc.

Here's a distribution of heating systems in Concord for our 5500 residences³:

¹ Energy Master Plan, Comprehensive Sustainable Energy Committee, Town of Concord, February, 2011, p. 19.

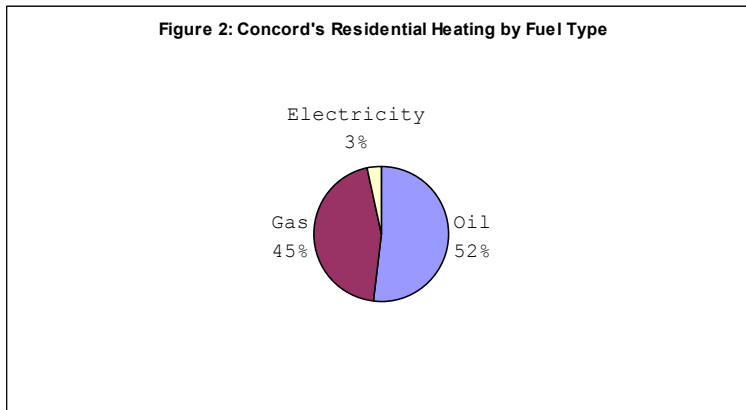
² Energy Master Plan, Comprehensive Sustainable Energy Committee, Town of Concord, February, 2011, p. 19.

³ Town of Concord, property assessment data, 2008.



Second, let's review the options by fuel type, using Concord's data²:

- **fuel oil** is used by over half of Concord's residences and is currently the most expensive fuel type
- **natural gas** is used by slightly less than half of residences and has three big advantages over oil as it's currently less expensive, burns more efficiently to produce heat, and is 40% less polluting (CO²) than oil⁴
- **electricity** which can be used for air-sourced or ground-sourced heat pump solutions, for Electric Thermal Storage, or for electric baseboard heat. Electricity-based solutions are similar in price to natural gas and are a second alternative to fuel oil.



The following table summarizes the various heat technology and fuel type combinations:

<u>Heating technology or device</u>	<u>Fuel type/energy source</u>
Forced hot water boiler	Fuel oil or natural gas
Forced hot air	Fuel oil or natural gas
Heat pumps – Ground or Air Source	Electricity
Electro Thermal Storage (ETS)	Electricity

⁴ Other important demographic data on gas: 200 residences have gas in their homes but do not use it for heating. Another 1200 Concord residences are located 'on the gas main' (i.e. have a gas line running by their homes). For these residences, switching to natural gas as a fuel source for heating is very straightforward. If you are interested, contact the National Grid Business Office. Telephone number is listed in the Concord phone book.

Discussion of Heating Systems Options

Boiler and furnace efficiencies have improved dramatically in the past 20 years. If your heating system is 20+ years old, it's likely that its efficiency is between 70% and 80%, while newer, high efficiency heating systems are rated as high as 96% for hot water boilers and 91% for forced hot air systems. Aging systems are good candidates for replacement. Because a new system has a 25-30 year life cycle, you need to carefully consider your choice of fuel type and the specific technology. Fuels were discussed briefly above and will be discussed further in the section below on cost considerations and environmental considerations. The second factor is technology which will be discussed in this section.

If you have decided to replace your boiler or furnace while retaining your existing infrastructure of hot air ducts, steam pipes, or circulating water plumbing, you are replacing 'in-kind', i.e. you will continue with a boiler for circulating hot water or for steam heat or with a forced hot air system. Each of these are available for use with natural gas or oil. And, in each case, there are some important environmental factors and efficiency factors, such as Annual Fuel Efficiency ratio or AFUE⁵.

Natural Gas and Oil-Fired Boilers for Hot Water Systems

Hot water boilers using natural gas or fuel oil are available in two basic types – condensing boilers and non-condensing or conventional boilers. Condensing boilers are more efficient but more expensive to purchase than a non-condensing model. The latter are considered 'conventional' and are not recommended if you are interested in reducing overall fuel consumption.

A condensing boiler works in the following way: one of the hot gases produced in the combustion process is water vapor and a condensing boiler extracts additional heat from this water vapor by condensing it to liquid water, thus recovering its available heat. Condensing boiler manufacturers claim that as high as 96% efficiency can be achieved, compared to 80%-85% with conventional boiler designs.

By contrast, conventional systems do not condense the water vapor and thus, do not capture the heat that results from the condensation process. This accounts for the difference in overall efficiency between the two designs. For manufacturers of 'high-efficiency boilers' the differences between their best models and their conventional systems are in the following range:

	High Efficiency Condensing	Conventional (same manufacturer)
Natural gas boilers	96% AFUE ⁴	87% AFUE
Fuel oil boilers	91% AFUE	87% AFUE

A summary of all of the efficiency opportunities is as follows:

- *Condensing vs. conventional:* explained above.
- *Gas vs. oil:* Natural gas is a more efficient fuel than oil in a condensing system.

⁵ AFUE is a measure of efficiency - actual, season-long, average efficiency of the specific boiler or furnace model. Each heating system has an AFUE rating. While there's some risk of oversimplification, an AFUE of 90 means that 90% of the BTUs from the fuel (oil or natural gas) are used to heat your home, while 10% are vented out as flue gases. (As electric heating does not have flue gases, this measurement is not applicable to ETS, which employs 100% efficient electric resistance elements.)

- *Indoor-outdoor temperature reset*: This feature includes a thermostat that is mounted outside your home and communicates the outside temperature through a controller to your boiler. Based on this information, the reset mechanism 'turns down' your boiler's internal operating temperature. This enables a boiler of a given size to operate as a much smaller boiler on warmer days by using less of its capacity, resulting in reduced energy consumption during the warmer part of the season. Of course, when it's colder outside, the boiler ramps-up its capacity, based on what's needed at the time.
- *'Sealed combustion' design*: The advantage of sealed combustion design is the use of cooler, outdoor air for combustion, as opposed to the air inside your home that you've already heated. For combustion, oxygen is mixed with fuel in the presence of an igniter (e.g. pilot light). Older systems pulled air directly from your basement. The alternative is to pull-in air directly from the outside through a duct that's designed for this purpose. This enables you to use outdoor air for combustion as opposed to 'preheated basement air'. This saves energy that would otherwise be used to heat cold air that would have been pulled into your basement to replace the air that was used in combustion.
- *ECM pumps*: ECM (electronically commutated motor) technology can be used in place of standard boiler pumps. According to two of the companies which manufacture these motors, 'these variable-speed pumps with ECM motors can reduce pumping energy by 70-90 percent--and that's a lot of electricity savings'.⁶ The savings are a result of the ECM pump's ability to optimize its use of power, based on the actual demand for hot water (i.e. demand in the house for heat).

Boilers for Steam Heat

If you have steam heat and plan to retain it, there are several ways to optimize. First, the same cost savings are possible in moving from oil to natural gas. Second, large efficiency gains in steam heat may be gained through proper tuning, operation, and maintenance. If you are upgrading your heating system and want to continue with steam, consult with an HVAC specialist with a steam heat specialty.

Forced Hot Air Furnaces

Forced hot air furnaces are available in both natural gas and oil-fired models with AFUE in the 80-94%+ range. The high-end models with 90%+ efficiency are generally available (a) as gas furnaces and some models incorporate 'condensing' features to improve efficiency by taking advantage of the heat from the water vapor that's produced in the burning of fuel, similar to condensing boilers, (b) as 'sealed combustion' systems where the intake for the furnace's flame uses outdoor air, via PVC pipe through your wall or roof, and (c) with ECM motors to reduce power consumption for the fan. Forced hot air furnaces with lower efficiencies do not include the 'sealed combustion' or 'condensing' features.

Electric Thermal Storage (ETS) Systems

ETS systems convert low-cost, off-peak electricity to heat and then store the heat in high-density ceramic bricks housed in the system for use 24 hours a day. An ETS system contains electric heating elements embedded in the ceramic bricks, and heat is generated when electric current is passed through the elements. Outside air temperature is monitored with a thermostat which regulates heat delivery, and the heat stored in the ceramic bricks is released when called for by the thermostat. ETS systems are available in many storage capacities and configurations depending on your specific heating requirements and have been used as a replacement for oil-fired systems or as an auxiliary heating system.

⁶ BuildingGreen.com, Grundfos (and Wilo) "Smart" Circulator Pumps for Hydronic Heating, Alex Wilson, August 12, 2010

When ETS is part of a centrally-ducted forced hot air system, a blower forces air through the bricks. The air, heated by the bricks, is then distributed throughout your house via air ducts. When ETS is part of a forced hot water heating system, coils full of water run through the bricks. Once the water in the coils has been heated by the bricks, a pump circulates the hot water through radiators in your home.

The biggest advantage to the home owner of ETS is low operating costs⁷. Because ETS converts its input (electricity) at 100% efficiency and because off-peak⁸, less expensive electricity is being used (1/3 the price of standard residential Tier 1 electricity), you get a significant amount of heat output/dollar. (The other important efficiency factor is at the point of power production. While oil and natural gas are fed directly to their respective heating devices in a residence, in the case of ETS, the electricity needs to be generated in the first place at a utility. Because our power generation efficiency from these plants is 43% at off-peak, ETS requires roughly 2x as much energy per BTU vs. a conventional, high efficiency system. Refer to the appendix on Heat Rates: power generation efficiency definitions and the data for New England's plants).

Heat Pumps

There are two basic heat pump technologies: air sourced (ASHP) and ground sourced (GSHP). In the first case, the 'source' is outside air. In the second, the pipes are installed directly into the ground which is the 'source'. But, in both cases, the fundamental principles are the same in that heat is transferred to/from the source using a technology that's similar to the internals of a refrigerator.

For the ASHP, outside air, necessarily existing at some temperature above absolute zero, is a heat container. In the winter, an air-source heat pump moves some of this heat indoors to warm the home. During the summer, a heat pump can operate in reverse, as an air conditioner, by moving heat from indoors to the outside air. During the coldest months of the year, a heat pump alone cannot keep up with your home's heating needs⁹. Therefore, some other sort of back-up heating system is generally needed, such as ETS or a natural gas system.

The second heat pump technology, GSHP, also known as a geothermal heat pump, is based on a central heating and/or cooling system that pumps heat to or from the ground. It uses the earth as a heat source (in the winter) or a heat sink (in the summer). This design takes advantage of the moderate temperatures in the ground to boost efficiency and reduce the operational costs of heating and cooling systems. A ground source heat pump is much more energy-efficient than an air source heat pump because underground temperatures are more stable than air temperatures throughout the year. However, GSHP's are beyond the scope of this paper because they aren't generally appropriate for upgrades or refurbishment.

Efficiency and Cost Comparisons

Four system and fuel type combinations will be compared: oil boilers, natural gas boilers, Air Sourced Heat Pumps, and ETS. The table¹⁰ below provides summary data on the costs for each fuel type per million BTU's of heat. For example, one million BTU's of oil heat cost \$27.73. The exact same amount of heat from natural gas costs \$15.63. As you can see, the table accounts for differences in price by normalizing fuels to BTUs and factoring for the efficiencies of the heating systems:

⁷ In addition, ETS improves the load profile of Concord Light which has a positive impact on the price Concord pays for energy.

⁸ Off-peak for the Concord Municipal Light Plant is from 10PM to 6AM, 7 days/week.

⁹ Some heat pumps are rated to be effective for heat at temperatures below freezing.

¹⁰ US EIA Heat Calculator. XLS spreadsheet tool which allows for inputting current pricing information. For more information on this calculator, contact: Paul Hesse: 202-586-8800; InfoCtr@eia.gov

Fuel Type	Fuel Unit	Fuel Cost	Heat/Unit (BTUs)	Cost \$/M BTUs	Heat Device	*Rating* Type	#	Approx. Effic.	Cost(\$)/M BTUs
Oil	Gal.	\$3.50	138690	\$25.24	Boiler	AFUE	91	91	\$27.73
N.Gas	Therm	\$1.50	100000	\$15.00	Boiler	AFUE	96	96	\$15.63
Elect	kWh	\$0.16	3412	\$46.89	ASHP	HSPF	10	293	\$14.21
Elect	kWh	\$0.055	3412	\$16.12	ETS	Est.	100	100	\$16.12

The least efficient and most expensive choice is an oil-fired system. While we are not making comparisons for steam and forced hot air, the same basic principles apply. In each case, oil's cost per million BTU's is higher due to less device efficiency (AFUE, etc) and to the fact that oil is both imported and in high demand. The two alternatives to oil are:

- *Natural gas* is more efficient than oil (96% AFUE) and its cost per million BTU's is approximately 50% less than oil at the present time. Natural gas is currently plentiful in the United States and is supplied to Concord via pipeline.
- *Electricity* from the grid for ASHP's and ETS is similar in costs to operate these two technologies. As a result, electricity is competitive with natural gas and is a second alternative to oil:
 - Costs to operate ETS systems are relatively low because the Concord Municipal Light Plant is able to offer electricity for ETS at an attractive, off-peak price (\$0.055/ kWh or approximately 1/3 of Concord's standard residential tier 1 rate).
 - ASHP operating costs are competitive with both natural gas (and similar to ETS), even though the electricity pricing used is the standard residential tier 1 rate of \$0.16/kWh. This is due to the high efficiency¹¹ of heat pumps which approaches 300%. One caveat: the need for a back-up heating source for ASHP's will change the overall seasonal cost picture.

CO² and Emissions Comparisons

The table below provides the specific CO² content for each fuel type. Each of the fuels are converted to BTU's and a heating efficiency factor is applied to each fuel, based on industry standards.

Fuel Type	lbs CO ² per M BTU	Heat System Efficiency %	Source	Factor
Fuel Oil	173	91	EPA	22.1 lbs CO ² /gallon
Natural Gas	122	96	EPA	0.005 tons CO ² /therm
Electricity – ASHP	95	293	Est.	1.077 lbs CO ² /kWh
Electricity - ETS	285	100	ISO NE	0.972 lbs CO ² /kWh–off pk

- *Fuel-oil based systems*: Clearly inferior, contributing 40% more CO² than natural gas or ASHPs.
- *Natural gas-based solutions*: Better than an oil-based solution by a wide margin but not as good as ASHP.

¹¹ HSPF or Heating Season Performance Factor is the measure of the seasonal efficiency of an ASHP in heating mode. It takes into account the variations in temperature that can occur within a season and the average number of BTUs that can be delivered per unit of electricity consumed by the heat pump over the season.

- *Electricity – ASHP*: The big winner for a lean CO² profile is the ASHP (22% less CO² than natural gas). As discussed above, this technology benefits from the availability of ambient heat in the environment (approximate efficiency of 300%!). As such, it is extracting heat that's already available in one environment and moving it to another. However, while 300% efficiency is good news, it is somewhat offset on a seasonal basis by back-up heating for the colder months.
- *Electricity - ETS*: While a resistance-based electric heating system is 100% efficient at the device in your home, ETS has an overall environmental profile that's more similar to electricity itself, because you need to account for the efficiency of the power plants (see table above). For example, if we add 1 MW of generating capacity to support additional load from an ETS system, we need to add 1 MW of capacity at 'off-peak' when the electricity is being produced. Because it's likely that the fuel for that additional capacity will be natural gas (refer to the Appendix on Wind Power), we need to calculate the environmental effects of ETS based on gas generators that are running off-peak. While those generators will be more efficient than many that run at peak, the efficiency on average for off-peak gas generators won't exceed 43% (see Appendix on Heat Rate). This means that to add an ETS system into the residential heating mix, we are also adding sufficient gas-fired generating resources on an after hours basis to support that requirement and the resulting CO² emissions from that choice are going to be more than 2X the emissions from a conventional, high efficiency gas boiler system (and also worse than an oil-based system).

Renewable Energy

Another factor which adds complexity to these comparisons is the evolution of our power production to include renewable sources of energy.

- *Solar*: The Town of Concord plans to add 25 MW of solar over the next 25 years and that may account for as much as 33% of demand. This will have a positive effect on Concord's carbon footprint for any use of electricity during daylight hours.
- *Wind and it's effect on off-peak CO²*: Wind energy, produced outside of Concord, will have a positive effect on the CO² from electricity generation in the long term. This is especially true of off-peak electricity used for ETS as wind is more available after hours and because wind produces more wind generator capability in cold weather. If the region achieves the NE ISO's High-Wind Penetration target of 20% wind energy by 2020 and 30% by 2030, we could displace a portion of off-peak natural gas consumption. But, if the DOE's projections for 30 growth in electricity consumption to 2030 are born-out, we never reach that point before 2030. Instead, over the next 20 years, an incremental use of electricity for ETS is accompanied by an increase in the consumption of natural gas to produce the electricity. This points to the need to aggressively pursue both strategies: electricity conservation where possible and renewable sources of energy if we are to reduce our reliance on fossil fuels.

For a complete discussion, refer to the Appendix.

Conclusion

The choice of a new heating system is not a simple one. There are constraints on the availability of some fuel types (i.e. natural gas 'main' does not support the entire Town). In other cases, a solution may not be technically feasible for your property and dwelling (e.g. Ground Source Heat Pump). And, you have the environmental effects to consider.

But, amidst all of the complexity, several points are worth restating:

- A switch from oil to gas makes sense, both in terms of cost and the environment.
- If you are planning to upgrade your oil or gas boiler, carefully evaluate your options based on AFUE ratings and features. There are significant gains from the adoption of advanced technologies such as the condensing feature, especially for a gas boiler, indoor-out door temperature reset, and ECM Pumps. Pursue the same strategy for a forced hot-air furnace.
- Air Source Heat Pumps make sense as an alternative to oil and could also be a supplement in situations where natural gas is available. ASHPs are a good choice in terms of both energy costs and environment/emissions. While more expensive than oil or gas heat systems for initial installation if viewed only in the context of heat, AHSPs also provide the added benefit of cooling/AC through the same heat pump unit at no additional 'first' cost. Ground Source Heat Pumps (GSHP) are more efficient than ASHP's but there are technical challenges and higher costs in installing this solution.
- ETS is the least expensive to operate due to lower, off-peak electricity rates. But, any incremental MW of ETS over the next 20 years to support ETS will likely involve a corresponding increase in the use of natural gas to produce the electricity. Because off-peak, gas-fired plants don't generally exceed 43% efficiency, this option produces approximately 2X the emissions of a gas-fired boiler and is also worse than oil-fired alternatives. While wind power is being pursued in New England, it's not certain that we'll have sufficient wind-power over the next 20 years to make ETS a cleaner choice (for a complete discussion, refer to the Appendix). However, ETS is a complex option as much is unknown about the future of renewable energy and its effect on the New England grid. And, there are other possible benefits to consider, including 'load shedding' which allows for ETS units to be used by the utilities during on-peak periods as a convenient storage vehicle for disposing of excess power on the grid. Load shedding is helpful to Concord's position with utilities and may make ETS more attractive financially in the future.

There's no free lunch here or magic technical solution. However, using the data will enable us to make better, more informed choices. And, over time, better choices will have a positive economic and environmental effect.

Appendix

Average Heat Rates for Jan 1-March 25, 2011

The ISO-New England tracks a statistic referred to as 'average heat rate'. This is a measure of the total BTU's of input to produce a kWh of output. This measurement includes all fuel sources – oil, natural gas, coal, nuclear, biomass, etc. In conjunction with the BTU content of a kWh (3412 BTU's), heat rate is used to calculate the efficiencies of power production for peak and off peak:

3412/9001 = 38% peak efficiency
 3412/6823 = 50% off-peak efficiency
 3412/8275 = 41% overall efficiency

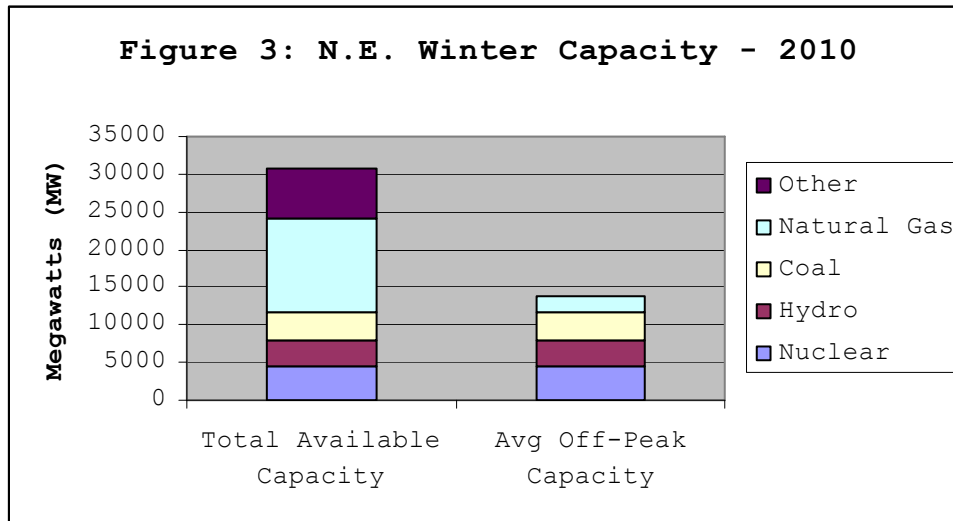
3412/8000 = 43% average efficiency for off-peak natural gas generator

For example, if it takes 9001 'units' (or BTU's) of energy to produce one kilowatt hour (kWh) of electricity, that's an efficiency of 38%, as a kWh contains 3412 BTU's of energy. In other words, at the power plant, and before transmission losses are computed, we get a yield of about 1/3 of the energy in natural gas as electricity that can be sent across power lines to Concord.

AVE HR	AVE OFF PEAK HR	AVE ON PEAK HR
6,899		
6,617		
6,406		
6,322		
6,484		
6,976		
8,333		
8,734		
8,952		
9,137		
9,201		
9,037		
8,688		
8,372		
8,086		
8,060		
8,959		
10,509		
10,328		
9,954		
9,323		
8,343		
7,606		
7,278	6,823	9,001
8275 avg		32% Higher

Effect of WindPower on ETS CO² Effects

Figure 3¹² shows the ISO-NE generating stack in MWs¹³ of overall available capacity for winter. This stack is important because it shows the relationship between the fuels and the order in which they are used to provide a given level of capacity. Because capacity requirements vary based on time of day, day of week, seasonality, and weather, at any given time, the extent to which some or all fuels (or capacity layers in the stack) are used differs. For example, at peak in the winter, all generating capacity is required and the entire stack of fuels is deployed to the various generating resources. By contrast, the off-peak hours, where generating capacity might not exceed 14,000 MWs, could be limited to nuclear, hydro, coal, and some natural gas.



The average off-peak deployed capacity was established using data from ISO-NE for January (2011) from 10PM-6AM where the 'off-peak' averaged 13,792 MW. Using this off-peak capacity as the basis for the discussion, we can recast the part of the stack that will generally be in service for that period of time. In this winter off-peak case, the bottom four fuels in the generator stack are required: nuclear provides 34% of the capacity, hydro provides 27%, coal 28%, and natural gas 11%. While coal resources are deployed at close to 100% because it's the least expensive fossil fuel, the variable capacity is natural gas. Natural gas consumption increases as the demand for off-peak capacity increases. For example, adding 2 MW of capacity during off-peak adds 2 MW of natural gas resources that would otherwise not be in production.

The implication is that the emissions/environmental effects of ETS heating systems or Electric Vehicles (EV's) are equivalent to the underlying marginal or incremental power source and in this case it's likely to be natural gas-fired utilities which average 8000 BTU's input per kWh produced or 43% efficiency average efficiency for off-peak natural gas generator. This makes ETS a less attractive choice from an environmental perspective, under today's operating conditions.

However, this can change as renewable sources of energy are developed. For off-peak, wind is the best renewable energy to displace electricity sourced from fossil fuel generators. Figure 4 shows the effect of wind on the grid at off-peak where natural gas is displaced to some extent. The scenarios displayed in the graph are as follows:

¹² Gil Myette, Energy New England, from ISO-NE data.

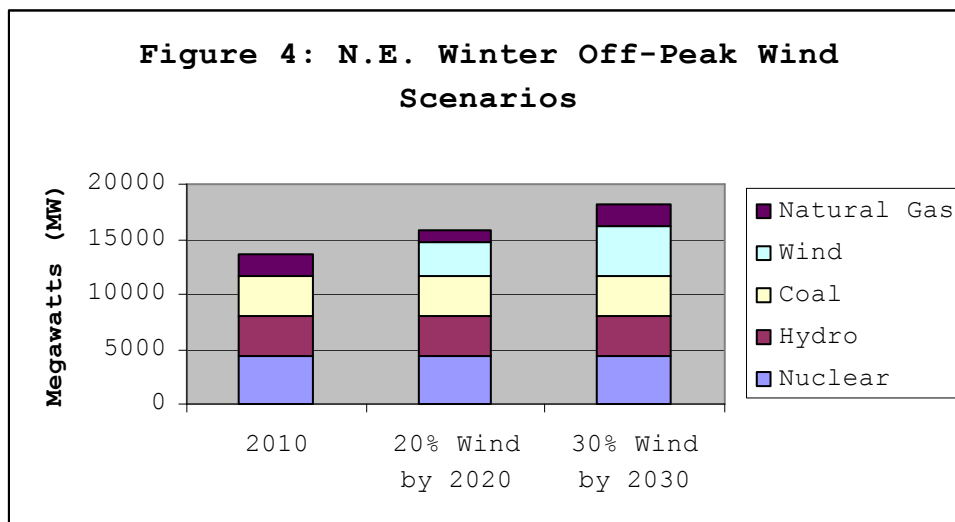
¹³ MW: Megawatt = 1000 Kilowatts's (kW's) or 1,000,000 Watts (W).

- 2010 – no wind
- 2020 – the ‘high wind’ projection from the ISO NE’s forecast is used. High wind at 20% is one of four projections, the other projections for 2020 are shown in the table below¹³. We are using the estimate of installed wind capacity but we apply a factor of 30% to the nameplate capacity to derive the contribution to the after hours mix. (30% is the number used by the ISO for credit toward a producer).

Level of Build-Out	Represents MW’s Capacity	% of Fcst Annual Energy Demand
Partial build-out	1,140	2.5%
Full queue build-out	4170	9%
Medium wind penetration	6130 – 7250	14%
High wind penetration	8,290 -10,240	20%
Extra-high wind penetration	9,700 – 12,000	24%

- 2030 – we don’t have any studies that take us out to 2030 or to 2050, but, for the sake of discussion, we’ll use 30% for 2030. The Union of Concerned Scientists believes we’ll see 50% of our electrical energy in New England sourced from wind by 2050 but a more conservative projection of 30% by 2030 is still very aggressive and allows us to have the ‘what-if’ discussion. (The other relevant projection was from the DOE for the entire United States – ‘20% wind by 2030 ‘may be feasible’: *20% Wind Energy by 2030, DOE, July 2008*).

Also, to make the projection, we built-in growth of 15% every 10 years in the overall demand for electricity in the Region:



From a scale-up point of view, the ‘high-wind penetration scenario’ for 2020 for New England is aggressive as the requirement for between 8,000 – 10,000 MW of wind equates to between 17 - 21 projects the size of Cape Wind (468 MW)¹⁵ over this period. That’s a rate of nearly two Cape Wind projects every year for 10 years. Likewise, the projection for 2030 is also aggressive as it increases the ‘high-wind penetration’ forecast by 50% which will most likely necessitate major upgrades to the transmission infrastructure. However, for the sake of argument, let’s assume we achieve these wind numbers. As you can see from the graph, the use of coal remains unchanged and we continue to rely on natural gas on an off-peak basis. After hours natural gas

¹³ New England Wind Integration Study, ISO-NE, December 5, 2010, p.9.

consumption declines somewhat by 2020 but grows by 2030 as overall demand increases. This means that an incremental MW of electricity for ETS is not supported by wind or any other renewable resource. In the main, it creates demand for additional natural gas consumption at a rate that's 2x what would be required in the way of natural gas in a gas fired boiler.

Overall, this points us toward a policy of conservation if we want to leverage wind power to reduce the emissions effects of fossil fuels. To reduce our reliance on coal and natural gas, we need to do two things: (a) restrain the growth of demand through efficiency and conservation measures, and (b) move ahead aggressively with the deployment of wind power and the necessary upgrades to the transmission infrastructure to facilitate its delivery to customers.

¹⁵ Commonwealth of Massachusetts, Department of Public Utilities, DPU 10-54, 11/22/11, page xvii.

Question and Answer Summary

There are no silver bullets or easy answers for our energy situation in New England or in Concord. The technologies are complex and the circumstances of each residence are different. Here's a question and answer summary that might help you through your decision process:

Question: It sounds like oil is the most expensive fuel. Is it likely to stay that way?

Answer: While it's difficult to forecast prices, it is safe to say that we currently have abundant and stable supplies of domestically produced natural gas. The same cannot be said for oil. Additionally, the spread between oil and natural gas may continue to widen. While natural gas is used for a variety of commercial and residential applications, it does not compete with oil as a transportation fuel. And, demand for transportation, especially autos, continues to grow world-wide. Given these cost differences between oil and natural gas (and oil's negative CO² picture), it makes sense to seriously assess the alternatives to an oil-based heating system.

Question: What are the best alternatives to oil heat?

Answer: If you have natural gas on your street or it's already in your house for other purposes, natural gas is superior to oil from an environmental perspective and you'll save as much as 50% per year on operating expenses. Plus, you can reuse your circulating hot water plumbing or your forced hot air ductwork. This eliminates the need for any changes in the living areas of your home. And, natural gas adds 40% less CO² to the environment per BTU of heat produced.

Question: What if natural gas isn't available? Are there any other options?

Answer: Yes. An Air Source Heat Pump is another alternative. It's similar in price to natural gas and it's got a far more attractive energy/CO² footprint. While you will most likely need some sort of back-up (oil, propane, or ETS), an ASHP is a flexible way to replace part or most of your oil heat system and it provides air conditioning as well using technologies that meet or exceed Concord's building 'stretch' code..

Question: What if I decide to stick with oil?

Answer: Move to the most efficient oil boiler or furnace you can find. Given the cost of oil, these efficiencies will pay-off quickly. If you have a boiler, consider a condensing boiler over a conventional model and be sure to install an indoor-outdoor reset, sealed combustion design, and smart (ECM) pumps. For a hot air furnace, also look for high efficiency and condensing, as well as an ECM motor for the blower fan. And, look for ways to supplement your oil system with ETS and/or heat pumps.

Question: What about electricity as a heating 'fuel'?

Answer: As mentioned above, heat pumps are one possible route to less dependence on oil. If you are interested in an Air Source Heat Pump (ASHP), this will support both heating and cooling requirements, but you will most likely need a second, supplementary heat source. While the systems are more costly to install than conventional oil or gas systems, the savings are significant when compared to oil (currently competitive with natural gas). Of course, an added plus is the availability of high-efficiency AC in the same system which off-sets some of the added expense for the system (alternatively, you are confronted with the additional cost of a separate AC system). Importantly, ASHP's are also a positive move for environmental reasons with a profile that's between 30-80% less CO² intense than heating with natural gas or oil. Ground Source Heat Pump solution is a second possibility, but it's more complex and costly than an ASHP, as engineering and construction for the in-ground system is required.

Question: Will I need a back-up system if I heat with an ASHP?

Answer: It's hard to give a definitive answer to this question. Some ASHP's are rated to provide heat on days as cold as – 11 degrees F. Whether you will need a back-up depends on the thermal efficiency (insulation, etc) of your home, your personal preferences for heating, and the specific manufacturer that you select. It's definitely the case that many ASHP users in this region have a back-up to their ASHP, however your situation may be different. Consult a specialist and review the performance attributes of each prospective system.

Question: What about ETS?

Answer: ETS is a second viable solution for electricity as it's similar for operating costs to both gas and ASHP heat. One of the interesting aspects of ETS that it stores less expensive 'off-peak' electricity as heat during the evening hours; however, ETS is less attractive from an emissions perspective than the other three choices because the electricity generating resources are relatively inefficient. And, it's unlikely that we'll produce enough wind over the next 20 years to reduce the impact of additional capacity for ETS. (More complete discussion in the Appendix).

Question: I have an old gas system. What should I do?

Answer: One strategy that makes sense: stay with natural gas for the beneficial pricing and environmental factors but purchase a more efficient, condensing natural gas boiler with an AFUE of 96% and install the other enhancements (Indoor-Outdoor Reset and ECM pumps). You should get a 20-30% improvement in efficiency. The same applies to a gas forced hot air system. While the performance gains won't be as dramatic, gas for hot air is still a viable solution. A second possibility is to move to an ASHP or ETS while retaining gas as a back-up.

Question: What if I have an aging steam heat system?

Answer: Some of the same principles discussed above apply to you. But, first, as far as steam heat as a system type is concerned, while it isn't as efficient as other alternatives, such as circulating hot water, significant gains in efficiency are possible through tuning and proper operation. Consult an expert in steam heat. If you need to replace your steam boiler but want to retain steam as your technology, you have several choices. First, you could upgrade to a more efficient boiler. And, if you are 'on the gas main', you could move from oil to gas at an annual savings of better than 50%.
