An Affordable Clean Energy Future:

A Superior Energy Paradigm for New England

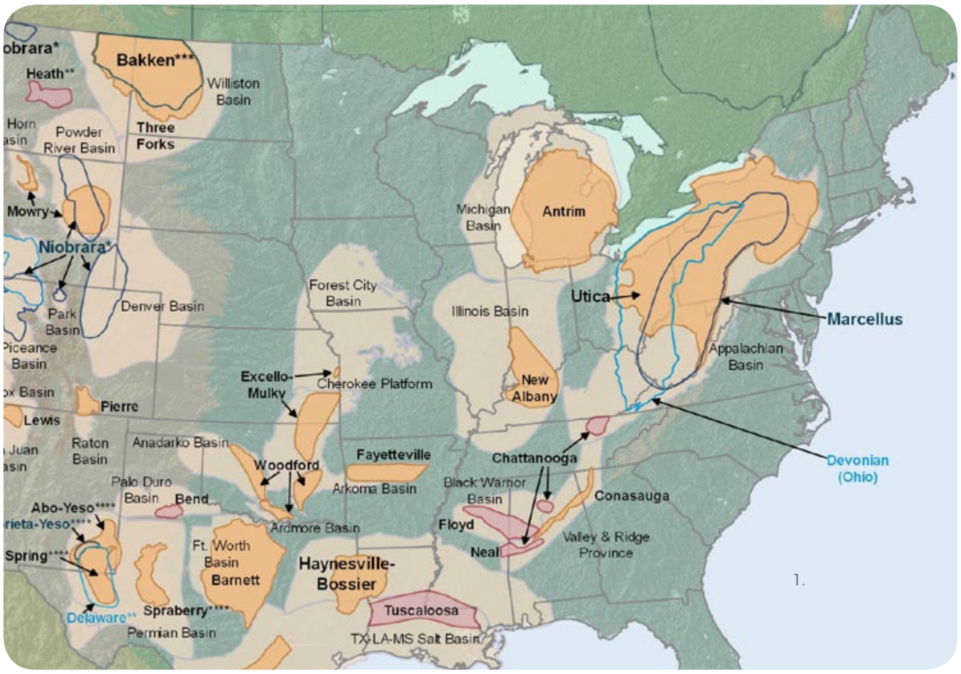
COALITION TO LOWER ENERGY COSTS

R. Benjamin Borowski
Anthony W. Buxton
Todd J. Griset

@CLECNewEngland
www.energycostcrisis.com

INTRODUCTION:

After decades of suffering the highest energy costs in the continental United States, New England has finally encountered some good fortune: close proximity to the cleanest, cheapest, and one of the most prolific shale gas formations in the world, the Marcellus Shale.



In 2015, Marcellus Shale gas leaves the ground less than 300 miles from Boston at unimaginably low prices; the cost equivalents would be gasoline at $0.15/gallon (versus about $2.25 today) and heating oil at $0.20/gallon (versus about $3.00 since 2010). Even when delivery costs are added, Marcellus Shale gas has generated electricity in New England for record lows of under $.02/kilowatt-hour (kWh) when gas pipelines are not constrained. But when natural gas pipelines coming into New England are constrained during the winter heating season, electricity is increasingly generated using expensive alternatives to pipeline gas: oil, coal, propane, and liquefied natural gas (LNG). When these fuels are used, the price of electricity reaches record highs of over $0.16/kWh for entire months. With adequate natural gas pipeline capacity, New England could eliminate these extreme price spikes and pay reasonable electricity prices year-round.

Extremely high electricity costs uniquely burden New England relative to the regions with which it competes. Economists have calculated that New England has overpaid for electricity by over $7 billion in the last three winters alone, solely because of inadequate gas pipeline capacity. As Marcy Reed, President

Marcellus Shale gas is being produced today for less than $1/mmBtu, which is equivalent to:

1 — Gasoline **$0.15/gallon** vs. $2.25 today

2 — Heating Oil **$0.20/gallon** vs. $3.00 since 2010

Natural gas this cheap produces electricity for:

3 — Electricity **$0.02/kWh** vs. $0.16

of New England's second largest electric utility, National Grid, recently observed, we must act "so we don't have to watch another $7 billion go up in smoke."[2]

Two facts are clear: no other region of the United States suffers these huge burdens and New England need only build adequate pipeline capacity from the Marcellus Shale region to eliminate them. The entire cost of the pipeline capacity necessary to heat our homes and meet the region's electricity needs will be fully recovered in consumer electricity savings in as few as 5 to 8 years, even under conservative assumptions.

After reviewing scores of economic and scientific studies and consulting hundreds of energy officials and experts, the Coalition to Lower Energy Costs ("CLEC") has concluded that New England will reap enormous economic and environmental benefits with sufficient access to Marcellus Shale gas. The necessary access will be provided by developing two bilion cubic feet per day (2 Bcf/d) of new or expanded gas pipeline capacity, as currently proposed, in New England to the Marcellus Shale. Opponents of the necessary gas pipelines, however, argue that their construction will "lock" New England into carbon-based future with grave climate implications. Invigorated by pipeline battles far beyond New England, these opponents raise many local, state, and federal objections to pipelines. These conflicting viewpoints present a decision of historic importance for New England: will we seize the good fortune presented by our proximity to Marcellus Shale gas or persist in the belief that we must pay the highest energy prices, regress on climate progress, and wait to develop the "perfect" energy solution?

Opponents of adequate pipeline capacity consistently fail to consider the full scope of the opportunity presented by a sufficient supply of low-cost natural gas. For example, they ignore the short-term environmental harms of not having sufficient natural gas and thus reverting to coal and oil in winter as well as the medium-term environmental gains that can be achieved in the electric and heating sectors through natural gas displacing coal and oil. Pipeline opponents also fail to acknowledge that in the long-term, natural gas pipeline infrastructure provides the foundation for a future based on renewable energy, allowing flexible natural gas generators to turn on and ramp up whenever renewables cannot meet demand, even as they are needed for fewer hours each year.

Less obvious, but perhaps more critical, constructing adequate natural gas pipeline capacity is the synergistic next step in the energy advances New England has made in recent decades. This will allow the region to drastically lower energy costs and most aggressively mitigate climate change. These energy advances include:

- deregulating virtually all electric generation in New England, creating a more competitive electric market and eliminating incentives to favor utility-owned generation over better technologies;
- constructing over 12,000 MW of efficient combined-cycle natural gas-fired generators, with far fewer emissions and greater flexibility than the legacy fleet of oil- and coal-fired power plants;
- permanently retiring most, but not all, of the coal- and oil-fired power plants due to their inability to compete based on price, reliability, and environmental attributes;
- creating the regional grid operator, ISO-New England, to plan and operate New England's high voltage transmission grid and manage its electricity markets;
- investing seven billion dollars in strengthening the high-voltage transmission backbone of the electric grid, with several billion dollars of investment planned, including high-voltage direct current lines to renewable energy sources in northern New England and Canada;

- establishing state energy efficiency programs that invest nearly a billion dollars each year in a wide array of energy-saving measures and largely eliminate the incentive for utilities to promote wasteful consumption;
- implementing mandatory and increasing renewable energy goals in nearly every state;
- creating the Regional Greenhouse Gas Initiative, a compact spanning nine Northeastern states, to ratchet down of greenhouse gas (GHG) emissions from electric generators;
- developing and integrating nearly 1,000 MW of onshore wind generation in New England, with nearly 4,000 MW more proposed; and
- facilitating a burgeoning solar power industry, relying first on extensive use of net metering and increasingly on larger solar arrays, with over 1,000 MW of distributed solar generation developed and nearly 2,500 MW expected by 2024.

Despite these remarkable achievements, stubborn challenges persist, threatening both past gains and further progress:

- New England consistently suffers the highest energy costs in the continental U.S.;
- high energy costs continue to hollow out our manufacturing base, including driving the export of desirable investment in emerging digital technologies;
- New England uses dramatically more heating oil than any other region, imposing serious hardship on low- and middle-income consumers and creating millions of tons of unnecessary CO_2 emissions;
- New England has reverted to relying on inefficient coal- and oil-fired generation when gas pipeline bottlenecks occur during winter, driving up electricity costs and increasing emissions;
- natural gas pipeline constraints, and their attendant reliability and pricing effects, threaten grid integration of intermittent renewable energy, potentially stifling the full development of renewable energy;
- adoption of smart-grid technologies in New England has been slow and uncoordinated, delaying the significant efficiencies available from combining the grid effectively with "the internet of things;" and
- reductions in transportation sector emissions have eluded the region, with gasoline and diesel persisting as the fuels of necessity for New England's highly dispersed population.

The opportunity to resolve each of these remaining challenges is at hand. Natural gas from the Marcellus Shale is projected to last nearly a century given current demand. It lies on top of the Utica Shale deposits that will last even longer. These deposits far exceed what New England needs to transition to a future dominated by lower costs and reliance on renewable energy, energy efficiency, and smart grid technologies. As we simultaneously battle high energy costs and global warming, the Marcellus Shale gives New England the opportunity to determine its own energy future by creating a superior energy paradigm hallmarked by:

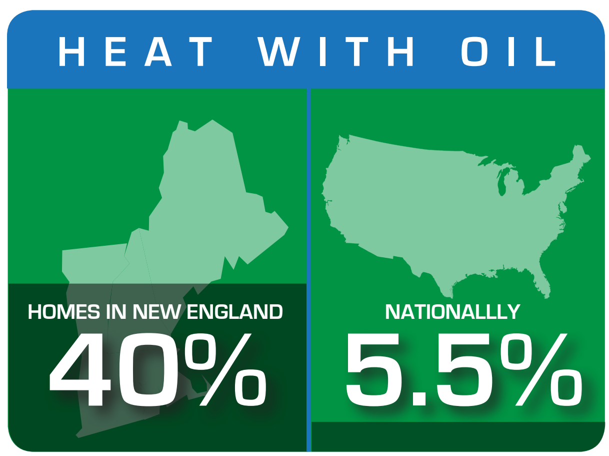
- the final displacement of coal and oil in the electric sector and a rapid reduction in our excessive reliance on oil for heating;
- billions of dollars in annual consumer energy cost savings, some of which can be used to fund expansion of renewables and energy efficiency;
- an adequate natural gas infrastructure capable of backstopping an electric grid increasingly reliant on intermittent renewable energy and smart grid technologies; and, eventually
- increased use of electricity, generated through a cleaner fuel mix, to power vehicles and heat our homes and businesses.

Despite the overwhelming and obvious benefits, this new energy paradigm will not arise unless we take decisive action. Even as we recently retreated from energy advances, some who helped lead positive changes not long ago now argue that we must start over. To the contrary, CLEC firmly believes that we must finish what we have begun.

The essential step is to build the gas pipeline capacity necessary to meet our current needs. Energy facts tell why: on a typical winter day, New England needs about 3.4 Bcf of natural gas solely for heating homes, businesses, and institutions. On a cold day, we need about 4.5 Bcf for heating. On these days we also typically need 1 Bcf of gas to power about half of our existing natural gas-fired power plants, the minimum necessary to meet electricity demand not already met by the resources normally dispatched first: wind, solar, hydro, and nuclear plants. That totals a need for 5.5 Bcf on cold days, unless we are content to burn coal, oil, or unreliable and costly LNG imported from unstable nations, such as Yemen. Unfortunately, we have only about 3.6 Bcf/d of pipeline capacity coming into New England. Simple arithmetic dictates the need for about 2 Bcf/d of additional natural gas pipeline capacity to meet New England's needs. The good news is that by meeting our current needs this way, New England can transition to a new, superior energy paradigm.

New England can finally and rapidly end consumption of coal and oil for electricity with adequate gas pipeline capacity, lowering energy costs by billions annually, immediately decreasing GHG emissions, and increasing the grid's tolerance for more renewable energy. The nearly immediate savings of billions of dollars will create disposable consumer income. New England can use some of the consumer savings to fund greater reliance on renewables and energy efficiency.

New England remains the most oil-dependent region of the nation, largely because about 40 percent of our households still heat with oil, compared to 5.5 percent of households nationally. Due in part to moratoria on the hook-up of new natural gas customers, we continue to burn billions of gallons of fuel oil each winter in relatively inefficient oil burners, contributing heavily to particulate pollution and to global warming. Converting from oil to cleaner, cheaper, more efficient natural gas for heating creates a geometric increase in societal energy efficiency. The effect will be to lower the annual heating costs of individual households by over a thousand dollars and eliminating millions of tons of CO_2 emissions each year.



As more renewable energy comes online, the amount of electricity generated from natural gas will necessarily decline because of the way renewable energy is bid into the competitive market, thereby lowering GHG emissions. Adequate pipeline capacity linking our natural gas-fired generators to fuel will ensure that whenever the wind stops blowing or the sun goes behind clouds, they will have the fuel to ramp up electricity production to meet demand. Many of the world's energy experts, including Commissioner Tony Clark of the Federal Energy Regulatory Commission have reached this conclusion:

> If we didn't have the shale gas that we have and if we didn't have adequate infrastructure, as they've seen in New England, gas prices would skyrocket[.] … From a variable energy resource standpoint, those renewables don't work without natural gas backup and the fast … abilities that natural gas generators can bring to the table, so it's critically important from a compliance standpoint that the infrastructure be there[.] You have to have more pipelines to deal with the natural gas hookup to generators so that they have a further source of fuel so that we don't have fuel security issues.[3]

The presently underutilized New England electric grid is capable of a more critical societal role than ever before. New England has invested billions dollars in strengthening high-voltage transmission grid, with billions of dollars in more upgrades planned. Additional direct current transmission lines to northern Maine and Canada are almost certain. These investments enable us to access remote sources of renewable energy and move it to demand centers in southern New England. Further, the increased mass of grid facilities allows the acceptance of smaller, distributed renewables closer to load, as well as implementation of efficient smart grid technologies. Instead of serving only as an energy "tunnel," with the application of smart grid technologies on both sides of customer meter, the grid will be a neural and circulatory network of inestimable value in lowering energy costs, reducing GHG emissions, and providing unprecedented electricity reliability.

This superior energy paradigm does not "flood" New England with natural gas or "lock" us into a carbon-based future. Natural gas will replace far more harmful and less efficient coal and oil. The concept does not rely on building significantly more new natural gas-fired power plants. Instead, it urges use of existing gas-fired power plants when they are most needed yet currently unavailable because of insufficient pipeline capacity. The new energy paradigm will speed the transition to a future based on efficiency, renewable energy, and smart grid technologies by saving billions of dollars in energy costs and devoting part of these savings to strengthening our efforts on these fronts. In fact, under its new paradigm, New England will achieve its environmental objectives far more rapidly than by continuing the current "strategy" of high energy costs, loss of economic vitality, and disproportionately harming our most vulnerable citizens.

This is not a future invented or first imagined by CLEC. The feasibility of such a future has been confirmed by energy experts from many nations and perspectives whose brilliant work is detailed in this paper. The role of CLEC as a consumer advocate whose members have experienced and shaped the energy decisions of recent decades is solely to call attention to the opportunity at hand. This paper provides CLEC's blueprint for achieving New England's superior energy paradigm: an affordable clean energy future.

COALITION TO LOWER ENERGY COSTS

Who is The Coalition to Lower Energy Costs?

CLEC is a regional incorporated association of energy consumers advocating for pragmatic solutions to New England's energy cost crisis. CLEC was formed to help to ensure that New England does not fail to take advantage of its historic energy opportunity. CLEC advocates for an affordable, diverse, and sustainable energy portfolio that includes natural gas, energy efficiency, renewables such as wind, solar, and hydroelectricity, and demand response.

Under the leadership of two former Commissioners of the Massachusetts Department of Public Utilities, one of whom was also an Energy Undersecretary under Governor Deval Patrick, CLEC's growing and diverse membership includes, among others:

- pulp and paper mills
- ski resorts
- a commercial real estate firm
- a toy manufacturer
- the Massachusetts Restaurant Association
- labor unions
- the operator of several data storage centers
- the Fall River, Massachusetts Chamber of Commerce
- an automobile/aerospace parts manufacturer.

CLEC's members have pioneered many New England energy initiatives, including:

DEMAND RESPONSE

THE REGIONAL GREENHOUSE GAS INITIATIVE

ENERGY EFFICIENCY

NET METERING

DISTRIBUTED GENERATION

COMMUNITY RENEWABLES

They have realized benefits from commercial solar arrays, EPA-certified "Energy Star" efficiency projects, and converting from oil to natural gas for process and space heat. CLEC knows that lowering costs, reducing emissions, and increasing resource diversity are not mutually exclusive because its members have done all three. This experience has uniquely positioned CLEC to offer practical solutions to New England's energy crisis.

By its long, hard work and current geographic good fortune, New England can substantially advance both its environmental and economic goals through the construction of at least 2 Bcf/d of natural gas pipeline capacity. After years of discussions and over 30 studies by government agencies, public advocates, non-profits, and industry associations, several New England states have initiated proceedings to explore whether and how to increase natural gas pipeline capacity into the region. In Massachusetts and New Hampshire, CLEC has offered extensive analysis of the causes and effects of New England's energy crisis, and proposed a cost-effective solution thereto supported by testimony and modeling from energy economics experts.

I. EXECUTIVE SUMMARY

In this paper, CLEC establishes that natural gas is the foundation for a new energy paradigm: an affordable clean energy future based increasingly on renewable energy. As recognized by energy experts, natural gas is an ideal complement to renewable electricity for technical, environmental, economic, and political reasons. Despite overwhelming evidence that New England needs natural gas to meet its environmental policy goals and renewable energy needs, some natural gas pipeline opponents assert that natural gas and renewables are enemies, that increased natural gas pipeline capacity will slow or prevent a transition to renewable energy. This paper, relying on studies from around the world, refutes that assertion, and proves that New England must build a strong foundation of natural gas infrastructure to support a significant and rapid increase in reliance on renewable energy.

New England's Unnecessary Energy Cost Crisis

New England's environment and economy stand at risk because of insufficient natural gas pipeline capacity. At critical times, and for prolonged periods, the region has been forced to revert to burning coal and oil for electricity, increasing GHG and other harmful emissions and decreasing the electric grid's ability to integrate intermittent renewable energy. New England remains by far the most oil-reliant region of the country, wasting billions of dollars annually on imported oil, while unnecessarily emitting tens of millions of tons of GHGs. These realities are exacerbated in New England by the highest natural gas and electricity prices in the continental United States, unnecessarily costing consumers billions of dollars each year.

To transition to a clean energy future based on renewables, New England must end its unnecessary energy cost crisis, while maintaining and then enhancing the flexibility of its electric grid. Natural gas located just a few hundred miles from Boston is the resource that will power the transition to New England's superior energy paradigm.

The Paradigm-Changer: Adequate Access to Marcellus Shale Gas

Natural gas produced in the Marcellus Shale region is the cheapest and cleanest in the world. With reliable access to Marcellus Shale gas, through the construction of about 2 Bcf/d of pipeline capacity, New England will create the foundation upon which to:

- finish displacing coal and oil in the electric sector;
- reduce consumer costs by billions of dollars each year;
- maintain and then increase the grid's ability to integrate intermittent renewable energy;
- decrease dependence on costlier, imported, and more polluting oil for heating; and
- begin the process of electrifying transportation and heating with an electric fuel mix based on renewable energy.

Critically, when adequate natural gas infrastructure drastically lowers electricity costs, it will boost New England's economic circumstance and create the political will to meet and strengthen renewable energy and climate change goals.

The Advantages of Natural Gas

Natural gas is the strongest foundation for a clean, affordable energy future because of its unique set of attributes complementary to renewable energy. The National Renewable Energy Laboratory (NREL), the only independent national laboratory focused on renewables and efficiency, has said that "natural gas and renewable energy technologies enjoy many complementarities spanning economic, technical, environmental, and political considerations."[4] NREL adds: "natural gas and renewable energy each contribute to economic growth, energy independence, and carbon mitigation, sometimes independently and sometimes together. New technologies, policies, and practices are emerging that may allow businesses to consider these energy sources as more 'bankable' partners."[5]

Domestic shale gas has revolutionized the U.S. energy landscape, particularly low-cost, clean Marcellus Shale gas.[6] Economically, this natural gas has repatriated a manufacturing sector that long ago fled the United States, while providing an energy-secure, low-cost, clean alternative to coal.[7] The price advantage of domestic natural gas has, in turn, provided an affordable, politically acceptable means to achieving significant environmental goals, through various state and federal regulatory schemes, including near-term GHG emission reduction programs. Further, operational characteristics of modern natural gas-fired generators make them the only grid-scale capacity resource flexible enough to balance significant quantities of renewable energy today at a reasonable cost.

Summary of CLEC'S Strategic Energy Plan for an Affordable Clean Energy Future

By increasing natural gas pipeline capacity by approximately 2 Bcf/d, New England will be able to:

STEP 1:

Stabilize and lower rising electric generation sector emissions by finishing the displacement of coal and oil in the electric sector and reducing oil use in other applications; do not retreat on the environmental progress already gained.

New England must lock-in and advance, rather than retreat on, the emission reductions it has already achieved through its turn-of-the-millennium decision to displace expensive, inefficient coal- and oil-fired generation with cheaper, cleaner, more efficient natural gas-fired generation. This is a prerequisite to an affordable clean energy future.

Coal and oil are the most polluting fuels. Their use in New England had been declining under environmental policy and market forces, but due to natural gas pipeline constraints, the region's remaining coal- and oil-fired generators have become critical energy producers once again, increasing electric sector emissions. Constructing adequate natural gas pipeline capacity (2 Bcf/d via two pipelines) will ensure the region's existing natural gas-fired generators can reliably obtain fuel throughout the year. In turn, the region's existing coal- and oil-fired generators can finally be displaced with a strategic combination of flexible natural gas-fired generation, energy efficiency, wind, solar, and hydro. Constructing gas pipeline capacity now will immediately prevent further re-entrenchment of coal and oil, and cause their ultimate displacement, thereby reducing emissions.

STEP 2:

Lower and stabilize the cost of electricity and natural gas to create increased consumer support for renewables, efficiency, and alternatives to oil.

New England must lower and stabilize its skyrocketing energy costs.

Coal and oil have enjoyed nearly a century of support, giving them substantial economic momentum today. As a consequence, renewable energy frequently requires either high electricity prices or public subsidies to be competitive. Having both, however, risks rising citizen resistance. Currently, New England has the highest energy costs in the continental United States and some of the strongest subsidies for renewables and efficiency. If energy costs cannot be controlled, the political will to support renewables and efficiency will likely wane. Increasing natural gas pipeline capacity into the region will substantially lower the price of natural gas and electricity, and in turn sharpen the political will to support renewables and strengthen environmental goals.

At the same time, the 5,248,000 Northeast households relying on inefficient oil for heating spent an estimated $7.2 billion more on heating in 2013-14 than what they would have if using natural gas. This continued reliance on oil is equivalent to the annual emissions of approximately 9 coal-fired power plants.

STEP 3:

Rapidly increase deployment of renewables and efficiency, while ensuring sufficient grid flexibility, to continue lowering emissions; rapidly deploy alternatives to oil

With coal and oil finally displaced in the electric sector, and electricity and natural gas costs under control, New England can increase its efforts to significantly reduce emissions through renewable energy and efficiency. To rapidly integrate substantially more renewable energy—which varies, sometimes unexpectedly, on timescales ranging from milliseconds to years—requires significant grid flexibility. This grid flexibility will be provided overwhelmingly by natural gas-fired generators from 2015 to 2030 because of their unique ability to turn on and off in just minutes, many times per day, and efficiently ramp up and down their energy production. Natural gas-fired generators can balance the intermittency of renewables and ensure electricity supply instantaneously meets demand. The construction of natural gas pipeline capacity will ensure that New England's current natural gas-fired generators, and possibly a few strategic new plants replacing coal, oil, and nuclear plants, can turn on and ramp to full output whenever the wind stops or clouds cover the sun. Without natural gas pipeline capacity sufficient to fuel these generators on-demand, their valuable flexibility cannot be utilized to benefit renewables.

Reductions in oil use for heating and heavy transportation enabled through additional natural gas pipeline capacity can save consumers billions of dollars and avoid millions of tons of pollution. Alternatives to oil include natural gas as a fuel, as well as electricity derived from a clean resource mix developed on the foundation of natural gas.

STEP 4:

Transition natural gas-fired generation to flexible back-up capacity that can cost-effectively balance increasing amounts of renewable energy, while burning less natural gas

As the region progresses toward 2030 and integrates more renewable energy, its existing fleet of natural gas-fired generators will begin to retire at the end of its useful life. By this time, the region will have other tools to help ensure the grid flexibility needed to integrate renewable energy, likely including large- and small-scale energy storage. The natural gas-fired generators that remain will be vital, not for their energy production, but for their capacity—that is, the ability to produce energy on demand when renewable energy fluctuates or drops to zero. Under the current electric market structure, renewables, with little or no fuel costs, will almost always displace natural gas-fired generators at the margin. In short, natural gas-fired generators will produce less energy, and thus burn less natural gas, as more renewable energy comes online. This will substantially reduce emissions from the electric sector beyond the reductions enabled by eliminating our most carbon-intensive fuels, coal and oil.

STEP 5:

Begin electrifying the transportation and heating sectors with a clean electric fuel mix based on renewable energy

The electric grid goes nearly everywhere cars and trucks travel in New England. Further, the vast majority of the energy carried by the grid is more benign environmentally than are diesel fuel and gasoline. These facts create an opportunity: hybrid and electric vehicles powered by a cleaner electric grid will allow reduction in the GHG and other emissions of vehicle fleets. Use of compressed natural gas and LNG by heavier vehicles also will lower costs and emissions, although likely more dependent on fleet refueling. Progress in these areas will depend heavily on federal vehicle requirements, but the facilities obviously will be local in nature.

Powering the transportation sector increasingly by the electric grid and by natural gas will allow genuine progress toward clean air objectives. Additionally, motor vehicles will supply a form of energy storage that will aid in the efficient use of distributed and grid-scale renewable energy.

II. BACKGROUND: NEW ENGLAND'S ENERGY COST CRISIS

Skyrocketing energy costs driven by inadequate gas pipeline capacity directly harm New England's economy. Pipeline bottlenecks in winter have affected energy costs in New England for several years, but have grown to crisis levels. Such crises will continue until New England constructs approximately 2 Bcf/d of new natural gas pipeline capacity. In Massachusetts, for example, consumers will end up paying about $1.8 billion more for just electricity in the winter of 2013-14 than they did for the winter of 2011-12, when natural gas pipelines coming into New England from New York were not constrained. [8]

The shortage of natural gas pipeline capacity hurts every New England consumer of natural gas or electricity. When pipeline space becomes limited, the price of transporting natural gas, not the price of the gas commodity itself, gets bid up through market forces. Obviously, direct purchasers of natural gas, such as large manufacturing facilities, pay an immediate premium. Homes and businesses, however, get their natural gas through their local gas utility. The price they pay is usually averaged out through a portfolio of staggered long-term contracts, but gas utilities have begun to increase their prices to reflect the high costs that they have had to pay for gas to replace expiring contracts in 2012, 2013, 2014, and 2015.

The electricity side is more complicated but also more prevalent. Everyone in New England uses electricity. In the New England wholesale electricity market, a natural-gas-fired generator is the "marginal generator" for the vast majority of the year (around 70 percent), which means it is the last generator that is ordered to turn on to meet all electricity demand in New England. The costs incurred by that generator, primarily fuel costs, represent the market-clearing price that all generators running at that time in New England receive for their electricity regardless of their actual costs. Thus, when the price of natural gas rises from $4 to $78/MMBtu, and the marginal generator's costs increase by $74/MMBtu, every single generator in New England receives an equivalent price increase. Roughly, such an increase works out to the cost of a single kilowatt-hour rising from 4 cents to 78 cents at wholesale.

Most New England electricity consumers buy electricity through their local electric utility. They pay retail rates, which are partially insulated from wholesale price fluctuations through a portfolio of long-term electric supply contracts. However, as New England's electricity consumers are quickly learning, their rates are rising dramatically, and will stay high for at least several more years just to reflect the substantially higher costs of winter 2012-13, 2013-14, and 2014-15.

Those most hurt by the shortage in natural gas pipeline capacity are low-to-middle income consumers and businesses, who simply cannot afford higher energy bills.

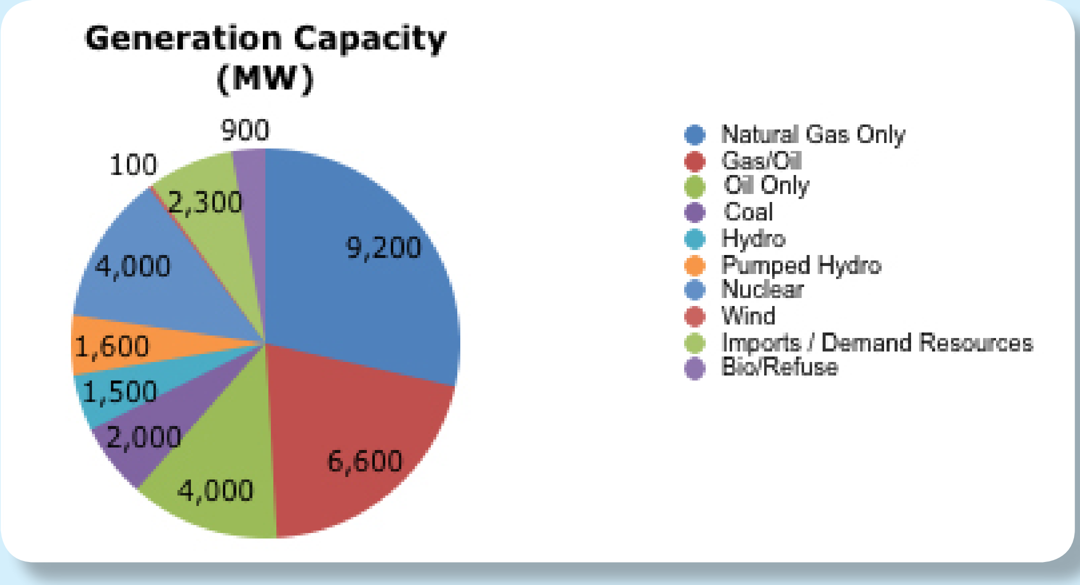
A Snapshot Of New England's Energy Sector

A look at New England's electric sector illustrates key dynamics: a significant amount of coal- and oil- fired generation is considered "at risk" of closing; renewables and energy efficiency are rapidly growing; electricity storage is still in its infancy; and the heating and transportation sectors are nearly entirely powered by forms of energy other than electricity, mostly by oil.

- 8,300 MW of coal- and oil-fired electric generation capacity "at risk"
- Renewables and energy efficiency rapidly growing
- Modern electricity storage still in early stages
- Heating and transportation sectors nearly entirely non-electric today, but could grow

Installed Capacity Requirement (ICR): ICR is the amount of electric capacity required by New England to ensure grid reliability. In 2015, the ICR was about **35,000 megawatts (MW).** As peak demand in summer increases, coupled with the addition of intermittent renewable capacity requiring backup from other capacity resources, the ICR is expected to slowly grow. ISO New England explains: "The total quantity of resources needed should be expected to grow as more variable and renewable resources are added to the system; these resources typically make contributions to reliability that are only a fraction of the value of their nameplate capacity."[9]

Electric Generation Capacity: Today, New England has about **30,000 MW** of electric generation capacity. ISO New England has identified 8,300 MW of old coal- and oil-fired capacity to be "at risk" of retirement. To retire this capacity and maintain reliability, about 1,000 MW of energy efficiency and 6,000 MW of new generation capacity is needed, with about 5,100 MW located at or integrated with the "Hub" in central/western Massachusetts.[10] New generation is also being developed. As of March 2015, about 11,000 MW of new projects were proposed, about 40% of which is wind. Proposed generation usually suffers a 70% attrition rate. The current composition of the electric generation capacity is as follows, with 50% of the capacity having the ability to run on natural gas when it is available:



Renewable Capacity and Energy Efficiency are Rapidly Growing:

WIND:

Wind generation has experienced tremendous growth in New England. In 2005 the region had just 2 MW of installed wind capacity. By 2014 wind capacity had grown to about 800 MW, with over 4,000 additional MW of capacity proposed for development as of March 2015. Additionally, ISO New England concluded in its New England Wind Integration Study that 12,000 MW of wind capacity was technically feasible, producing up to 24% of the region's electricity, assuming no generation retirements, sufficient transmission upgrades, and increased grid flexibility. It is worth noting, however, that in this high wind penetration scenario, natural gas remained vital, producing about 30% of the region's electricity, while coal and oil still unacceptably contributed 15%. While the rapid growth and future potential of wind are good for the region, wind also creates grid operation challenges. For instance, due primarily to the fact that wind is intermittent and frequently idle, the region's nearly 800 MW of wind capacity produced only 1% of New England's energy in 2014, while comprising some 2.7% of total capacity.

SOLAR (PV):

Solar energy is growing even faster than wind. In 2010, the region had a mere 50 MW of PV capacity. As of April 2015, 1,009 MW of PV was installed in New England. ISO New England projects that 2,450 MW will be installed by 2024, and the effects are significant. PV is forecast to reduce the 2024 baseline peak (about 32,000 MW) by 450 MW and reduce 2024 baseline energy use (about 152,000 gigawatt-hours (GWh)) by 2,200 GWh. Despite these clear benefits, PV also presents grid operation challenges, primarily because it is night half the time and often cloudy during the day. In 2024, 2,450 MW of PV is projected to produce only 2% of the region's annual energy needs. Moreover, during the winter peak, occurring around 6:30 p.m., PV always will contribute nothing. However, PV is projected to meet up to 17% of New England electricity demand needs during certain summer hours, displacing some of the need for high-priced thermal generators and offsetting some of the growing air conditioning load.

ENERGY EFFICIENCY (EE):

Energy efficiency is a critical tool in New England, which is a national leader in EE policies, programs, and forecasting. New England is projected to invest $1 billion annually over the next decade on EE, which will have significant effects on peak and annual energy consumption. EE investment is cumulative, as virtually all EE measures have useful lives of more than one year. ISO New England projects that by 2024 EE will reduce the 2024 baseline peak (about 32,000 MW) by 1,300 MW, or 212 MW annually from 2015-24. Moreover, EE will reduce 2024 baseline energy use (about 152,000 GWh) by 22,000 GWh, or 1,616 GWh annually from 2015-2024.

EE AND PV COMBINED:

When EE and PV are combined they dampen the growth of peak energy consumption to only .6% from 2015 to 2024 (28,395 MW to 30,180 MW) and keep energy consumption flat at around 128,000 GWh. This will likely avoid the need for the construction of non-replacement electric generation capacity.[11]

How Much Renewable Energy Can New England Technically and Economically Integrate?

While CLEC knows of no comprehensive study done in New England to answer this question, the results of a 2014 analysis by the New York State Energy Research and Development Authority (NYSERDA) titled "Energy Efficiency and Renewable Energy Potential Study of New York State" are instructive.

NYSERDA found absent financial constraints, renewable energy had the bounded technical potential to provide up 41% of New York's primary energy needs by 2030.

When economic constraints were considered, renewable energy could meet slightly more than 20% of New York's primary energy needs by 2030.

In just the electric sector, given technological and economic constraints, renewable energy could meet 30% of New York's electricity demand by 2030.

What would this cost? *"Developing the economic potential for renewable energy by 2030 as identified in the study would require cumulative capital investments of roughly $54 billion over a 20 year period."*

Future Resources to Consider

ELECTRICITY STORAGE:

Electricity storage is considered by some to be the "holy grail," because once it is widely available, renewable energy can be stored to reduce current reliance on fossil fuels. Today, electricity storage is largely pumped-hydro, the technique of using cheap or excess electricity to pump water uphill and then releasing that stored energy when needed. In 2013, there were 24,600 MW of electricity storage in the U.S., 95% of which was pumped hydro.[12] New England currently has about 1,600 MW of pumped hydro. In 2014, there was only 350 MW of non-pumped hydro storage in the U.S., including from flywheels, batteries, and compressed air combined. Generously assuming half of this capacity is in New England, it would equal only about .005% of the ICR, the amount of capacity needed for reliability. The current cost of energy storage is also prohibitive. "In 2007, large-format lithium-ion storage cost about $900 per kilowatt-hour; today, the cost is about $380, and it's on track to drop below $200 in five years."[13] Assuming continued cost-reductions and improvements in the energy densities of batteries—how much can be stored per unit of volume or weight—electricity storage could become a significant part of New England's renewable future by 2030 and beyond.

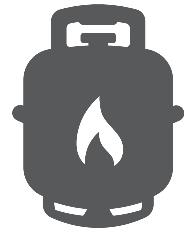
ELECTRIC CARS:

Electric and hybrid cars can significantly reduce GHG emissions, assuming a clean electricity mix. In 2014, however, electric car sales accounted for only about .05 percent of all vehicle sales.[14] While the industry is experiencing rapid growth, substantial electrification of transportation will take decades. For example, "McKinsey's Energy Insights unit projects that in 2030, about 10 percent of all cars in the 34 member countries of the Organization for Economic Co-operation and Development will be at least partially electric."[15]

ELECTRIC HEATING:

Electric heating can offer consumers options to use distributed renewable energy and other clean, grid-sourced energy to provide heating for homes, businesses, and institutions. While electric resistance heating systems are disfavored in many applications because of inefficiency, modern technologies like electricity-powered heat pumps can be highly efficient sources of heat. Heat pumps now compete with pellet stoves to replace oil heat where natural gas is unlikely to be available.

III. THE PATH FORWARD



The construction of 2 Bcf/d gas pipeline capacity from the Marcellus Shale region into New England via two new or expanded gas pipelines enables the five steps in CLEC's Strategic Energy Plan. More than thirty economic studies have measured the need for and benefits of such increased pipeline capacity. CLEC has carefully reviewed all the studies, obviously including those CLEC has funded in New Hampshire and Massachusetts by Competitive Energy Services. CLEC also has found the 2015 Synapse Energy Economics, LLC study funded by the Deval Patrick administration and recent studies by ICF International, Inc. to be enlightening. These and other studies confirm that 2 Bcf/d of additional pipeline capacity will eliminate virtually all of the gas and electricity price spikes that have cost New England consumers some $7 billion over the last three years. CLEC has assumed a conservatively high gas pipeline capacity price of $1.40/MMBtu, creating a fifteen year total amortization cost for the two pipelines of slightly more than $1 billion per year. Applied to the last three years, for example, the net benefit to electric consumers ranges from more than one to three billion dollars a year. These calculations do not include consideration of consumer savings from reduced heating oil reliance, decreased gasoline and diesel use and reductions in air pollution. Other resources, such as LNG, may be available opportunistically from time to time to reduce the basis differential-driven price spikes, but there is no serious prospect of their availability cheaply and dependably over the long term. Further, these other resources have little likelihood of helping to materially reduce New England's oil heating and gasoline and diesel reliance. In sum, adequate access to clean, low-cost Marcellus Shale gas creates revolutionary benefits unavailable to New England from any other sources. Only natural gas infrastructure adequate to access Marcellus Shale gas can be the foundation for a new energy paradigm for New England.

STEP 1:

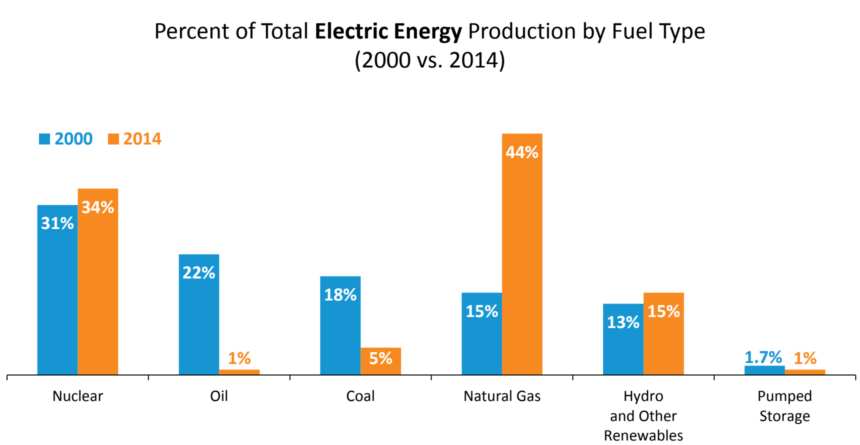
Stabilize and lower rising electric generation sector emissions by finishing the displacement of coal and oil in the electric sector and reducing oil use in other applications; do not retreat on the environmental progress already gained

Electric sector emissions are rising, and poised to rise further, because natural gas pipeline constraints are driving a region-wide reversion to coal and oil throughout winter. After almost a decade of declining average emission rates of CO_2, SO_2, and NO_X from the electric sector, those rates are increasing.[16] According to ISO New England (ISO-NE), the independent regional grid operator, the spike in emission rates is caused by "a decrease in natural gas (lower emission rates) to more coal- and oil-fired generators (higher emission rates)."[17]

The emissions benefits to New England of using new, efficient, combined-cycle natural gas-fired generation (CCNGG) are staggering. From 2001-13, regional electric generation sector emissions of CO_2, SO_2, and NO_X decreased respectively by 23, 91, and 66 percent, overwhelmingly because of increased use of natural gas, displacing coal and oil.[18] Since 2007, for example, Massachusetts' electric sector GHG emission reductions have far exceeded those of all other sectors combined.[19] The Massachusetts Executive Office of Energy and Environmental Affairs states: "The decline was principally caused by reduced generation from oil and coal, and increased generation from natural gas, renewables, and nuclear, as well as energy efficiency."[20] These emissions reductions are now at risk.

New England has constructed about 12,000 MW of CCNGG capacity since 1999.[21] Today, that capacity is grossly underutilized for about 2,500 hours each winter because these generators cannot access or afford fuel when they need it. In the example below, natural gas-fired generators were contractually obligated to provide nearly 11,500 MW of capacity, but could only provide around 3,000 MW.[22] Oil and coal picked up the slack, with huge financial and environmental consequences. For example, Massachusetts citizens and businesses will end up paying about $1.8 billion more for electricity used in the winter of 2013-14 than they did for electricity in the winter of 2011-12, when natural gas pipelines coming into New England were not constrained.[23]

New England Has Seen Dramatic Changes in the Energy Mix: From Oil and Coal to Natural Gas



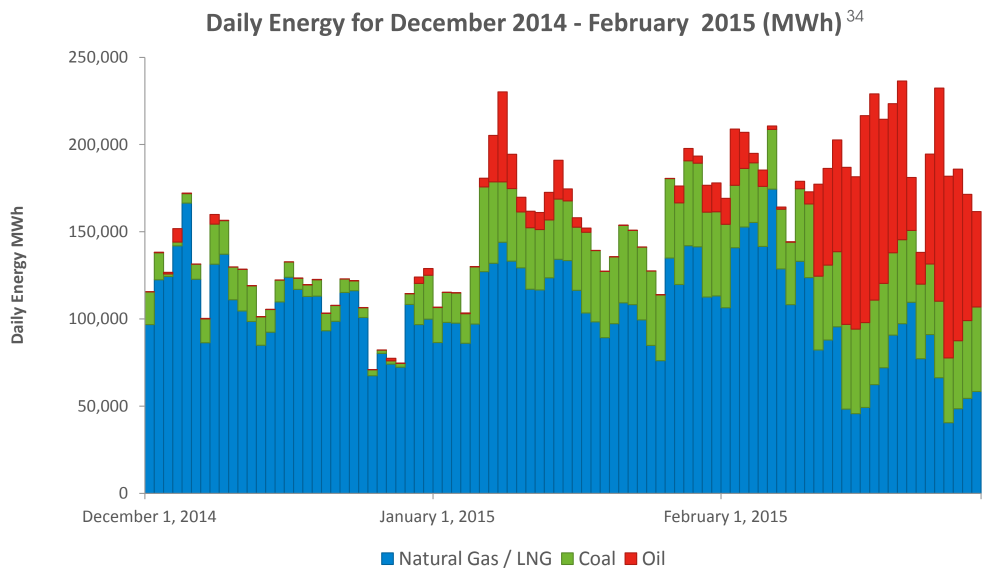
Natural gas pipeline constraints have limited the physical and/or financial ability of New England's existing natural gas-fired generators to obtain fuel. In response, coal and oil have at peak times generated 42% of our electricity,[24] and created well over 20% of our electricity for entire months, including January 2014[25] and February 2015.[26] For comparison, in 2012, coal and oil combined to produce just 3.4% of the region's electricity.

Part of New England's reversion to dirty, inefficient, and expensive fuels is due to reliability concerns precipitated by natural gas pipeline constraints and the historic unreliability of oil. Last year, for the second consecutive year, ISO-NE was forced to implement a "Winter Reliability Program" ("WRP") "to address concerns about the ability of power system resources to perform when dispatched, especially during cold weather conditions."[27] The WRP is essentially an emergency oil subsidy. In the 2013-14 WRP, oil-fired generators earned approximately $66 million (above-market) to burn over 2.7 million barrels of oil, which "was critical in keeping the lights on, especially during times when the gas pipelines were severely constrained and also when oil was more competitively priced than natural gas, which resulted in many oil plants running more than usual and for extended hours."[28] The 2014-15 WRP changed slightly, including becoming open to LNG, another historically unreliable fuel. In 2014-15, 79 oil and dual-fuel units participated, burning 2,717, 500 barrels of oil through February.[29] While two gas-fired generators contracted for over 500,000 MMBtu of LNG, none was used.[30] The total cost of the 2014-15 WRP was around $47 million, though the end of February.[31]

For those arguing that the "market" sufficiently responded to the energy crisis in 2014-15, it is worth noting that the Federal Energy Regulatory Commission has reluctantly approved a continuation of the WRP through at least 2018-19.[32] While vital to reliability, the WRP has increased, and will continue to increase, emissions of CO_2, SO_2, and NO_X relative to what would have been emitted if New England's existing natural gas-fired power plants had adequate access to fuel.

In short, because natural gas pipelines have not expanded commensurately with increased demand for natural gas (for heating, industry, and electricity), the coal and oil generators the region sought to retire through the competitive pressure of efficient natural gas-fired generation have been revitalized.[33] The persistence of pipeline constraints, which worsen as non-electric demand for natural gas increases and natural gas supply from Atlantic Canada dwindles, risks delaying or preventing the retirement of New England's coal- and oil-fired generators. This trend will continue to increase average emission rates and possibly total emissions, despite increased use of renewables and energy efficiency. Moreover, the coal- and oil-fired resources made critical by pipeline constraints are inflexible, (long start-up and minimum run times and slow and inefficient ramping capabilities) decreasing the grid's ability to rapidly respond to intermittent renewable energy and slowing regional progress on emissions.

New England Shifted to Coal and Oil this Winter



To exacerbate the situation, Vermont Yankee, one of the region's largest carbon-free baseload resources, retired in 2014 and the 2019 retirement of Pilgrim Nuclear Station, a 680-MW nuclear generator, was recently announced. What can be used to replace these units, and other baseload electric capacity, as reliable and environmentally and economically acceptable? Coal and oil cannot be the answer. Hydro will continue to play an important but overall small role, even in light of proposals to increase imports into the region.

Natural gas-fired generators are the only viable solution because of their low cost, ability to be permitted, high and increasing efficiency, and high and increasing operational flexibility. The region's existing CCNGG have thermal efficiencies of about 42%,[35] meaning they transform 42% of the useful heat content of natural gas to electricity.[36] However, new CCNGG now exceed 60% thermal efficiency.[37] To the extent that a coal- or oil-fired generator or older natural gas-fired generator, with a thermal efficiency only about 30-35%, is directly displaced by a next-generation CCNGG, the fuel (and thus emissions) savings will be enormous. For example, from 2001 to 2013, the system heat rate of California's natural gas-fired generators (totaling over 50,000 MW) dropped from about 10,300 Btu/KWh to about 8,500 Btu/KWh, meaning thermal efficiency increased from 33% to 40%. Staff at the California Energy Commission reported:

> The successful development of new combined-cycle plants continues to be the primary reason for the improvement in California's system wide heat rate. The thermal efficiency of the state's current portfolio of natural gas power plants has resulted in 12 percent more energy being generated while using 7 percent less natural gas compared to 13 years ago.[38]

Modern CCNGG can thus serve as baseload resources with lower carbon intensity than many existing generators.

Moreover, CCNGG is becoming much more operationally flexible and better equipped to respond quickly to variations in renewable energy. Coal and nuclear can take more than 12-24 hours to reach full output. First-generation CCNGG can respond in 100 minutes.[39] Next-generation CCNGG can respond in less than 40 minutes.[40] Simple-cycle gas turbines can start-up and reach full load in as little as 2 minutes.[41] As explored further below, this flexibility is critical in the next 20 years while cost-effective, large-scale energy storage is being developed.

Modern natural gas-fired generation's versatility and ability to adapt to variable renewable energy have led some to call it a "Swiss Army knife."[42] As discussed earlier, since around 2000 over 22 natural gas-fired generators were built in New England. These plants still exist, but are dramatically underutilized in winter. Today, coal and oil overwhelmingly fill the void (not renewables), decreasing the flexibility of the grid and increasing costs and emissions. It would be wasteful to under-utilize these investments for the next 20 years, reverting to coal and oil instead, while we wait for other tools to be designed, commercialized, and placed in the region's toolbox (e.g., cost-effective large-scale energy storage). This would effectively leave New England with primarily broken Swiss Army knives in our toolbox for the next two decades and hinder the region's ability to integrate renewables.

In sum, it is possible some regions should be concerned with over-investment in natural gas-fired generation, but New England has a far different circumstance. We have not over-invested in natural gas generation; we have under-invested in the pipelines essential to operate these plants. New England has a fleet of natural gas-fired generators that goes underutilized in winter, while more than 8,300 MW of "at-risk" coal- and oil-fired generation has become vital again. To remedy this, and effectively use its existing "Swiss Army knives" to balance increasing renewable energy, the region must reliably supply them with fuel through additional natural gas pipeline capacity. The enormous electricity cost savings from such investment will ensure the benefits vastly exceed the costs, even as less energy is produced by the natural gas-fired generators and more is produced from renewable resources.

If we build natural gas pipeline capacity now to reliably supply the Swiss Army knives the region has already constructed, their useful lives will expire about the time that other tools will be available. The pipeline investment will have paid for itself many times over in electricity cost-savings, while simultaneously helping other sectors decrease reliance on oil. Additionally, to replace the 8,300 MW of "at-risk" coal- and oil-fired generation, CLEC advocates that efficiency and renewable energy play significant roles. While some (much less than 8,300 MW) new natural-gas fired generation may be necessary, it will be next-generation technology with greater efficiency and flexibility, drastically reducing cost and emissions, while further increasing the ability of the grid to deal with fluctuations in renewable energy.

Independent analysis supports these conclusions. For example, Harvard Business School's 2015 study "America's Unconventional Energy Opportunity: A Win-Win Plan for the Economy, the Environment, and a Lower-Carbon, Cleaner-Energy Future" states:

> Our analysis shows that long-term carbon emissions lock-in from gas power plants and pipeline infrastructure is highly unlikely. Natural gas power plants have a useful life of 30 years, after which retrofitting and maintenance of obsolete turbines becomes more costly than building new, efficient plants. … While new natural gas power plants will be required to meet the 30% reductions in the power sector by 2030 [under the EPA's Clean Power Plan], the vast majority of gas plants needed in 2030 are already in operation today. A large portion of them were built in the early 2000s, and our analysis shows that half of the natural-gas capacity in use in 2030 would be naturally retired by 2040, and 100% would be retired by 2060. (See Figure 26.) Thus, the U.S. will actually have substantial flexibility post-2030 to utilize the most competitive power investments then available and achieve ambitious climate goals by 2050. … Moreover, there will be substantial long-term requirements for natural gas in sectors outside of power, including residential and commercial uses, as well as petrochemical feedstocks and fuel. By 2040, the EIA projects that nearly 60% of U.S. natural gas demand will originate outside the power sector. Even if there is a decline in natural gas use for power generation after 2030, to meet further carbon emissions reduction targets significant demand for natural gas will remain, and pipeline and distribution infrastructure are highly unlikely to become stranded assets.

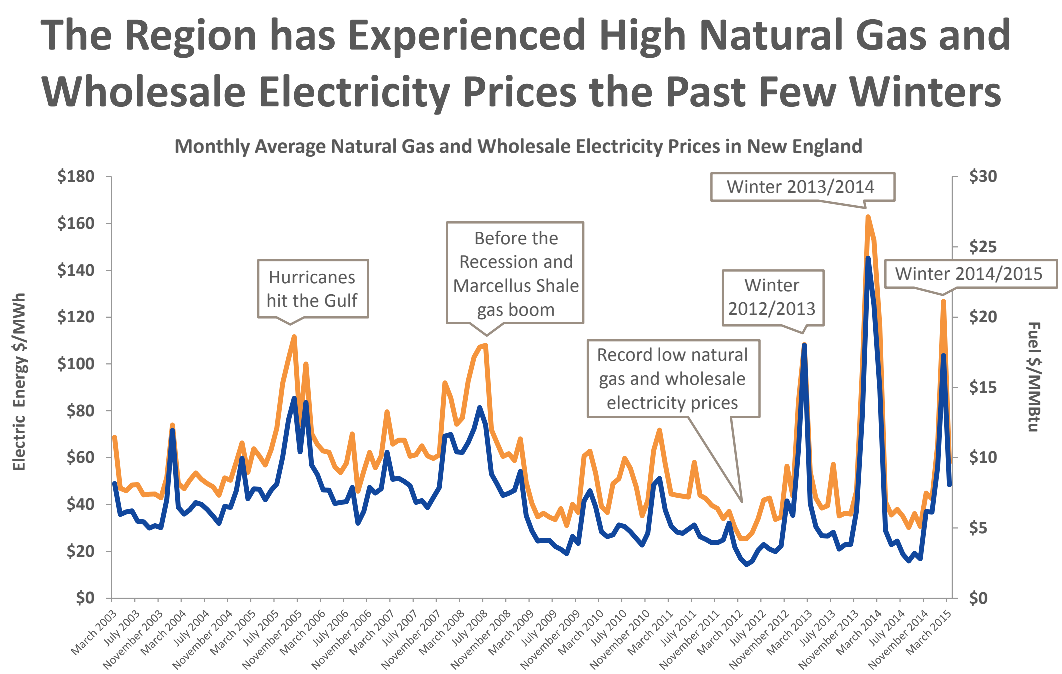
Further, in Michael Levi's (David M. Rubenstein senior fellow for energy and the environment at the Council on Foreign Relations), 2015 article, "Fracking and the Climate Debate: Natural gas isn't holding us back from a carbon-free future. In fact, it may help us get there," Mr. Levi states that shale gas: "can play a critical role in confronting global warming. Without shale gas, U.S. greenhouse gas emissions would be higher, our climate policies would be weaker, and the odds of slashing future carbon dioxide emissions and meeting U.S. climate goals would be greatly reduced." He ultimately concludes:

> Betting entirely on renewables or nuclear power, or treating all fossil fuels as the enemy, is dangerous. These approaches could easily leave the country saddled with massive dependence on coal-fired electricity—with all the public health and climate damage that entails. This is the real alternative to the difficult work of making sure shale gas development is done right and harnessing it to help transform U.S. emissions. It is an alternative that no one should be willing to risk.

STEP 2:

Lower and stabilize the cost of electricity and natural gas to create increased consumer support for renewables, efficiency, and alternatives to oil

Much of the United States has undergone an energy revolution, with natural gas as the catalyst; New England has not. Gas is now cheap and abundant just a few hundred miles away from New England in the Marcellus Shale region. With sufficient pipeline capacity, natural gas would drastically lower New England electricity prices, as occurred in 2012 and during the relatively unconstrained periods in 2013, 2014, and 2015. The chart below shows the price of New England electricity almost perfectly tracking the price of natural gas since market reform in 2003.



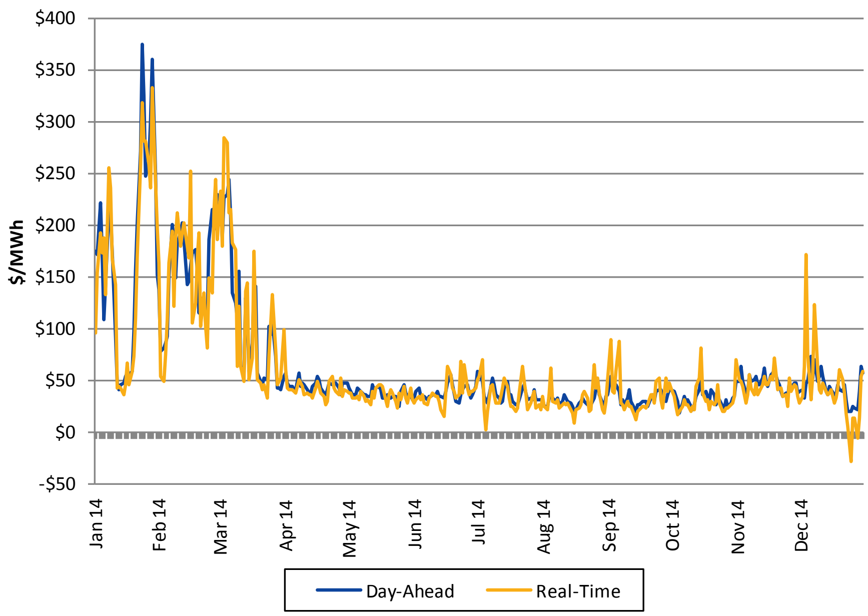
In June 2015, New England enjoyed its lowest-ever monthly average electricity and natural gas prices under the current market design, at $19.61/MWh ($.1961/kWh) and $1.68/MMBtu, respectively. This demonstrates how natural gas can provide low-cost electricity when the region's pipeline capacity exceeds the region's demand for natural gas:

> Matthew White, chief economist at ISO New England, said the explanation for such low power prices is simple. "It's supply and demand. With June's mild weather, demand for natural gas and electricity were both low, and the pipeline capacity was available to deliver a plentiful supply of exceptionally low-priced natural gas to generators in New England. Seasonal demand for natural gas has abated, and New England is able to access that low-cost supply because we aren't seeing winter's recurring pipeline constraints.
>
> But the swing in prices over just five months, going from the third-highest power price during February to the lowest in June, underscores the price volatility attributable to pipeline infrastructure constraints," White added. "During February's record cold, demand for natural gas was so high that the pipelines into New England—which haven't expanded at the same pace as natural gas demand growth—were running at or near capacity.

When natural gas demand is so high and the supply available to generators is limited, the price for natural gas delivered to New England rises dramatically—and so does the price for the electricity made from it.

During February, the average wholesale price of power was $126.70/MWh, while the average price of natural gas was $17.27 per million British thermal units (MMBtu), the fourth-highest monthly level since 2003.[43]

The graph below illustrates the price impact and volatility attributable to natural gas pipeline constraints in 2014.[44] Due to pipeline constraints, electricity prices spiked above $350/MWh and averaged nearly $150/MWh during the 4-month heating season. However, from April to November, when lower demand for natural gas meant pipelines were not constrained, prices never reached $100/MWh and averaged only about $40/MWh.



Importantly, these price impacts do not reflect the price of natural gas as a commodity. As ISO-NE President and CEO, Gordon van Welie explained during his 2015 "State of the Grid" address: "[t]here's a distinction I want to make clear as we talk about pipeline constraints. There's not a shortage of natural gas supply—there's plenty of natural gas, in nearby states. The high prices come from the bottlenecks on the gas system. The pipelines into New England aren't big enough to carry in all the gas that's in demand, especially in winter, and there's not enough gas storage in the region. While demand is growing, the pipelines bringing natural gas into New England have not expanded at the same pace."[45]

Some—who apparently misunderstand how New England's energy markets work—say a little pain (i.e., high prices) is good because it will force New England to transition to renewable energy, but businesses and people living on lower incomes cannot withstand high prices and price volatility. In Maine, paper mills closed for weeks at a time during the past few winters because of energy costs, sending thousands of hourly workers home without pay, and permanently laying off others.[46] Massachusetts provided low-income heating assistance to over 183,000 households in 2014, and has a 2015 LIHEAP budget of over $146 million.[47] The Massachusetts Department of Housing and Community Development found: "The rising cost of heating oil and high utility prices disproportionately affect the low-income population of the Commonwealth" and "that households with income below 100% of the Federal Poverty Level spend … 8.5% to 10% [of their income] on home heating bills alone."[48] Building a solid foundation of natural gas pipelines is the most cost-effective way to alleviate this burden on the economy and lower-income households.

High prices, extreme price volatility, and subsidies for oil also threaten the persistence and growth of renewable energy. Financial subsidies or other support for renewables and efficiency are an economic necessity today, even as their production costs rapidly decrease with technological improvement and increased scale. Thus, the political will to support renewables and efficiency is inextricably linked to the ultimate cost that consumers pay for electricity. Simply put, high-priced electricity will put political pressure on renewables and energy efficiency; low-priced electricity will engender more support for renewables and efficiency.

If gas opponents continue to oppose the construction of natural gas pipeline capacity that will drastically lower the price of electricity and natural gas, the political will to meet and strengthen renewable energy goals will likely wane. For example, due to increasing energy bills, New Hampshire and Maine have recently seen legislative efforts to leave the Regional Greenhouse Gas Initiative, rescind long-term contracts for renewable energy, repeal renewable portfolio standards, cut funding for efficiency programs, and curtail net metering programs. The efforts in these states, though largely ineffective to date, should be especially concerning to New England as a region, because New Hampshire and Maine have the vast majority of regional wind and hydro potential. The effects of New England consumers paying the highest electricity and natural gas prices in the continental United States could affect all the New England states.

Elin Swanson Katz, the Connecticut Consumer Counsel, recently expressed a similar opinion:

> My concern is as a consumer advocate, I'm constantly approached by people who say, "I have a great idea. It's just going to be another penny a month on a utility bill." But those charges add up and I am constantly saying, "What are the benefits to the grid?" And we have to measure benefits in terms of not the participants, but the non-participants as well. … There's lots of people, including myself, who are very concerned about a renewable future and how do we integrate it, but we can't ask the people who can least afford it to bear the transition costs if we don't make sure we're also keeping an eye on the benefits for them. That's what I worry about. We're in a period of transition and we don't see enough focus on reducing costs.[49]

The Brattle Group, a Boston-based consultancy studying the integration of renewables into the Texas grid, concluded that the financial boon provided by natural gas will help lower emissions:

> Low natural gas prices also facilitate Texas' continued transition towards a low-carbon emissions electricity sector by dampening any potential additional costs of renewable over conventional power generation sources. … Due to low natural gas prices, electricity bills, as a percentage of household income, are near their historical lows. Consequently, increased levels of a combination of renewable energy and new lower-cost gas power can likely be accomplished without materially increasing the share of income Texans have to dedicate to paying for electricity relative to the past.[50]

The U.S. Environmental Protection Agency has acknowledged the vital role of natural gas in making more stringent carbon regulations politically possible. U.S. EPA Administrator Gina McCarthy, a former Massachusetts environmental official and architect of President Obama's Clean Power Plan, recently stated:[51]

> "Fracking has changed the game for me in terms of how the energy system is working. The inexpensive gas that's being produced has allowed us to make leaps and bunds in progress on the air pollution side, and frankly, to make the Clean Power Plan."

An analysis by Harvard Business School confirms that natural gas will not hurt renewables:

> Natural gas is highly unlikely to retard the development of renewables or slow the rapid improvement in their economic viability. Both policy and economics continue to create incentives for the development of renewable technologies. At a minimum, existing renewable portfolio standards will ensure that the mandated generation capacity of renewables increases by at least 40% by 2030. More importantly, competitive improvements will continue to encourage renewables growth, which is well underway. … Just as many natural gas plants begin to reach retirement age in the 2020s and 2030s, renewably sourced energy should be more competitive with natural gas-derived energy—even in regions with less favorable conditions for wind and solar.[52]

McKinsey & Company went a step further in finding that natural gas could facilitate growth in renewable energy:

> And because energy investment is long term, changes in the spot price of gas will not in themselves derail investment in other sources. As long as renewables keep getting cheaper, there is room for both. … Counterintuitively, there is even a way in which much lower oil and gas prices can actually help renewables. Many countries have helped pay for the cost of fossil fuels through consumer subsidies; in 2012, the [International Energy Agency] estimated that these subsidies cost governments $544 billion. As all subsidies do, these policies led to higher consumption than if people had to pay the market price. When oil prices crashed, several countries in Africa, as well as Egypt, India, Indonesia, Ukraine, and others, took the opportunity to cut these subsidies. China raised gas taxes, which had the same effect of dampening demand. When oil and gas prices increase, as they have already begun to do, renewables will be in an improved relative position. [53]

Together, these consumer advocates, scholars, consultants, and regulators credibly bolster the conclusion that lowering energy prices through the expansion of natural gas pipeline capacity is a critical step for New England to increase its reliance on renewable energy in the near future.

STEP 3:

Rapidly increase deployment of renewables and efficiency, while ensuring sufficient grid flexibility, to continue lowering emissions; rapidly deploy alternatives to oil

An unavoidable (and inconvenient) truth is that "switching the U.S. to all-renewable power in the near term is neither technically nor economically viable."[54] This is unequivocally true in New England, but New England is well-positioned to transition rapidly to a future based largely on renewables if additional natural gas-pipeline capacity is constructed.

Given New England's energy cost crisis detailed in the previous section, it is not economically feasible to transition to an all-renewables future in the near term. But there are other practical limitations as well. A 2013 Stanford University study titled "Examining the feasibility of converting New York State's all-purpose energy infrastructure to one using wind, water, and sunlight"[55] reveals the scale of the effort required to convert New York's energy system to one entirely dependent on wind, water, and sun by 2030. The numbers are staggering. New York's 2030 hypothetical energy mix would look as follows:

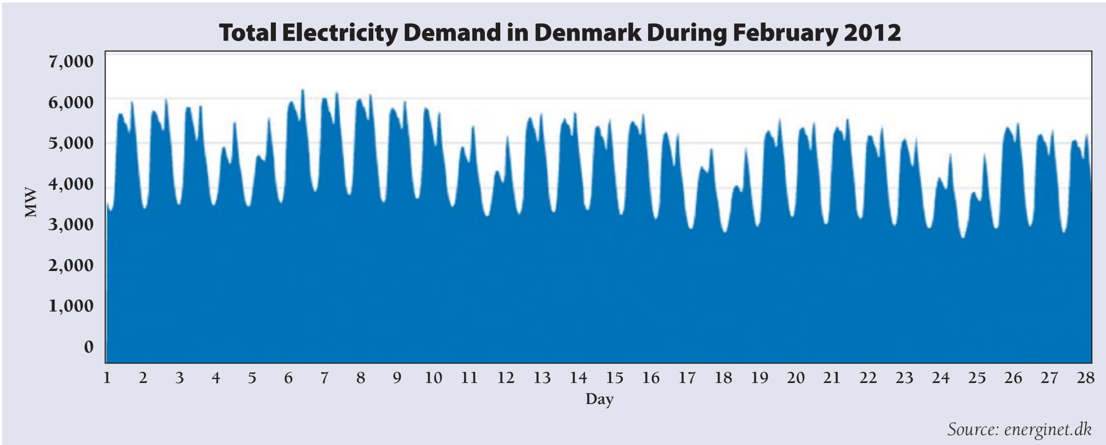
- 10% onshore wind (4,020 5-MW turbines);
- 40% offshore wind (12,700 5-MW turbines);
- 10% concentrated solar (387 100-MW plants);
- 10% solar-PV plants (828 50-MW plants);
- 6% residential rooftop PV (~5 million 5-kW systems);
- 12% commercial/government rooftop PV (~500,000 100-kW systems);
- 5% geothermal (36 100-MW plants);
- 0.5% wave (1,910 0.75-MW devices);
- 1% tidal (2,600 1-MW turbines); and
- 5.5% hydroelectric (6.6 1,300-MW plants, of which 89% exist).

Considering just the footprint of wind, over 6% of the surface area of New York would need to be devoted to wind energy production from nearly 17,000 turbines. If the 10-year attempted development of the Cape Wind project in Massachusetts is even remotely indicative, it would take decades to achieve this, if ever, in New England.

But despite the cost and other practical considerations of renewable energy, it remains a vital means of achieving New England's environmental policy goals, and certainly must be developed rapidly in a practical manner.

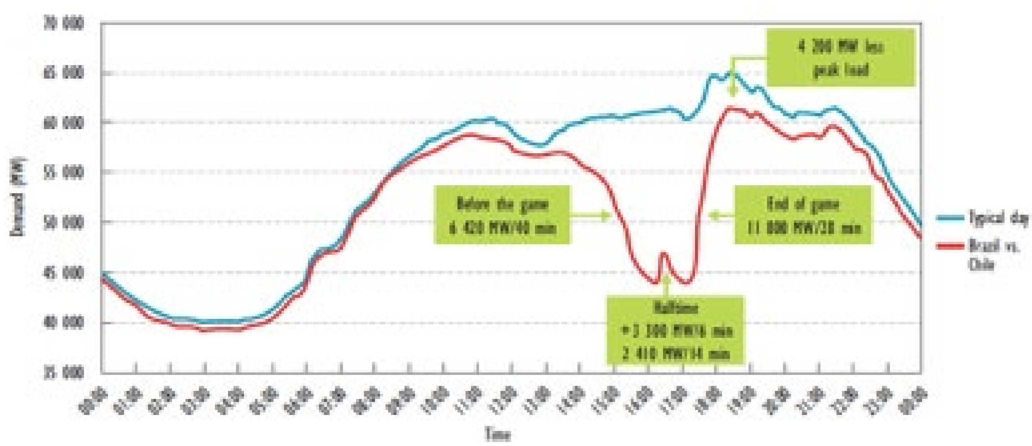
Reducing New England's GHG emissions in the short- to medium-term will require more renewables, in turn requiring increased grid flexibility. Renewable energy from the wind and sun will necessarily decrease electric sector GHGs emissions because it will almost always displace natural gas as the marginal fuel used to generate electricity. But because wind and solar energy fluctuate, sometimes unpredictably and substantially, the fast-response, efficient-ramping capacity provided natural-gas-fired generators is critical. At times of little, no, or less-than-expected wind or sunshine, natural-gas-fired generation capacity can turn on in as little as 2 minutes, multiple times per day, and quickly and efficiently ramp up and down its output to perfectly meet electricity demand, at a scale and cost unlike any other electric supply or demand resource currently available.

Consider this example from Denmark, showing the country's electricity demand net of wind power in February of 2012.[56] With few exceptions, this widely varying demand must be reliably met at all times by flexible on-demand generation, including on days with too much wind generation (February 24) and nearly no wind generation (February 2 and 8).



Another example from Brazil is amusing and instructive: [57]

Figure 1.1 • Exceptional load variability in Brazil during the 2010 Soccer World Cup, 28 June



Notes: during the game of Brazil (3) vs. Chile (0) on 24 June 2010.

This graph demonstrates the peculiar challenge of having to always, instantaneously meet electricity demand, a task complicated by increased amounts of variable renewable energy. Brazil had to supply nearly 15,000 megawatts of additional power within 28 minutes of the end of the World Cup soccer game. Not having electricity available is simply not an option in today's world. As the Department of Energy's 2015 Quadrennial Technology Review points out: "Electricity disruptions are estimated to cost the economy roughly $80 billion or more annually and seriously endanger public health and safety."[58]

Given New England's current costs, infrastructure, and indigenous resources, one cannot credibly argue that New England can transition to an all renewables future in the next 20 years. Rather, natural gas must form the foundation for renewables as their penetration increases substantially. Many reputable studies conclude that flexible natural gas-fired generators are necessary to integrate large amounts of renewable energy, and thus reduce GHG emissions. Below is a non-exhaustive survey of those studies and their relevant conclusions:

MIT Energy Initiative, "Managing Large-Scale Penetration of Intermittent Renewables" (2011)

- "The characteristics of intermittent generation combined with the need to maintain a constant balance between load and generation create challenges for system operators, who **will require greater flexibility** in the system to ensure reliability and meet policy goals."
- "As the penetration of intermittent renewables increases, thermal plants will likely need to ramp, cycle, and operate at reduced output more frequently to accommodate the additional variability and unpredictability of the "net load."
- **"Natural gas-fired power plants provide the greatest generation flexibility to mitigate large-scale penetration of intermittent renewables** with ramp rates of 8% per minute. New natural gas combined-cycle (NGCC) plants continue to improve their capabilities for responding to the intermittency of renewable generation."
- "[NGCC plants and Single Cycle Gas Turbines (SCGTs)] are designed for higher levels of flexibility and responsiveness than baseload technologies. **These design characteristics include faster starts, quicker ramping, and limited heat rate penalty at minimum load, making these units well suited to meet the challenges posed by intermittent renewable generation."**
- **"New NGCC designs with an increased focus on the ability to operate in a system with a large capacity of intermittent renewables are expected to produce 150 MW in 10 minutes and to ramp to full load in 30 minutes."**

National Renewable Energy Laboratory, "Opportunities for Synergy Between Natural Gas and Renewable Energy in the Electric Power and Transportation Sectors" (2012)

- "Natural gas can be dispatched flexibly, which offers more capacity for system reliability. **The quick ramping ability of natural gas generators makes them ideal for complementing variable renewable generation. ... A balanced electricity portfolio of both natural gas and renewable energy assets can adjust generation shares based on continuous optimization of resource availability, fuel costs, and emission requirements."**

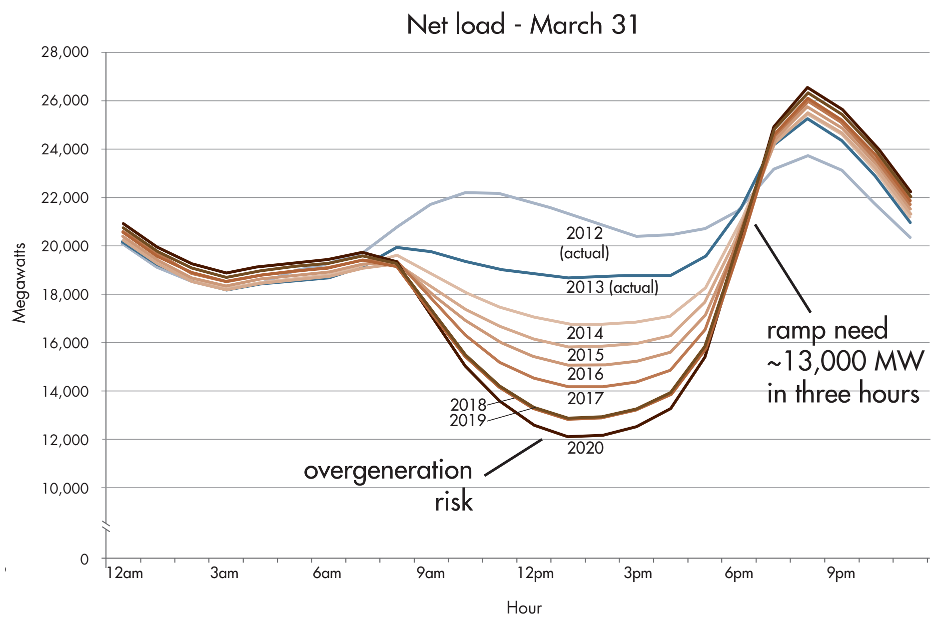
MIT Energy Initiative, "Growing Concerns, Possible solutions: The Interdependency of Natural gas and Electricity Systems" (2013)

- "**Power systems with a high penetration of such intermittent generators need to be flexible** in order to handle large fluctuations in their output. Flexibility can come from several sources, including storage, demand response, and reservoir hydro, but single-cycle gas turbines are often the most economical source. Thus, **increased penetration of wind and solar power is likely to increase the value of gas-fired generation and, accordingly, to increase its importance."**
- "Generating units that can start up quickly and/or change output rapidly without violating environmental constraints are more valuable than less flexible units with the same capacity."

California ISO, "Shaping a Renewed Future, Fast Facts: What the duck curve tells us about managing a green grid" (2013)

- **"To ensure reliability under changing grid conditions, the ISO needs resources with ramping flexibility and the ability to start and stop multiple times per day. To ensure supply and demand match at all times, controllable resources will need the flexibility to change output levels and start and stop as dictated by real-time grid conditions.** Grid ramping conditions will vary through the year. The net load curve or duck chart in Figure 2 illustrates the steepening ramps expected during the spring. The duck chart shows the system requirement to supply an additional 13,000 MW, all within approximately three hours, to replace the electricity lost by solar power as the sun sets."

Figure 2: The duck curve shows steep ramping needs and overgeneration risk



Regulatory Assistance Project, "Teaching the "Duck" to Fly" (2014)

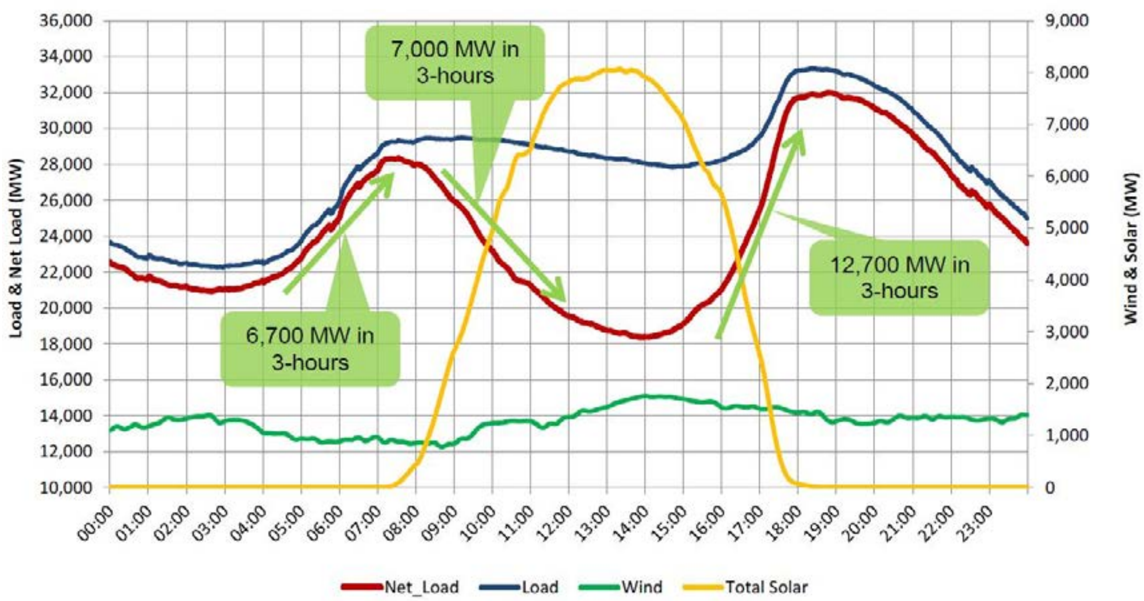
- "... California utilities are retiring older steam gas-fired units, generally repowering these sites with high-efficiency natural gas combined-cycle units. While these retirements do not alter the utility's total load or residual load— the load filled by wind and solar which must be met when these resources are absent — they do reduce its "must run" thermal capacity during both night hours and mid-day hours. **Older gas steam units must be run at about 20 percent of their maximum capacity overnight in order to be available to meet higher loads during the daytime, whereas modern "flex" natural gas combined-cycle plants can operate on an as-needed basis.** ... This strategy leaves more room on the system for replacement units, generally natural gas fueled, which can be ramped more readily to meet load. ... We discuss the ultimate net load after our proposed strategies in the context of a more flexible generating fleet after describing each of the strategies. **If the residual ramping requirement is within the capability of a modern high-efficiency natural gas generation fleet, we have met our challenge."**

National Renewable Energy Laboratory, "Exploring the Potential Business Case for Synergies between Natural Gas and Renewables Energy" (2014)

- "Power generation based on **natural gas offers the flexibility and increased dispatchability that complements renewable energy power generation** but at the risk of increased fuel price volatility and the challenge, in some regions, of ensuring adequate and timely gas deliverability."

National Conference of State Legislatures, "Integrating Renewables" (2014)

Figure 4. Effect of Wind and Solar Power on Net Energy Demand



Sources: North American Electric Reliability Corporation (NERC) and the California Independent System Operator Corporation.

- "Since renewable energy resources are often capital intensive to build, but are the least costly to operate since they require no fuel, the least cost approach is to run them as much as possible and use dispatchable generation to adjust to fluctuations in renewable output. **Dispatchable power plants that can start, stop and ramp their energy production up and down quickly and efficiently, will help the system run more efficiently and lower operating costs. Natural gas plants are the most flexible while coal and nuclear plants are less flexible,** although there is a range of flexibility among each category of plant based on the type of technologies that are being used."

Energy Sector Management Assistance Program, "Bringing Variable Renewable Energy Up to Scale: Options for Grid Integration Using Natural Gas and Energy Storage" (2015)

- **"Unlike coal or nuclear, natural gas can be utilized for a number of centralized or distributed flexible generation technologies in a wide variety of capacity ranges that can contribute to VRE [variable renewable energy] integration. Natural gas-fueled assets can run in different operating modes, from peak to base-load, in stand-alone or standby applications, or even combined with VRE systems in hybrid power plants."**
- **"At the system level, [natural gas]-fired generation can add flexibility and can contribute to addressing some of the issues associated with VRE integration during scheduling, dispatching, and regulation. Fast startup time and ramp rates are highly desirable when operating with VRE. Whereas coal or nuclear steam cycle generators can take more than 12 hours to reach full load, some gas combustion technologies have start-up times measured in minutes."**
- "One approach to providing a relatively high level of flexibility while also minimizing emissions during operations for the overall system is to install a combination of micro-turbines, reciprocating engines, simple cycle gas turbines, and CCGTs with different rated capacities. To avoid operating gas turbines and CCGTs at part load (and reduced efficiency), micro-turbines and reciprocating engines can be dispatched when the net load is relatively small, operating near design capacity. When the load increases, the larger gas turbines and CCGTs can be brought online (NOVI 2012)."

Harvard Business School, "America's Unconventional Energy Opportunity: A Win-Win Plan for the Economy, the Environment, and a Lower-Carbon, Cleaner-Energy Future" (2015)

- **"Natural gas power plants are a necessary complement to the scale-up of renewables.** As renewables gain share, backup capacity will need to grow significantly to ensure that a large volume of on-demand power can come online over extremely short periods to compensate for absences of wind or sun."
- **"Natural gas power plants are by far the most efficient source of backup power, at least over the medium term.** Natural gas plants can be brought online in under an hour, in some cases as rapidly as 15 minutes, compared with eight to 48 hours to start up a coal-fired plant. Natural gas plants can also operate more efficiently across a variety of load factors, allowing them to meet varying needs throughout the day. **While energy storage solutions, such as large-scale batteries, may eventually become economic to provide backup power, they are years away from being competitive with gas- fired plants."**

Synapse Energy Economics, Inc., "A Problem Solved: Existing measures provide low-cost wind and solar integration" (2015)

- "Variable resources experience rapid swings in generation caused by both expected solar declines at the end of the day and unexpected swings due to forecast errors. If conventional fuels and other resources were more flexible in two key ways (minimum loads and ramping needs), they could better support wind and solar technologies[.]"
- "Flexible plants can increase and decrease their level of power production rapidly—this change in production is referred to as "ramp." The faster a flexible plant can increase or decrease its operating level, the more helpful it is in maintaining system balance. Ramp need not only be served by gas plants: storage, imports, and other flexible generation can also provide ramping needs."

In sum, these studies demonstrate the value of natural gas-fired generators in providing the grid flexibility needed to support renewable energy. Looking toward the future, CLEC observes that renewable energy and energy efficiency are small but growing, and increasingly important, segments of New England's electric mix. They alone cannot be the solution to the current energy crisis. For example, ISO New England has stated:

> The results of the final [Energy Efficiency (EE)] forecast for 2019 to 2024 … indicate that the region will save about 1,616 gigawatt-hours (GWh) of electric energy per year and about 9,696 GWh of energy over the forecast period. **To put these energy savings in context, in 2014, the total energy output from the region's generation sources was approximately 108,352 GWh; thus, the average annual energy savings attributable to EE was about 1.35% of total generation. The savings from EE on average over the forecast timeframe also will be slightly lower than the region's wind power production in 2014 (1,928 GWh).**
>
> The results of the final EE forecast for 2019 to 2024 indicate that the region will reduce peak energy use about 212 MW per year and about 1,274 MW over the forecast period. **To put these peak demand savings in context of the New England system, the average annual reduction of peak energy demand resulting from EE was about 0.64% of the total capacity requirement for the region in the 2014/2015 period, roughly 33,000 MW.** The total peak savings from EE over the 10-year forecast timeframe also will be roughly equivalent to some of the region's largest generation resources, when comparing EE peak capacity reductions and the seasonal claimed capability of generator output.[59]

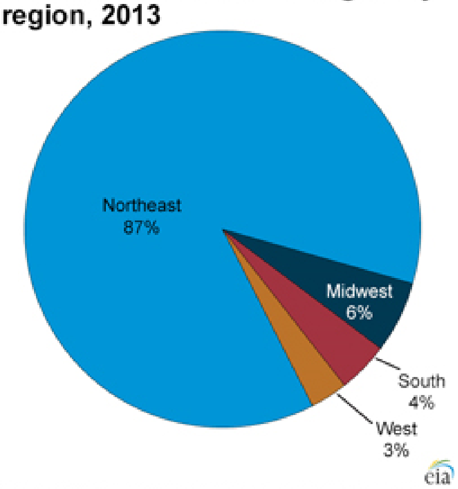
Further, consider that efficiency and solar combined, even with impressive growth spurred by state support, are expected to reduce New England's 2024 peak demand of about 32,000 MW by just 1,750 MW. During the middle of winter, when peak demand occurs around 6:30 p.m., ISO New England cannot dispatch energy efficiency, and solar energy will be unavailable because the sun already set. To increase penetration of renewables and efficiency even further, the grid will physically require the flexibility that can only be provided cost effectively, at a sufficient scale by natural gas-fired generators. Ensuring these generators have fuel at all times, to maximize this flexibility, must be a priority for renewable energy advocates.

Top five heating oil consuming states, 2013

Source: U.S. Energy Information Administration, *Fuel and Kerosene Sales 2013 (December 2014)*

In addition to lowering emissions through renewable electricity, New England has a substantial—and long overdue—opportunity in the heating sector. New England still relies excessively on oil for heating, despite the fact that oil has nearly a third more carbon emissions than natural gas,[60] is generally combusted in less efficient equipment, and is usually significantly more expensive and imported from foreign countries. Approximately 87 percent of all U.S. residential fuel oil sales were to households in the Northeast in 2013, which consumed a staggering 3.2 billion gallons of oil just to heat homes (not businesses).[61] Such continued reliance should concern all consumer and environmental advocates, especially considering that the New England states received about $343 million in Low Income Heating Assistance Program funding in 2015 and supported 424,000 low-income households in 2014.[62]

Sales of residential heating oil by region, 2013



Source: U.S. Energy Information Administration, *Fuel and Kerosene Sales 2013* (December 2014)

Huge emissions benefits will be gained in the Northeast by converting to natural gas from heating oil. Antiquated oil furnaces and boilers turn as little as 56% of the energy stored in oil into useful heat.[63] By comparison, a state-of-the-art natural gas furnace or boiler can convert up to 98.5% of the energy stored in natural gas into useful heat.[64] This means to keep a house at 70 degrees Fahrenheit, one would have to burn up to 125 units of oil versus about 71 units of natural gas, with the oil creating nearly a third more carbon pollution. Like modern CCNGG, new gas furnaces offer rare geometric opportunities for efficiency gains.

As an illustrative example of the emissions advantage of natural gas over oil as a heating fuel, consider if all of the homes in the Northeast census region converted to natural gas from oil:

Percentage of Households Heating w/Distillate Fuel Oil in New England, 2013							
Country/State	U.S.	MA[65]	CT[66]	RI[67]	ME[68]	NH[69]	VT[70]
Percentage	5.5	29.2	43.7	32.6	64.2	46.1	43.8

How Much CO2 Pollution Could the Northeast Avoid by Converting from Fuel Oil to Natural Gas?

Year	Consumption/ Northeast Household	# of Northeast Households[71]	Heat Content	CO_2 Pollution[72]	Total CO_2 Pollution
Fuel Oil					
2013-14	1,100 gallons / 42 = 23.81 barrels[73]	5,248,000	5.855 MMBtu/barrel[74]	161.3 lbs/MMBtu	129,807,112,076 pounds of CO_2
Natural Gas					
2013-14	84.1 thousand cubic ft. (Mcf)[75]	Assume 5,248,000	1.031 MMBtu/Mcf[76]	117 lbs/ MMBtu	53,239,546,714 pounds of CO_2
Carbon Dioxide Emission Savings					**76,567,565,362 pounds of CO_2**

If all 5,248,000 households burning heating oil in the Northeast in 2013-14 converted to natural gas, they would have directly emitted only about 53,239,546,714 pounds of carbon dioxide, a staggering 76,567,565,362 pounds less than with oil. The emission savings for commercial and industrial consumers, who use more polluting residual fuel oil (173.7 pounds of CO_2/MMBtu), consume natural gas at higher pressures, and have more efficient gas systems, would be greater. For context, the 76,567,565,362 pounds of CO_2 that could be avoided through conversion to natural gas is about 34.7 million metric tons of CO_2. The Environmental Protection Agency estimated that in 2010, each of the country's 454 coal-fired power plants emitted an average of about 3.8 million metric tons of CO_2.[77] Thus, the Northeast's continued reliance on oil for heating is analogous to continuously operating almost 9 coal-fired power plants.

The cost savings of converting to natural gas from heating oil are similarly significant.

How Much Money Could the Northeast Households Save by Converting from Fuel Oil to Natural Gas?

Year	Expenditures Per Household[78]		# of Northeast Households[79]	Total Cost
Fuel Oil				
2013-14	$2,355 (U.S. Average, with 81% in Northeast)		5,248,000	$12,359,040,000
Natural Gas				
2013-14	$971 (Northeast)		Assume 5,248,000	$5,095,808,000
Direct Heating Cost Savings				**$7,263,232,000**

Considering the same 2013-14 hypothetical of converting the 5,248,000 Northeast households burning heating oil to natural gas, the Northeast region would save about $7.2 billion dollars. While it is not possible to convert all Northeast heating oil users to natural gas, especially those widely dispersed in rural areas, the principle is clear. Hundreds of thousands more households should have the option to convert to natural gas for economic and environmental reasons.

Example: Cost Savings in Connecticut

As of 2013, about 44% of Connecticut's households still used oil for heating, compared to the U.S. average of 5.5%. The typical household heating with oil in the U.S. (81% in the Northeast) spent $2,355 in 2013-14, while the average Northeast household heating with natural gas spent $971. If the approximate 596,574 Connecticut households still heating with oil could have switched to natural gas, they would have saved about $826 million in 2013-14. This is one reason that Connecticut Governor Malloy's Comprehensive Energy Strategy calls for the conversion of approximately 300,000 customers to natural gas in the next decade.

The Connecticut Office of Consumer Counsel recently warned of the "human cost of inadequate natural gas pipeline," revealing that the number of non-hardship customers making arrearage or other payment arrangements has gone from 53,869 in 2012 (totaling $15 million) to 218,850 in 2014 (totaling $50 million). This shows that in addition to the over 100,000 households in Connecticut receiving LIHEAP benefits, low- and middle-income Connecticut residents are also significantly stressed by high energy costs.

Example: Cost Emissions Savings in Maine

The typical Northeast household burns between 850 and 1,200 gallons of heating oil per winter. Assuming a Maine household burns 1,100 gallons of oil, it emits 24,608 pounds of carbon dioxide (11.16 metric tons) per year. A typical Northeast household heating with natural gas emits only 10,144 pounds of carbon dioxide (4.6 metric tons) per year. The huge emissions advantage of natural gas exists because it contains about 70% of the carbon of heating oil and modern natural gas boilers and furnaces are much more efficient than the old oil boilers and furnaces common to New England. If all 355,554 Maine households still using heating oil could convert to natural gas, the state would save approximately 5,142,733,056 pounds of carbon dioxide (2,332,728 metric tons) in a year.

Maine households continue to burn about 391 million gallons of heating oil per year, which is equivalent to almost 36 Exxon Valdez oil spills. Most of this oil is transported to the region via supertanker from countries such as Venezuela and Mexico.

STEP 4:

Transition natural gas-fired generation to flexible back-up capacity that can cost-effectively balance increasing amounts of renewable energy, while burning less natural gas

In 2030 and beyond, natural gas-fired generation will become more important to large-scale renewables penetration in New England, but less natural gas will be consumed for electricity. Simply put, the role of natural gas is the electric sector will shift from primarily producing energy to providing flexible back-up capacity. As a 2011 study by MIT found, "Natural gas-fired power capacity will play an increasingly important role in providing backup to growing supplies of intermittent renewable energy, in the absence of a breakthrough that provides affordable utility-scale storage. But in most cases, increases in renewable power generation will be at the expense of natural gas-fired power generation in the U.S."[80]

The National Renewable Energy Laboratory agrees, finding that as renewable energy supply increases, conventional fossil generation decreases through plant retirements and reductions in capacity factors. Natural gas capacity, meanwhile, remains largely constant in order to meet overall reliability needs, but the generation of electricity from those plants declines steadily over time as renewable electricity generation increases.[81]

The Regulatory Assistance Project concluded that natural gas-fired generation doesn't have to meet every need, but plays a crucial backup role in balancing micro-grid and large-scale renewable energy:

> Building a smart gas fleet with the flexible capabilities needed to support [microgrid and large-scale renewables] likewise is relatively low risk, as it complements a wide variety of low-carbon resource futures and relies on relatively low-risk resources. In both the "microgrid" and "large-scale renewables" futures, gas generation and infrastructure investment will be optimized to complement zero-carbon resources at least-cost, least-carbon emissions, and low risk of stranded gas assets.
>
> In other words, the fossil fuel fleet should be optimized to complement cleaner resources. And to the extent "hybrid" technologies that combine renewable energy and co-located gas generation prove a least-cost option, they are worth considering as part of the optimized gas fleet. Implementing the so-called Clean First policies in a fashion that keeps electricity supply reliable and affordable implies using natural gas strategically as part of a diversified portfolio, and implementing complementary planning, market, and regulatory reforms that together can achieve ambitious low-carbon futures at least-cost.
>
> Effective permitting also can support the construction of well-placed gas facilities with the right operating capabilities. For example, the 692-MW Footprint Power Project in Salem, Mass., approved in September 2014, displaces generation by dirtier fossil plants and includes environmental mitigation measures that support a cleaner Salem Harbor.[82]

Below is a non-exhaustive survey of studies and their relevant findings supporting the conclusion that as New England utilizes the flexibility of its existing natural gas-fired generation capacity to integrate more renewables, less natural gas will be consumed for electricity:

MIT Energy Initiative, "Managing Large-Scale Penetration of Intermittent Renewables" (4.20.11)

- "The economic impacts of flexible operation will also place constraints on thermal generation plants in systems with large-scale intermittent renewable penetration. Ramping, cycling, and partial load operations will **reduce the amount of electricity generated in a year relative to baseload operation** while increasing the operational costs; this impacts overall plant profitability. Under current market structures and dispatch rules, this will make it more difficult for thermal plant owners to recover costs because **there will be fewer megawatt-hours across which to amortize their capital costs."**

MIT Energy Initiative, "The Future of Natural Gas: An Interdisciplinary MIT Study" (2011)

- "Natural gas-fired power capacity will play an increasingly important role in providing backup to growing supplies of intermittent renewable energy, in the absence of a breakthrough that provides affordable utility-scale storage. But in most cases, **increases in renewable power generation will be at the expense of natural gas-fired power generation in the U.S."**
- "[W]e can observe a consistent pattern for the impact of intermittent renewable generation: We see that **an increase of wind or solar output systematically results in a proportionally significant reduction of natural gas fueled production, while, at the same time, the total installed capacity of flexible generation (typically also natural gas fueled plants) is maintained or increased.** Precise numerical estimations and any second order impacts are heavily dependent on the specific energy policy instruments and the assumptions on the future costs of fuels and technologies. The detailed operational analysis of plausible future scenarios with large presence of wind and solar generation reveals the increased need for natural gas capacity (notable for its cycling capability and lower capital cost) to provide reserve capacity margins. **This does not however necessarily translate into a sizeable utilization of these gas plants."**

National Renewable Energy Laboratory, "Renewable Electricity Futures Study: Exploration of High-Penetration Renewable Electricity Futures" (2012)

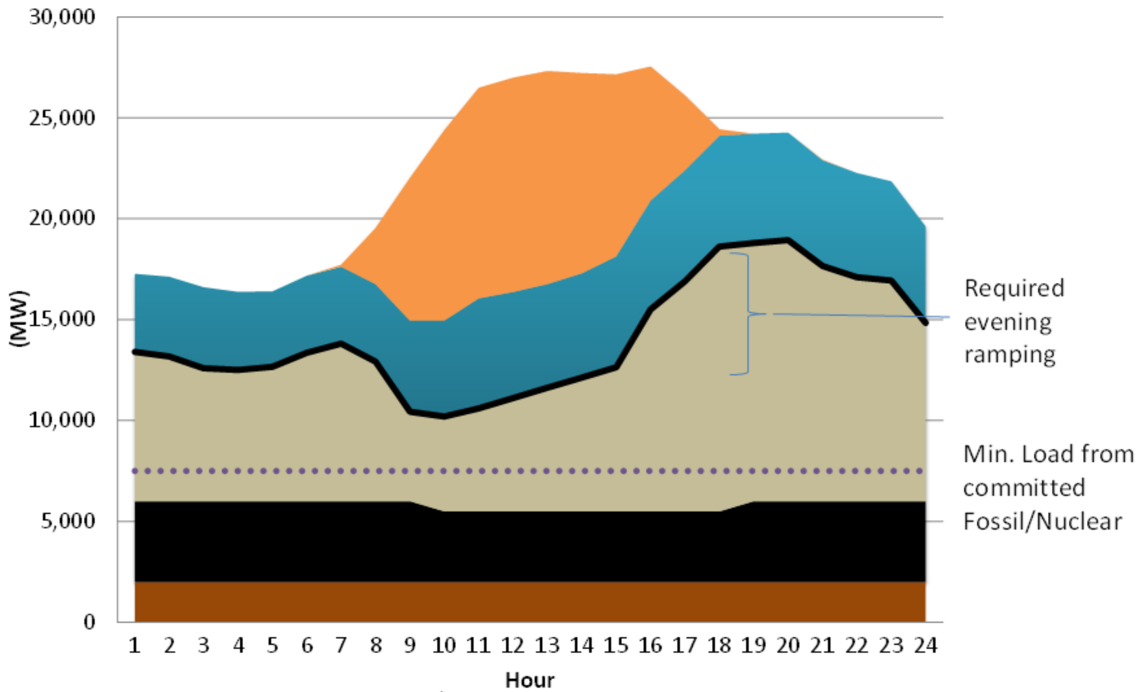
- "As renewable energy supply increased, the overall balance between generation and demand was maintained through a reduction in conventional fossil and nuclear generation. **Although substantial natural gas capacity remained even at the highest renewable energy levels, the supply of electricity from those plants was found to decline rapidly with renewable energy penetration.** Even under the relatively more-modest 30%–50% renewable electricity scenarios, the percentage of generation from natural gas in 2050 dropped substantially with increasing renewables (from 16% in the Low-Demand Baseline scenario to about 4% in the 50% RE scenario)."
- "As renewable energy supply increases during the study period, conventional fossil and nuclear generation decreases through plant retirements and reductions in capacity factors. ... **Natural gas capacity, meanwhile, remains largely constant in order to meet overall reliability needs, as discussed in Section 2.5.1, but the generation of electricity from those plants declines steadily and significantly with time as renewable electricity generation increases."**

The Brattle Group, "Partnering Natural Gas And Renewables in ERCOT—PART I" (2013)

- "The main conclusions of this white paper are that **in the short run low gas prices are extremely unlikely to change the fact that existing renewables will nearly always have priority over gas-fired plants** since, due to the absence of fuel costs, their variable costs are lower than those of essentially all other resources."

Synapse Energy Economics, Inc., "A Problem Solved: Existing measures provide low-cost wind and solar integration" (2015)

- **"Some conventional power plants may generate little electricity during the day while solar generation is at its maximum, and need to ramp up quickly as the sun sets.** ... Older coal units are particularly poorly suited to the task of ramping up quickly, but as retired coal units are replaced by more efficient and flexible gas units, the system will gain flexibility, and therefore an increased ability to integrate intermittent generators."



Another instructive study titled "Flexibility in 21st Century Power Systems"[83] compares the analytical frameworks used to measure power system flexibility. The study stresses the importance of flexibility—"the ability of a power system to respond to change in demand and supply"—for increasing reliance on variable renewable energy. "In addition to enabling supply to match demand at all times, power system flexibility can facilitate the transformation toward 21st century power systems by improving investment climates, lowering consumer prices, and reducing emissions." Conversely, insufficient flexibility may require system operators "to frequently curtail (decrease the output of) wind and solar generation[,]" which "can degrade project revenues and contract values, impact investor confidence in renewable energy revenues, and make it more difficult to meet emissions targets." A primary takeaway from the study is that "flexibility is system specific. For example, all else being equal, systems with many fuel options (e.g., natural gas, wind, demand response, and pumped storage) will be more flexible than ones dominated by coal or nuclear. Flexibility in power systems is also inherently tied to the regulatory and market rules that help shape operations."

One basic flexibility metric examined is simply the "percent of GW installed capacity of generation relative to demand." The "flexibility chart" show below is a graphic example of this metric, showing the types and ratios of generation capacity that have been used to achieve desired flexibility, including dispatchable plants (hydropower, combined cycle gas turbine (CCGT), combined heat and power (CHP)), pumped-hydro storage, and interconnections with other grid systems.

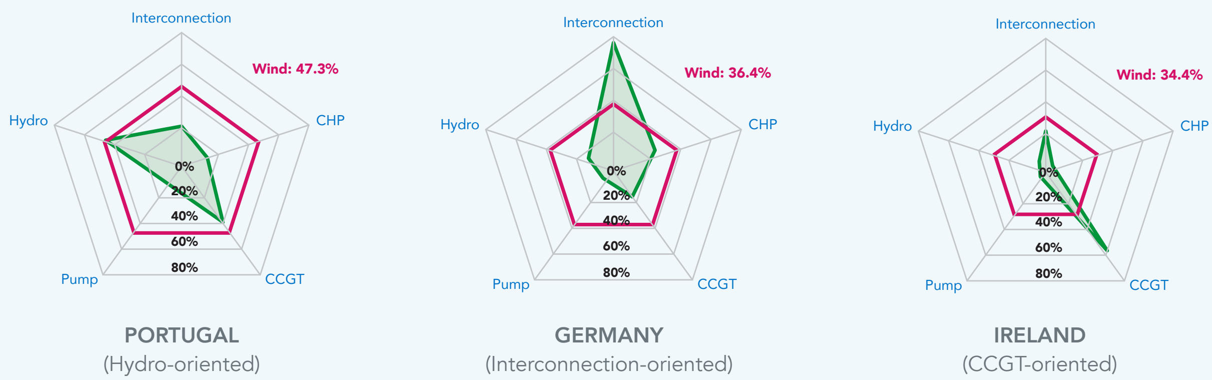


FIGURE 2. Frameworks and metrics for measuring power system flexibility are evolving. These flexibility charts, developed by Yasuda et al.,[1] provide a snapshot overview of what types of generation-based flexibility each country has, and the maximum share of wind power (red text) during one hour relative to demand. The charts show in green the percentage of installed capacity of each potential source of flexibility relative to peak demand, i.e., high installed capacity translates to a possible source of flexibility. However, since capacity does not map directly to flexibilty, the size of the green area relative to red does not have a direct meaning. Instead, the charts only highlight potential flexibility sources.

1 Yasuda, Y. 2013. "Flexibility Chart: Evaluation on Diversity of Flexibility in Various Areas." Wind Integration Workshop. London. 22 October.

The study importantly notes, however, that "capacity is not a proxy for flexibility." For example, "limited natural gas fuel supply could render large capacities of CCGT inoperable" and "interconnection is only valuable if the neighboring power system can contribute to system flexibility." As applied to New England, these conclusions underscore that New England risks underutilizing the inherent flexibility of its gas-fired generation through insufficient natural gas pipeline capacity. As explored previously, the region's natural gas-fired generators do not have reliable access to fuel throughout the winter, rending highly inflexible coal and oil power generators critical to reliability and reducing grid flexibility. Moreover, during the same winter period, New England's interconnectivity to Canada is weakened when energy from Hydro-Quebec is used to power that region's high demand and less is imported to New England.

Opponents of natural gas pipeline expansion either intentionally ignore or fail to recognize the benefits natural-gas fired generation capacity, despite the fact that less natural gas will be burned over time. A common argument proffered against natural gas pipeline capacity expansion is that it would be wasteful since it would not be utilized at levels above 75% for the entire year. In New England, pipeline capacity is historically used more during winter, when in addition to fueling electric generators, it must also supply gas utilities for heating purposes. However, the spare capacity in natural gas pipelines throughout most of the year is exactly what is needed to account for variable renewable energy. If pipelines were full or mostly full of contracted-for gas at time when renewable energy production declined or even dropped to zero, natural gas generators could not quickly obtain the additional fuel they would need to ramp up their production to match electric demand.

Moreover there is even a way that natural gas pipeline capacity can be further utilized as a form of renewable energy storage. As touted by the Energy Information Administration,[70] power-to-gas technology converts electricity generated during times of high production and low demand into a gas for later use. The process of electrolysis splits water into hydrogen and oxygen. Hydrogen is a valuable and storable fuel, while oxygen can be sold for industrial use or harmlessly emitted into the atmosphere. Critically, the hydrogen created can be used directly to fuel power electric generators, fuel cells, or vehicles and also combined with natural gas for the same applications. The true potential of this technology is that when the wind is blowing at night, the excess electrical energy can be converted to hydrogen, which can in turn be injected into the region's natural gas pipeline system. Pipelines have the ability to act as large "batteries'" through techniques such as line-packing (packing more gas into a pipeline than is being taken off through increased pressure) and park-and-loan contracts. Thus, in addition to providing necessary fueling capabilities for natural-gas-fired generators to quickly ramp up production when needed to meet electric demand net of renewable energy, pipelines can act as renewable energy batteries when renewable energy production exceeds electric demand. One or more new natural gas pipeline projects in New England have now offered storage and time-variable service.

3 Case Studies of Renewables Integration: How the New England New Energy Paradigm Can Work

In considering how New England might achieve or maintain the flexibility needed to transition to an affordable clean energy future based primarily on renewables, it is useful to look at three recent case studies. Eric Martinot, the author of the National Renewable Energy Lab's landmark "Renewables Energy Futures Report," has assessed how three very different energy systems in Germany, Denmark, and California are integrating and balancing renewable energy in 2015.[85] These three case studies provide illustrative examples of what New England could do, and more likely what it should do, given its existing fleet of flexible natural gas-fired generators.

DENMARK:

Denmark, as of 2013, had about 5 GW of renewable energy capacity, mostly from onshore wind. This capacity met 33% of Denmark's annual power demand and as much as 105% on certain days.

Mr. Martinot attributes Denmark's ability to integrate and balance so much renewable energy primarily to its strong integration with other power grids in Europe. He also stresses other innovations. For one:

> Half of all electricity in Denmark is produced by small combined heat-and-power (CHP) plants. These plants feed into district heat-supply networks that include large water tanks for thermal energy storage. This whole system was designed starting in the 1980s with flexibility in mind, and heat plants have been built to allow varying the proportion of heat and electricity, and for storing heat to allow changing the output of the CHP plants without affecting heat supply and indoor comfort. This means that CHP plants can vary their electricity output in response to changes in wind output, and thus provide balancing. Many of these CHP plants are fueled by biomass, which thus provides a long-term pathway for balancing variable renewables like wind and solar with a non-variable but still-renewable resource like biomass.

While it is unlikely that New England can meet its balancing needs with biomass CHP, a comparable, but more efficient, resource exists that is grossly underutilized during winter: natural gas-fired generation capacity, including some gas-fired CHP.

Another of Denmark's innovations is hourly ramping and daily cycling of coal power plants. "In most of the world, coal power plants are designed to run at constant output, and electric utilities typically claim that ramping and cycling reduces efficiency, increases costs, lowers equipment lifetime, and is generally ill-advised or even impossible." However, in Denmark coal-fired plants were specially designed and/or retrofitted to ramp and cycle. Importantly, Mr. Martinot notes that Denmark's coal plants can ramp at rates of 3-4% per minute and cycle down to a minimum level of 10-20% of rated output. He compares this flexibility to new CCGT plants in Denmark, which ramp at 3% of rated output per minute and can cycle down to 50% levels. While it is interesting that coal-fired plants can in fact provide flexibility if designed or retrofitted to do so, it is highly unlikely that New England would accept the continued operation of coal plants for any reason. This is especially true because New England already has an existing and much cleaner fleet of natural gas-fired generators which have the same, if not better, flexibility characteristics.

Mr. Martinot also notes Denmark's innovative practices with regard to day-ahead weather forecasting, transmission planning, and the operation of Denmark's electricity market, which contains four ancillary/balancing markets and three that provide generators with capacity payments.

GERMANY:

Renewables provide almost 30% of Germany's annual power. Solar and wind have met nearly 80% of Germany's peak demand during specific hours. A feed-in tariff law gives renewables dispatch priority over conventional resources, often leaving very little power demand left to be supplied by coal, nuclear, and natural gas plants.

Mr. Martinot attributes Germany's ability to integrate and balance high levels of variable renewable energy to seven primary reasons. "The two most important reasons are: (1) the existing strength of its power grids; and (2) flexible operation of coal and nuclear plants (and to a lesser extent gas and pumped hydro)." With regard to grid strength, Germany rarely experiences outages because "the grid has more capacity than necessary given current demand." Given New England's adversity to infrastructure projects, it is hard to imagine achieving regional renewable energy goals by overbuilding transmission to transmit renewable energy from the northern states to the demand centers in Boston and Hartford. New England, from 2003 to 2014, has already invested over $7 billion to strengthen its transmission system, and another $4.5 billion investment in transmission is expected through 2018.[86]

With regard to flexible operation of power plants in Germany, "there is a surplus of coal power capacity, and this excess coal power capacity is being used very effectively to provide sufficient balancing power to offset (or balance out) the variability of renewables." This coal capacity has been "originally designed or later modified for flexible output—the ability to 'ramp' on an hourly basis to much less than full output, and 'cycle' on and off on a daily basis." Amazingly, in Germany more coal is burned than natural gas. Similarly, nuclear plants in Germany have also been designed to be flexible and ramp their output up and down. In New England, due to economic and environmental factors, the clear trend since 2000 has been declining energy from nuclear and coal power plants. As a result, coal and nuclear capacity has decreased, and that is expected to continue. It seems unlikely, given the opposition to coal and nuclear in New England, that these resources could provide the excess capacity and balancing requirements that have allowed Germany to substantially increase its penetration of variable renewable energy. New England invested billions in the early 2000s in highly efficient natural gas generation capacity in order to displace coal and oil, and to a lesser extent nuclear. This capacity already has the flexibility needed to accommodate large quantities of renewable energy, provided it has fuel.

CALIFORNIA:

California currently obtains about 20% of its electricity from renewables, excluding large hydro. Under California's Renewable Portfolio Standard, 33% of its power must be renewable by 2020, and 50% by 2030.

Mr. Martinot attributes California's current and expected future ability to integrate and balance high levels of variable renewable energy to a variety of regulatory "frameworks," the most important of which "is simply California's electricity market."

California relies extensively on flexible natural gas-fired capacity, "which altogether provide[s] about 60% of California's power." These power plants sell into the normal day-ahead energy market, as well as the "ancillary" markets, "designed to provide balancing power for short-term fluctuations in demand and generation." "Most of the newer gas turbine power plants built in California have been designed with high levels of flexibility, which enables them to respond quickly to system conditions and profit from selling into the balancing markets. These gas turbines routinely and profitably provide the balancing power necessary to balance variable renewables, through the normal operation of the wholesale and ancillary/balancing markets."

Two innovative features of California's energy markets are: (1) a rule "which requires power generators to bid a portion of their most flexible capacity into the market at all times, so that he grid operator can call upon that capacity when needed to balance renewables" and (2) the "Flexible Ramping Product," which is designed "to enable the ISO to shift generation in time, from 'low-ramp' periods to 'high-ramp' periods." "Of particular concern to the ISO is the 'high ramp' period in the late afternoons of the future, when solar output declines rapidly as the sun goes down, and total system demand simultaneous increases towards an early-evening peak. … With the Flexible Ramping Product, the ISO pays generators to remain 'off' during low-ramp periods, so that the generator is then available to turn 'on' during high-ramp periods, at the request (dispatch) of the ISO. The payments made to remain off during low-ramp periods, coupled with the payments when the generator is used during high-ramp periods, should be sufficient to compensate the generator for lost revenue while 'off.'"

Another framework critical to achieving California's renewable energy goals is "the Long-Term Procurement Planning (LTPP) process, which ensures that enough flexible capacity will be built in the future, on 10-year planning time scales."

California's power system is the most comparable to New England's of the three systems studied. California relies heavily, to a greater extent than New England, on natural gas. Unlike in New England however, California's natural gas-fired generation capacity does not endure sustained periods of fuel unavailability or uncertainty due to limited pipeline capacity. In order to integrate greater amounts of renewable energy, New England could consider creating market mechanisms like California's rule requiring that flexible capacity be bid into the market and the "Flexible Ramping Product." To do that, however, New England's natural gas-fired generation capacity would need to have reliable access to natural gas at all times. It appears abundantly clear that New England must find a way to effectively utilize its existing natural gas-fired capacity, rather than abandoning it for less flexible coal and oil.

Why Isn't Energy Storage Viable Now?

An analysis of energy storage titled "How much bulk energy storage is needed to decarbonize electricity" was published in the Journal of Energy & Environmental Science in September 2015, which demonstrates why energy storage cannot be used in New England today to solve its energy crisis.

The authors examine bulk energy storage (BES), including mechanical, i.e., pumped hydro and compressed air storage, and electrochemical, i.e., batteries, in the context of several emission reductions scenarios, including 70% and 100% reductions from business-as-usual projections. Critically, the study finds: "Even under the low 150 kgCO2e per MWh scenario [70% reduction from BAU], gas turbines (particularly CCGT) can cost-effectively manage the variability of wind … Despite their higher fuel and operational cost, the relatively low CapEx of gas turbines allows them to out-compete BES in managing the variability of wind."

To manage a high penetration of intermittent renewables, the study concludes that: "the optimal capacities of BES and gas are roughly 20% and 60% (respectively) of the capacity of wind. **So one could say that BES is three times less important than gas in providing peaking power, under this tight emissions constraint and with current capital cost estimates.** Under these conditions, about a third of annual load comes from gas, 6% from BES and the rest from wind." "**In other words, intermittent renewables (wind, as modeled here) can be used to decarbonize the electricity supply with a proportionally small requirement for BES since gas can provide much of the intermittency management, even when the emissions intensity is cut to less than 30% of today's U.S. average.**"

The overarching conclusion is: "large-scale adoption of bulk electricity storage compared to variable renewables and gas turbines is neither technically required nor cost effective as a means to reduce carbon emissions even when variable renewables play a large role. In other words, intermittent renewables need not to wait for the availability of cheap bulk storage to become an effective tool for decarbonization. This conclusion breaks down only when emissions must be reduced by more than about 70% or when the cost of dispatchable-low-carbon power sources is very high (above $9000 per kW with an emissions cap of 150 kgCO2e per MWh at current BES cost estimates… .)"

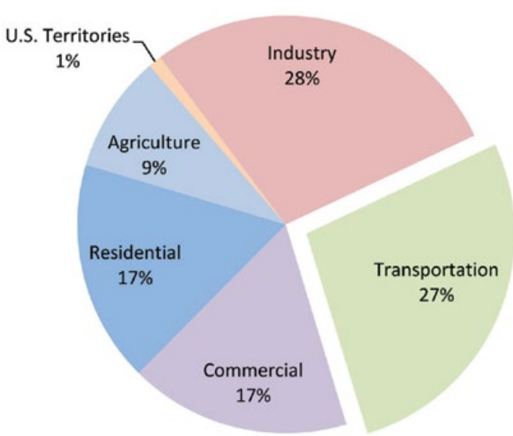
STEP 5:

Begin electrifying the transportation and heating sectors with a clean electric fuel mix based on renewable energy

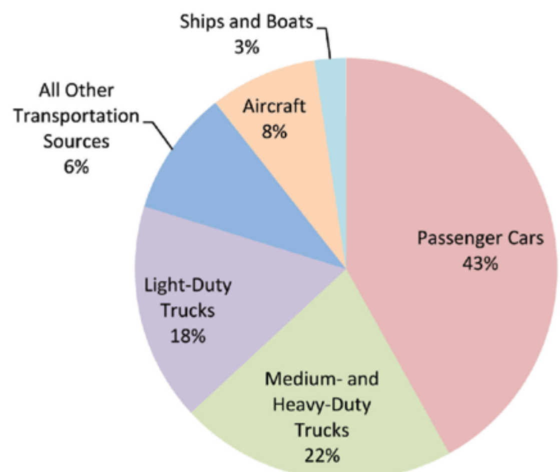
The new energy paradigm lays the groundwork for smart grids and the electrification of heating, but perhaps most importantly, transportation.

The transportation sector is one of the largest contributors to both U.S. energy expenditures and GHG emissions. We can displace billions of gallons of annual gasoline and diesel use, and the related cost and environmental impacts, by electrifying the transportation sector with a cleaner electric mix. Indeed, as New England shifts to its new energy paradigm and seeks to reach very aggressive emissions goals, electrifying transportation offers a significant opportunity.

The transportation sector is the nation's second largest emitter of GHG emissions due to highly persistent dependence on oil. With over 100 billion gallons of gasoline consumed by light-duty vehicles and over 56.3 billion gallons of diesel consumed by medium- and heavy-duty trucks, the U.S. transportation sector accounted for about 70% of the U.S.'s petroleum consumption in 2012 and over 1,700 million metric tons of carbon dioxide emissions.[87] These emissions comprised over 28% of all GHG emissions in the U.S. in 2012.[88]



Share of U.S. GHG Emissions by End-Use Sector*



Share of U.S. Transportation End-Use Sector GHG Emissions by Source*

These characteristics make transportation a key target for decarbonization within New England's new energy paradigm, and especially for northern New England, where vehicle-miles-traveled per capita is high due to a highly dispersed population.

Technological advances have enabled new types of vehicle power systems: all-electric vehicles (EVs) powered entirely by electricity, hybrid vehicles capable of being powered by both a fossil fuel and electricity, vehicles whose engines are fueled by compressed natural gas (CNG), and even fuel cells that generate power without combusting fuel. Each of these technologies typically produces lower emissions than conventional vehicles, and can provide significant benefits over traditional gasoline and diesel combustion.

EVs are one particularly promising technology, in its infancy. EVs are propelled by electric motors powered by rechargeable battery packs. According to the U.S. Department of Energy, EVs have several advantages over vehicles with internal combustion engines, including the fact that "EVs emit no tailpipe pollutants."[89] However, "the power plant producing the electricity may emit them."[90] EVs have average annual CO_2 equivalent emissions of only 4,295 pounds, whereas conventional vehicles have average annual CO_2 emissions of 13,043 pounds.[91] Transitioning to a cleaner electricity mix using natural gas as the foundation is a critical step New England must take to realize the emissions reduction opportunity presented by EVs.

EVs can also play an important role as grid-connected energy storage while they are parked. In vehicle-to-grid applications, cheap electricity from the grid can charge the vehicles during low-demand night-time hours, while the vehicles can provide regulation (balancing short-term variations between load and generation affecting grid stability) or demand response services to the grid during the daytime. By aggregating large numbers of plugged in EVs as a single resource, they could serve as a large "battery on the grid" and provide many electricity services similar to a power plant.

EVs also have the potential to support micro-grids and distributed and grid-scale renewable energy. A 2010 report by the National Renewable Energy Laboratory found that smart, bi-directional charge management of parked EVs "will aid in regulation of variable renewable generation loads and help stabilize the micro-grid" at military installations with distributed renewable generation.[92] Indeed, the very existence of significant plug-in EV load during nighttime charging "helps address wind energy integration challenges."[93]

Natural gas vehicles are another promising innovation. As the Department of Energy has noted, CNG as a vehicle fuel can offer life cycle greenhouse gas (GHG) emissions benefits over conventional fuels and may reduce some types of tailpipe emissions.[94] Because natural gas is a low-carbon, clean-burning fuel, a switch from gasoline to natural gas in smaller applications can result in substantial reductions of hydrocarbon, carbon monoxide, oxides of nitrogen, and GHG emissions. The Argonne National Laboratory estimates the life cycle petroleum use and greenhouse gas emissions of light-duty vehicles running on compressed natural gas (CNG) and liquefied natural gas (LNG) as approximately 6%-11% lower levels of GHGs than gasoline throughout the fuel life cycle—and that natural gas vehicles will be even cleaner as natural gas production continues to improve.[95] Natural gas can also be produced renewably, in the form of biomethane. This renewable natural gas (RNG) is chemically identical to fossil natural gas, yet yields fewer GHG emissions during the production process. Indeed, a 2011 study by Argonne National Laboratory of RNG production methods concluded that all RNG methods show significantly less GHG emissions and fossil fuel consumption than conventional fossil natural gas and gasoline.[96] The more New England's transportation sector adopts any of these natural gas fuels instead of gasoline or diesel, the lower the sector's cost and emissions impacts will be.

Given the technology and resources available and on the horizon, New England will have a significant opportunity to displace oil used for transportation with lower cost, cleaner alternatives in its new energy paradigm. Joint research by the National Renewable Energy Laboratory and U.S. Department of Transportation has identified EV adoption as the most concrete opportunity for transformative reduction of transportation greenhouse gas emissions.[97] Environmental advocates too make the case for electrifying passenger transportation, identifying EVs as "a near-term option for improving local and regional air quality"[98] and "essential to strategies to reduce greenhouse gas (GHG) emissions to very low levels by mid-century."[99]

But despite broad agreement on their benefits, EVs are not yet widely adopted. Until the first Tesla Roadster EVs were delivered to customers in 2008, EVs were nearly unheard of in the U.S. highway-capable vehicle market. Since then, a number of auto makers have launched EV models, with continued interest in product development. Worldwide, EVs and hybrids made up over 3% of new vehicle sales in 2014. Studies show they could comprise up to 7% of car sales by 2020 as prices decrease and battery technology improves.[100]

Indeed, EVs make up only a tiny fraction of the vehicles on the road despite the recent interest. For example, in 2014, electric car sales accounted for only about .05 percent of all vehicle sales in the United States. From 2008 through May 2015, only about 335,000 highway-legal plug-in EVs were sold in the US.[101] This represents a tiny drop in the ocean of over 253 million vehicles registered in the United States.[102] Looking at the energy consumed instead of vehicle count, in 2012, almost 97 percent of the energy consumed in vehicles came from gasoline, just over 3 percent came from natural gas, and not even 0.1 percent came from electricity.[103]

One constraint holding back EV adoption is the lack of sufficient public charging infrastructure. Public chargers need to be widespread, affordable, convenient, and able to use the existing energy grid. While gasoline filling stations proliferated in the twentieth century, their EV equivalent is still of a work in progress. But the electric grid goes nearly everywhere cars and trucks travel in New England. It overlaps most of our road, rail, water and air transportation systems. The electric grid is thus well positioned to play an increasing role in serving consumers' energy needs, lowering energy costs, reducing GHG emissions, and providing unprecedented electricity reliability. Where clean electricity as a transportation fuel is impractical, use of compressed natural gas and LNG by heavier vehicles can also lower costs and emissions.

Another key constraint is the electricity used to power transportation. Electrifying transportation is a practical solution only if electricity is clean and affordable. It makes little sense to electrify transportation in the name of the environment if the electricity is coming from a dirty, costly, or risky source. As the National Renewable Energy Laboratory has found, "Plug-in electric vehicles (PEVs)—which include all-electric vehicles and plug-in hybrid electric vehicles—provide a new opportunity for reducing opportunity for reducing oil consumption by drawing power from the electric grid. To maximize the benefits of PEVs, the emerging PEV infrastructure—from battery manufacturing to communication and control between the vehicle and the grid—must provide access to clean electricity, satisfy stakeholder expectations, and ensure safety."[104]

If New England takes the steps offered in this paper, thereby reducing costs, increasing grid flexibility, and obtaining significantly more electricity from renewable energy, it will have created an ideal platform for widespread EV penetration. Cracking the transportation nut in this way will allow for the deep GHG emission cuts required to abate global warming, while at the same time allowing New England to thrive economically and socially.

IV. CONCLUSION

In this paper, CLEC has described the current energy crisis crippling New England's economy and offered a realistic plan for natural gas to form the foundation of an affordable clean energy paradigm based on renewable energy, energy efficiency, smart grid technologies, and alternatives to oil in heating and transportation. Expanding natural gas pipeline capacity today by approximately 2 Bcf/d will enable this new energy paradigm economically, politically, and physically.

We must first use natural gas to lock-in the emissions reductions already achieved and to finish the displacement of our dirtiest, least efficient, and most expensive generators fueled by coal and oil. This will at a minimum allow the region to utilize its existing flexible natural gas-fired generators to integrate desired short-term levels of renewable energy, while preventing the re-entrenchment of inflexible coal and oil. It will also allow for natural gas to penetrate a heating market still dominated by oil in New England.

Expansion of natural gas pipeline capacity will also significantly reduce the cost of electricity and natural gas in New England. Lowering costs is absolutely essential to maintaining and increasing the necessary political support for renewable energy and energy efficiency.

When coal and oil are displaced, and New England's energy costs are competitive with other regions, New England can significantly increase its reliance on intermittent renewable energy. However, this will require grid flexibility that can only be provided cost-effectively at the scale needed by the region's existing natural gas-fired generators. These "Swiss Army" knives were built around the turn of the millennium and their inherent flexibility will be "stranded" unless they have reliable access to fuel. As their useful lives begin to expire around 2030, the region will have developed additional flexibility tools to further enable reliance on renewable energy.

As the region's electric fuel mix is increasingly based on renewable energy, the region's fleet of existing natural gas-fired generators, and a few strategic new ones, will transition from primarily producing electricity to primarily providing the back-up capacity for renewable energy. Less natural gas will be burned, and thus emissions will decrease. However, sufficient natural gas pipeline capacity is essential to ensure that this generation capacity can turn on and fully ramp energy production when renewable energy production inevitably wanes or is non-existent on various time scales.

Finally, with the framework for a significantly cleaner electric fuel mix in place, New England can tackle emissions from the stubborn transportation sector, which today relies almost exclusively on imported oil. EVs are a promising technology that can use renewable electricity to reduce tailpipe emissions, while providing ancillary services to the grid and enabling a smarter, more dynamic grid grounded in small-scale renewable energy.

RECOMMENDED LITERATURE

Jacobson, et al. (Stanford study), "Examining the feasibility of converting New York State's all-purpose energy infrastructure to one using wind, water, and sunlight" (2013), available at https://web.stanford.edu/group/efmh/jacobson/Articles/I/NewYorkWWSEnPolicy.pdf.

MIT Energy Initiative (Director, Ernest Moniz), "Managing Large-Scale Penetration of Intermittent Renewables" (4.20.11), available at http://mitei.mit.edu/system/files/intermittent-renewables-full.pdf.

MIT (Chair, Ernest Moniz), "The Future of Natural Gas: An Interdisciplinary MIT Study" (6.6.11), available at http://mitei.mit.edu/system/files/NaturalGas_Report.pdf.

National Renewable Energy Laboratory, "Opportunities for Synergy Between Natural Gas and Renewable Energy in the Electric Power and Transportation Sectors" (2012), available at http://www.nrel.gov/docs/fy13osti/56324.pdf.

National Renewable Energy Laboratory, "Renewable Electricity Futures Study" Volumes I-IV (2012), available at http://www.nrel.gov/analysis/re_futures/.

MIT Energy Initiative, "Growing Concerns, Possible Solutions: The Interdependency of Natural gas and Electricity Systems" (4.16.13), available at http://mitei.mit.edu/system/files/2014-MITEI-Report-Growing-Concerns-Possible-Solutions.pdf.

The Brattle Group, "Partnering Natural Gas and Renewables in ERCOT, PART I" (6.11.13), available at http://www.texascleanenergy.org/Brattle%20report%20on%20renewable-gas%20FINAL%2011%20June%202013.pdf.

The Brattle Group, "Exploring Natural Gas and Renewables in ERCOT, PART II: Future Generation Scenarios for Texas" (12.10.13), available at http://www.ourenergypolicy.org/wp-content/uploads/2014/01/TCEC_Report-Final-Clean-12-3-13.pdf.

National Renewable Energy Laboratory, "Realizing a Clean Energy Future: Highlights of NREL Analysis" (December 2013), available at http://www.nrel.gov/docs/fy14osti/60894.pdf.

California ISO, "Shaping a Renewed Future, Fast Facts: What the duck curve tells us about managing a green grid" (2013), available at https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf.

Regulatory Assistance Project, "Teaching the "Duck" to Fly" (January 2014)

New York State Energy Research and Development Authority, "Energy Efficiency and Renewable Energy Potential Study of New York State," Summary (April 2014), available at https://www.nyserda.ny.gov/-/media/Files/EDPPP/Energy-Prices/Energy-Statistics/14-19-EE-RE-Potential-Study-Summary.pdf.

The Brattle Group, "Exploring Natural Gas and Renewables in ERCOT, PART III: the Role of Energy Efficiency, Demand Response, and Combined Heat & Power" (5.29.14), available at http://www.brattle.com/system/publications/pdfs/000/005/013/original/Exploring_Natural_Gas_and_Renewables_in_ERCOT_Part_III_Shavel_Weiss_Fox-Pennerf.pdf?1401907416.

Center for Strategic & International Studies, "Remaking American Power" (11.18.14), available at http://csis.org/files/publication/141107_Ladislaw_RemakingAmerPower_Web.pdf

National Renewable Energy Laboratory, "Exploring the Potential Business Case for Synergies between Natural Gas and Renewables Energy" (2014), available at http://www.nrel.gov/docs/fy14osti/60052.pdf.

21st Century Power Partnership, "Flexibility in 21st Century Power Systems" (May 2014), available at http://www.nrel.gov/docs/fy14osti/61721.pdf.

Eric Martinot, "How is Germany Integrating and Balancing Renewable Energy Today?" (January 2015), available at http://www.martinot.info/Martinot_DE_Integration_Jan2015.pdf; "How is Denmark Integrating and Balancing Renewable Energy Today?" (January 2015), available at http://www.martinot.info/Martinot_DK_Integration_Jan2015.pdf; "How is California Integrating and Balancing Renewable Energy Today?" (January 2015), available at http://www.martinot.info/Martinot_CA_Integration_Jan2015.pdf.

Energy Sector Management Assistance Program, "Bringing Variable Renewable Energy Up to Scale: Options for Grid Integration Using Natural Gas and Energy Storage" (February 2015), available at https://openknowledge.worldbank.org/bitstream/handle/10986/21629/ESMAP_Bringing%20Variable%20Renewable%20Energy%20Up%20to%20Scale_VRE_TR006-15.pdf?sequence=4.

Regulatory Assistance Project, "Power Market Operations and System Reliability in the Transition to a Low-Carbon Power System A Contribution to the Market Design Debate" (May 2015), available at http://www.raponline.org/document/download/id/7600.

Forbes (Peress, Environmental Defense Fund), "How to Ensure Natural Gas Infrastructure Doesn't Lock Out Renewables" (6.5.15), available at http://blogs.edf.org/energyexchange/2015/06/05/how-to-ensure-new-natural-gas-infrastructure-doesnt-lock-out-renewables/.

Vox, "Why wind and solar power are such a challenge for energy grids" (June 19, 2015), available at http://www.vox.com/2015/6/19/8808545/wind-solar-grid-integration.

McKinsey & Company, "Lower Oil Prices but more Renewables: What's Going on? Why the renewables sector is more resilient than ever" (June 2015), available at http://www.mckinsey.com/insights/energy_resources_materials/lower_oil_prices_but_more_renewables_whats_going_on.

The Brattle Group, "Integrating Renewable Energy into the Electricity Grid: Case studies showing how system operators are maintaining reliability" (June 2015), available at http://info.aee.net/hubfs/EPA/AEEI-Renewables-Grid-Integration-Case-Studies.pdf.

Harvard Business School, "America's Unconventional Energy Opportunity: A Win-Win Plan for the Economy, the Environment, and a Lower-Carbon, Cleaner-Energy Future" (June 2015), available at http://www.hbs.edu/competitiveness/Documents/america-unconventional-energy-opportunity.pdf.

Leonardo Maugeri, Global Energy Trends, Briefing #6: "Solar Photovoltaics: A Silent Energy and Geopolitical Revolution in Sight?" (7.20.15)

McKinsey & Company, "Peering into Energy's Crystal Ball" (July 2015), available at http://www.mckinsey.com/insights/energy_resources_materials/peering_into_energys_crystal_ball.

Regulatory Assistance Project, "Smart Gas Investment-As a bridge to a low-carbon future, natural gas can't – and shouldn't – meet every need" (July 2015), available at http://www.raponline.org/document/download/id/7691.

Synapse, "A Solved Problem-Existing measures provide low-cost wind and solar integration" (8.25.15), available at http://synapse-energy.com/sites/default/files/A-Solved-Problem-15-088.pdf.

Regulatory Assistance Project, "A Smarter Role for Natural Gas in Clean Power Plan Compliance" (August 2015), available at http://www.raponline.org/document/download/id/7717

Democracy Journal.org, Michael Levi (David M. Rubenstein senior fellow for energy and the environment at the Council on Foreign Relations), "Fracking and the Climate Debate: Natural gas isn't holding us back from a carbon-free future. In fact, it may help us get there" (Summer 2015)

ISO New England

ISO NE, "New England Wind Integration Study" (12.5.10)

ISO NE, ISO Newswire – Updates: "ISO-NE marks Earth Day with an update on energy-efficiency, solar, and wind resources in New England" (4.22.15)

ISO NE, ISO Newswire – Updates: "Long-term forecasts electricity usage will remain flat and peak demand is expected to grow slowly" (5.5.15)

ISO NE, Press Release: "Beating the heat-How ISO-NE prepares for summer peak demand" (6.2.15)

ISO NE, White paper draft: "The Importance of a Performance-Based Capacity Market to Ensure Reliability as the Grid Adapts to a Renewable Energy Future" (6.3.15)

Energy Information Administration

EIA, Today in Energy, "Pumped storage provides grid reliability even with net generation loss"

(7.8.13)

EIA, Today in Energy, "California continues to set daily records for utility scale solar energy" (6.25.14)

EIA, Today in Energy, "California drought leads to less hydropower, increased natural gas generation" (10.6.14)

EIA, Today in Energy, "Solar photovoltaic output depends on orientation, tilt, and tracking" (11.19.14)

EIA, Today in Energy, "Wind generation seasonal patterns vary across the United States" (2.25.15)

EIA, Today in Energy, "Scheduled 2015 capacity additions mostly wind and natural gas; retirements mostly coal" (3.10.15)

EIA, Today in Energy, "Nonhydro electricity storage increasing as new policies are implemented" (4.3.15)

EIA, Today in Energy, "Natural gas, renewables projected to provide larger shares of electricity generation" (5.4.15)

EIA, Today in Energy, "Under the proposed CPP natural gas then renewables gain" (5.27.15)

EIA, Today in Energy, "Proposed Clean Power Plan would accelerate renewable additions and coal plant retirements" (6.5.15)

EIA, Today in Energy, "Power to gas brings a new focus to the issue of energy storage from renewable sources" (7.24.15)

REFERENCES

1. EIA, map of "Lower 48 Shale Plays," available at http://www.eia.gov/oil_gas/rpd/shale_gas.pdf. (4.13.15).
2. Worcester Telegraph, "Natural gas pipelines must be part of the energy portfolio" (10. 25.15).
3. SNL, "FERC's Clark presses for more gas pipelines while praising 'helpful' dissent" (10.7.15).
4. National Renewable Energy Laboratory, "Opportunities for Synergy Between Natural Gas and Renewable Energy in the Electric Power and Transportation Sectors" (2012).
5. National Renewable Energy Laboratory, "Renewable Electricity Futures Study: Exploration of High-Penetration Renewable Electricity Futures" (2012).
6. See. e.g., MIT Technology Review: "Where Is the Global Shale Gas Revolution?" (7.20.15); Forbes; "Shale Revolution: Opportunity To Jump-Start Economic Growth" (11.19.14); United States Department of Energy, Quadrennial Energy Review: "Energy Transmission, Storage, and Distribution Infrastructure" at 1-6 (April 2015).
7. See, e.g., EIA, Today in Energy: "New methanol and fertilizer plants to increase already-growing industrial natural gas use" (7.29.15).
8. The wholesale cost of New England's energy market was about $1.2 billion in the winter of 2011-12 and $5.05 billion in the winter of 2013-14. Since Massachusetts uses about 46.6% of New England's electricity, that proportion of the $3.85 billion increase can be roughly ultimately attributed to Massachusetts ratepayers.
9. ISO New England, "The Importance of a Performance-Based Capacity Market to Ensure Reliability as the Grid Adapts to a Renewable Energy Future" (June 2015).
10. ISO New England, "Strategic Transmission Analysis: Generator Requirements Study" (12.13.12).
11. ISO New England, "ISO-NE marks Earth Day with an update on energy-efficiency, solar, and wind resources in New England" (4.22.15).
12. EIA, Today in Energy, "Nonhydro electricity storage increasing as new policies are implemented" (4.3.15).
13. McKinsey & Company, "Peering into Energy's Crystal Ball" (July 2015).
14. Mckinsey & Company, "Lower oil prices but more renewables: What's going on?" (June 2015).
15. McKinsey & Company, "Peering into Energy's Crystal Ball" (July 2015).
16. ISO NE, "2013 ISO New England Electric Generator Air Emissions Report," at 1, 38 (December 2014).
17. Id.
18. Id. at 16, 38.
19. http://www.mass.gov/eea/docs/eea/gwsa/alt-text-version-of-graphs/homepage-chart-1.pdf.
20. http://www.mass.gov/eea/air-water-climate-change/climate-change/massachusetts-global-warming-solutions-act/.
21. ISO NE, "2012 ISO New England Electric Generator Air Emissions Report," at 16 (January 2014).
22. ISO NE, "Oil inventory key in maintaining reliability through colder weather during winter 2013-2014" (4.4.14).
23. The wholesale cost of New England's energy market was about $1.2 billion in the winter of 2011-12 and $5.05 billion in the winter of 2013-14. Since Massachusetts uses about 46.6% of New England's electricity, that proportion of the $3.85 billion increase can be roughly ultimately attributed to Massachusetts ratepayers.
24. ISO New England, "New England power system performed well through winter 2014/2015" (4.7.15).
25. ISO NE, "State of the Grid presentation," slide 21 (1.21.15).
26. ISO New England, ISO Newswire – Updates "Wholesale electricity prices and demand in New England" February 2015 (4.7.15) ("Coal units generated 12.3% of the energy produced in New England …Oil was less expensive on 86% of the days in February, and oil-fired resources produced 5.3% of the energy generated within New England. Dual-fuel units, which generally are capable of burning natural gas or oil and typically use the less expensive fuel, generated about 10%.")
27. ISO New England, "Resources' participation in 2014/2015 Winter Reliability Program improves fuel adequacy this winter" (1.12.15), available at http://isonewswire.com/updates/2015/1/12/resources-participation-in-20142015-winter-reliabilityprogr.html.
28. Id.
29. ISO New England, "Planning Advisory Committee: Post Winter 2014/2015 Review," slide 5 (4.22.15).
30. Id.
31. Id. at slides 2-4.
32. ISO New England Inc., 151 FERC 61,052 (April 17, 2015)("Thus, we grant rehearing to allow the possibility that ISO-NE may file additional out-of-market winter reliability programs until the two-settlement capacity market design becomes effective in 2018").
33. ISO New England, Northeast Forum on Regional Energy Solutions, Remarks by Gordon van Welie, President & CEO, ISO New England(April 23, 2015).
34. ISO New England, "Challenges Facing the New England Power System," Gordon van Welie presentation at the 2015 2015 IEEE Power & Energy Society General Meeting, at slide 11 (July 28, 2015).
35. Competitive Energy Services, "Assessing Natural Gas Supply for New England for the Winter of 2013-14 and its Impact on Natural Gas and Electricity Prices," at 7-8 (4.5.13).
36. EIA, "What is the efficiency of different types of power plants?" available at http://www.eia.gov/tools/faqs/faq.cfm?id=107&t=3To.
37. GE Power Systems, "GE Combined-Cycle Product Line and Performance," available at http://physics.oregonstate.edu/~hetheriw/energy/topics/doc/elec/natgas/cc/combined%20cycle%20product%20line%20and%20performance%20GER3574g.pdf.
38. California Energy Commission, Staff Paper: "Thermal Efficiency of Gas-Fired Generation in California: 2014 Update" at I (September 2014).
39. Energy Sector Management Assistance Program, "Bringing Variable Renewable Energy Up to Scale: Options for Grid Integration Using Natural Gas and Energy Storage" at 3 (February 2015).

40. Id.
41. Id. at 28.
42. Regulatory Assistance Project, "Smart Gas Investment: How Many Swiss Army Knives do We Need?", webinar (July 9. 2015).
43. ISO New England, ISO Newswire – Updates "Wholesale electricity prices and demand in New England" June 2015 (7.15.15).
44. ISO New England, Internal Market Monitor, "2014 Annual Markets Report" at 15, 29 (5.20.15).
45. ISO New England, "State of the Grid" presentation, at 15 (1.21.15).
46. See, e.g., Portland Press Herald, "Some Maine mills forced to idle lines as price of power soars" (12.19.13).
47. Massachusetts LIHEAP Clearinghouse, available at http://www.liheapch.acf.hhs.gov/profiles/Mass.htm.
48. Massachusetts Department of Housing and Community Development Low-Income Home Energy Assistance Program (LIHEAP), "Fiscal Year 2012 Annual Report" at 8 (2013).
49. SNL, "Conn. consumer counsel: More ratepayers struggling with monthly bills" (7.22.15).
50. The Brattle Group, "Partnering Natural Gas And Renewables in ERCOT—PART I" (6.11.13)
51. SNL Energy Power Daily, "EPA chief: Cheap natural gas enabled clean air rules," (April 29, 2015).
52. Harvard Business School, "America's Unconventional Energy Opportunity: A Win-Win Plan for the Economy, the Environment, and a Lower-Carbon, Cleaner-Energy Future" (June 2015).
53. McKinsey & Company, "Lower oil prices but more renewables: What's going on?" (June 2015).
54. Harvard Business School, "America's Unconventional Energy Opportunity: A Win-Win Plan for the Economy, the Environment, and a Lower-Carbon, Cleaner-Energy Future" (June 2015).
55. Jacobson, et al. (Stanford study), "Examining the feasibility of converting New York State's all-purpose energy infrastructure to one using wind, water, and sunlight" (2013).
56. Regulatory Assistance Project, "Power Market Operations and System Reliability in the Transition to a Low-Carbon Power System A Contribution to the Market Design Debate" (May 2015)
57. International Energy Agency, "Wind, Sun and the Economics of Flexible Power Systems" (2014).
58. Department of Energy, "Quadrennial Technology Review" at 59 (September 2015).
59. ISO New England, "Energy-Efficiency Forecast for 2019 to 2024" at 2-3 (5.1.15)
60. Home heating oil and diesel fuel produce about 161.3 lbs of C02/MMBtu when combusted. Natural gas is the cleanest of all fossil fuels, producing 117 lbs of C02/MMBtu when combusted. EIA, "How much carbon dioxide is produced when different fuels are burned?", available at http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11.
61. EIA, "Heating Oil Explained, Use of Heating Oil – Basics", available at http://www.eia.gov/energyexplained/index.cfm?page=heating_oil_use.
62. LIHEAP Clearinghouse website, available at http://www.liheapch.acf.hhs.gov/.
63. Department of Energy, "Energy Saver 101 Infographic: Home Heating" available at http://energy .gov/articles/energy-saver-101-infographic-home-heating.
64. Department of Energy, "Energy Saver 101 Infographic: Home Heating" available at http://energy .gov/articles/energy-saver-101-infographic-home-heating.
65. EIA, "Massachusetts State Profile and Energy Estimates", available at http://www.eia.gov/state/print.cfm?sid=MA.
66. EIA, "Connecticut State Profile and Energy Estimates", available at http://www.eia.gov/state/print.cfm?sid=CT.
67. EIA, "Rhode Island State Profile and Energy Estimates", available at http://www.eia.gov/state/print.cfm?sid=RI.
68. EIA, "Maine State Profile and Energy Estimates", available at http://www.eia.gov/state/print.cfm?sid=ME.
69. EIA, "New Hampshire State Profile and Energy Estimates", available at http://www.eia.gov/state/print.cfm?sid=NH.
70. EIA, "Vermont State Profile and Energy Estimates", available at http://www.eia.gov/state/print.cfm?sid=VT.
71. EIA, "Short-Term Energy Outlook" (March 2015).
72. EIA, "Carbon Dioxide Emissions Coefficients," available at http://www.eia.gov/environment/emissions/co2_vol_mass.cfm.
73. EIA, "Heating Oil Explained: Factor Affecting Heating Oil Prices – Basics", available at http://www.eia.gov/energyexplained/print.cfm?page=heating_oil_factors_affecting_prices. ("A homeowner in the Northeast might use 850 gallons to 1,200 gallons of heating oil during a typical winter, while consuming very little during the rest of the year.")
74. http://www.ct.gov/deep/lib/deep/energy/energyprice/energy_conversion_factors.pdf.
75. EIA, "Short-Term Energy Outlook" (March 2015).
76. http://www.ct.gov/deep/lib/deep/energy/energyprice/energy_conversion_factors.pdf.
77. EPA, "Clean Energy Calculations and References," available at http://www.epa.gov/cleanenergy/energy-resources/refs.html.
78. EIA, Short-Term Energy Outlook (March 2015).
79. EIA, Short-Term Energy Outlook (March 2015).
80. MIT Energy Initiative, "The Future of Natural Gas: An Interdisciplinary MIT Study" (2011).
81. National Renewable Energy Laboratory, "Renewable Electricity Futures Study: Exploration of High-Penetration Renewable Electricity Futures" (2012).
82. Regulatory Assistance Project, "Smart Gas Investment - As a bridge to a low-carbon future, natural gas can't – and shouldn't – meet every need" (July 2015).
83. 21st Century Power Partnership/NREL, "Flexibility in 21st Century Power Systems" (May 2014).
84. EIA, Today in Energy, "Power-to-gas brings a new focus to the issue of energy storage from renewable sources" (7.24.15).

85. Eric Martinot, "How is Germany Integrating and Balancing Renewable Energy Today?" (January 2015), available at http://www.martinot.info/Martinot_DE_Integration_Jan2015.pdf; "How is Denmark Integrating and Balancing Renewable Energy Today?" (January 2015), available at http://www.martinot.info/Martinot_DK_Integration_Jan2015.pdf; "How is California Integrating and Balancing Renewable Energy Today?" (January 2015), available at http://www.martinot.info/Martinot_CA_Integration_Jan2015.pdf.
86. ISO New England, State of the Grid presentation, slide 11 (1.21.15).
87. "Fast Facts: U.S. Transportation Sector Greenhouse Gas Emissions 1990-2012", U.S. Environmental Protection Agency (2015), available at http://www3.epa.gov/otaq/climate/documents/420f15002.pdf.
88. "Table 4-4: U.S. Energy Consumption by the Transportation Sector (Quadrillion Btu)," U.S. Dept. of Trans., available at http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_04_04.html.
89. U.S. DOE, "All-Electric Vehicles," available at https://www.fueleconomy.gov/feg/evtech.shtml.
90. U.S. DOE, "All-Electric Vehicles," available at https://www.fueleconomy.gov/feg/evtech.shtml.
91. Alternative Fuels Data Center, "Laws and Incentives for Electricity," available at http://www.afdc.energy.gov/fuels/laws/ELEC/US.
92. Simpson et al., "Vehicle to Micro-Grid: Leveraging Existing Assets for Reliable Energy Management," (December 2010), available at http://www.nrel.gov/docs/fy11osN/49870.pdf.
93. 79 Tony Markel, "Plug-in Electric Vehicle Infrastructure: A Foundation for Electrified Transportation," (2010), available at http://www.nrel.gov/docs/fy10osti/47951.pdf .
94. U.S. DOE, "Natural Gas Vehicle Emissions," available at http://www.afdc.energy.gov/vehicles/natural_gas_emissions.html.
95. Argonne NaNonal Laboratory, Center for Transportation Research, "A Full Fuel-Cycle Analysis of Energy and Emissions Impacts of Transportation Fuels Produced from Natural Gas," available at http://www.ipd.anl.gov/anlpubs/2000/01/34988.pdf.
96. Argonne National Laboratory, "Waste-to-Wheel Analysis of Anaerobic-Digestion-Based Renewable Natural Gas Pathways with the GREET Model," (September 2011), available at http://www.ipd.anl.gov/anlpubs/2011/12/71742.pdf.
97. Vimmerstedt et al. "Transformative Reduction of Transportation Greenhouse Gas Emissions: Opportunities for Change in Technologies and Systems," (2015).
98. Ryan and Lavin, "Engaging Utilities and Regulators on Transportation Electrification," (2015), available at https://ethree.com/documents/E3-NRDC_EVs_Paper_Final_20150129.pdf.
99. See, e.g., James H. Williams et al., "The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050: The Pivotal Role of Electricity," (2012); and Max Wei et. al., "Deep Carbon Reduction in California Require Electrification and Integration Across Economic Sectors," (2013).
100. U.S. DOE., "The History of the Electric Car," available at http://energy.gov/articles/history-electric-car.
101. Jeff Cobb, Hybirdcars.com, "Top 6 Plug-In Vehicle Adopting Countries – 2014." Cumulative plug-in electric car sales in the U.S. totaled 291,332 units between 2008 and December 2014. Jeff Cobb, HybridCars.com and Baum & Associates, "May 2015 Dashboard." A total of 43,560 plug-in electric cars were sold during the first five months of 2015, consisNng of 15,100 plug-in hybrids and 28,460 battery electric cars.
102. U.S. DOT, "Table 1-11: Number of U.S. Aircraft, Vehicles, Vessels, and Other Conveyances," available at http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_11.html.
103. U.S. DOT, "Table 4-4: U.S. Energy Consumption by the Transportation Sector (Quadrillion Btu)," available at http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_04_04.html.
104. Tony Markel, "Plug-in Electric Vehicle Infrastructure: A Foundation for Electrified Transportation," (2010), available at http://www.nrel.gov/docs/fy10osN/47951.pdf.

COALITION TO LOWER ENERGY COSTS

@CLECNewEngland
www.energycostcrisis.com