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New Hampshire's Electricity Markets: Natural Gas, Renewable Energy, and Energy Efficiency

Cameron P. Wake
University of New Hampshire, Durham, cameron.wake@unh.edu

Matthew Magnusson
University of New Hampshire, Durham, magnusson3@gmail.com

Christina Foreman
University of New Hampshire - Durham, maria.foreman@unh.edu

Fiona Wilson
University of New Hampshire, Durham, fiona.wilson@unh.edu

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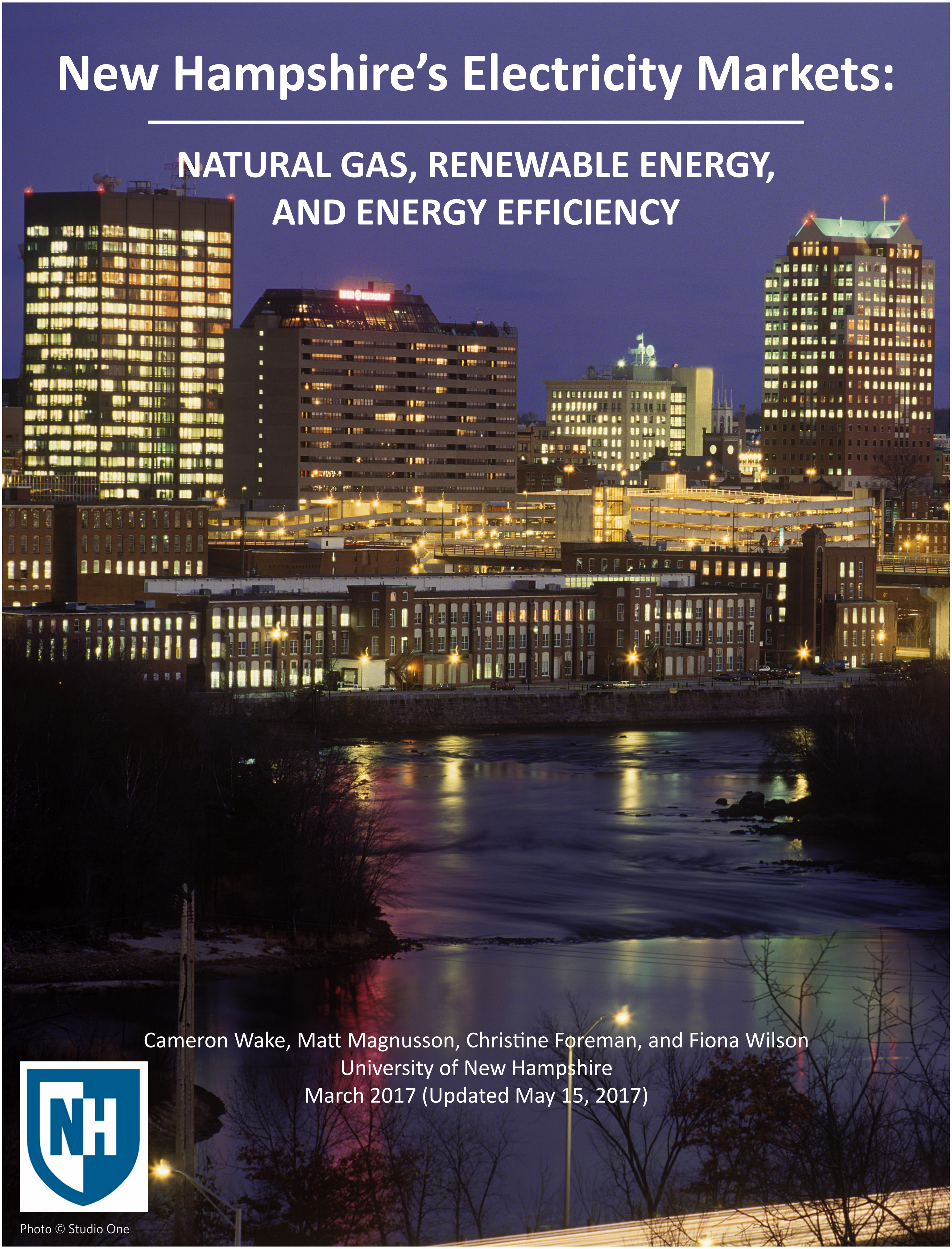

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University of New Hampshire
March 2017 (Updated May 15, 2017)

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May 2017 Update

PointLogic Energy, a source for natural gas pipeline flow and capacity in the original report, has recently updated their models for calculating natural gas flow in the Tennessee Gas Pipeline in New England. This model update has resulted in significant changes to their previous estimates. Most importantly, data obtained from PointLogic Energy in December 2016 supported the finding that overall net gas flow in the "Tennessee Gas Pipeline: NY to MA" was from Massachusetts to New York from 2013-2016; their revised models indicate a net flow during the same period from New York to Massachusetts. To be conservative, we have removed analysis of natural gas pipeline flow and capacity from this report that relied on the original data obtained from PointLogic Energy. Instead, we use estimates of natural gas pipeline flow and capacity published in an a 2014 ICF International report that was commissioned by ISO New England (Exhibit 2-3, pp. 12) (a) and information provided by the U.S. Energy Information Administration (b).

a. ICF International, "Assessment of New England's Natural Gas Pipeline Capacity to Satisfy Short and Near-Term Electric Generation Needs: Phase II," 2014 (see endnote 63).

b. U.S. Energy Information Administration. U.S. State-to-State capacity. Updated 12/31/2015, U.S. Energy Information Administration. New England natural gas pipeline capacity increases for the first time since 2010. December 6, 2016 (see endnote 66, 67).

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FRONT MATTER

To better understand the opportunities and challenges for New Hampshire's energy future resulting from emerging trends in the supply and demand for energy, the New Hampshire Chapter of The Nature Conservancy and the New Hampshire Community Finance Development Authority engaged the University of New Hampshire to perform a rigorous and impartial study that examines the current and potential future of New Hampshire's energy system. Guided by a diverse advisory board, this study investigates emerging global and national trends in energy markets, analyzes the current context and future choices regarding the New Hampshire and New England electrical energy system, and develops recommendations for policy options that benefit both energy security and affordability for New Hampshire.

The team at the University of New Hampshire was led by and Dr. Cameron Wake (UNH Institute for Earth, Oceans and Space, and UNH Sustainability Institute) and Dr. Fiona Wilson (UNH Peter T. Paul School of Business and Economics/UNH Center for Social Innovation & Enterprise). Research and analysis were performed primarily by Matthew Magnusson (Doctoral student in the College of Engineering and Physical Sciences at UNH and MBA from the UNH Peter T. Paul School of Business and Economics) with support from Dr. Christine Foreman (UNH Carsey School of Public Policy and UNH Institute for Earth, Oceans and Space, and currently working for the Economic Analysis Division at the Volpe National Transportation System Center in Cambridge, Massachusetts).

An advisory board was assembled to represent diverse points of view, and be active, engaged, and committed to an open dialogue on energy issues in NH. The advisory board provided input and guidance on the project at multiple stages, including a set of face-to-face meetings, participation in energy stakeholder meetings, and commenting on several drafts of the report. The members of the advisory board included:

- Jesse Devitte, Borealis Ventures
- Kate Epsen, NH Sustainable Energy Association
- Michael Ettlinger, Carsey School of Public Policy, UNH
- Mike Fitzgerald, Air and Resources Division, NH Department of Environmental Services
- Richard Grogan, NH Small Business Development Center
- Robert Mohr, Associate Professor at Paul College, UNH
- Kevin O'Maley, City of Manchester
- Venu Rao, Energy Committee in Hollis

- Jack Ruderman, Revision Energy
- Eric Worthen, Worthen Industries

Additional input was obtained via roundtable discussion with industrial energy users. Additional feedback on the preliminary findings and recommendations was also gathered at a New Hampshire energy stakeholder forum at UNH. While the UNH team has sought input and feedback from a wide range of energy stakeholders from across New Hampshire, the findings and recommendations presented in the report remain those of the authors. The key findings of this report are summarized in a 2017 UNH Carsey Perspective: New Hampshire's Electricity Future: Cost, Risk, and Reliability.[1]

1. INTRODUCTION

New Hampshire's economy, energy generation, and energy use are inextricably linked. Energy is vital to the welfare of every NH resident. Stable and uninterrupted access to cost-competitive and affordable energy resources is part of the foundation of a resilient New Hampshire economy. When considering energy affordability and security, it is important to remember that New Hampshire is not its own "energy island," but instead part of a large, complex, New England, national, and global energy system. What impacts the regional, national, and international energy markets has direct impact on New Hampshire's energy system. This report examines the electrical power sector in New Hampshire and New England, with a focus on the current context and future choices regarding natural gas, renewable energy, and energy efficiency.

Global energy prices for oil and natural gas are currently low compared to historical values over the past 2 decades and global storage levels for oil and natural gas are at historic highs. However, there remain risks to energy security in global energy markets,[2] which are in a period of rapid change and uncertainty.[3] The world's energy markets have been described as being out of balance as the production and demand for fossil fuel resources have shifted.[4]

Two global energy trends that are significant factors in driving the global and New England energy marketplace are the rapid growth in the use of natural gas and renewable energy for electric power generation. A significant increase over the past 5 years in the supply of natural gas has put significant downward pressure on the wholesale price of natural gas. This, combined with increasingly stringent environmental regulations, has resulted in a dramatic increase in the amount of natural gas powered generation in the United States. Natural gas is now displacing other forms of energy (especially coal and oil) at a rapid pace, with 2016 expected to be the first year that natural gas-fired power generation exceeds coal generation (Figure 1.1).[5]

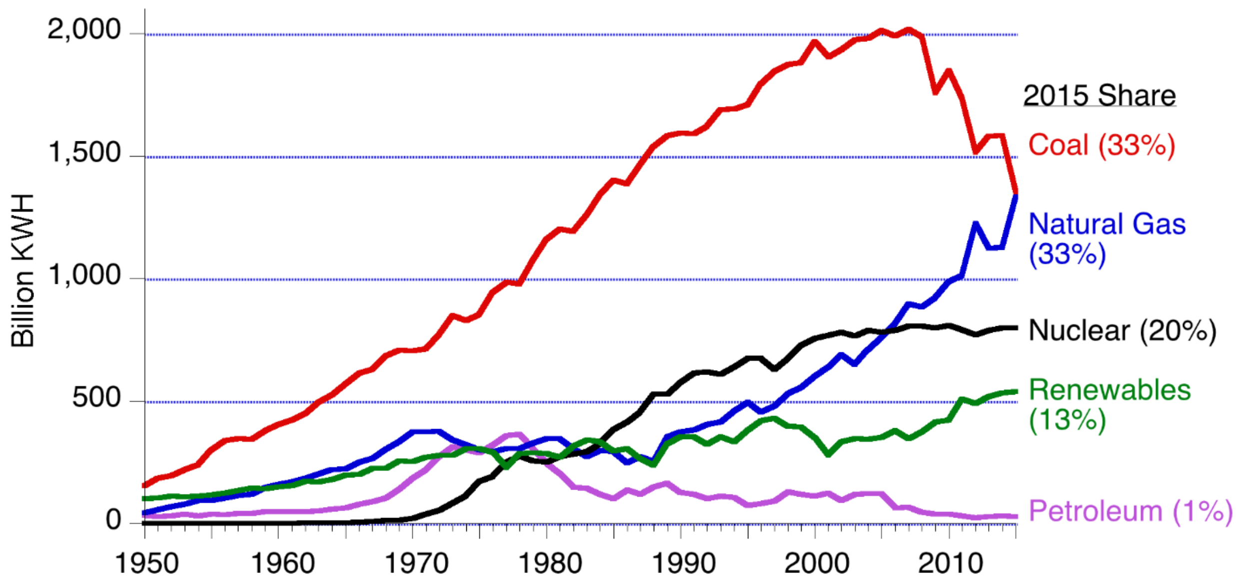

Figure 1.1. Annual total U.S. electricity generation by source from 1950 to 2015.[6]

Another important trend is the decoupling of energy consumption and economic growth. Historically, economic growth was accompanied by a corresponding increase in energy consumption. The good news is that new, less energy intensive industries, combined with more energy efficient technologies and practices, are achieving economic growth and decreases in energy consumption.[7] For example, real gross domestic product (GDP) rose 15.2 % in the U.S. between 2005 and 2015, while energy use dropped 3.4% (Figure 1.2).

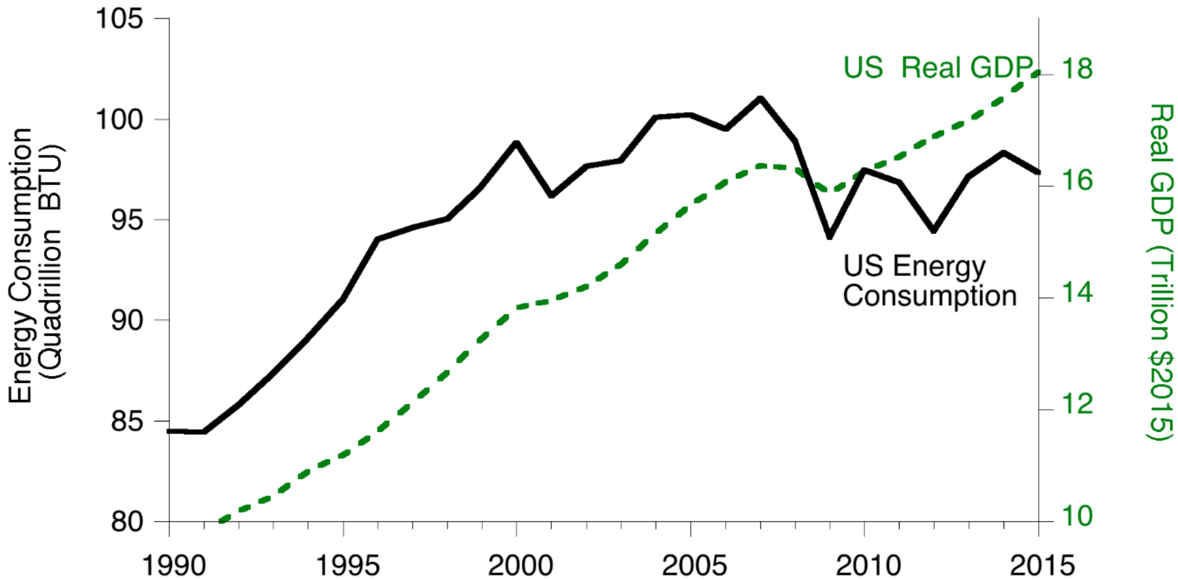

Figure 1.2. U.S energy consumption[8] (black solid line) and real U.S. GDP[9] (dashed green line), 1990 – 2015.

Renewable energy has experienced significant decreases in cost, especially energy produced by wind turbines and solar photovoltaics (PV). This, combined with state and federal policies that have favored renewable energy as a mechanism to reduce pollution (including the emissions of heat-trapping gases such as carbon dioxide) are driving rapid growth in the amount of electric power generated in the United States from renewable technologies (Figure 1.1). These policies have also supported the implementation of energy efficiency technologies and programs. In terms of public perception, a recent national poll found that 81% of voters think the Unites States should use more renewable energy and 55% think the country should use less fossil fuel.[10]

While uncertainty remains, 2 specific policies that could drive further demand for renewable energy and energy efficiency are the Clean Power Plan[11] at the national level and the Paris Agreement[12] at the international level. Both policies call for a reduction in the emission of heat-trapping gases, which would be expected to provide increased market opportunities for both renewable energy and energy efficiency.

These national trends are also present in the New England and New Hampshire energy marketplace.[13] Electricity is and will continue to be an essential part of the energy system that supports the New Hampshire economy and quality of life and well-being of NH residents. Electricity use is also a significant part of expenditures in the NH economy with approximately $1 out of every $4 spent on energy ($1.7 billion of $6.4 billion total) paying for electricity in 2014.

The New England region has been rapidly transitioning to natural gas for its electric power generation, growing from just under one-fifth of generation in 2000 to approximately half of generation in 2015.[14] The rapid transition to natural gas has been brought on by a combination of relatively low natural gas prices (which resulted from the discovery and drilling of large, previously untapped natural gas resources in the United States), the increase in environmental regulations, and interest in strengthening national energy security. While New England's electric system has increasingly become dependent on natural gas, the region has also experienced an expansion of renewable energy and energy efficiency. A specific challenge and opportunity for New England and New Hampshire is that the region does not have any indigenous sources of fossil fuels. Therefore the region must either import fossil fuels from other regions of the country or the world or develop more indigenous forms of energy and energy efficiency.

An expressed area of concern by the region's electric utility industry has been that the rising demand for natural gas in New England requires new pipeline capacity. Specifically, ISO New England, the organization responsible for coordinating the region's power grid, has issued strong calls for new natural gas infrastructure investment.[15] The premise is that future increased natural gas demand (driven in part by the projected closure of existing nuclear and coal-fired power plants) will further overburden the existing pipeline infrastructure and could jeopardize reliability.[16] Their reasoning is that without additional pipeline infrastructure, natural gas prices and price volatility, and by extension electricity prices and price volatility, will increase in New England. The decision to invest in new natural gas pipeline capacity and determine how the costs are distributed is a crucial one as it will chart the future course for energy affordability, energy choice, and energy security for New Hampshire and New England, likely for decades given the significant infrastructure costs associated with pipeline expansion.[17] Any large capital investment from public sources in pipeline infrastructure may limit financial resources that otherwise could be used for other energy projects. There is also the risk posed by stranded costs[18] if public sources are used since energy markets continually evolve and change.

New Hampshire is at a key juncture in determining its energy future. Because of the tight relationship between the cost of natural gas and the cost of electricity in the region, it is important for New Hampshire policy makers and New Hampshire energy stakeholders to consider this relationship in any actions ultimately selected. Choices made today regarding natural gas infrastructure investments will impact the quality of life, economic prosperity, and carbon footprint of New Hampshire residents over the upcoming year, decade, and beyond. Given the new developments in the energy marketplace, what energy choices should New Hampshire make?

The New England power grid system is emerging at the nexus of global trends as it experiences a period of significant change. These combined forces are challenging the incumbent infrastructure: 1) increasing natural gas use, 2) increasing adoption of renewable energy and energy efficiency, and 3) developing smart-grid technologies that integrate large power plants with small distributed generation.[19] This is driving debate on what types of energy policies should be put in place, and who pays the costs and receives the benefits from these policies.[20]

This report is rooted in the fact that energy is the lifeblood of modern economies. Secure and reliable access to cost-effective energy is critical to economic development and growing prosperity. At the same time, there is a growing realization that global and US economies face significant risks from climate change and that a failure to address the causes of the change, including energy sources, broadens and deepens the risk.[21] This report evaluates direct costs and benefits associated with different potential options, including increased natural gas infrastructure and increased levels of clean energy investment. It concludes with a set of recommendations for New Hampshire's energy stakeholders and legislators.

In addition to analyzing a variety of energy data provided by the U.S. Energy Information Administration (EIA) and PointLogic Energy, the technical team conducted a review of prior/existing studies that focused on natural gas infrastructure, and energy efficiency and renewable energy implementation. These studies included both the New England region and additional regional, national, and international studies.[22] Costs of implementation and energy-cost-saving opportunities were considered for these different energy technologies. This resulted in a compilation of the most useful or comprehensive studies to date. An in-depth assessment of findings within key studies was performed, and a specific scenario analysis comparing similar levels of investment in natural gas infrastructure and clean energy infrastructure was conducted. We have also included summary information on the perception of New Hampshire residents regarding future energy choices based on the responses to three energy related questions from interviews conducted as part of the October 2016 Granite State Poll.

2. BACKGROUND

2.1 Natural Gas

2.1.1 Global, National, and Regional Natural Gas Market

Natural gas has been rising in importance as a global energy source over the past 2 decades. In 2015, global production of natural gas hit an all-time record at 126.7 thousand billion cubic feet (Bcf).[23] A primary factor for the emergence of natural gas has been hydraulic fracturing, or fracking, which has opened access to new, vast, untapped sources of oil and natural gas in the United States, and is emerging in other regions of the globe.[24] Fracking is a process of drilling down into the earth and then injecting a high-pressure water mixture into rock to release trapped oil and gas. This technique has improved fossil fuel extraction productivity in the United States.[25] As a result, global gas markets are changing rapidly and creating new challenges for the energy industry and policy makers. For example, since the 1950s, the United States has been dependent on foreign sources for its oil and gas needs, but fracking has been a key factor in reducing total energy imports from 30 quadrillion British thermal units (BTU) in 2014 to 11 quadrillion BTU in 2015.[26] The United States has emerged as the world's largest oil and natural gas producer in 2016, displacing Russia.[27] The shift in energy has been large enough that the United States is expected to transition from a net importer of energy to a net exporter of energy by 2019.[28]

Overall natural gas use has expanded in the United States by 23% between 2001 and 2015, from 22,239 to 27,475 Bcf per year. The growth in overall national natural gas consumption during this time period has been driven primarily by growth in the electric generation sector with consumption of natural gas increasing 78% (almost 6% annually) (Figure 2.1). During the summer of 2016, the United States hit an all-time record for the total amount of electricity generated by natural-gas-fired generation.[29] Conversely, between 2001 and 2015, residential, commercial, and industrial natural gas consumption have been relatively flat with annual growth rates of -0.2%, 0.5% and 0.2% respectively.

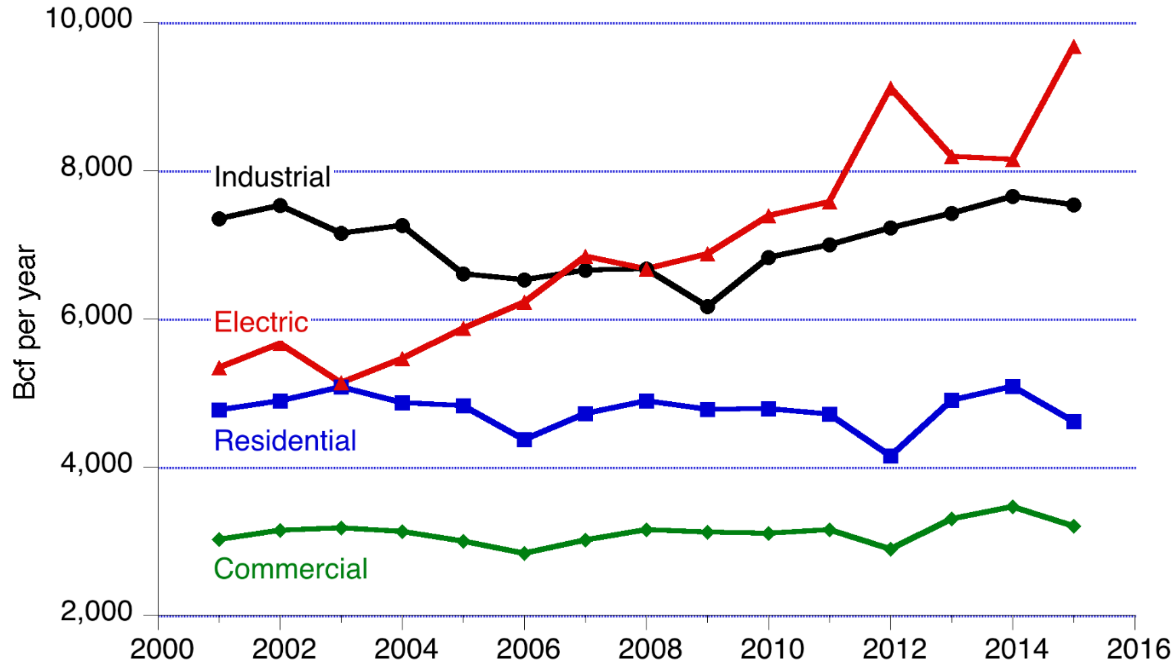

Figure 2.1. U.S. natural gas consumption (Bcf per year) by the commercial sector (green diamonds), residential sector (blue squares), electric sector (red triangles), and industrial sector (black circles) from 2001 to 2015. Note the 78% increase in natural gas consumption by the electric sector since 2001. Data from EIA.[30]

Box 1: Methane: Global Warming Potential

Burning natural gas creates about half the carbon dioxide emissions of coal, but the process for extracting and transporting it emits a more potent greenhouse gas, methane. Methane is a more effective absorber of long-wave radiation emitted by the earth and therefore has a global warming potential 86 times greater than carbon dioxide over a 20 year period, and atmospheric concentrations of methane have increased 1.8 times since 1750. While challenges remain in terms of quantifying methane emission from different sources, about two-thirds are directly linked to human activities, including natural gas wells and pipelines. Systematic analysis across a range of spatial scales indicates that inventories consistently underestimate actual measured methane emissions, with natural gas and oil sectors being important contributors. At least one analysis concludes that global warming associated with the burning of natural gas is equivalent to or worse than burning coal or oil. A detailed analysis of methane leaks from North American natural gas systems concludes: "If natural gas is to be a 'bridge' to a more sustainable energy future, it is a bridge that must be traversed carefully: Diligence will be required to ensure that leakage rates are low enough to achieve sustainability goals."

A major source of new domestic natural gas supply has emerged in the Northeastern region of the United States. The Marcellus shale play (known as the "Saudia Arabia of Natural Gas"), located in the Appalachian Basin, occupies an area of approximately 100,000 square miles and is predominantly located in Pennsylvania and West Virginia, and to a lesser extent in Ohio and New York (Figure 2.2).[31] The Marcellus shale play is the largest single source of natural gas in the nation. The EIA has placed estimates of the total shale reserves in Pennsylvania and West Virginia at 84,500 Bcf.[32] This amount of gas is equivalent to approximately a 100 year supply for New England at current demand levels.[33] The amount of fossil fuel extracted from this energy resource has grown rapidly over a relatively short period of time. The first "unconventional" well in the Marcellus shale play was drilled in 2004; by January 2012 daily natural gas production had grown to 6.1 Bcf per day (Bcf/d). As of Aug 2016, Marcellus had grown to production of 18 Bcf/d.[34] Three days at this level of production provides the equivalent of New Hampshire's current annual use of natural gas.[35] Natural gas production from the Marcellus shale play is projected to grow to 35 Bcf/d by 2035.[36]

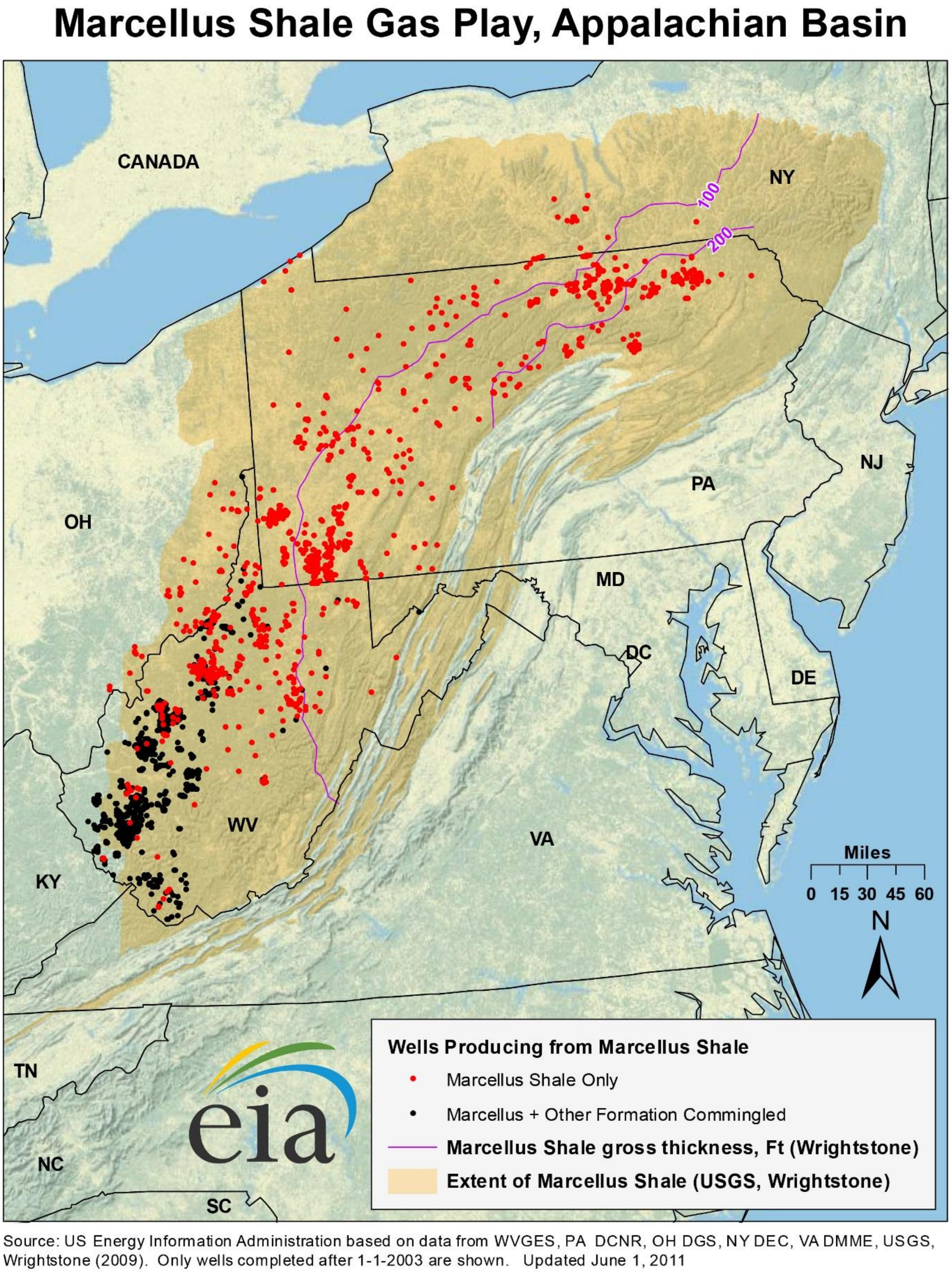

Figure 2.2. Map of Marcellus shale play in the Appalachian Basin. Image from the EIA.

The way that natural gas flows through pipelines in the United States has changed due to fracking in the Appalachian Basin (and other regions of the United States) and will continue to change as new pipeline infrastructure is added to adjust to production levels from new sources of domestic supply and national and global demand.[37] Several Appalachian Basin pipeline "takeaway" projects are under various stages of development that will connect the Marcellus shale play with other regions of the country (Table 2.1). At least 7 major projects are in different phases of development for a total addition of 9 Bcf/d of capacity at an estimated cost of $17.6 billion.

Table 2.1. Major Appalachian Basin pipeline projects under development. Data from PointLogic Energy and project sponsor websites.[38]

Pipeline	Capacity (Bcf/d)	Location	Estimated Cost (Billions)	FERC* Status	Expected Completion Date
Access Northeast	0.9	Northeast/New England	$3.0	Pre-Filing**	Winter 2018
Access South	0.3	South/Texas	$0.3	Applied	Fall 2017
Atlantic Coast Pipeline Project	1.5	Southeast	$5.1	Applied	Fall 2018
Constitution Pipeline	0.7	New York	$0.7	Approved	2nd half of 2017
Mountain Valley Pipeline	2.0	Mid-Atlantic	$3.5	Applied	Winter 2018
Nexus Gas Transmission	1.5	Midwest	$2.0	Applied	Fall 2017
Rover Pipeline Project	2.2	Midwest	$3.0	Applied	Spring 2017
Total	9.1		$17.6		

*FERC: Federal Energy Regulatory Commission
** Status of the Access Northeast pipeline reviewed in Box 2: Proposed New Hampshire Natural Gas Pipeline: Access Northeast

Another major factor impacting the U.S. natural gas markets is that U.S. liquefied natural gas (LNG) export capabilities are expected to increase dramatically over the next several years. LNG is natural gas that has been chilled to compress its volume down 600 times. The process of chilling natural gas, or liquefication, allows large volumes of natural gas to be transported by means other than pipelines, including ship, rail, and truck. This chilling and regasifying process also requires a significant amount of energy, making its heat-trapping gas footprint potentially greater than regular natural gas.[39]

In February 2016, the first of 6 LNG processing plants was completed at Sabine Pass Liquefaction in Louisiana (on the border with Texas). When the final LNG processing plant comes online (with an anticipated commissioning date in 2019) the total processing capability of Sabine Pass Liquefacation will be 3.5 Bcf/d. This facility has stated that it will be one of the largest buyers of natural gas in the country and will be able to access supplies from every supply source in the United States east of the Rocky Mountains, including the Marcellus shale.[40] Another major milestone was the first export of LNG using the newly widened Panama Canal, which is expected to provide further export opportunities for U.S. produced natural gas.[41]

Including Sabine Pass Liquefaction, a total of $42.4 billion is being invested in further development of LNG export facilities that are anticipated to come online from 2017 through 2020 (Table 2.2). By 2020 an additional 9.9 Bcf/d of natural gas in the United States could be subject to export. This was just under three times the average daily consumption of 3.4 Bcf/d for New England in the winter of 2014/15 (a winter with below average winter temperatures).[42] This development is significant for New England as it represents a large change in the national natural gas marketplace, and may represent risks to the wholesale cost of natural gas due to competition. Conversely, these LNG developments could also provide new opportunities for LNG import to New England.

Table 2.2. LNG export terminals under construction that would draw Appalachian Basin natural gas. Source: PointLogic Energy, project sponsor websites.[43]

Project	Capacity (Bcf/d)	Location	Estimated Cost ($Billions)	Expected Completion Date
Cameron LNG Terminal	1.7	Louisiana	$10.0	2018
Corpus Christi LNG	2.1	Texas	$12.0	2018
Cove Point	0.8	Maryland	$3.8	Winter 2017
Freeport LNG	1.8	Texas	$11.0	2018-2019
Sabine Pass	3.5	Louisiana	$5.6	2016 – 2019
Total	9.9		$42.4	

The impact of increased natural gas extraction from the Appalachian Basin has helped drive overall natural gas prices lower over the past 8 years (Figure 2.3). The last significant peak in wholesale natural gas prices at the national level occurred in June 2008 at $13 per million BTU (the Henry Hub price in Figure 2.3) and the market recently bottomed in March 2016 at $1.50 per therm. The Henry Hub spot natural gas price represents the overall national delivery price, while the Algonquin Citygate spot natural gas price represents delivery prices to New England.

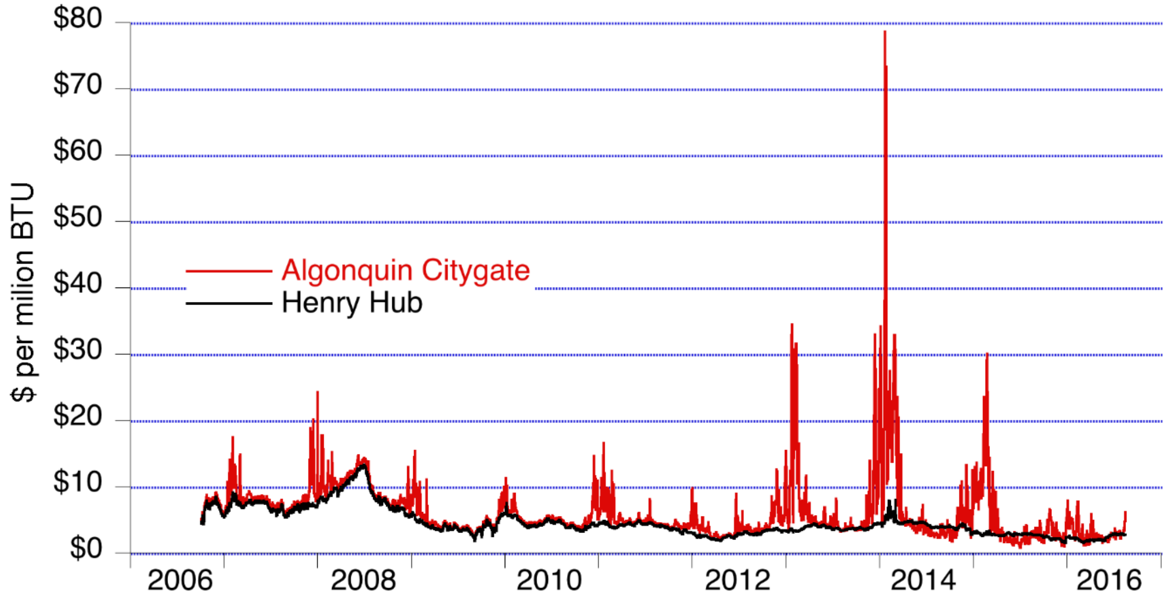

Figure 2.3. Historical daily natural gas spot price ($ per million BTU) at Henry Hub (black line, representing overall national delivery price) and Algonquin Citygate (red line, representing delivery prices in New England). Data from PointLogic Energy.[44]

Historically, Algonquin Citygate (AGT) prices have tended to spike during the winter months (Figure 2.3). Starting in the winter of 2012/13, there was a noteworthy increase in the magnitudes of the spikes with one plausible explanation being that, in the market structure of that time, the demand for natural gas exceeded supply during peak periods, causing price spikes. Between 1997 and 2015, the average number of heating degree days (HDD, a measure of average coldness) across New England during the heating season between October and April was 5,860.[45] The winter of 2012/13 was an average heating winter with 5,735 HDD. The increase in peak magnitude in the price of natural gas was more pronounced during the winter of 2013/14, which was colder than average (6,430 HDD), especially during the associated "polar vortex" event in January of 2014. However, the winter of 2014/15 was also colder than average with 6,467 HDD. While there were price spikes during the winter of 2014/15 (Figure 2.3) they were of smaller magnitude than those observed during the winter of 2013/14. The winter of 2015/16 was warmer than average with 5,244 HDD, and price volatility was significantly muted relative to historical price spike activity. Because the winter of 2014/15 was actually slightly colder than the winter of 2013/14, it implies that factors other than physical pipeline capacity are impacting natural gas prices in New England. One factor that could help explain the reduced price volatility is the Winter Reliability Program implemented by ISO New England to ensure power grid reliability.[46] In addition, a change to ISO New England's rules re-aligned the timing of the electric market so that generators had improved information and opportunity to schedule gas deliveries that better correlated to their expected power output. These changes demonstrate that "soft infrastructure" changes (i.e., changes that involve changes to rules, regulations, or policies) may be an effective tool for mitigating wholesale price impacts.

Another factor that served to reduce price spikes during the winters of 2014/15 and 2015/16 was the increase of LNG imports to the region (Table 2.3). LNG imports serve as an effective option for price spike mitigation given New England's significant LNG infrastructure. The import of LNG into Everett, Massachusetts had averaged at approximately 163 Bcf annually between 2003 and 2011. Imports peaked at 184 Bcf in 2007 and had been declining annually with a significant drop in 2013 to only 87 Bcf. LNG imports bottomed in 2014 at 28.8 Bcf and grew to 49.7 Bcf in 2015 and have increased to 56 Bcf between January and August of 2016.[47]

Table 2.3, LNG Imports into Everett, Massachusetts from 2003 to 2016.[48]

Year	LNG Imports (Bcf/yr)
2003	158.3
2004	173.8
2005	168.5
2006	176.1
2007	183.6
2008	165.3
2009	155.8
2010	149.0
2011	135.3
2012	86.6
2013	64.0
2014	28.8
2015	49.7
2016*	58.7

*2016 consists of deliveries from January to September

The natural gas market has been trading in a weekly range between $2.00 and $3.20 per million BTU from August through November 2016.[49] The low cost of natural gas coupled with the large anticipated domestic natural reserves are market-based factors driving the surge in new pipeline and LNG project development observed across the country.[50] LNG continues to be an important factor in the market. LNG prices have decreased dramatically over the past year going from the recent peak of $17.34 in April 2014 to a low of $3.21 in July of 2016, with current prices through November 2016 remaining at the pricing level observed in July.[51]

Concerns over the environmental and technological risks associated with fracked natural gas have led to several regions banning fracking. For example, both Germany and France have placed bans on fracking.[52] In the province of Newfoundland in Canada, fracking has been frozen since 2013. A report released in 2016 supported continuing the freeze, citing science, technological, and risk-assessment gaps.[53] Within the United States, New York passed a ban on fracking in 2014 and Maryland passed a ban on fracking in 2015.[54] In Pennsylvania (home of the Marcellus shale play) the Pennsylvania Medical Society called for a moratorium on fracking due to public health impacts from the practice in 2016.[55]

2.1.2 New England Natural Gas Markets

Overall total natural gas use has been growing in New England annually at approximately 1%. While demand for natural gas to power electrical generation plants has grown (Figure 2.4), New England is one of the few regions of the country that is also experiencing some growth in the residential and commercial natural gas base as New Englanders transition from older oil-based heating systems to high-efficiency natural gas heating systems.[56] Natural gas demand for heating cycles seasonally with the heating season; peak demand occurs during the winter months (Figure 2.5). Natural gas consumption has shown an overall increasing trend during the winter, however there has not been a consistent linear increase in demand. Instead, demand has varied due to complex interactions of weather, economic conditions, and energy prices. The summer (June, July, and August) of 2016 had an average daily demand in New England of 2.0 Bcf/d with a peak daily demand of 2.6 Bcf/d, while the winter (December, January, and February) of 2015/16 experienced an average daily demand of of 2.8 Bcf/d, with a daily peak of 4.1 Bcf/d.

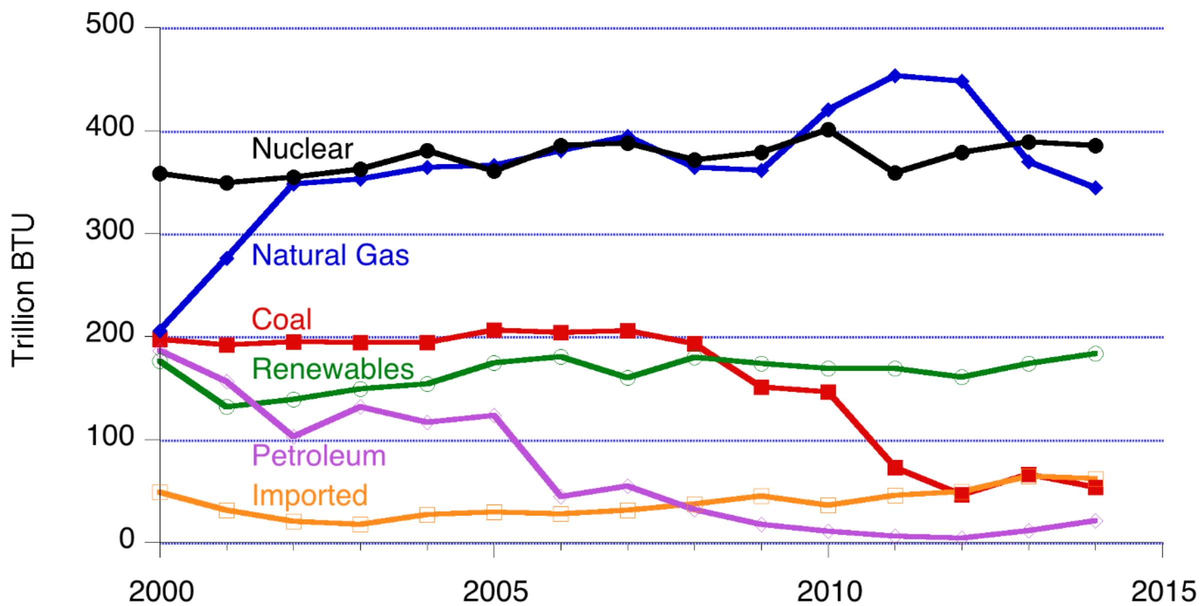

Figure 2.4. Trends in different energy sources used to produce electricity for all 6 New England States from 2000 to 2014.[57] This also includes electricity imported from Canada.

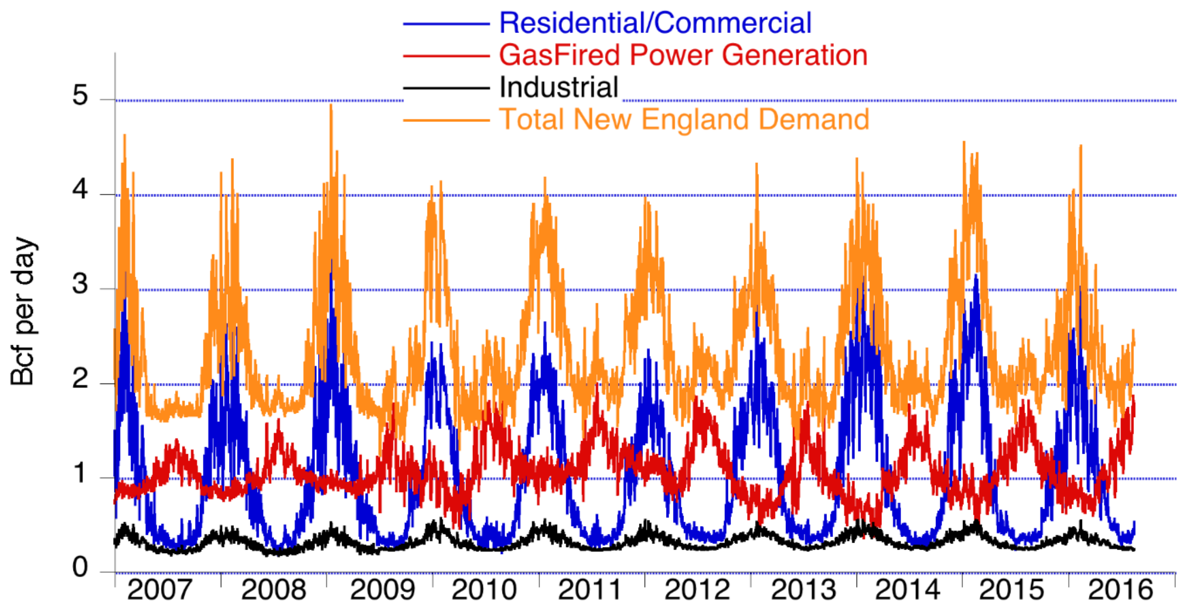

Figure 2.5. Daily natural gas consumption by sector in New England from 2007 to 2016 in Bcf/d.[58] Note the wintertime peaks in consumption by the residential/commercial (blue line) and industrial (black line) sectors, and summertime peaks in consumption by gas-fired power generators (red line). Total daily New England demand is shown in the orange line.

While there has been low but positive growth in the use of natural gas by the residential and commercial sectors (primarily for heating) the main factor driving the increased demand for natural gas as a fuel source in New England has been its increased use in regional power generation. The New England region's transition to natural gas for its electric power generation has been a rapid one; growing from 15% of generation in 2000 to 49% in 2015 (Table 2.4). This has occurred primarily through the displacement of oil and coal-based power generation (Figure 2.4). In 2000, coal and oil accounted for 40% of New England's power generation, but now only accounts for 6%. The same national trend of increased domestic supply, low natural gas prices, and emissions considerations that is increasing the national percentage of electricity generated by natural-gas-fired power generation is also resulting in an increase in the percentage of natural-gas-fired power generation in New England. New England is also influenced by regional environmental policies that are more stringent than current national policies, including the Regional Greenhouse Gas Initiative (RGGI), and strict federal air, water, and waste regulations for power generators. Natural gas is associated with lower combustion emissions over other forms of fossil-fuel-based generation, including coal and oil.[59]

Table 2.4. Comparison of the total electric energy production by fuel type in New England for the years 2000 and 2015.[60]

Fuel Type	2000	2015
Natural Gas	15%	49%
Nuclear	31%	30%
Hydro & Other Renewables	13%	15%
Coal	18%	4%
Oil	22%	2%
Pumped Storage	2%	1%

The primary delivery mechanisms for natural gas in New England are through pipelines (Table 2.5) and via ship for imported LNG transported to the region (Table 2.6). Natural gas is supplied through a network of 5 major feeder pipelines: Tennessee Gas, Algonquin Citygas Transmission, Maritimes and Northeast Iroquois Gas Transmission, and Portland Natural Gas Transmission. The pipelines carry gas produced domestically or in Canada. New England pipeline supply capability has been estimated to be 4.17 Bcf/d.[61]

There are 3 LNG terminals located in Massachusetts (Table 2.6). The Everett terminal is located on-shore in Everett, Massachusetts and the Neptune Deepwater port and Northwest Gateway Deepwater port are located off-shore from Gloucester, Massachusetts. The Canaport LNG facility in Canada can deliver gas from LNG through the Maritimes and Northeast pipeline. LNG is brought in to the New England region via ship and subsequently stored in above-ground tanks or re-gasified and injected into the pipeline system. The sum of the three Massachusetts LNG terminals indicates these facilities might be able to achieve a peak delivery capacity up to 2.4 Bcf/day and a sustained capacity of 1.7 Bcf/d. Other sources of natural gas include peak shaving above-ground storage that uses LNG capable of injecting 1.45 Bcf/d.[62]

Table 2.5. Estimates of New England Natural Gas Supply Capabilities. Data from ICF International.[63]

Natural Gas Source	Winter Supply Capability 2016-17 (Bcf/d)
Pipeline Capacity	4.17
Peak Shaving Capacity	1.45
Direct LNG Import Capacity*	0.72
Total	6.34

* LNG only includes Everett; it does not include LNG from Northeast Gateway or Neptune.

Table 2.6. LNG terminals serving New England. Data from LNG terminal websites and sum of stated capacity.[64]

Pipeline	Location	Year operations began	Cost (millions)	Stated Peak Capacity (Bcf/d)	Stated Sustained Capacity (Bcf/d)
Everett Marine Terminal	Boston Harbor	1971	N/A	1.0	0.7
Neptune Deepwater port	Off-shore, 10 miles from Gloucester	2010	$400	0.8	0.4
Northeast Gateway Deepwater port	Off-shore, 13 miles from Gloucester	2008	$350	0.6	0.6
Canaport (through Maritimes and Northeast Pipeline)	Saint John, New Brunswick, Canada	1970	N/A	1.2	1.2
Total (excluding Canaport)				2.4	1.7

An estimate of the total New England natural gas supply capability for the winter of 2016/17 is 6.34 Bcf/d when including pipeline capacity, peak shaving capacity, and LNG import capability.[65] The capacity value of 6.34 Bcf/d exceeds recent New England peak winter demand (compare Table 2.5 values to the peak demand of under 5 Bcf/d illustrated in Figure 2.4). A separate indicator of pipeline capacity is the sum of all the state inflow capacities obtained from the U.S. Energy Information Administration (U.S. EIA) for natural gas pipelines in New England estimated at 4.96 Bcf/d by US EIA. [66] [67] This represents an estimate of the total pipeline capacity available into New England. However, some pipeline in-flow capacity may not be fully available due to technical capacity constraints in the New England natural gas system. [68] The difference between the state in-flow pipeline capacity and the estimates of pipeline capacity obtained from the ICF study raises the possibility that pipeline capacity may be underutilized and/or that changes in New England internal gas pipeline infrastructure might allow for greater utilization of existing in-flow pipeline infrastructure. Eversource Energy (a New England based electric and natural gas utility) has also stated that another factor that may limit available capacity is "that imported LNG requires downstream pipeline capacity to be delivered on peak which is not available at the maximum regasification capacity … for each facility as the pipelines reach capacity from both the western and eastern ends of the system."[69]

Table 2.7. Natural gas pipeline state inflow capacity (Bcf/d). U.S. EIA[70] [71]

Pipeline	From	To	State Inflow Capacity (Bcf/d)
Tennessee Gas Pipeline Co	New York	Massachusetts	1.17
Iroquois Pipeline Co	New York	Connecticut	0.87
Algonquin Gas Trans Co	New York	Connecticut	1.36
Portland Gas Trans Co	Quebec	New Hampshire	0.22
Tennessee Gas Pipeline Co	New York	Connecticut	0.15
Maritimes/Northeast PL Co	New Brunswick	Maine	0.87
Algonquin Incremental Market project	New York	Connecticut	0.34
Total			4.96

New England gas generators typically do not contract for firm transportation services to obtain natural gas, instead they take what is left over. We argue that the primary cause of deliverability challenges stems for the manner in which natural gas is contracted in New England. The reason is that gas generators have stated they do not find it profitable to contract for access to gas under the current New England power system rules because firm gas transportation arrangements are structured as take-or-pay contracts.[72] Thus generators would be required to pay for transportation capacity whether or not they are operating. During most days of the year, generators are able to access gas and use transportation that would otherwise be surplus, and at far lower cost than contracting for firm transportation. While this contracting structure works for the vast majority of the year, during days of high demand this can result in periods where all gas is being used by other sources that have contracts for gas, including natural gas utilities for their customers and large industrial users. Such scarcity can result in increased spot natural gas and electricity prices when demand increases rapidly due to very cold periods during the winter (such as the winter of

2013/14) or when other major electricity generation stations go off-line (for example, nuclear power plants). Despite this, 75% of wholesale real-time electricity prices were set by natural-gas-fired generation in 2015.[73]

ISO New England has identified that one of the critical challenges facing New England is the retirement of coal, oil, and nuclear power generating stations. ISO New England reports that 4,200 megawatts (MW) of the region's non-gas capacity has retired recently or will be retiring in the near future, and that another 6,000 MW of coal and oil-fired generators are at risk of retirement.[74] The concern is that natural gas powered generation will need to bridge the gap left behind by the retirement of non-gas generation. However, many existing and newly proposed electrical generation plants are dual-fuel capable (primarily natural gas and oil), which adds a reliability factor through fuel diversity. There has been growth in dual-fuel facilities and one explanatory factor is the incentives provided by ISO New England for these types of plants.[75] Almost 40%, or 4,200 MW, of proposed generation in New England up to 2020 are dual-fired natural gas/oil plants.[76]

One program that has been implemented to enhance the near-term reliability of the New England power grid is the ISO New England Winter Reliability program. This program obtains commitments from oil-fired and dual-fuel generators to increase fuel oil inventory, from natural gas power plants to contract for LNG and from demand-response resources to reduce load upon request. This program has been instrumental in augmenting fuel security in the region primarily through increased oil inventories.[77] Generators are incentivized to secure fuel arrangements that offset any risks associated with unused fuel. This program has existed since the winter of 2013/14 and has been cost effective at meeting power grid reliability needs during the winter.[78] During the first winter of the program (2013/14), 2.7 million barrels of oil were burned at a cost of $45 million, which was less than 2% of total wholesale regional electricity costs. The program was determined by ISO New England to have had a positive impact on reliability. The cost for the 2015/16 winter was $35.9 million for 77 plants with oil capabilities, $2.58 million for 8 plants capable of contracting for LNG, and $210 thousand for 6 demand reduction resources and was determined to be non-eventful in relation to grid reliability.

Box 2: Proposed New Hampshire Natural Gas Pipeline: Access Northeast

Access Northeast is a $3.2 billion project sponsored by Spectra, National Grid, and Eversource. If built, it would enhance pipeline capacity by 0.9 Bcf/d through a combination of new above-ground LNG storage, new pipeline, and enhanced natural gas compressors on the pipeline. This project has been controversial for several reasons, including the funding mechanism of requiring electric rate payers to underwrite the financial risk associated with the project, the project footprint, and environmental objections to increased reliance on natural gas in the New England region. This relationship is further compounded by the mechanics of how subscribed capacity could be sold to generators. On August 17, 2016, the Massachusetts Supreme Court ruled that existing law did not allow electric utilities to directly contract for capacity using rate payer funds. On August 31, 2016, the Federal Energy Regulatory Committee (FERC) rejected a waiver that would have allowed electric utilities to directly participate in natural gas transactions, but would have allowed for a third party to manage natural gas transactions. On October 6, 2016, the New Hampshire Public Utility Commission rejected a proposal to fund pipeline expansion through electric rates.

2.2 Renewable Energy and Energy Efficiency

2.2.1 Global, National, and Regional Renewable Energy and Energy Efficiency Markets

Renewable energy and energy efficiency (also known as clean energy—see Box 3: Clean Energy for a definition) are growing rapidly worldwide. In 2015, total global energy investment was $1.8 trillion with clean energy accounting for $533 billion, which is 30% of total global energy spending.[79] Within the clean energy investment category, renewable energy accounted for $313 billion (17.4% of global energy spending) and energy efficiency accounted for $220 billion (12.2% of global energy spending).[80] Renewable energy investment was 6 times that experienced in 2004 and was twice the global investment in new coal and gas generation.[81] Clean energy is now the fastest growing global energy source and is projected by Bloomberg to surpass natural gas in terms of total annual production of electricity by 2027.[82] Historically, clean energy development has been strongest in developed nations. However, this has recently changed dramatically with emerging markets in China, India, and Brazil experiencing investment growth of 19% over 2014.[83] Clean energy also includes energy storage technologies. In 2015, 250 MW of utility-scale electricity storage was installed globally, up 56% from 2014. There were over 360 MW of energy storage projects announced worldwide in 2013 and 2014. Navigant Research forecasts the global energy storage market to grow from 538 MW in 2014 to 21 gigawatts (GW) by 2024, growing from $675 million in revenue in 2014 to $16 billion by 2024.[84]

Historically, the capital cost of renewable energy has been high relative to conventional fossil-fuel-based generation. However, the installed cost in the United States is rapidly approaching or exceeding the lower cost threshold of fossil fuels. For example, the cost of electricity production for wind power has decreased by 60% in the past 6 years and solar cost has fallen by over 80%.[85] The EIA calculates the levelized cost of electricity in per-kilowatt-hour cost (in real dollars) as a convenient summary measure of the overall competitiveness of different generating technologies. The levelized cost of electricity, including tax credits for natural gas combined cycle plants ranges from $57 to $65 per megawatt hour (MWH), compared to $38 to $70 per MWH for wind, and $50 to $99 per MWH for solar.[86]

The rapidly declining cost of clean energy, specifically solar renewables, has been the most significant market factor in the growth of clean energy development. However, it is not the only market trend impacting clean energy growth. Not only has the cost of clean energy been decreasing, its effectiveness and efficiency have been increasing through technological innovation.[87] Global regulations for air emissions control and greenhouse gas emission reductions are also driving the demand for clean energy. For example, Germany has set a goal of reducing emissions of heat-trapping gases by 40% by 2020 and 95% by 2050. Renewable energy sources are required to make up 80% of the countries electric power consumption by 2050.[88] Unstable fossil fuel energy prices have also been cited as another reason for clean energy market growth.[89] The role of renewable energy in a region's energy security has long been recognized.[90] Another anticipated regulatory driver of growth is the 2016 Paris Agreement.[91] This is an agreement within the United Nations Framework Convention on Climate Change that entered into force on 4 November 2016. The agreement mitigates global greenhouse gas emissions starting in 2020.

Globally, the construction of new energy generating capacity crossed a symbolic threshold in 2015. Not only was the 134 GW of new capacity 34% larger than the 100 GW installed in 2011, but 2015 was also the first year when the addition of new renewable capacity (not including large hydroelectric projects) was greater than new capacity from the combination of coal, gas, and nuclear plants and large hydroelectric projects (Table 2.8).

Table 2.8. New generating capacity added globally in 2015 by energy source.[92]

Energy Source	New Generating Capacity (GW)	Percent
Renewable w/o large hydro	13.5	53%
Coal	42	17%
Gas	40	16%
Large hydro	22	8%
Nuclear	15	6%

Wind and solar electricity capacity in the United States has experienced rapid growth in recent years.[93] In 2015, the United States produced just over 13% of its electricity from renewable sources,[94] with hydro and wind providing the majority of renewable energy (Table 2.9). The burning of natural gas and coal each provided 33% of the nation's electricity, and nuclear power accounted for 20%.

Table 2.9. Relative sources of renewable energy used to generate electricity in the United States in 2015.[95]

Energy Source	Percent
Hyrdo	46.3%
Wind	35.6%
Biomass waster	5.6%
Biomass wood	4.9%
Solar	4.6%
Geothermal	3.0%

Box 3: Clean Energy

While "clean energy" has a variety of definitions, it is commonly used to refer to energy sources that emit relatively low to no emissions of pollution when compared to forms of energy generation that are associated with relatively high pollution emissions.

The U.S. Environmental Protection Agency (EPA)'s definition of clean energy includes demand and supply side resources that meet energy demand with less pollution compared to energy created by conventional, fossil-based generation. Clean energy resources include energy efficiency, renewable energy, cogeneration, and clean distributed generation.

- *Energy efficiency* refers to the use of less energy to provide the same or improved level of service to the energy consumer in an economically efficient way. It is also called virtual supply.
- *Renewable energy* refers to energy generated partially or entirely from non-depleting energy sources for direct end use, or electricity generation either on-site or at a central station. The definition may vary across states, but it usually includes wind, solar, and geothermal energy. Some states also consider low impact or small hydro, biomass, biogas, and waste-to-energy to be renewable sources.
- *Combined heat and power or cogeneration* is a clean and efficient technology that improves the conversion efficiency of traditional energy systems by using waste heat from electricity generation to produce thermal energy for heating and cooling in commercial or industrial facilities.
- *Clean distributed generation* refers to small-scale renewable energy and combined heat and power (CHP) at the customer or end-use site.

For this report, we use the term clean energy for sources of energy production that are renewable (such as wind, solar, hydro, geothermal, and biomass) or are energy efficient (including LED lightbulbs, well-insulated buildings, and high-efficiency appliances and motors). While there have been arguments both for and against considering nuclear energy as clean, we take no position on nuclear energy as a clean energy source for the purpose of this report because: 1) there are no new proposals for nuclear power stations in New England; 2) Vermont Yankee Nuclear Power Plant was recently retired; and 3) the Pilgrim Nuclear Power station is expected to be retired in 2019.

Renewable energy markets surged in the United States in the first half of 2016 despite uncertainty over federal tax credits and a sluggish national economy.[96] As well as reaching record levels of investment, renewable capacity added in 2015 was the highest ever, with spending 3% higher than in 2011. The major customer-base of new clean energy installations is changing as well. Over half of all new national wind installations are through power-purchasing agreements signed by large companies, universities, and cities. Much of this demand is being driven by large organizations (including General Motors and Google) who collectively signed 2,074 MW of power-purchasing agreements in 2015.[97]

Solar photovoltaic (PV) continues to be a source of clean energy with significant growth potential. The average cost of installing solar has dropped to half its cost in 2010 (Figure 2.7) and a new solar system is being installed in the United States every 4 minutes.[98] In the first quarter (Q1) of 2014, 1.3 GW of solar PV was installed in the United States, which was 80% greater than Q1 in 2013, accounting for 3/4 of all new electric generating capacity in the United States. PV installations were forecast to reach 6.6 GW by 2014, nearly double the market size of 2012.[99] There are approximately 800,000 solar projects across the country and the United States is now the third largest consumer of solar energy in the world. While solar energy has been viewed as being accessible primarily by higher income households, the majority of recent growth in rooftop solar households in Arizona, California, and New Jersey are located in middle-class neighborhoods with median incomes between $30,000 and $50,000.[100] Installations in Massachusetts overall closely matched the distribution of income throughout the state (Figure 2.8).[101] A study by Yale University found that income was not a key factor in adoption, and that the largest factor influencing adoption was the presence of other solar installations in a neighborhood.[102]

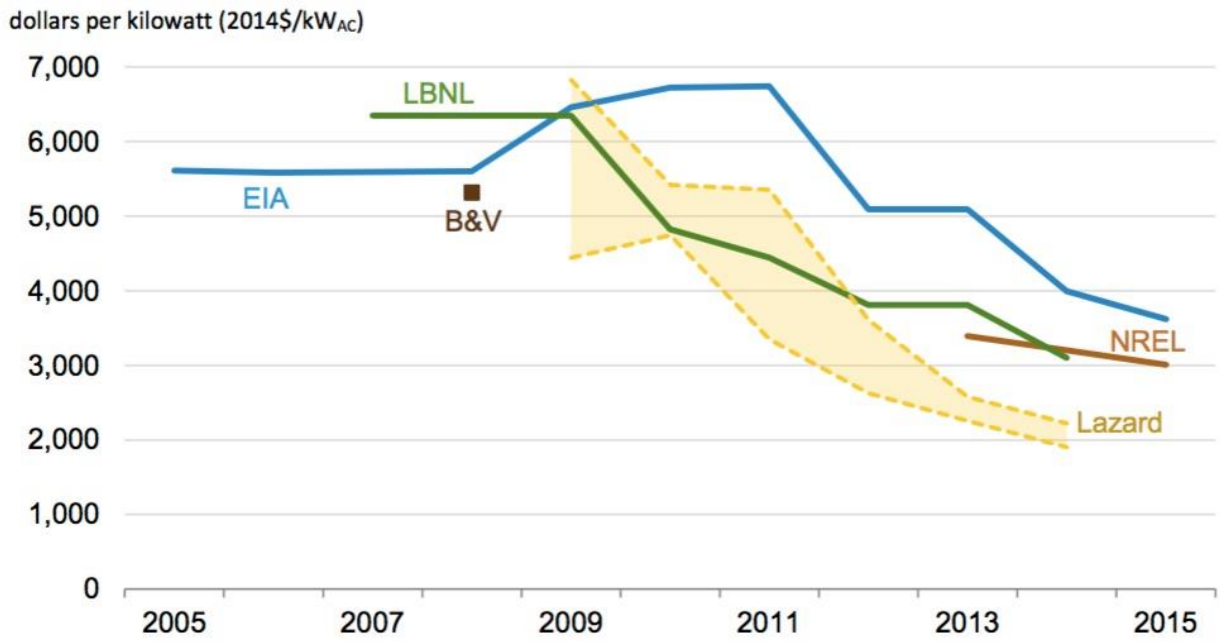

Figure 2.7. Annual estimated capital costs for utility-scale solar PV technologies from various agencies, 2005 to 2015. Figure from EIA.[103] Data from the EIA, Annual Energy Outlook (2003 to 2015); LBNL, Tracking the Sun 2014; LBNL, Utility-Scale Solar (2013 to 2014); Black & Veatch, Cost and Performance Data for Power Generation Technologies; NREL, Annual Technology Baseline 2014; Lazard, Levelized Cost of Energy (version 3–8).

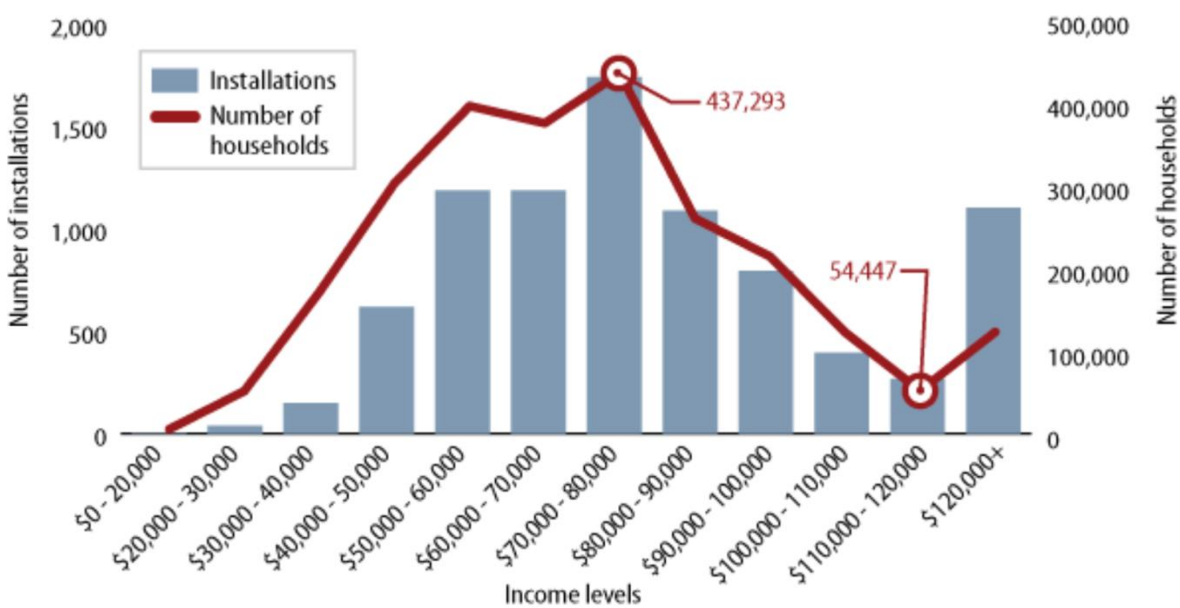

Figure 2.8. Solar installations and household income levels in Massachusetts. Figure from Hernandez (2014).

In recent years, energy efficiency has become increasingly recognized as the least-cost mechanism to meet a regional energy demand.[104] Energy efficiency is a conservation mechanism that has reduced the demand for energy, and can be viewed as "virtual supply," in that it can meet the same required services by displacing another energy source and therefore reduce the need for additional—and often more expensive—generating capacity.[105] Energy efficiency investment across the 29 member countries that make up the International Energy Agency—which includes the United States, Canada, Australia, and many European and Asian countries—has avoided approximately $6 trillion in energy costs since 1990, with $550 billion saved in 2014 alone.[106] Buildings account for more than 30% of global energy demand and received $90 billion in worldwide investment in energy efficiency capital projects in 2014. In the United States, utility companies spent $7.7 billion for energy-efficiency programs nationwide in 2015, an increase of 5.4% from 2014.[107]

In terms of public opinion, clean energy has received broad bipartisan support. Nationally, 4 out of 5 registered voters support accelerating the development of clean energy.[108] Evidence of this bipartisan support is seen in the Portman-Shaheen energy bill that was introduced in the U.S. Senate in 2015 by Senator Jeanne Shaheen (D-NH) and Senator Rob Portman (R-OH). The bill expands energy efficiency through a model building energy code, provides funding for energy efficiency programs in buildings, manufacturing, and federal government. The bill is projected to create 192,000 new jobs, save $16 billion annually in U.S. energy costs, and avoid 95 million tonnes of greenhouse gas emissions by 2030.[109] Energy efficiency preserves household income and is associated with other economic benefits, including job creation with fair wages and environmental benefits, which include reduced levels of pollution.[110]

Box 4: Pricing Carbon
by Julie Fox Gorte, PAX World Mutual Funds

Pricing carbon is shorthand for putting some sort of levy on emissions of heat-trapping gases, through, for example, a carbon tax, fee and dividend, or a cap-and-trade system. Many nations and a few states already do this; some have taxes and others have systems that establish carbon markets. These policy instruments share a common aim: to reallocate the costs imposed by unpriced or free emissions of heat-trapping gases from those who suffer the consequences of climate change to the emitters.

Pricing carbon does 3 things. The simplest is establishing accountability, placing the burden for environmental damage on those who create it. Environmental pollution of all types imposes costs on

Box 4 (continued): Pricing Carbon

society so long as it is free to the polluter. This polluter-pays principle underpins most environmental regulation. In the case of emissions of heat-trapping gases, the value at risk from climate change is staggering, from a mean present-value estimate of $4.2 trillion (roughly equivalent to the entire GDP of Japan), to the possibility of $43 trillion if we continue along a business-as-usual path, which leads to approximately 6^{0}C warming over the 21st century. The Stern Review, one of the most comprehensive efforts to date to examine the economics of climate change, estimates that inaction will penalize global GDP to the tune of 5% annually, "now and forever."

For individual companies, the risks of inaction may also be significant. Risky Business, an initiative to assess economic risks associated with climate change, noted that American businesses and consumers face escalating risks, particularly in damage to coastal property and infrastructure due to increasingly severe coastal storms and sea-level rise, declining labor productivity and human health due to extreme heat, shifting agricultural productivity, and rising electricity costs due to climate change. In the Northeast region, the major impact is expected from sea-level rise. Risky Business points out that 88% of the population in this region lives in coastal counties, and over two-thirds of the region's GDP is also concentrated in those counties. The cost of inaction in coastal Northeast communities from storm surge could increase 2-to-4-fold over the century. For businesses, this creates additional risks in addition to their own vulnerability to the physical changes made by climate change. The biggest emitters will face reputational risks, which McKinsey defines as "the probability of profitability loss following a business's activities or positions that the public considers harmful." Moreover, the greater the losses, the higher the probability of increased regulation of emissions, and businesses that are not prepared to assess and manage their carbon footprints could lose competitive ground.

Carbon pricing also creates market incentives for action on 2 fronts: 1) reducing emissions, and 2) producing alternatives to polluting activities. Experts agree that reducing emissions cannot be done without phasing out the use of fossil fuels (coal, oil, and gas); putting a tax or levy on burning these fuels would create economic incentives to reduce their use, or at least significantly improve the efficiency of their use.

Box 4 (continued): Pricing Carbon

Carbon prices also create economic stimuli to produce alternatives to the activities that result in the highest emissions, including renewable energy in producing electricity, electric power trains for motor vehicles, and stepped-up research and development in things like electricity storage, carbon sequestration, and other zero-emissions technologies.

Many governments already impose carbon prices around the world, and increasingly, businesses are as well. According to CDP, 437 companies were using an internal carbon price in 2015, and more than 500 companies were planning to use one by 2017. Experience with carbon taxes and pricing mechanisms in the Northeast, the Canadian province of British Columbia, and Sweden show that carbon levies can be imposed without harm to economic growth. Canada recently announced that the federal government had come to an agreement on a national carbon pricing plan.

2.2.2 New England and New Hampshire Renewable Energy and Energy Efficiency Markets

All of the New England states share natural gas and electric power infrastructure and therefore regional decisions on infrastructure have a direct impact on energy affordability and security for each individual New England state, including New Hampshire. As New England does not have any indigenous forms of fossil fuel, it depends upon a combination of locally produced energy from renewable resources (i.e., hydro, wood biomass, wind, solar, and geothermal), nuclear energy, and imported fossil fuels.

Electricity is generated from a variety of sources in New England (Figure 2.4). Since 2000, there has been a significant shift in the source of energy used to generate electricity in New England with an increase in the burning of natural gas displacing coal and oil-based power generation. The New England region's transition to natural gas for its electric power generation has been a rapid one, growing from 15% of generation in 2000 to 49% in 2015 (Table 2.4). Nuclear energy remains an important source of energy for New England (Figure 2.4, Table 2.4); however the proportion of electricity generated by nuclear energy will likely decrease in the future with the proposed retirement of the Pilgrim nuclear power plant in 2019.

In response to mounting scientific evidence that human activities are now the major driver of global climate change,[111] New England has been a leader in developing policies and practices to reduce the emission of heat-trapping gases.[112] This includes the New England Governors/Eastern Canadian Premiers (NEG/ECP) 2001 Climate Change Action Plan that called for a reduction in emission of heat-trapping gases of 75% to 85% below 2001 levels by 2050,[113] and the subsequent development of detailed state Climate Action Plans in all 6 New England states between 2004 and 2009.[114] In August of 2015, the NEG/ECP adopted an interim goal of reducing emission of heat-trapping gases by 35% to 45% below 1990 levels by 2030.[115]

Even as the combined state GDP for all six New England states has increased by 9.7% from 2005 - 2015 overall energy use and electricity consumption have declined 9.6% (Figure 2.9), clearly illustrating the separation of energy use from a growing economy over the past decade. Energy intensity (energy use divided by GDP) for 5 of the 6 New England states (the exception is Maine) is lower compared to the U.S average, and much lower for the southern New England states (Figure 2.10), demonstrating that New England consumes less energy per dollar of GDP compared to the U.S. average. Over the past decade, New England's average energy intensity has improved by 12.7%. This has been a factor in the corresponding decrease in the emissions of heat-trapping gases from energy use across New England. Emissions associated with energy use have decreased 15% from a high of 183 million tonnes of carbon dioxide equivalent (MMTCO2e) in 2003 to 156 MMTCO2e in 2014.[116] Emissions from the electric power sector have fallen 26% since 2003, from 42 to 31 MMTCO2e.

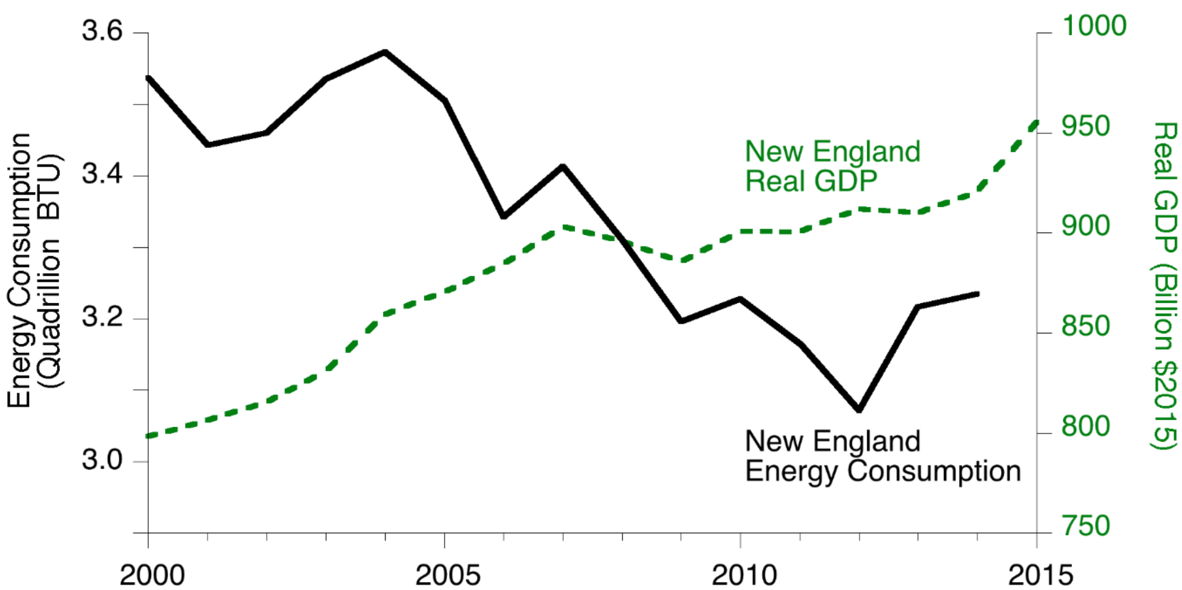

Figure 2.9. New England energy consumption[117] (black solid line) and real state GDP[118] for New England (dashed green line), 2000 – 2015.

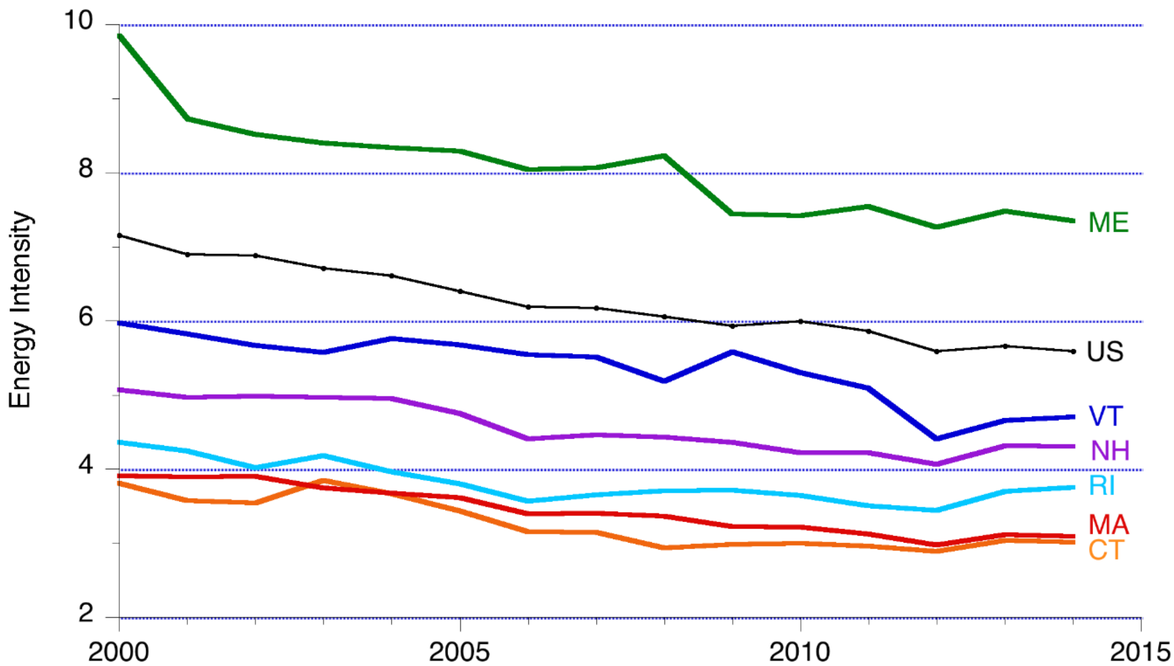

Figure 2.10. Energy intensity (energy use in trillion BTU divided by real state gross domestic product in billion $2015) for the New England states and the entire U.S. from 2000 – 2015. Lower values of energy intensity indicate a decrease in the amount of energy consumed per dollar of GDP.

A major driver in the New England region for clean energy has been public policies to improve energy efficiency (and thereby reduce overall energy use), increase the amount of renewable energy produced, and reduce the emissions of heat-trapping gases. State-based public policy programs in support of clean energy include renewable portfolio standards (RPS), net metering, and energy efficiency resource standards (EERS).[119] Two additional programs that have had a significant impact on clean energy in the New England region are the RGGI,[120] and the Massachusetts Global Warming Solutions Act.[121] Both have been factors in support of increased clean energy penetration in the New England marketplace.

From 2001 to 2014, the generation of electricity from renewable energy in New England increased from 132 to 183 trillion BTU (Figure 2.4), an increase of 39%. In 2014, renewable energy was used to generate over 17.5% of the total electricity generated by electric utilities in New England. Most of this renewable energy was provided by wood, hydroelectric power plants, and wind turbines (Table 2.10). In 2014, contributions from distributed solar PV in New England provided an additional 16.5 trillion BTUs of energy.[122]

Table 2.10. Renewable energy used by electric utilities to generate electricity in New England in 2014.[123] (Table does not include energy from distributed solar energy).

Energy Source	Trillion BTU	Percent
Wood	93.3	50.9%
Hydro	67.6	36.9%
Wind	19.2	10.5%
Solar/PV	3.3	1.8%
Total	183.4	

New England has also led the nation in improving the efficiency of energy use. The American Council for an Energy-Efficient Economy (ACEEE) produces an annual ranking of state policies for energy efficiency (Table 2.11). This index was developed to highlight differences in state energy efficiency activity through a well-grounded foundation comparing policy and program choices. The 6 policy areas evaluated are: 1) utility and public benefits programs and policies, 2) transportation policies, 3) building energy codes, 4) policies encouraging CHP systems, 5) state government–led initiatives around energy efficiency, and 6) appliance and equipment standards.[124]

Table 2.11. Partial list of ACEEE state scores in 2016.[125]

Rank	State	Utility & public benefits programs & policies (20 pts.)	Trans-portation policies (10 pts.)	Building energy codes (7 pts.)	CHP (4 pts.)	State gov't initiatives (7 pts.)	Appliance efficiency standards (2 pts.)	TOTAL SCORE (50 pts.)	Change in rank from 2015	Change in score from 2015
1	California	15	10	7	4	7	2	45	1	1.5
1	Massachusetts	19.5	8.5	7	4	6	0	45	0	1
3	Vermont	19	7	7	2	5	0	40	0	0.5
4	Rhode Island	20	6	5	3.5	5	0	39.5	0	3
5	Connecticut	14.5	6.5	5.5	2.5	6	0.5	35.5	1	0
5	New York	10.5	8.5	7	3.5	6	0	35.5	4	3
7	Oregon	11.5	8	6.5	2.5	5.5	1	35	-3	-1.5
8	Washington	10.5	8	7	2.5	6.5	0	34.5	0	1
9	Maryland	9.5	6.5	6.5	4	5.5	0	32	-2	-3
10	Minnesota	12.5	4	6	2.5	6	0	31	0	0
11	Maine	10.5	5.5	3	3	5	0	27	3	3.5
21	New Hampshire	9.5	1.5	4	1	3.5	0	19.5	-1	0
	New England Average	15.5	5.8	5.3	2.7	5.1	0.1	34.4		
	U.S. Average	5.9	3.6	4.4	1.3	3.9	0.1	19.2		

In 2016, the national average score was 19.2. Massachusetts tied California for the highest rank at a total score of 45 out of 50. Vermont, Rhode Island, and Connecticut were all within the top 5 for energy efficiency. Maine ranked 11th and NH ranked the lowest out of New England with a rank of 21 and a score of 19.5. While New Hampshire was in line with the overall nation for supportive energy efficiency policy, the state lags far behind the New England region's average score of 34.4.

In 2015, the energy efficiency programs in the New England states spent a total of $937 million on electric energy efficiency (Table 2.12), while the entire United States spent $6.7 billion on electric energy efficiency.[126] Massachusetts was the highest in New England by total spend at $558 million; Vermont had the highest per capita energy efficiency spend in New England at $86.90. In contrast, New Hampshire had both the lowest total spending and amount spent per capita out of the New England states with $26 million in total spend and a per capita spend of $19.20. New Hampshire's per capita spend was almost 80% less than that observed for Vermont.

Table 2.12. Electric efficiency program spending, 2015.[127]

State	Electric Efficiency Spending ($ millions)	$ per capita
Vermont	$54	$87
Massachusetts	$558	$82
Rhode Island	$83	$79
Connecticut	$174	$48
Maine	$43	$32
New Hampshire	$26	$19
New England	$937	
U.S. Median	$51	$16

The RGGI is the first mandatory "cap and trade" greenhouse gas emissions program in the United States. RGGI is a regional program that includes the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. This program places a limit or "cap" on the emissions of greenhouse gases from the electric power sector, and allowances are issued to the states who auction off the allowances. Power plants are required to acquire allowances or "trade" equivalent to their emission levels. The 2016 RGGI cap is 86.5 million short tons, and this declines 2.5% annually until 2020. The proceeds from the auctions are used to fund programs that benefit rate payers and, in New Hampshire, a portion of the proceeds are refunded to rate payers.

Through 2014, $1.37 billion in auction proceeds have been invested in energy efficiency, renewable energy, greenhouse gas reduction projects, and direct bill rebates.[128] Investment to date is expected to generate a return of $4.67 billion in lifetime energy bill savings to 4.6 million participating households and 21,400 businesses. In addition to energy cost savings, these investments are expected to support energy security by reducing 76.1 trillion BTU of fossil fuel use and 20.6 million MWH of electricity.

While the amount of energy used to generate electricity in New England shows a decrease over the past decade (from a peak of 1,261 trillion BTU in 2005 to 1,049 trillion BTU in 2014), winter peak demand has remained relatively flat since 2004 (except for the peak during the winter of 2013/14), and summer peak demand has remained relatively flat since 2006 (Figure 2.11). ISO New England has forecast winter peak demand under severe conditions to reduce by 0.3% annually from 22,026 MW in 2017 to 21,405 MW in 2025 when adjusted for passive demand reduction. ISO New England has also forecast a decline demand with New England's annual electricity use. They expect it to decline by 0.2% annually over the next decade, from 128,014 gigawatt-hours (GWH) in 2016 to 125,213 GWH in 2025 when adjusted for solar PV and passive demand reduction.[129]

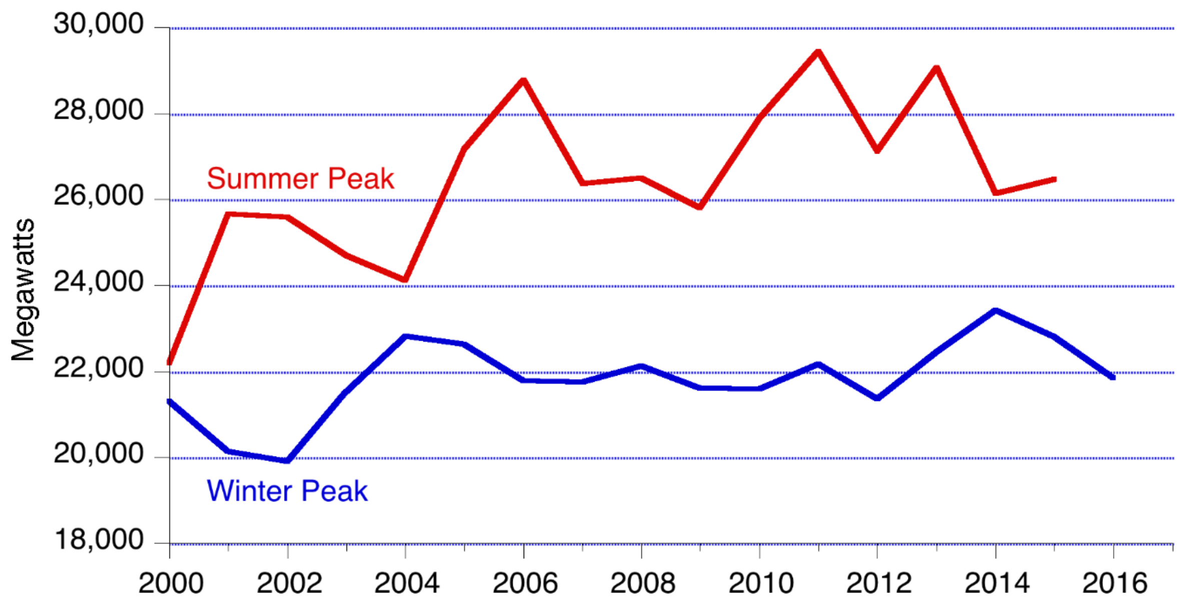

Figure 2.11. ISO New England reconstituted peak load during summer and winter from 2000 to 2016.[130]

Interconnection requests (requests made by companies to connect electric generation assets to the regional power grid) indicate how the generation mix may change over the next several years. Between 2016 and 2020, more than 11,000 MW of capacity have been proposed (Table 2.13), representing 35% of total existing generating capacity of 31,000 MW[131] . Note that Table 2.13 does not include interconnection requests for imported hydroelectric energy from Canada. Almost 60% of proposed generation is natural gas or dual fuel (natural gas and oil). Approximately 35% of proposed generation is wind, mostly in Maine. The remaining 8% is other generation types, which is predominantly renewable energy. Approximately 600 MW or two-thirds of the proposed other generation is solar. While not all projects will necessarily be constructed, is the interconnection requests still serve as a useful indicator of how new generation may impact the energy mix over time. From a reliability perspective, one report suggests that the current buildout plan evidenced by the interconnection requests is sufficient over the short term.[132]

Table 2.13. New England interconnection requests (in MW).[133]

Generation Type	2016	2017	2018	2019	2020	Total
Natural Gas	22	858	209	1,203	---	2,292
Natural Gas/Oil	20	14	1,008	1,176	1,973	4,191
Wind	503	345	1,633	1,544	---	4,025
Other	123	258	193	266	71	910
Total	668	1,474	3,043	4,189	2,044	11,418

Among plans to build new transmission lines to import hydropower from Quebec into New England include the Northern Pass project[134] designed to bring 1,090 MW through New Hampshire and the 1,000 MW New England Clean Power Link transmission line underneath Lake Champlain and into Vermont.[135] This analysis does not specifically focus on imported hydroelectric as that topic is beyond the scope of this research project. However, given that New Hampshire energy stakeholders have expressed interest in the issue of imported hydropower, we direct the reader to the Analysis Group report.[136] They found that under a 2,400 MW firm import scenario, the annual costs to implement were greater than the estimated cost savings by approximately $285 million per year—but they also found that this scenario did reduce greenhouse gas emissions by roughly 7 million tonnes per year.

The potential future expansion of nuclear power plants was also not considered in this study as there are currently no interconnection requests for new nuclear power plants through 2020. However, the 2014 retirement of the Vermont Yankee Nuclear Power Plant in Vernon, VT (nameplate capacity of 604 MW) and the proposed retirement of the Pilgrim Nuclear Power in Plymouth, MA (nameplate capacity of 685 MW) in 2019 has raised concerns regarding the reduction in carbon-free generating capacity across New England.[137]

2.3 New Hampshire in the Context of the New England Electrical System

Within the New England regional power grid in 2014, New Hampshire accounted for approximately 12% of the New England region's total electricity sales and 19% of total electric generation.[138] The single largest source of electricity generated in New Hampshire is the Seabrook Station nuclear power plant

(Figure 2.12). In terms of clean energy, renewable energy has been one rapid area of growth for New Hampshire. From 2001 to 2014, the generation of electricity from renewable energy in New Hampshire increased from 27 to 40 trillion BTUs (Figure 2.12), an increase of 48%. In 2014, renewable energy generated over 20% of the total electricity generated by electric utilities in New Hampshire; most of this renewable energy was generated by wood and hydroelectric power plants (Table 2.14). Distributed solar PV provided minor contributions at 0.3 trillion BTU.

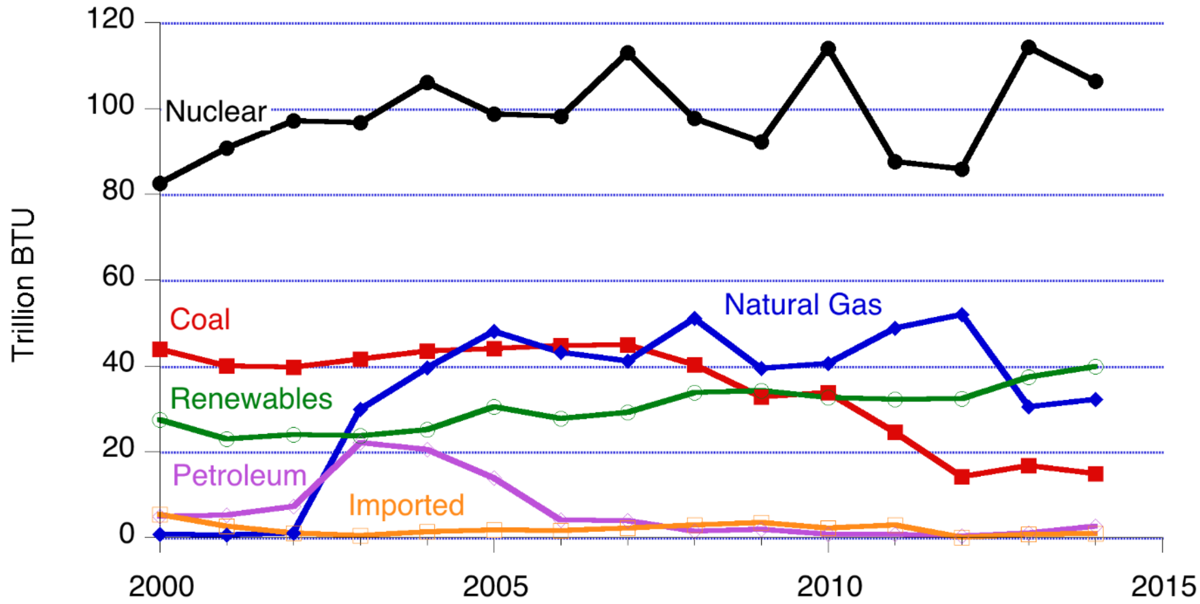

Figure 2.12. New Hampshire electric power generation from fossil fuels (coal, oil, natural gas), nuclear, and renewable sources of energy from 2000 to 2014.[139]

Table 2.14. Renewable energy used by electric utilities to generate electricity in New Hampshire [140](Data does not include distributed solar energy).

Energy Source	Trillion BTU	Percent
Wood	22.9	57.4%
Hydro	13.1	32.8%
Wind	3.9	9.8%
Solar/PV	0.0	0.0%
Total	39.9	

New Hampshire also invests in energy efficiency as a demand side resource, such as it has done through its participation in the RGGI and its CORE energy efficiency electric and gas utility programs. The utility efficiency programs are funded both through the System Benefits Charge (SBC), Forward Capacity Market Payments and through RGGI auction proceeds. SBC funds have been consistent for over a decade, while the RGGI funds have not.

Through 2014, New Hampshire received $76.3 million in RGGI proceeds. Energy efficiency spending accounted for $46.1 million, or 60%, of all spending. This was higher than the overall regional average where spending on energy efficiency was 44%. In New Hampshire, direct bill assistance accounted for $23.8 million, or 31%, of all spending. This was also higher than the overall regional average of 11%. The remaining 9% of expenditures went to administrative costs, future contractual commitments and a one-time diversion of $3.1 million to the state general fund in June 2010.

New Hampshire House Bill 1434 (effective June 11, 2008) created the state's Greenhouse Gas Emissions Reduction Fund (GHGERF), which was funded from allowance auction proceeds. The GHGERF offered a competitive grant program in 2009 and 2010. The majority of energy efficiency investment occurred through a series of grants awarded during this time period.[141] Through June 2012, $21.8 million had been paid out in 36 grants; cumulative energy savings due to projects that received GHGERF funds are expected to be $107.8 million through 2030 based on current energy prices.[142] For every dollar spent by the GHGERF program as of June 2012, the expected total return was almost $5 in energy savings.

In 2012, the New Hampshire legislature enacted HB 1490, which ended the GHGERF at the end of 2012, and replaced it with the Energy Efficiency Fund (EEF). The bill also placed a cap of $1 for each RGGI allowance with any leftover proceeds to be rebated back to rate payers. RGGI funds that were not rebated were directed to the CORE energy efficiency programs administered by the state's utilities. In 2013, the New Hampshire legislature enacted SB 123, which required 15% of EEF funds to go to the CORE low-income weatherization program, and up to $2 million of the remaining RGGI funds for CORE municipal and local government energy efficiency projects. SB 268, enacted in June 2014, directs that any RGGI proceeds remaining after the rebate to rate payers, the set-asides for the low-income CORE efficiency program, and municipal and local government energy efficiency projects be allocated "to all fuels, comprehensive energy efficiency programs administered by qualified parties which may include electric distribution companies as selected though a competitive bid process."[143]

In August 2016, the New Hampshire Public Utilities Commission approved an EERS to reduce energy use in the state.[144] An EERS establishes specific, long-term targets for energy savings that are met through utility customer energy efficiency programs. EERS programs have been found to be highly effective, with states that have them experiencing 3 times the level of energy savings as those states that do not.[145] The NH EERS takes effect in January 2018 and has established an initial 3year (2018 to 2020) goal of 3.1% electric savings and 2.25% natural gas savings relative to 2014 kilowatt hour (KWH) sales. The long-term goal is to capture all cost-effective energy efficiency savings. Given the experience of other states, this policy is expected to be a cost-effective way to meet New Hampshire's energy needs.

New Hampshire also has a statewide RPS. An RPS is a public policy designed to help influence the amount of electricity generated from renewable energy resources. RPS policies are meant to encourage the development of new renewable energy resources and to help maintain existing renewable energy sources. In 2007, the bill to create RSA 362-F passed, which enacted New Hampshire’s RPS through 4 distinct resource classes.[146] New Hampshire’s RPS calls for 24.8% of retail electricity sales to come from renewable energy resources by the year 2025. The Renewable Energy Fund (REF) was created by the New Hampshire RPS to directly support renewable energy initiatives. The REF is funded by Alternative Compliance Payments (ACPs) made by retail electric providers under the RPS when there is a market shortage of Renewable Energy Certificates at prices at or below the ACP. The REF revenues from ACPs fluctuate from year to year. The REF leverages non-state funding nearly 5:1 into projects for towns, schools, businesses and homes all around New Hampshire. This amounts to $108 million in non-state investment into New Hampshire, as of June 2016.[147]

Net metering is a billing arrangement that allows renewable energy generation systems under 1 MW to spin the electric meter backward when they are producing more electricity than is being used on-site (behind the meter), thereby exporting electricity to the electric grid. The customer receives a credit or payment for the net exported electricity. New Hampshire passed its current net metering law in 2010, which amended an earlier version of the law (RSA 362-A). New Hampshire passed Group Net Metering in 2013, which enables rate payers to participate in renewable energy projects that are not directly behind their own meter. Currently, approximately over 50 MW of generation are net metered across the state.[148]

Future growth in electricity consumption in New Hampshire is estimated to be modest based on the baseline ISO New England forecast for New Hampshire from 2014 to 2025 and on calculating an annual growth rate (Table 2.15). ISO New England demand forecast differs slightly from how NH utilities report consumption to the NH Public Utility Commission. In 2014, ISO New England reported NH electricity consumption of 11.7 million MWH, while the utilities reported 10.7 million MWH, or a 7.8% difference. This difference is explained by transmission losses that are included in the ISO New England figure but not the utilities. The annual growth rate from the ISO New England forecast was applied to the 2014 utility-based consumption figure from 2015 through 2025. The slight growth in the New Hampshire electricity demand forecast runs counter to the slight decline in the New England forecast; one explanatory factor is New Hampshire's low level of investment in energy-efficiency programs.

Table 2.15. ISO New Hampshire baseline forecast for electricity demand.[149]

Year	GWH	Annual Change
2017	10,859	0.7%
2018	10,934	0.7%
2019	11,003	0.6%
2020	11,040	0.3%
2021	11,081	0.4%
2022	11,128	0.4%
2023	11,180	0.5%
2024	11,232	0.5%
2025	11,281	0.4%

2.4 Price and Cost of Energy in New Hampshire

In 2014, New Hampshire spent $6.36 billion on energy, with energy expenditures increasing at a rate of 5.4% per year since 2010 (Table 2.16).[150] Of the total energy expenditures in 2014, approximately one out of every $4 ($1.67 billion) was spent to pay for electricity. The largest single expenditure was for fuel for transportation (motor gasoline and jet fuel; $2.45 billion, almost 40% of total) followed by oil and propane (used primarily for heating; $1.83 billion). The NH Office of Energy and Planning has estimated that almost 70 cents out of every dollar spent on energy immediately leaves the state to pay for imported energy.[151]

Table 2.16. Expenditures ($ billions) on energy in New Hampshire from 2010 to 2014.[152]

Energy Source	2010	2011	2012	2013	2014
Gasoline & jet fuel	$2.04	$2.55	$2.57	$2.54	$2.45
Oil & propane	$1.26	$1.58	$1.53	$1.63	$1.83
Retail electricity	$1.62	$1.60	$1.54	$1.58	$1.67
Natural gas	$0.27	$0.29	$0.26	$0.30	$0.35
Biomass	$0.04	$0.05	$0.05	$0.07	$0.07
Total	$5.23	$6.07	$5.95	$6.12	$6.36

In 2013, the average New Hampshire household paid $4,400 on household utilities, fuels, and public services (as defined by the U.S. Bureau of Labor and Statistics), $700 above the U.S. average of $3,700.[153] However, median family income in New Hampshire is also substantially higher than the national median at $80,600 versus $65,900.[154] When adjusted for income, NH residents pay a similar portion of their income to household energy-related expenses as the overall U.S. resident at 5.5% compared to 5.6%. The prices and costs in New Hampshire are similar to those across the other New England states. It can be challenging to benchmark energy bills across different regions of the country due to different climate conditions, different sources of energy, and different overall costs of living. While direct cost comparisons are not perfect, they do provide a reasonable basis for energy cost comparison. The evidence suggests that the overall percentage of income paid by NH residents towards household energy is similar to the United States average.

In 2015, New Hampshire ranked 5th highest in the United States for residential natural gas prices and 3rd highest in United States for commercial natural gas prices. The average NH residential gas price was $16.18 per thousand cubic feet and the average NH commercial natural gas rate was $13.63 per thousand cubic feet.[155] The residential price was 36% higher than the U.S. average ($10.38) and the commercial price was 42% higher than the U.S. average commercial retail natural gas price ($7.91).

In 2015, New Hampshire ranked 8th highest for electricity prices in the United States with an average retail electricity rate of 18.5 cents per KWH (Figure 2.13). This was 46% higher than the U.S. average retail electricity rate and was the fourth highest in New England. Connecticut (20.9 cents per KWH), Rhode Island (19.3 cents per KWH), and Massachusetts (19.8 cents per KWH) all paid higher electric rates than New Hampshire in 2015. Since at least1990, New Hampshire has consistently experienced electric rates that are about 50% higher than the U.S. average. Over this same time period, New England has also experienced the highest electricity rates of any region in the country. Figure 2.13 shows the New

Hampshire, overall New England, and overall U.S. average electricity rate when adjusted for inflation.[156] Current rates are within historical bounds when all rates are adjusted for inflation. However, in 2015, the average monthly NH residential electricity bill was $115, lower than the New England monthly average of $122 but very close to the U.S. monthly average $114.[157]

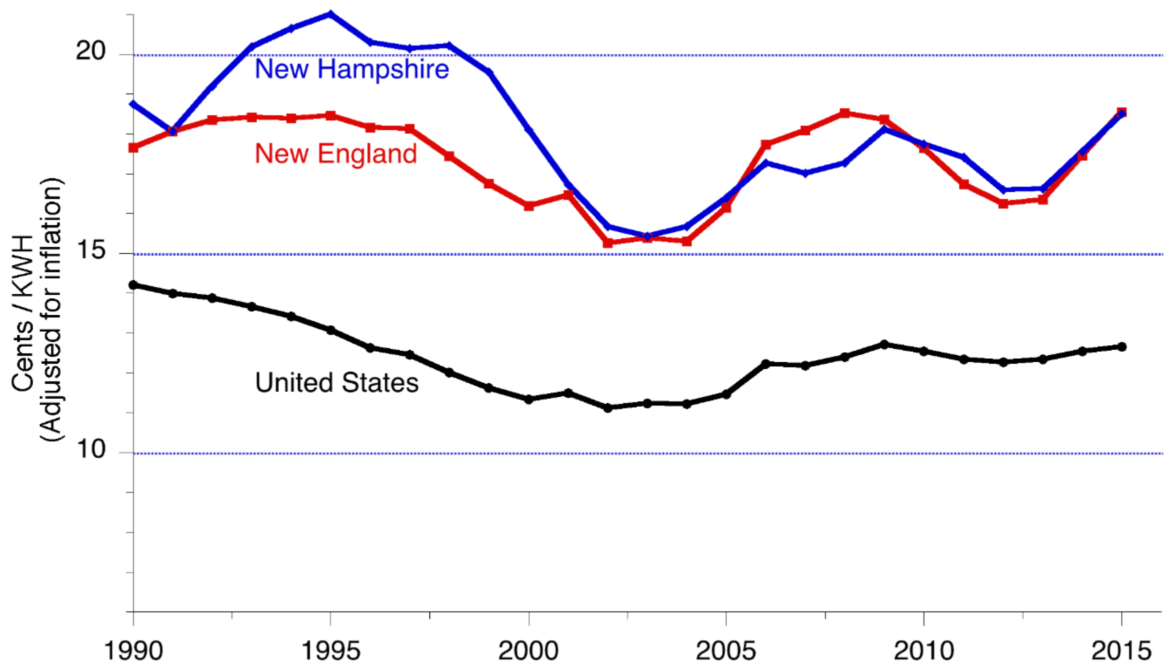

Figure 2.13. Residential electricity rates[158] (adjusted for inflation) in New Hampshire, New England, and the United States from 1990 to 2015.

Transmission costs are one of the variables that explain why New England's energy rates are higher. In comparison with other regions of the country, New England's transmission costs make up a larger share of electric costs.[159] Since 2002, New England has invested $12 billion in transmission projects, which is relatively higher than the overall country.[160]

The average monthly NH commercial electric utility bill in 2015 was $529, much lower than the New England monthly average of $786 and lower than the U.S. monthly average commercial bill of $671.[161] Also, overall NH business activity, as reflected by state GDP, was similar the national average. In 2014, the U.S. GDP per capita was $54,629 and the New Hampshire GDP was slightly less at $53,261, a difference of less than 2%.[162] This is also consistent with the overall trend of continuing growth of U.S. GDP while energy use is decreasing, primarily due to transition to more service-oriented, less energy intensive business sectors.[163]

We conclude that New Hampshire's current electric bills reflect a long-standing trend compared to national averages and overall do not disproportionately impact NH residents or businesses. However, there are some customers and industrial users of large quantities of electricity who are likely disproportionately impacted by higher electricity rates, which could negatively impact their household finances or business profits.

While the average electric bill in New Hampshire is lower than the overall national average despite having higher prices for electricity, there are opportunities to further reduce the overall cost of electricity. This is specifically important for electricity customers that have higher exposure to New Hampshire's higher electricity prices. This includes commercial and industrial electric users with high electricity demand and low-income residential households that pay a greater portion of their income for energy. The costs to New Hampshire for supporting low-income electricity assistance are not insignificant. In 2015, approximately 33,000 low-income NH households participated in the Electric Assistance Program. The annual cost of this program is approximately $16 million and is funded through a systems benefit surcharge paid by all NH residents.

The high price of energy faced by New Hampshire is a result of several factors, including a generation mix that is cleaner but has a higher direct cost than the less expensive and dirtier power production that characterizes the national average.[164] New Hampshire and the rest of New England also have higher transmission and distribution costs that have been steadily increasing and are becoming a larger portion of the overall electric bill.[165] Historical investment decisions, high population density, and the region's lack of indigenous fuel sources and location at the "end of the pipeline" for the transport of fossil fuel contribute to higher prices. However, New England has adapted to being a higher cost region. This is due in part to the industry mix that has adapted to higher energy costs in the region through energy efficiency and other energy management investments.

Box 5: The Polar Vortex of 2013/14

In early January 2014, an extreme arctic cold front descended across the United States and Canada. Temperatures fell dramatically across the nation, resulting in business and school closures and large number of flight cancellations. This event strained that national power system and several regions experienced forced service outages. On January 6 and 7, record high electrical demand occurred in the Midwest, South, Central, and Eastern regions of the nation. This, coupled with high heating demand, increased the demand for natural gas nationally. Natural gas prices spiked in New England (see Algonquin Citygate natural gas spot price, Figure 2.3) as it competed nationally for natural gas to meet heating and electrical demand. The price spikes associated with this event have been frequently cited by industry as justification for new pipeline expansion in the Northeast. However, not only did the ISO New England power grid provide sufficient electricity to New England consumer during this time period, ISO New England actually assisted the PJM (Mid-Atlantic) energy marketplace by dispatching additional generation units in New England. Subsequent analysis of the challenges and commercial conditions experienced during the 2013/14 polar vortex point towards market coordination problems as a primary cause for the high prices experienced at that time.

Box 6: The Price Spike on August 11, 2016

As daytime temperatures soared above 90°F, a lighting strike on August 11, 2016 caused a significant capacity deficiency (ISO Operating Procedure No. 4: Action During a Capacity Deficiency) on the New England power grid. This caused the 918-MW Millstone 2 nuclear reactor in Connecticut nuclear power plant to go off-line. Real-time wholesale power prices experienced spikes to almost $3.00 per KWH compared to a more typical value of $0.06 per KWH. At the time of the event, there was only between 100 to 200 MW of wind electrical energy production to help offset the loss of the nuclear generation facility. As a result, 65% of the region's power demand was met through natural gas.

Box 7: Stranded Costs from Mercury Scrubbers at Merrimack Station, Bow, New Hampshire

In March 2012, the 440-MW Merrimack Station coal power plant (in Bow, New Hampshire) completed the installation of a scrubber system to remove mercury from its emissions created during power generation. The total cost of the scrubbers was $409 million. This was the result of legislation passed to approve the addition of the scrubbers. However, changes in energy market conditions, in large part due to relatively low natural gas prices, has caused coal-based generation in New England to run less frequently. In 2015, a compromise was made with the NH legislature to allow Eversource, the plant's owner, to sell the plant and recover the investment in the scrubbers through stranded costs charge to rate payers. This resulted in a 0.4 cent per KWH surcharge being added to all New Hampshire electricity rate payer electric bills. The estimated sale price of Merrimack Station is $10 million.

Box 8: Aligning Growth with Positive Environmental Impact

Economists have long legitimized the idea that to provide societal or environmental benefits a company must take on added cost which will necessarily temper their economic success. By comparison, new ideas of “shared value” suggest that companies can enhance their competitiveness in the marketplace, and therefore continuing to maximize shareholder returns, while simultaneously making a positive impact on social and environmental issues.

Perhaps one of the clearest examples of this comes from Nashua, NH based Worthen Industries, who are making significant investments in renewable energy, including the construction of what will be the largest rooftop array in the State of NH when completed at the end of January 2017.

Worthen Industries innovatively develops and manufactures “world class” adhesives and coatings; coated flexible webs and extruded films to the highest quality standards for selected markets worldwide. Competing in global markets in a high specialized field requires the company to continually assess their productivity and efficiency relative to competitors.

In 2016 Worthen Industries designed and constructed solar photo-voltaic installations at two of their manufacturing facilities in the Northeast. Together, these two systems will offset a significant percentage of facility energy usage in this relatively energy-intensive business. The energy production will not only offset carbon emissions of natural gas energy generation and respond to increasing interest from their customer base in procuring from firms with strong environmental stewardship, but it will provide Worthen with a strategic hedge on energy pricing, and provide long term reliability and price stability of one of the company’s key sources of cost.

	Clinton, MA Solar PV	Nashua, NH Solar PV (Cellu Drive)
Technical Details	System capacity of 199 KW on a 20,000 sq ft roof area producing 245 MWh annually	• 1 Mw installed capacity • 2740 panel solar PV project • 80,000 sq ft array will produce approximately 1,222,000 kWh annually
Percentage of Annual Operational Electricity Requirements (at location)	• 80%	• 50%
Full Burdened Payback	• Less than 4 years	• Less than 5 yrs

Worthen's renewable energy projects are anticipated to provide a return on investment in under 5 years. The company effectively utilized State and Federal incentives to make these projects possible. Worthen's Clinton, MA facility was their first project because, in part, the Massachusetts Solar Renewable Energy Credits (SRECs) were highly attractive. Without State and Federal incentives, the projects would have had a longer payback period, emphasizing the importance of public policy and renewable energy investments to accelerate the adoption of new, cleaner technology.

For Worthen's leaders, it would have been fiscally irresponsible to not follow this course. While Worthen's leaders have a strong commitment to practicing sound environmental stewardship, promoting the efficient use of energy and natural resources, and minimizing waste, their commitment is driven as much from an understanding that these practices are linked to their competitive advantage with customers and the financial returns, as much as their personal environmental values.

3. NEW HAMPSHIRE'S FUTURE ENERGY CHOICES: NATURAL GAS

New Hampshire needs to assess the opportunities and challenges presented by our future energy needs. The choices New Hampshire makes will affect the affordability and reliability of electricity in the state. As reviewed in Section 2, there are 2 global energy trends driving New Hampshire's and New England's energy markets: the rapid growth in the use of natural gas for electric power generation and the rapid growth in renewable energy and energy efficiency. To help inform NH policymakers and energy stakeholders regarding the economic impacts of different energy policy options, several key studies focused on the addition of new intrastate pipelines were reviewed (Table 3.1) and our findings summarized in this section. A similar review of clean energy studies was performed (Table 4.1), with findings summarized in Section 4. In addition, NH stakeholders have explicitly expressed an interest in a direct comparison of the economic impact of investments in new natural gas pipeline infrastructure versus investments in renewable energy and energy efficiency. The result of our comparative analysis is provided in Section 5.

3.1 Summary of Interstate Natural Gas Pipeline Expansion Studies

A suite of relatively recent studies have been performed by energy consulting firms funded by different entities (Table 3.1) to estimate the economic impacts of adding new pipeline infrastructure in New England. Each particular study employed different methodologies, data, geographic regions within New England, and assumptions, and also considered different forecast periods and different approaches to identify economic costs, savings, and associated benefits.

Here, we emphasize common themes identified in the suite of studies that serve to inform stakeholders and policy makers regarding potential economic impacts that may flow from the addition of new pipeline infrastructure in New England. The Annotated Bibliography included at the end of this report provides a brief summary of the key findings of each individual study reviewed in this section.

In this section, key takeaway points are synthesized; the reader is directed to the underlying study for additional information on the assumptions, analysis, and specific conclusions.

Table 3.1. Recent New England interstate natural gas pipeline expansion studies and key findings.

Title:	Assessing Natural Gas Supply Options for New England and their Impacts on Natural Gas and Electricity Prices
Author & Date:	Competitive Energy Services, LLC; February 2014
Sponsor:	The Industrial Energy Consumer Group
Key Findings:	The addition of 1 Bcf/d of new pipeline capacity will result in $1.9 billion in annual electricity wholesale savings in New England.
Title:	New England Cost Savings Associated with New Natural Gas Supply and Infrastructure
Author & Date:	Concentric Energy Advisors; May 2012
Sponsor:	Spectra Energy Corporation
Key Findings:	The reduction in wholesale energy cost in New England was estimated to range from approximately $240 to $310 million with up to an additional 1.5 Bcf/d of new interstate pipeline.
Title:	Natural Gas Infrastructure and Electric Generation: Proposed Solutions for New England
Author & Date:	Black & Veatch; August 2013
Sponsor:	New England States Committee on Electricity (NESCOE)
Key Findings:	New Interstate pipeline capacity would provide $118 million in economic benefit for consumers with an additional 1.2 Bcf/d. No long-term infrastructure solutions are needed under a low demand scenario, and the outcome of not building any infrastructure under this scenario yields a positive net benefit of $411 million compared to normal demand scenario.
Title:	Assessment of New England's Natural Gas Pipeline Capacity to Satisfy Short and Near-Term Power Generation Needs: Phase II
Author & Date:	ICF International; November 2014
Sponsor:	ISO New England Inc.
Key Findings:	Natural gas is expected to remain constrained in New England by 1.1 Bcf/d through 2020.
Title:	Maine Public Utilities Commission Review of Natural Gas Capacity Options
Author & Date:	Sussex Economic Advisors; February 2014
Sponsor:	Maine Public Utility Commission
Key Findings:	New interstate pipeline capacity would provide $18 million in annual net savings for New England consumers with an additional 1.0 Bcf/d.

Title:	Power System Reliability in New England, Meeting Electric Resource Needs in an Era of Growing Dependence on Natural Gas
Author & Date:	PJ Hibbard and CP Aubuchon, Analysis Group, Inc.; November 2015
Sponsor:	Massachusetts Office of the Attorney General
Key Findings:	New interstate pipeline capacity would provide $61 million in annual net savings for New England consumers with an additional 0.4 Bcf/d. Other alternatives evaluated were LNG contracts for an annual savings of $27 million and energy efficiency for an annual savings of $146 million.
Title:	Access Northeast Project - Reliability Benefits and Energy Cost Savings to New England
Author & Date:	ICF International; February 2015
Sponsor:	Eversource Energy and Spectra Energy
Key Findings:	New interstate pipeline capacity would provide $780 million to $1.2 billion in annual electric savings for New England consumers with an additional 0.9 Bcf/d.
Title:	Winter Reliability Analysis of New England Energy Markets
Author & Date:	Energyzt Advisors, LLC; October 2014
Sponsor:	New England Power Generators Association
Key Findings:	New England does not have near-term power grid reliability issues, and therefore new pipeline capacity is not necessary.
Title:	The Economic Impacts of Failing to Build Energy Infrastructure in New England
Author & Date:	LaCapra Associates, Inc. & Economic Development Research Group; August 2015
Sponsor:	New England Coalition for Affordable Energy
Key Findings:	The region will pay $5.4 billion in higher energy costs between 2016 and 2020 due to inadequate natural gas infrastructure relative to a scenario, including 1.7 Bcf/d of new pipeline capacity.

Two common topics addressed in the studies were: 1) power system reliability, and 2) wholesale natural gas prices. Analysis of power system reliability considers whether existing natural gas delivery infrastructure limitations are expected to lead to grid failure (including forced blackouts) under certain conditions and assumptions. Analysis of wholesale natural gas prices considers the context of additional pipeline infrastructure as an intervention mechanism to alter the price of wholesale natural gas delivered to the New England marketplace. These studies also considered different scenarios involving the level of natural gas demand, infrastructure outages, and fuel type availability (including oil and LNG) to draw conclusions on reliability and/or wholesale natural gas prices.

The majority of the studies focused on the impact of increased pipeline infrastructure on wholesale natural gas prices; short-term grid system reliability was less of a focus. However, the 2015 La Capra and Economic Development report (2015, p.4) stated “Indeed, the region may be able to continue over the short term with the current buildout from a reliability perspective…” Energyzt Advisors (2014, p.4) reached a similar conclusion stating “New England has adequate energy infrastructure to meet its winter reliability objectives now and into the near future.” ICF International (2014) projects that power plant retirements under nominal demand would increase the demand for natural gas by approximately 0.5 Bcf/d by 2020. However they did not indicate that this increased demand would negatively impact grid reliability. Black & Veatch (2013) found under a base case that demand growth for natural gas could be problematic by 2022, but that infrastructure solutions were not warranted under a lower demand scenario. Analysis Group (2015, p. iii) found that “Under the base case analysis, power system reliability can and will be maintained over time, with or without additional new interstate natural gas pipeline capacity.” Analysis Group (2015) did however find that under a stressed system scenario, power system reliability issues could emerge by the winter of 2024/25.

While the polar vortex event of the winter of 2013/14 has been cited as evidence of the need for further investment in natural gas infrastructure,[166] the event also demonstrates the resiliency of the New England power grid in severe operating conditions. The event impacted the Midwest, South Central and East Coast regions of the United States. The demand for natural gas was at record or near record levels throughout this time period at many of the nation’s reliability coordinators, including PJM Interconnection,[167] and Tennessee Valley Authority. Not only did the ISO New England power grid not fail during this time period, ISO New England actually assisted the PJM marketplace by dispatching additional generation units in New England.[168]

The overall consensus was that, under baseline New England demand growth scenarios, grid reliability issues are not expected in the near future, and none of the studies reviewed stated even the possibility of reliability issues emerging until after 2021. However, several studies found that under extreme scenarios of significant but rare power grid system events (such as a nuclear plant outage—see Box 6: The Price Spike on August 11, 2016) combined with worst case winter weather conditions or significantly higher than expected reliance on natural gas, power grid reliability issues could potentially emerge.

A common theme that emerged across the studies is that with an unchecked increase in natural gas demand, there will be a need for new natural gas capacity, and this would result in New England having significantly higher natural gas wholesale and electricity prices relative to the overall nation. The common analysis supporting this conclusion is to compare the historical price spread between the

Algonquin Citygate spot natural gas price (representing delivery prices to New England) in comparison to either the Texas Eastern M-3 (representing delivery price immediate to the Appalachian Basin) and/or the Henry Hub (representing the overall national delivery price) spot natural gas price.

A variety of statistical techniques were employed across these studies to demonstrate a historical relationship between an elevated Algonquin Citygate price spread during time periods of natural gas pipeline constraints. One consistent relationship that emerged was a positive correlation between Algonquin Citygate prices and regional wholesale electricity prices; when New England natural gas prices were high or spiked, a similar elevation or spike in New England wholesale electricity prices was more likely to occur. The widely used explanation was that, because of New England's high reliance on natural gas for power generation and its high frequency as the marginal price setter for electricity prices, an increase in wholesale natural gas increased natural gas plant operating costs. Therefore, natural gas power plants generated higher bids to deliver electricity into the regional power grid during periods of elevated natural gas prices, which increased the overall wholesale electric power cost for the region. In general, these elevated prices have been experienced during a limited number of "needle peak" days during periods of high natural demand due to cold weather.

Another consistent relationship identified was an increasing frequency from the late 2000s through 2014 in the number of days when the price spread between Algonquin Citygate and other baseline price points was elevated. This means that the number of days in which natural gas prices were higher in New England relative to other areas of the country has been showing an increasing trend. A conclusion drawn across several studies is that the market is signaling (through prices) that some form of capacity addition is necessary to prevent the trend of increased frequency of days with elevated natural gas prices in New England.

The range of new pipeline infrastructure that has been evaluated in studies ranges between 0.3 Bcf/d and 2.0 Bcf/d with a range of 1.2 to 1.5 Bcf/d representing the "typical" value for the amount of new pipeline infrastructure required to reduce the price spread between the Algonquin Citygate and other common reference natural gas prices. Reported savings varied. ICF International (2015) projected ongoing annual wholesale electric savings between $780 million and $1.2 billion for approximately an additional 1 Bcf/d. This appears representative of the overall range for other studies that have only examined the gross wholesale savings (meaning that they did not include the annualized costs associated with new pipeline infrastructure). Studies that included net savings have ranged from approximately $20 to $60 million annually.

Some studies also considered other scenarios for comparison. Black & Veatch (2012) and Analysis Group (2015) specifically considered investment in energy efficiency and demand reduction in lieu of new natural gas pipeline additions. Black & Veatch (2012) calculated a total net benefit of $497 million in a “negative demand growth” scenario of increased renewable energy and energy efficiency compared to a net benefit of $118 million for 1.2 Bcf/d of increased new pipeline capacity. Analysis Group (2015) found a similar relationship with energy efficiency/demand reduction having a net rate payer impact of $146 million compared to $61 million for up to 0.4 Bcf/d in new pipeline capacity.

Many of the studies either directly or indirectly included analysis of LNG infrastructure. The results for these analyses were more mixed, ranging from projections that LNG would not be economically viable to meet future natural gas needs in New England to projections that LNG would economically meet any incremental demand for natural gas. For example, ICF International (2015) stated that LNG will compete with the global market for spot LNG cargos and noted that few spot cargos were delivered during the winter of 2013/14; therefore they assumed low to no future LNG terminal sendout. In contrast, Analysis Group (2015) projected a potential enhanced role for LNG through contracting, resulting in net ongoing annual savings of $27 million.

3.2 Analysis of Interstate Natural Gas Pipeline Expansion Studies

3.2.1 Overview

New Hampshire is in the position of trying to understand a complex topic with potentially high costs for rate payers depending upon the choices made (for an example of a previous misstep in NH energy policy with high cost impacts, see Box 7: Stranded Costs from Mercury Scrubbers at Merrimack Station, Bow, New Hampshire). Proponents of expanding pipeline infrastructure include utility companies, energy consulting firms, ISO New England, industry trade groups, and large energy users. They highlight pipeline and transmission constraints as the root cause of New England’s and New Hampshire’s high energy costs. They further argue that continued inaction on pipeline infrastructure will result in energy costs that will only increase and may reduce the reliability of the regional power grid.

On the other hand, opponents of new pipeline infrastructure (which include New England power generators, LNG providers, environmental groups and citizen action groups) question the calls for new infrastructure and the use of rate payer funds to pay for pipeline expansion. A specific area of concern is that the high fixed-cost of new infrastructure may not provide an economic benefit if the projected rise in natural gas demand does not occur, or if wholesale cost savings do not materialize. Instead, opponents are advocating other approaches to meet energy demand, especially during the winter months. These alternatives include better use of existing infrastructure in New England, and rate payer subsidized expansion of energy efficiency and renewable energy development programs. In addition, regulatory bodies have already taken steps to implement "soft" infrastructure, or policy and rule changes, to help mitigate cost and reliability issues with natural gas, such as the ISO New England Winter Reliability program. This program provides financial incentives for generators to maintain on-site fuel oil reserves and for demand conservation.

The Analysis Group (2015) report analyzed the net benefits of pipeline expansion and compared those benefits with alternative options. Their study followed a transparent methodology and makes assumptions that are based on the current state of the energy marketplace, in contrast to some of the dated economic assumptions of previous studies. Their study also covered a wide range of scenarios using a consistent methodology to analyze each scenario. This provides a sound basis for comparing the net benefits of various policy options. Table 3.2 provides a summary of findings of 3 of the scenarios for New England from their study. These scenarios are ones that have generated high interest from New Hampshire energy stakeholders: 1) new pipeline expansion, 2) contract for LNG, and 3) energy efficiency.

Table 3.2. Summary of potential energy choices for New England. Data from Analysis Group (2015).[169]

Policy Choice	Total Annual Cost (Millions)	Total Annual Savings (Millions)	Net Annual Savings (Millions)	Return on Investment	Minimum Time Commitment (Years)	Annual Emissions Change (million tonnes)	Worst Case Dollars at Risk (Millions)
Contract for LNG (3 Bcf)	$18	$45	$27	150%	5	-0.03	$90
Intrastate pipeline expansion (0.42 Bcf/d)	$66	$127	$61	92%	30	0.08	$1,980
Energy efficiency and demand reduction	$101	$247	$146	145%	1	-1.86	$101

The new pipeline scenario assumed an expansion of 0.3 Bcf/d in 2024 and an additional 0.12 Bcf/d in 2028. The total capital cost of the 0.3 Bcf/d expansion was estimated to be $788 million with cost depreciated over a 30 year period. The capital cost for the 0.12 Bcf/d expansion is expected to scale linearly by size. The contract for LNG capacity assumed a 5 year contract period in increments of 3 Bcf. Investment in energy efficiency was assumed to result in 1,300 MW of peak winter energy efficiency and

1,100 MW of demand response by 2030. This investment would result in 950,000 MWH of energy efficiency installed annually at an all-in cost of $0.067 per KWH.

All 3 of these scenarios were projected to have a significant positive return on investment. The contract for LNG scenario had the lowest annual cost ($18 million) and the highest anticipated return on investment (150%). The energy efficiency scenario had the highest annual cost ($101 million) with a similar return on investment (145%). Pipeline expansion had an annual cost in between the 2 other scenarios ($66 million) and a lower but still significant return on investment (92%).

A measure of stranded cost potential was developed by calculating the worst case scenario for dollars at risk. This measure was calculated by multiplying the annual cost by the minimum anticipated contract period. This measure provides the worst case "out-of-pocket" cost if no energy savings are generated by that specific scenario. The purpose of this measure is to provide an indication of risk through the magnitude of the theoretical potential stranded cost.

The minimum anticipated contract period for pipeline expansion was based on the 30 year depreciation period, and the 5 year LNG contract was derived from the assumptions made in the Analysis Group (2015) report. We assumed a one year minimum commitment for the energy efficiency scenario. This reflects the fact that this scenario does not have any long-term contracts associated with it and in theory could be terminated in any given year therefore eliminating any future funding obligations.

The worst-case, dollars-at-risk measure indicates the magnitude of risk, not the likelihood. The probability of the risk occurring was not calculated for this study and in practice would be challenging to determine. For example, it is highly unlikely that with a $101 million annual investment in energy efficiency there would be no energy savings. However, it is possible that the actual energy savings may be higher or lower than the projected annualized savings of $247 million per year. Both the contract for LNG and energy efficiency scenarios have similar worst case stranded cost risk profiles ranging between $90 and $101 million. In contrast, the potential risk associated with stranded costs for the pipeline are significantly higher at approximately $1,980 million, or approximately 20 times greater than that of either of the other 2 scenarios.

3.2.2 Key Assumptions

A challenge in any economic impact assessment is key assumptions. A foundational concept in economic impact analysis is developing an alternative compared to a baseline or "business as usual" scenario. However, this can be challenging as there are actually 2 projections being made.[170] The researchers developing the economic model need to project: 1) what would happen if nothing is done, and 2) what would happen if something is done. The validity of any economic impact analysis relies on the credibility of the assumptions made and the methodology employed to make the projections.[171] If errors are made in either of the projections, the calculated net impact would have a higher likelihood of being invalid. Therefore, conclusions drawn from studies that have flawed assumptions or methodology would be expected to be less reliable than those that are drawn upon well-developed assumptions and methodology. This section reviews several key assumptions in the studies reviewed and discusses potential impacts on the validity of findings.

Regional Natural Gas Prices

A general assumption made in all of the key studies reviewed (Table 3.1) is that on days when natural gas demand is high, prices for natural gas can increase or spike in New England. This assumption appears to be valid based on the historical relationship between natural gas demand levels and natural gas prices, and is economically rational (see a review of historical price spikes in Section 2.2.1). The relationship between increased demand relative to fixed supply and increased price is well-established by economic theory.

A second common assumption is that constraints in the New England pipeline system are the root cause of the increased price of natural gas, and removing that constraint and allowing "unrestricted" access to natural gas will bring New England prices in line with national averages. One piece of evidence supporting this assumption is that, historically, spikes in natural gas prices in New England tend to occur during time periods when pipeline utilizations are near their physical limits, especially during winter time

Another closely related assumption is that the New England natural gas marketplace is constrained when pipeline utilization is at or greater than 75%. This assumption appears to have originated from Black & Veatch (2013, p. 57) and then propagated through to other studies. However, there was no evidence given by Black & Veatch (2013) to support this proposition. Furthermore, the EIA states that "Natural gas pipeline companies prefer to operate their systems as close to full capacity as possible to maximize their revenues."[172] This suggests that the underpinning assumption of most studies reviewed may be incorrect. This assumption is that the current utilization rate of New England natural gas infrastructure reflects a "constrained" condition, as opposed to standard market-driven operating conditions, and therefore contributes to negative economic impacts. In addition, at least one study on pricing at natural gas hubs in other areas of the country found that a significant increase in the difference between 2 spot prices occurs only after utilization rises above 95%.[173]

Pipeline Gas Flow

None of the New England based studies reviewed conducted an analysis of system-wide gas flow in the region. Instead, it was assumed (as discussed above) that the addition of pipeline capacity would reduce the marginal difference in natural gas price between New England and other pricing points (Henry Hub or TETCO-3). However, many different factors including Northeastern, national, and international demand all combine to ultimately impact the price that New England pays for natural gas. The U.S. Department of Energy performed a national study that did include modeling of regional natural gas flows in the Northeast. The study found that higher utilization of existing intrastate natural gas pipeline infrastructure will reduce the need for new pipeline because the current overall pipeline system is underutilized. In addition, the study found that any incremental increases in interstate natural gas pipeline required will be modest relative to historic capacity additions.[174]

We did not perform an in-depth analysis of the complete network of natural gas flows through the New England pipeline system. The difference between the sum of state in-flow capacity obtained from the U.S. EIA and the estimated available capacity by the ICF study discussed in section 2.1.2 is evidence that additional capacity in the existing pipeline infrastructure may be underutilized. To our knowledge, no study in the public domain has performed a rigorous analysis of the internal operating characteristics of the New England natural gas system. Additional study of the dynamics of the regional pipeline infrastructure might identify some opportunities for better utilization of existing internal of in-flow natural gas infrastructure.

Soft Infrastructure Changes

In general, “soft” infrastructure programs have not been considered in the economic models of the studies reviewed. A soft infrastructure program is a rule, law, or process change that is meant to address a program feature that is believed to cause the market to function less than optimally. A key program that has been frequently omitted is the ISO New England Winter Reliability program. This program obtains commitments from oil-fired and dual-fuel generators to increase fuel oil inventory, from natural gas power plants to contract for LNG, and from demand-response resources to reduce load upon request. Generators are incentivized to secure fuel arrangements that offset risks associated with unused fuel. This program has existed since the winter of 2013/14 and has been found to be cost-effective at meeting power grid reliability needs during the winter. During the first winter of the program (2013/14), 2.7 million barrels of oil were burned at a cost of $45 million, which was less than 2% of wholesale costs. This was determined by ISO New England to have had a positive impact on reliability.[175] The cost for the 2015/16 winter was $35.9 million for 77 plants with oil capabilities, $2.58 million for 8 plants capable of contracting for LNG, and $0.21 million for 6 demand reduction resources.

There was a significant policy change in 2015. Prior to that, national natural gas and electricity markets had separate scheduling time periods. This complicated efforts for natural gas based electricity generators to respond to requests for generation. However, on April 16, 2015 the Federal Energy Regulatory Commission issued Order No. 809 to revise regulations. This allowed for scheduling changes for the wholesale natural gas and electric industries and scheduling flexibility on interstate natural gas pipelines.[176] This change benefits the electricity and natural gas markets by allowing bids for energy to be better coordinated.

Another significant rule change that has not been factored into studies reviewed is ISO New England's Pay for Performance requirement. The requirement was approved in May 2014 and will take effect in 2018. Under this program, an energy resource (either generator or demand reduction) will receive a capacity payment consisting of a base payment and a performance payment. A resource's base payment will receive a positive or negative adjustment based on generation or demand reduction performance.

Rate Payer Funding

Many studies assume that new pipeline capacity should be funded through a surcharge on New England electric rate payer bills. For example, on July 19, 2016, Maine provided conditional approval for natural gas pipeline expansion funded through electric rate payers dependent upon the approval by 4 other New England states.[177]

More recently, several legal hurdles have emerged that call this assumption into question. On August 17, 2016, the Massachusetts Supreme Judicial Court found that current state deregulation laws did not give the Massachusetts Department of Public Utilities the legal authority to allow state utility companies to contract for natural gas funded by electricity rate payers.[178] On October 6, 2016, the NH Public Utility Commission rejected a proposal to fund pipeline expansion through electric rates. [179] On October 7, 2016, the Rhode Island Public Utility Commission placed a stay on an expansion for natural gas pipeline in the state.[180] The upshot is that most analyses do not consider alternative financing requirements on cost and how this impacts the calculated net benefits of pipeline expansion projects.

Input Assumptions

Another challenge is that these studies were performed at different periods in time with different sets of assumptions, including energy prices, fuel demand, resource availability, and levels of development. This makes direct comparison among study findings challenging. For example, LaCapra and Economic

Development (2015) assumed a scenario where the Forward Capacity Market (FCM) auction would cost $12.63 per KW/month if no additional pipeline was built, and $7.70 if additional pipeline was added for auction # 10 (2019 to 2020). The actual auction results in 2016 were $7.03.[181] The FCM payment adds to wholesale electricity costs. The LaCapra and Economic Development (2015) analysis overestimates the cost of FCM portion of wholesale energy costs by almost 80% given that pipeline expansion has not occurred. This alone accounts for a $1 billion reduction in 2019 for the energy savings expected from pipeline expansion. The takeaway is that these models are sensitive to inputs and variances in the predicted or baseline assumptions, which significantly impacts the short- and long-term economic benefits associated with any particular scenario.

Another assumption that has been made in some studies, specifically observed in those performed by ICF (2012, 2014) is that, in the absence of natural gas pipeline constraints, gas priced at TETCO-3 (Appalachian Basin pricing) will trade at a long-term discount of up to a $1.50 relative to national averages (that is, Henry Hub natural gas prices). However, the difference between Appalachian Basin pricing and Henry Hub pricing has been observed to narrow as new pipeline projects have been completed and national natural gas demand has increased. Given that the economic analyses from these studies are not based on the actual price of natural gas but instead on the marginal difference between New England and another pricing point, the pricing point assumptions used to calculate the marginal difference can significantly impact the net benefit calculation. In addition, New England's experience during the spring and summer months of 2016 (discussed above) where wholesale prices averaged at a slight premium to the national average also do not support the assumption that additional pipeline will cause New England natural gas prices to converge to the TETCO-M3 price.

3.3 Conclusions: Natural Gas

New England experiences periods when natural gas supply and demand are not well matched. The growth in demand for natural gas in New England is currently being driven primarily by natural gas power generation, but also to a smaller extent by a growing residential and commercial natural gas base. However, supply and demand factors outside of New England also factor into this mismatch. The unbalanced supply/demand relationship is most likely to occur during cold winter days, but can also occur on hot summer days. This mismatch can result in natural gas price spikes and periods of elevated prices that increases overall natural gas and electricity prices in the region.

This study finds that, while it is possible that constraints within the pipeline system lead to increased wholesale energy prices, this conventional line of reasoning does not provide conclusive evidence to support that such a relationship really exists. In general, studies view the increased frequency of price spikes during the winter months to indicate that constrained conditions cause price spikes. Overall physical or technical natural gas infrastructure capacity (pipeline, local distribution company injection, and LNG terminals) appears to exceed natural gas demand in New England. This implies that market rules that encourage better use of existing infrastructure may reduce the extent and magnitude of price spikes, and there is evidence suggesting that market rule improvements are already having such an effect. What the region may lack is the ability to balance New England demand with gas specifically supplied from the Appalachian Basin region with the premise that increased access to Appalachian Basin gas will minimize wholesale natural gas prices in New England. However, we are unable to find evidence clearly supporting that this is the case. Past investments in specific segments of New England's natural gas infrastructure were made on natural gas supply and demand assumptions that turned out not to materialize, and this has resulted in underutilized areas of natural gas capital infrastructure as evidenced by the low utilization of LNG capital infrastructure.

While New England does have elevated natural gas prices, which can be viewed as a market signal for investment, New England's overall energy growth is low to flat as the region continues to mature as a stable, but low growth region of the country. Overall electricity consumption and peak winter electric demand are expected to decline. These are all market-based indicators that do not support increased natural gas infrastructure.

Predicting the future energy mix is challenging. Towards the late 2000s, there was a rush to build LNG infrastructure in New England over concerns about domestic natural gas availability. Seven hundred and 50 million in private capital was invested in 2 new off-shore facilities. However, plummeting natural gas prices relative to LNG dramatically reduced activity at New England terminals over the past several years. If rate payers had funded these projects, it is very likely there would be stranded costs related to this investment.

During this same time period, it appeared as though coal would be a dominant form of generation through at least 2030.[182] New Hampshire spent $422 million on scrubbers for the coal-based Merrimack Station. But as energy dynamics changed, the use of coal as a power generation source has decreased dramatically. Merrimack Station's coal-based generation has plummeted 75% from 3.1 million MWH in 2000 to 790 thousand MWH in 2015.[183] As part of a settlement, New Hampshire rate payers now face just under $400 million in stranded costs to be spread across residential, business, and industrial users.[184] This illustrates the importance of balancing potential benefits with potential stranded costs risks for any new large energy infrastructure investments.

We recommend that, if New Hampshire wishes to pursue market intervention to reduce wholesale electricity costs, an appropriate study be performed that models system-wide natural gas flows before any obligation of rate payer funds. To proceed without such a study would serve to place the New Hampshire rate payer in a position of being an energy market speculator. Evidence of the risk associated with this approach is that utility companies still have not chosen to fund the investment with shareholder capital. We also support the recommendation of the New Hampshire Public Utilities Commission that any contracts for natural gas capacity should be conducted via a request for proposals[185] that would be open to all forms of natural gas infrastructure, including new pipeline proposals, existing pipeline capacity, and LNG capacity.

Studies reviewed here suggest that new pipeline capacity is expected to reduce the marginal difference in natural gas costs between New England and the overall nation. If this finding is true—that new pipeline capacity will reduce New England wholesale natural gas prices—it cannot be ruled out that existing market interventions and new regional natural gas capacity additions won't also achieve similar results. While New England may currently face transient pipeline constraints that might negatively impact natural gas pricing to its west, existing and future domestic projects may allow better flow of gas to markets. Specifically, projects in progress in New York may reduce the demand for New England pipeline infrastructure. There is therefore the risk of overbuild. This possibility of overbuild is supported by evidence supplied by the study performed on national natural gas infrastructure by the U.S. Department of Energy.[186]

Ongoing transitions in global energy markets significantly increase the risk of stranded costs. Long-term energy investments may not be advised given the rapidly changing and volatile nature of the current global energy marketplace. This is not an environment that supports significant energy infrastructure expansion, especially given that there is underutilized capacity in the existing system, specifically, given that New England has underutilized capacity to its east through LNG. In addition, clean energy infrastructure, as discussed in Section 4, provides yet another source of energy infrastructure or "virtual clean energy pipeline" to reduce pipeline-based natural gas demand.

The current body of knowledge on the true marginal cost difference between building and not building new pipeline infrastructure is currently insufficient for well-informed policy-based decision making. No clear case has been made for why in a competitive, liquid energy marketplace that there is a market flaw that requires public dollars to be at risk versus corporate investment dollars. Changes in marketplace rules that allow for markets to align appear to be effective at ensuring that energy is available when needed.

Due to the suite of assumptions (described above) that our analysis has suggested have questionable validity, the projections of specific cost amelioration due to new pipeline infrastructure may be unreliable. Studies do consistently suggest that there would be some marginal cost impact improvement. However, at best, any cost-benefit analysis can be used for ranking alternative options, but is inconclusive against the potential cost-benefit of market interventions versus the current baseline market development trajectory.

In considering policies in the context of ranking based on expected net benefit, the least cost and most immediate impact would be experienced through contracting with existing infrastructure (that is, LNG and existing pipelines, existing coal and oil-based power generating stations). This is a lower-risk approach as it does not require long-term commitments (contracts greater than 5 years), and in general, could be fostered by actions that increase market efficiency and better match existing infrastructure capabilities with demand. In order of rank, the next highest net benefit is new pipeline expansion. There is a stated expectation by the utility industry and large industrial users that pipeline expansion will reduce the marginal difference in natural gas costs for the New England region. However, our findings do not support that expectation, and the long-term commitment increases the stranded costs risks associated with this approach. Energy efficiency and renewable energy demonstrate a high return on investment. This approach also offers the maximum commitment flexibility given that it does not require long horizon contract periods. Another benefit of energy efficiency and renewable energy is that this diversifies the energy mix in New England to reduce dependence on external sources of fossil fuel, and especially natural gas.

In conclusion, some have framed the solutions to New England's high energy prices to be expansion of natural gas pipeline infrastructure to reduce constraints. While this may appear intuitive at face value for natural gas infrastructure, a review of the assumptions made by studies that have investigated this topic and support infrastructure expansion have shown these assumptions to have questionable validity. Based on our analysis, it appears that New England's lack of indigenous fuel sources and "end of pipeline" status are likely significant influencers of the energy price that New England does pay. However, predicting the direction of energy markets is a challenging endeavor. Solutions that reduce New England's need to compete for external fossil fuel energy sources, including natural gas, are expected to have a higher likelihood of ultimate energy cost reduction, and to increase the energy diversity in New England compared to solutions that rely on high-cost new infrastructure to access external fossil fuel energy sources.

4. NEW HAMPSHIRE'S FUTURE ENERGY CHOICES: RENEWABLE ENERGY AND ENERGY EFFICIENCY

4.1 Summary of Recent New England Renewable Energy and Energy Efficiency Studies

State and local governments in the United States are actively promoting renewable energy and energy efficiency to seek economic development opportunities, generate clean energy-related employment, and reduce emissions of heat-trapping gases and other pollutants. However, in addition to the economic aspects of clean energy, health, environmental and electric system benefits of clean energy need to be considered. In this section, we review a suite of studies have analyzed the impacts of clean energy in New Hampshire and New England (Table 4.1) and present a summary of study methods and findings. These studies employ a wide range of methods, and direct comparison of the findings among different studies is challenging. However, key takeaway findings are provided and a set of clear general conclusions are summarized.

Table 4.1. Recent New England renewable energy and energy efficiency studies and key findings.

Title:	Massachusetts Clean Energy Industry Report
Author & Date:	BW Research; 2015
Sponsor:	Massachusetts Clean Energy Center (MassCEC)
Methods:	
Key Findings:	The report documents a vibrant and diverse cluster of activities that has demonstrated remarkably strong and consistent growth over the past 5 years. Massachusetts surpassed 1 GW of installed renewable energy capacity in 2015. Annual employment growth of 11.9% is the largest increase in any year since 2010. The number of clean energy jobs has grown by 64% since 2010, cumulatively adding almost 40,000 clean energy workers bringing the statewide total to 98,895. Clean energy jobs pay well, with nearly 3/4 of full-time workers earning $50,000 or more annually, compared to a median wage of $44,678 for all jobs across Massachusetts. Massachusetts is number 1 in attracting early-stage investments per capita, beating California by more than 149% on a per capita basis. Total public and private investment in the state's clean energy industry exceeded $549 million.

Title:	Efficiency in New Hampshire: Realizing Our Potential
Author & Date:	Vermont Energy Investment Corporation, GDS Associates, Jeffrey Taylor & Associates; November 2013
Sponsor:	NH Office of Energy and Planning
Methods:	Jobs and impacts were generated using a set of macroeconomic analysis, including input output method and impacts analysis using IMPLAN software.
Key Findings:	The potential for cost-effective reductions in energy use in NH buildings is equivalent to 715 million KWH per year, which is 10 times the savings achieved through current NH energy efficiency programs at a cost of 3.1 cents per KWH. This investment would require approximately $1 billion in investment, and would save $3 billion over a 15 year investment life time. This investment would create 2,300 jobs and add $160 million to the NH GDP.
Title:	Additional Opportunities for Energy Efficiency in New Hampshire
Author & Date:	GDS Associates; January 2009
Sponsor:	New Hampshire Public Utilities Commission
Methods:	Estimates of technical potential, maximum achievable potential, and maximum achievable cost-effective potential by the year 2018 are provided for electricity, natural gas and related propane and fuel oil savings at the state level and for each of the 4 New Hampshire retail electricity providers and 2 natural gas distribution companies. All results were developed using customized residential, commercial and industrial sector-level energy efficiency potential assessment models and New Hampshire Public Utilities Commission (NHPUC)-specified cost-effectiveness criteria, including the region's most recent avoided energy cost projections.
Key Findings:	There are technical potential savings of over 27% of projected 2018 electric and non-electric (natural gas, oil and propane) energy sales. The Maximum achievable cost-effective potential is over 20% of projected 2018 electric sales and over 16% of projected 2018 non-electric sales. A potentially obtainable scenario shows savings of ~11% of 2018 electric sales and ~8% of 2018 non-electric) sales.
Title:	New Hampshire Energy and Cost Savings for New Single and Multifamily Homes
Author & Date:	U.S. Department of Energy; September 2012
Sponsor:	U.S. Department of Energy

Methods:	Evaluates 2012 International Energy Conservation Codes (IECC) based on 3 measures of cost-effectiveness: life-cycle cost, cash flow, and simple payback.
Key Findings:	Life-cycle cost savings, averaged across climate zones and building types in New Hampshire, are $10,635 for the 2012 IECC. Simple payback period is 3.0 years for the 2012 IECC. Households save an average of $620 per year on energy costs with the 2012 IECC. Net annual consumer savings, including energy savings, mortgage cost increases, and other associated costs in the first year of ownership, average $507 for the 2012 IECC. Energy costs, on average, are 27.3% lower for the 2012 IECC.
Title:	Economic Impacts of Efficiency Spending in Vermont: Creating an Efficient Economy and Jobs for the Future
Author & Date:	Bower, Huntington, Comings, and Poor; 2012
Sponsor:	ACEEE Summer Study on Energy Efficiency in Buildings
Methods:	Recent efficiency potential studies and other data were used to develop inputs to the REMI economic model (Regional Economic Models, Inc.) to estimate job creation and the overall impact of efficiency spending on the state’s economy.
Key Findings:	Economic impacts of VT energy efficiency programs in 2012 (electric and not-electric energy): 370 jobs, $14 million in personal income, $14 million in GSP, and $22 million in business sales.
Title:	The Economic Impacts of the Regional Greenhouse Gas Initiative on Nine Northeast and Mid-Atlantic States: Review of RGGI’s Second Three-Year Compliance Period (2012-2014)
Author & Date:	Analysis Group; 2015
Sponsor:	Barr Foundation, Energy Foundation, The Thomas W. Haas Foundation at the NH Charitable Foundation, Merck Family Fund
Methods:	The IMPLAN economic model and PROMOD power sector model were applied to program expenditures coupled with a social discount rate.
Key Findings:	Through the RGGI program, power system reliability has been maintained and greenhouse gas emissions from power generation have decreased. Between 2012 and 2014, RGGI generated $520 million in net economic benefits and generated

	5,700 job-years in employment in New England. New England consumers have saved approximately $200 million through decreased energy bills.
Title:	The New Hampshire Greenhouse Gas Emissions Reduction Fund: Year 3 (July 2011 – June 2012)
Author & Date:	Carbon Solutions New England (CSNE); 2012
Sponsor:	NH Public Utility Commission
Methods:	Collection and aggregation of grantee program results. Economic impact analysis using the IMPLAN model. Direct measurement of full-time equivalent jobs.
Key Findings:	Positive economic impacts with a total return of $4.95 for every $1 spent for a total return of $108 million through 2030. Full-time jobs supported ranged by quarter from 2009 through 2012 between 15 and 75.

While there are a range of approaches to expanding renewable energy and energy efficiency, we have chosen to focus on investments in distributed generation like solar and energy efficiency. One consistent conclusion drawn across the clean energy studies reviewed here is that investment in clean energy yields a positive net economic benefit. One identified factor for the positive economic benefit observed is the long-term energy cost savings that result from reductions in overall energy consumption, or the avoidance in consumption of other energy fuel sources, including coal, oil, and natural gas. Because New England does not produce fossil fuel or nuclear fuel resources, all economic activity other than distribution and sale associated with energy occurs outside the New England region. Retained consumer expenditures from avoidance of fuel purchased from outside the region can be applied to other sectors of the New England economy, which then has an associated economic multiplier benefit. In other words, money that is not spent on imported energy can be applied to other expenditures in other areas of the economy. Investment in clean energy also serves to broaden employment opportunities in fields required to develop clean energy sources in the region. This creates opportunities for regional employers to either maintain current employment or expand employment depending on overall regional work demand and labor availability.

The methodologies used to model economic impact were relatively uniform across the studies. These studies rely on a method called economic impact analysis, which describes the current economic activity in a study area (such as a county, group of counties, state, or group of states) and it can be useful in estimating how a change—such as the loss of an existing industry or the addition of a new industry—would be expected to affect the wider local or regional economy in the study area. Impact analysis begins with evaluating the output of businesses included in the analysis. These direct expenditures trigger a series of additional spending flows throughout other sectors of the local economy as businesses spend money on indirect expenditures: 1) payroll and benefits, and 2) supplies, equipment, and service contracts with local vendors. The purchase of goods and services from local vendors supports the hiring of workers at those firms and also provides funds to enable those firms to purchase additional goods and services from suppliers situated further down the supply chain.

The activity at companies involved in direct or indirect expenditures results in their employees earning salaries and wages. A portion of their wages will be spent on local goods and services at different industries, including health care, retail, and leisure. These are referred to as household spending or induced expenditures. This round of spending by employees helps support workers in those industries who then will spend portions of their incomes locally, which triggers another round of spending. This entire chain of spending is referred to as the "ripple" or "multiplier" effect. The rounds of spending and re-spending do not continue indefinitely but typically diminish rapidly. The impacts of the initial economic activity rapidly leave or "leak" out of the local economy through the imports of goods and services produced in other regions, savings, spending in areas outside the local economy, and taxes.

Two common economic impact analysis models used in the studies reviewed were IMPLAN and REMI.[187] Both are widely used economic modeling tools that calculate multiplier impacts based on the modeled assumptions. To determine the appropriate inputs for the economic model, an energy model was also integrated into the analyses reviewed here. The energy models ranged from spreadsheet-based analysis to proprietary energy system models.

GDS Associates (2009) was unique in that it did not perform an economic impact analysis, but instead was a technical potential study that focused solely on identifying the technical potential and probable (in other words, realistic) potential for energy efficiency market growth in New Hampshire. They found the technical potential for energy efficiency was 27% of projected 2018 energy consumption levels. They found that potentially obtainable energy efficiency was lower at only 11% of projected 2018 energy consumption levels. The only other study that we analyzed that estimated the potential for energy efficiency in New Hampshire was Vermont Energy Investment Corporation (2013). This study concluded the potential for all cost-effective energy efficiency was 715 million KWH (for both electrical and thermal savings) in New Hampshire, which is 10 times the current potential of New Hampshire's energy efficiency programs. They determined that the cost to reach this efficiency potential was $941 million, and this would save $2.9 billion in energy costs over a 15 year period. This study did perform an economic impact analysis and found positive net impact with an annual benefit of 2,300 additional job-years and $160 million in state GDP.

The studies that have focused on New Hampshire (Table 4.1) found that investments in energy efficiency could yield the state benefits in terms of cumulative annual savings for residential and commercial-industrial ranging from 0.4% to 0.7%. The study by the Vermont Energy Investment Corporation (2013) found that energy efficiency investments would create 2,300 jobs and add $160 million to the New Hampshire GDP.[188] While the findings on economic impacts of clean energy are consistent among New Hampshire studies, the impacts on the energy capacity are more disparate, ranging from 28 million KWH to 49 million KWH per year.

In summary, the majority of studies in the Northeast United States have focused on impacts of energy efficiency. The positive economic impacts as well as carbon dioxide and nitrous oxide emission reduction findings were consistent across studies. However, the studies lacked consistency regarding impacts on sulfur dioxide emissions and energy capacity. For New Hampshire studies, defining residential energy capacity impact and commercial energy capacity impact narrows this gap.

4.2 Analysis of Recent New England Clean Energy Studies

A common outcome for studies that examine economic impacts from clean energy is that the overall economic net benefit is expected to be positive. We were unable to identify any studies that suggested an overall negative net impact from clean energy projects in New England or New Hampshire. However, studies that have considered regulation in the context of clean energy in other regions have expressed concerns that costs and benefits are not evenly distributed. In other words, there are “winners” and “losers” from clean energy policies. Therefore policy makers need to be cognizant of “unintended consequences,” or distribution of costs and benefits.

For example, Curtis (2014) examined the nitrogen oxide Budget Trading Program, which is a cap-and-trade program for air pollution in the United States. He found that while this cap-and-trade program substantially reduced air pollution, it also added substantial costs to energy producers. He concluded that it resulted in a 1.7% reduction in manufacturing employment.[189] Curtis found that younger worker employment declined and that it negatively impacted wages for newer employees. However, this finding of negative impact for this specific air pollution program is not universal. Resources for the Future (2005) conducted a comprehensive review of research performed on the impacts of the nitrogen oxide program. Their research supports Curtis’s (2014) finding that the program was associated with positive environmental impacts overall. However, their research found this cap-and-trade policy approach provided significant benefits relative to traditional "command and control" or prescriptive regulation. Furthermore, they concluded that different markets and pollutants require different pollutant mitigation strategies.

The EPA Clean Power Plan is a clean energy policy that has also proven to be controversial. Proponents of the Clean Power Plan, including the Obama administration and environmentally focused organizations, follow the same overall conclusions as those reached in the studies discussed in the Section 4.1: that increased investment in clean energy yields net positive economic benefits along with positive environmental benefits. The U.S. EPA projects that the Clean Power Plan will reduce emissions of heat-trapping gases from the power sector by over 30% by 2030, and provide $26 to $45 billion in net economic benefits.[190] However, some energy-focused non-profit organizations—especially prevalent in organizations receiving funding from fossil fuel oriented organizations or large energy groups—state that clean energy programs such as the Clean Power Plan will lead to "Higher energy bills for families, individuals, and businesses will destroy jobs and strain economic growth," while having negligible impact on global climate change.[191]

Loris (2015) raised several areas of economic concern related to clean energy policy, including: 1) carbon-emitting fuels have historically met 87% of America's energy needs during the previous decade and that U.S. economic growth is at a minimum correlated with energy availability, 2) carbon reduction policies would be expected to result in significant economic loss, and 3) costs impact the most disadvantaged specifically low-income and manufacturing companies.

The argument that fossil fuels have historically been an essential component of economic growth appears to be dated given the rapid transformation of the energy sector, specifically the rapid transformation in clean energy in the past several years. And this is clearly not true for New England, where successive annual growth in GDP since 2000 has occurred while energy use has declined (Figure 2.9). Loris cites fossil fuels as being essential to the U.S. industrial revolution. While this may be true, the level of global investment in clean energy is currently outpacing that of any specific fossil fuel type, with one factor being the increased market competiveness of clean energy technologies. An associated argument is that fossil fuels are reliable and dependable and in juxtaposition, clean energy technologies do not share that trait.

In New England, clean energy has not been shown to be associated with reliability issues. The Analysis Group (2015) specifically examined reliability issues related to investment in clean energy over additional natural gas infrastructure. They did not find reliability issues emerged through at least 2024 even under severe demand conditions. However, concerns have been raised that for power grid reliability in New

England, clean energy cannot scale to meet large immediate demand changes.[192] An illustrative example is the incident on August 11, 2016, when there was a severe power grid event where a nuclear plant was unavailable due to a lightning strike. This resulted in a large power resource dropping from the power grid. At the time it occurred, renewable resources of wind and solar were not producing large amounts of output. Oil-fired and demand-response resources were called by ISO New England and helped alleviate the event.[193] The power grid did not experience a power outage, but natural-gas-fired generation in the region rose to 65% to meet energy needs. While wholesale power prices transiently spiked, they did go to over $2.50 per KWH.[194]

ISO New England has also raised concerns about the availability of renewables during the winter months. They state that cold weather snaps can decrease wind speeds and winter peak occurs after sunset limiting the potential of solar PV to help reduce winter peak.[195] Other challenge areas for clean energy include relatively high up-front capital costs. The payback period at current energy rates is still higher than the threshold that many customers and businesses are willing to pay. A 3 to 5 year payback appears to be a typical time frame that is required for an investment in clean energy to occur by residential or business customers.[196] However, the cost continues to decrease rapidly as new technologies and production efficiencies reduce the cost of clean energy.

Another challenge is that, while there is no fuel-cost for some renewable energy technologies (such as solar, wind, hydro), the time of generation is not always directly matched to the time of demand and is instead often dependent on the underlying resource availability. The extreme power outage event on August 11, 2016 provides an illustrative example of this limitation. Large-scale energy storage is one option that is growing rapidly as performance increases and costs decrease. The Massachusetts's Energy Storage Initiative (ESI) is one strong regional example of efforts to increase the prevalence of electricity storage in the New England power grid system.[197] Current projections of market capacity indicate that large-scale energy storage could start having an impact on the market place with energy storage costs projected to decrease up to 70% over the next 15 years.[198]

One potential area of concern is that clean energy resources are beyond the control of utility companies and ISO New England, and therefore they are perceived as higher risk by utility companies in meeting forecast peak demands.[199] However, a strength of clean energy is its ability to help manage price uncertainty as in many cases it has no fuel costs. Furthermore, energy efficiency does not require periodic renewal of customer participation agreements or ongoing customer incentive payments.

In New Hampshire, the RGGI program has been controversial and has been the target of repeated repeal efforts.[200] This has resulted in transformations of the policy structure for RGGI New Hampshire fund expenditures, starting with the repeal of its initial implementation GHGERF in 2012. However, while the pattern of funding has evolved primarily towards rate payer rebate—which Gittell and Magnusson (2008) found to be have lower economic benefits than investment in energy efficiency[201]—current NH policy still has a portion of RGGI funds targeted towards low-income energy weatherization programs. This is an example of how program design can help mitigate any potential disproportionate cost impacts from clean energy policy.

Another issues identified is that additional expertise is required but there is no mechanism to recover costs. Areas required for consulting include: 1) current saturation levels and peak demands of targeted equipment, 2) consumer research, including required incentives, 3) costs associated with development and implementation of a "no-wires" alternative.[202]

Utilities are allowed to recover costs of traditional transmission and distribution infrastructure, including a return on investment. However, there is no mechanism in place to recover lost revenue or return on investment for non-wire solutions like distributed generation. Projects greater than 100 KW require engineering studies that are funded by the customer. Programs must also match the hourly and seasonal load profile of the energy efficiency measures to the profile of the system demand. If efficiency doesn't occur at the time it is needed, then it may not avoid the need for additional capacity.

Clean energy has also been considered in the context of deferral of transmission and distribution. While the results have been mixed, it has shown that it can be cost effective and reliable. It has also been found that clean energy can be useful as a tool to delay capital investment. Efficiency investments can be a strategy to validate forecasts before investing in new additional infrastructure.[203] In 2012, ISO New England found that energy efficiency and distributed generation investments had reduced demand on the power grid to such an extent in New Hampshire and Vermont that it led to the avoidance of over $200 million in previously anticipated transmission upgrades.[204]

4.3 Conclusions: Clean Energy

The body of evidence strongly suggests that clean energy has a positive impact on overall energy costs for a region, and that those energy savings and associated employment activity with the development of clean energy infrastructure result in a net positive economic impact. However, as with any public policy, it is important to consider unintended consequences and distribution of costs and benefits. Stakeholders that have been specifically identified as potential "losers" under clean energy policy include large energy users such as manufacturing companies and low-income households. This does not suggest a direct relationship between clean energy and negative cost impact for these stakeholders, but instead suggests that poorly formulated policies can result in costs that do negatively impact these important stakeholders. This highlights the importance of ensuring clean energy policies provide mechanisms to ensure that some stakeholders are not disproportionately impacted by a policy. Some clean energy programs (such as RGGI) have been the repeated target of repeal in New Hampshire, indicating that consistent and long-term clean energy policy in New Hampshire is challenging.

Benefits of clean energy are its disconnect with variable fuel costs (driven by regional and global markets) and that it can be considered a regional source of “virtual” supply. This has benefits for energy security and reduces reliance on external sources of energy. It helps hedge against price volatility and has consistently been associated with positive net economic benefits. While a select few studies have concluded negative impacts, some of the claims are questionable at best. As discussed several times in this report, it is essential to consider groups that may be disproportionately impacted by cost from policies that are designed to stimulate clean energy activity.

5. NH ENERGY SCENARIO ANALYSIS: COMPARISON OF LNG, NATURAL GAS, AND CLEAN ENERGY

Based on stakeholder interest, we analyzed different policy options that New Hampshire could pursue with its limited budget for energy investment. We did this by downscaling the results from the Analysis Group (2015) study, and by developing a New Hampshire specific model that compares a rate payer funded financing for new interstate natural gas pipeline capacity against a rate payer funded increases in intrastate distributed clean energy.

5.1 Downscaled Analysis Group (2015) Results

In 2015, New Hampshire accounted for 9.2% of the New England region's electrical sales.[205] If the 3 regional potential energy choices analyzed by the Analysis Group (2015) (Table 3.2) were scaled at the proportion of New Hampshire's electrical sales to those of New England, the total net annual energy savings in New Hampshire would be estimated at $2.5 million under a LNG contract, $5.6 million for 0.42 Bcf/d of increased regional pipeline capacity, and $13.4 million under increased energy efficiency investment in New Hampshire (Table 5.1).

Table 5.1. Summary of potential energy choices for New Hampshire. Original data from Analysis Group 2015.[206]

Policy Choice	Total Annual Cost (Millions)	Total Annual Savings (Millions)	Net Annual Savings (Millions)	Return on Investment	Minimum Time Commitment (Years)	Annual Emissions Change (Tonnes)	Worst Case Dollars at Risk (Millions)
Contract for LNG (3 Bcf per winter)	$1.70	$4.10	$2.50	150%	5	-3,000	$8.20
Intrastate pipeline expansion (0.42 Bcf/d)	$6.10	$11.70	$5.60	92%	30	7,000	$182
Energy efficiency and demand reduction	$9.30	$22.70	$13.40	145%	1	-170,000	$9.30

In the worst case, where an energy strategy yields no incremental improvement in energy prices, the dollars at risk for New Hampshire are approximately $8 to $9 million for either a regional LNG contract or an increase in intrastate energy efficiency activity, and approximately $180 million for New

Hampshire’s share of the expansion of 0.4 Bcf/d of new regional pipeline capacity. Under any of the scenarios the change in the emissions of heat-trapping gases for New Hampshire’s contribution is relatively small, ranging from an increase of 7,000 tonnes with an associate pipeline expansion to a decrease of 170,000 tonnes under the energy efficiency scenario.

5.2 New Hampshire Specific Model

An area of interest expressed by New Hampshire energy stakeholders was a direct comparison of similar levels of investment in either the expansion of natural gas pipeline or expansion of clean energy investment. In this scenario analysis, it was assumed that clean energy would be parameterized to only include energy efficiency and solar. While other clean energy technologies could be part of the near-term, economically-feasible, developed, distributed, clean-energy landscape, they are anticipated to be minor in comparison. To complete this comparison, the cost and savings were based on estimates provided by NH utility companies in NH PUC dockets DE 15-137 *Gas and Electric Utilities, Energy Efficiency Resource Standard* and IR 15-124 *Investigation into Potential Approaches to Mitigate Wholesale Electricity Prices.* A spreadsheet-based model was developed to evaluate the net benefit impact of near equivalent funding levels to each scenario (Table 5.2).

Energy Scenario	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Sum
BASELINE ELECTRICITY USE															
Power Consumption (Thousand MWH)*	10,859	10,934	11,003	11,040	11,081	11,128	11,180	11,232	11,281	11,331	11,382	11,432	11,483	11,533	
KWH Cost**	$0.150	$0.153	$0.156	$0.159	$0.162	$0.166	$0.169	$0.172	$0.176	$0.179	$0.183	$0.187	$0.190	$0.194	
Annual Power Cost ($ Billions)***	$ 1.63	$ 1.67	$ 1.72	$ 1.76	$ 1.80	$ 1.84	$ 1.89	$ 1.94	$ 1.98	$ 2.03	$ 2.08	$ 2.13	$ 2.18	$ 2.24	
PIPELINE SCENARIO															
Total Funds Available ($ Millions)+	$ 87	$ 87	$ 88	$ 88	$ 89	$ 89	$ 89	$ 90	$ 90	$ 91	$ 91	$ 91	$ 92	$ 92	$1,255
Wholesale cost increase absent pipeline ($/MWH)++	$ 4.31	$ 7.98	$11.08	$12.15	$12.15	$12.15	$12.15	$12.15	$12.15	$12.15	$12.15	$12.15	$12.15	$12.15	
Pipeline Savings ($ Millions)	$0	$0	$122	$134	$135	$135	$136	$136	$137	$138	$138	$139	$140	$140	$1,630
CLEAN ENERGY (CE) SCENARIO															
Total Funds Available (Millions)+++	$ 31	$ 43	$ 55	$ 73	$ 89	$ 89	$ 89	$ 90	$ 90	$ 91	$ 91	$ 91	$ 92	$ 92	$1,107
CE - ENERGY EFFICIENCY (AKA VIRTUAL SUPPLY)															
Funds Committed ++++	100%	100%	100%	100%	100%	100%	0	0	0	0	0	0	0	0	
Cost per MWH Saved	$ 500	$ 500	$ 500	$ 500	$ 500	$ 500	$ 500	$ 500	$ 500	$ 500	$ 500	$ 500	$ 500	$ 500	
New Supply (Thousand MWH)	62	86	110	146	177	178	0	0	0	0	0	0	0	0	
Cumulative Supply (Thousand MWH)	62	148	258	404	581	759	759	759	759	759	759	759	759	759	
CE - SOLAR															
Funds Commited	0%	0%	0%	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	100%	
Cost per KW	$ 3.43	$ 3.19	$ 2.97	$ 2.76	$ 2.57	$ 2.39	$ 2.22	$ 2.07	$ 1.92	$ 1.79	$ 1.66	$ 1.55	$ 1.44	$ 1.34	
Leveraged Capital	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	
New Capacity (MWdc)	0	0	0	0	0	0	134	145	157	169	183	197	213	230	
New Supply (Thousand MWH)	0	0	0	0	0	0	100	108	117	126	136	147	159	171	
Cumulative Supply (Thousand MWH)	0	0	0	0	0	0	100	208	324	450	586	733	892	1063	
CE - ENERGY EFF & SOLAR															
Total Cumulative Supply (Thousand MWH)	62	148	258	404	581	759	859	967	1,084	1,210	1,346	1,492	1,651	1,822	
Clean Energy Savings ($ Millions)	$ 9	$ 23	$ 40	$ 64	$ 94	$ 126	$ 145	$ 167	$ 190	$ 217	$ 246	$ 278	$ 314	$ 354	$2,268
Updated Consumption	10797	10786	10745	10636	10499	10369	10321	10264	10198	10122	10036	9940	9832	9711	
% of Load met through New Clean Energy	0.6%	1.4%	2.3%	3.7%	5.2%	6.8%	7.7%	8.6%	9.6%	10.7%	11.8%	13.1%	14.4%	15.8%	

NOTES

*	Projection from 2017 - 2025	From ISO New England 2016 CELTS report (REF)
	2025+ Annual Growth Rate	0.4%
**	2017 KWH Cost	0.15
***	Annual price increase	2%
+	0.8 CENTS PER KWH; FROM NH PUC Docket (REF)	
++	Numbers from LaCapra 2015 report (REF)	
+++	EERPS from NH PUC (REF)	
++++	All funds committed to EE until VEIC cap of 6% hit, then funds committed to solar	

Table 5.2. Spreadsheet model and basic assumptions used for estimating net benefits of natural gas pipeline expansion verses investment in energy efficiency and clean energy.

A 0.8 cents per KWH, distribution surcharge on all NH rate payer electric bills was assumed to be the funding source for natural gas pipeline expansion. This was based on the NH PUC Staff Report issued September 15, 2015 for docket IR 15-124, which estimated a 0.48 cent per KWH surcharge for the Access Northeast project and a 0.33 cent per KWH surcharge for the Northeast Direct Project.[207] These 2 proposed projects would have added approximately 2.2 Bcf/d in new pipeline capacity to the Northeast region of the country. Studies that have determined that additional pipeline capacity is required in New England have stated that between 1 and 2 Bcf/d of new pipeline capacity is the appropriate amount of capacity to add. Savings were derived from the increase in wholesale electricity rates projected by La Capra Associates and Economic Development Research Group (2015) absent any pipeline capacity additions.

The clean energy scenario consists of a ramp-up period following the funding proposed by the utilities for the NH EERS in docket DE 15-137. The funding starts at $31 million in 2017, rising to $73 million in 2020. After 2020, the funding is set to be the same as that projected under the natural gas pipeline scenario, starting with $89 million in 2021. Under this scenario, all funding is first directed towards energy efficiency, as this was projected to be the least costly source of clean energy. In 2022, all cost-effective energy efficiency is modeled as “exhausted” at 759,000 annual MWH, or approximately 6% of total load. This is based on the estimate of economic energy efficiency potential in New Hampshire in the VEIC (2013) report. Energy savings is based on utility savings projections by NH utilities for the proposed NH EERS. It is not an exact match but it is close. After that point, all funding was assumed to be directed towards new solar capacity and cover 30% of installed cost. While the assumption was made that energy efficiency would be the sole recipient of any additional infrastructure development under the clean energy model, this need not be the case. Funding could be devoted to other distributed clean energy projects in different proportions. This would impact the estimated rate of return, but is a viable option for policy makers to consider.

Under the natural gas expansion scenario, electricity use in New Hampshire is projected to grow from 10.8 million MWH in 2017 to 11.5 million MWH in 2030, for a total increase of 6% (Figure 5.1). Annual power cost is estimated to grow from $1.6 billion in 2017 to $2.24 billion in 2030. In 2017, the estimated cost of the pipeline distribution surcharge is estimated to be $87 million and to grow to $92 million in 2030 for a total cost during that time period of $1.3 billion. The savings, based on industry estimates of reduction, in whole-cost electricity costs over that same time period would be $1.6 billion (Figure 5.2; Table 5.1). This produces a simple return on investment over that time period of $1.30 for every dollar spent.

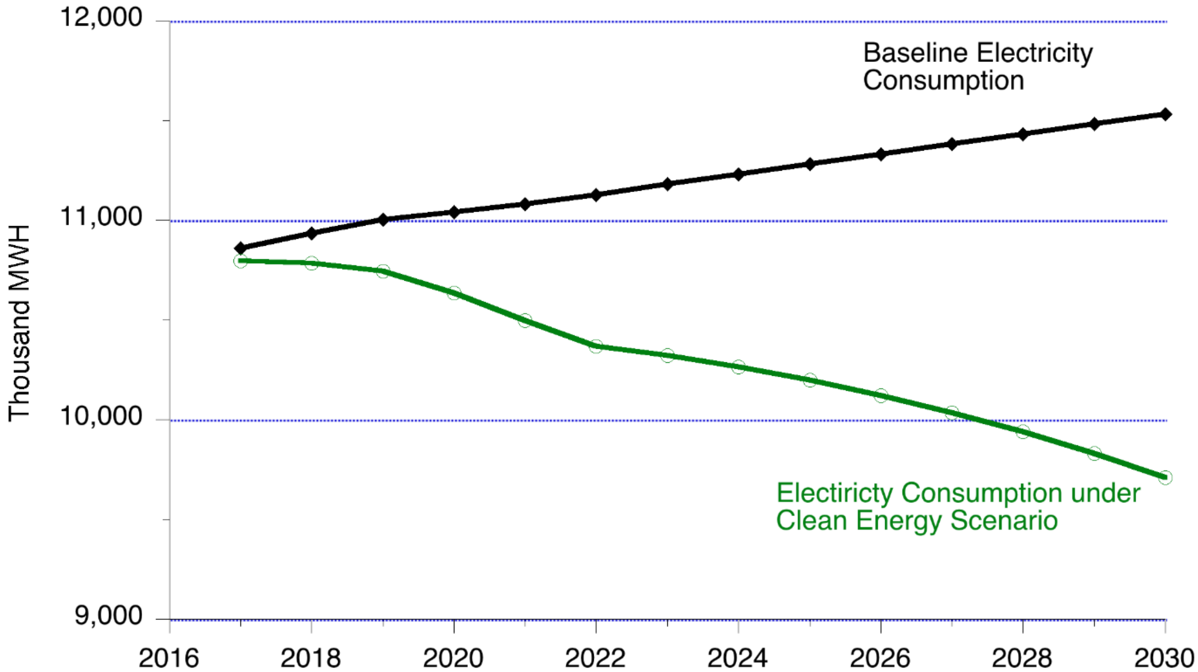

Figure 5.1. Results from a spreadsheet model baseline electricity consumption versus electricity consumption under a clean energy scenario (a modest expansion of energy efficiency and solar photovoltaic).

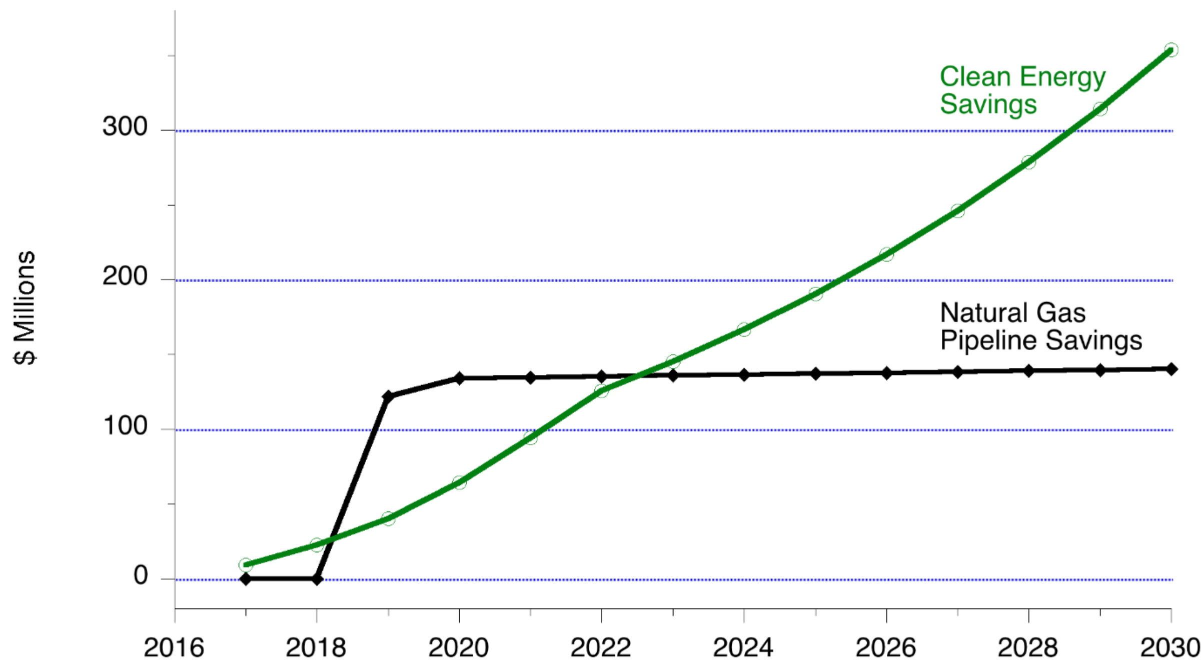

Figure 5.2. Results from a spreadsheet model comparing annual savings in New Hampshire based on investing in natural gas pipeline(s) versus investment in clean energy (in this case energy efficiency and solar panels). The total projected cumulative savings from 2017 to 2030 is $1.63 billion for the pipeline scenario and $2.27 billion for the clean energy scenario.

Under the clean energy expansion scenario, electricity use in New Hampshire from grid-based sources is projected to decline from 10.8 million MWH in 2017 to 9.7 million MWH in 2030 for a total decline of 11% (Figure 5.1). In 2017, the estimated cost of the clean energy distribution surcharge is estimated to be $31 million and to grow to $92 million by 2030 for a total cost during that time period of $1.1 billion. The savings over that same time period are estimated to be $2.3 billion without discounting for future value. This produces a simple return on investment over that time period of $2.00 for every dollar spent.

Electricity consumption in New Hampshire was developed by taking the baseline ISO New England forecast report for Capacity, Energy, Loads, and Transmission (CELT forecast)[208] for New Hampshire from 2014 to 2025 and calculating an annual growth rate. The demand forecast differs slightly from figures presented by the electric utilities to the NH Public Utility Commission. In 2014, ISO New England reported NH electricity consumption of 11.7 million MWH while the utilities reported 10.7 million MWH or a 7.8% difference. This difference is explained by transmission losses which are included in the ISO New England figure but not the utilities. The annual growth rate from the ISO New

England forecast was applied to the 2014 utility-based consumption figure from 2015 through 2025. The forecast was extended to 2030 by assuming the 2025 electricity consumption for each remaining year. Total projected load growth over this time period is 4.6%, or 0.3% annually. In other words, electric load growth is expected to be very modest and is best described as relatively flat over the forecast period.

Electricity rates were assumed to increase annually at a steady rate of 2% and at a price in 2017 of $0.15 per KWH. This was determined based on literature review and modeler judgment. The actual rate is not significant as both the pipeline and energy efficiency scenario had the same factor applied. This helps to provide an appropriate level of magnitude in terms of costs for decision makers.

Storage was not considered as part of the clean energy scenario either. While improvements have been made in storage cost and performance, they still are not at a level appropriate for wide-spread commercial use.[209] Storage technologies are an important component of the future energy marketplace due to the intermittent generation nature of several key clean energy technologies, especially solar and wind. However, at both the federal and regional level, efforts are under way to expand the market penetration of storage technologies. Massachusetts has launched the ESI that will put $10 million towards the acceleration of the storage technology marketplace in Massachusetts.[210] While storage is still a challenge area and needs to scale with the growth in renewable technology, efforts such as ESI will help support innovation in the storage marketplace.

The baseline electrical forecast only includes new potential load growth areas such as electric vehicles and expanded installation of heat pumps as projected in the overall electricity forecast provided by ISO New England (Table 2.13). However, these technologies may ultimately have a greater impact on future load then projected (although we feel this is unlikely over the next few years). In this highly dynamic energy marketplace, frequent updates on energy outlook should be conducted to determine if any shifts are warranted in NH energy policy.

6. PUBLIC PERCEPTIONS OF NATURAL GAS AND RENEWABLE ENERGY

Since 2001, the Granite State Poll has been conducting telephone interviews with random samples of New Hampshire residents every quarter. State and national political topics have been staple questions asked in this poll. Trained personnel at the University of New Hampshire Survey Center conduct the 10 to 15 minute telephone interviews. In 2010, the Granite State Poll began regularly including environmental topics among its mix of survey questions. Examples of these questions include views on climate change and ecosystem services, while others sought views on energy and the history of the state's forests.

6.1 Natural Gas versus Renewable Resources

Future development across New Hampshire and New England depends on reliable, cost-competitive and environmentally sound sources of energy. For years, the majority of energy used to generate electricity in New Hampshire and New England has been provided by the burning of fossils fuels (Figures 2.4 and 2.12). However, energy from renewable sources is growing in importance, both in terms of generating capacity and the regional push for a lower carbon energy system. Each source of energy has its respective economic, health, and environmental costs, benefits, and risks—factors that interact strongly with political and global priorities. Choices must be made, but in the certain knowledge that choosing an energy strategy inevitably means choosing an environmental strategy. With such challenges in mind, we asked 3 future-oriented questions in the October 2016 Granite State Survey. The answers to 3 energy-related questions from 577 interviews are reviewed below.

Question 1: Which do you think should be a higher priority for future energy sources for New Hampshire, increased use of natural gas, or increased use of renewable energy sources such as solar, wind, or biomass?

- Increased use of natural gas
- Increased use of renewable sources such as solar, wind or biomass
- Both equal
- Don't know

By almost a 3 to 1 margin, New Hampshire residents give higher priority for renewable energy sources (67%) compared to natural gas (24%). We also explored regional differences by comparing responses from counties in northern New Hampshire (85 interviews of residents in Coos, Grafton, and Carroll counties) to responses from counties in southern New Hampshire (478 interviews of residents in Belknap, Cheshire, Hillsborough, Merrimack, Rockingham, Strafford, and Sullivan counties). The results in terms of percentages in both regions are very similar to the statewide results, with residents placing a priority on renewable sources of energy over natural gas by a margin of 2.3 in northern counties and 2.9 in southern counties.

Survey responses on environmental topics often fall into partisan patterns.[211] For example, in a Pew Research Center survey from January 2014, 46% of republicans and those leaning republican said there was no evidence that the Earth is warming and 70% of Tea Party republicans think the same.[212] Hamilton and Wake (2013) find that large majorities among democrats (86%) and independents (62%), but only 44% of republicans, prefer renewable energy over drilling.[213] Figure 6.1 breaks down the responses to our future energy sources priority question by political ideology. Large majority of self-reported Liberals and Moderates prefer increased use of renewable energy sources (88% and 70%, respectively), while among self-reported conservatives, renewable energy finds substantial support (45%), although 46% give higher priority to natural gas.

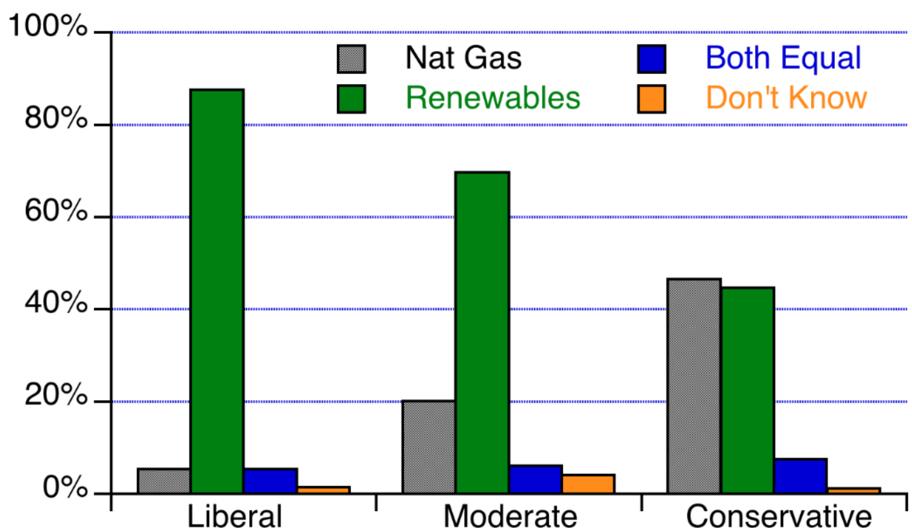

Figure 6.1. Responses from 577 interviews in New Hampshire in October 2016 on the question "Which do you think should be a higher priority for future energy sources for New Hampshire, increased use of natural gas, or increased use of renewable energy sources such as solar, wind, or biomass?" based on self-reported ideology.

To explore the effects of key demographics on respondent's views on future energy priorities, we performed a simple probit model. The dependent variable is a binary variable: 1 if the respondent views the increased use of natural gas as a higher priority for future energy use in New Hampshire, and 0 if otherwise. We then computed for the marginal effects of a unit change in key demographics on the probability of choosing natural gas as a higher priority.

The results show that age, political ideology and news sources were statistically significant (Table 6.1). Increasing age increases the probability of choosing natural gas as a higher priority by 8%. Residents who are registered conservatives are also more likely to choose natural gas as a higher priority for future energy sources, increasing the probability by 28%. All the discrete variables on news sources also yielded statistically significant results. Reading the Union Leader and Boston Globe increased probability of choosing natural gas as a higher priority by 33% and 9%, respectively. Reading local newspapers decreases the probability of choosing natural gas as a higher priority by 6%. Watching the NH television station WMUR was also statistically significant, although the marginal effect is small (positive 2%). Listening to New Hampshire Public Radio (NHPR) decreases the probability of choosing natural gas as higher priority by 22%, while listening to conservative radio increases the probability by 25%.

Table 6.1. Marginal effects on probability of choosing natural gas as a higher priority for future energy in New Hampshire.

Demographic Indicator	Marginal Effect (%)
Age	7.9
Conservative	28.0
Read Union Leader	33.3
Read Boston Globe	9.4
Read Local Newspaper	-6.4
Watch WMUR	1.9
Listen to NHPR	-21.9
Listen to Conservative Radio	25.5

6.2 Paying More Now to Ensure Future Cost Stability

The cost of energy is of concern to many New Hampshire residents and businesses, as is price volatility. To learn more about New Hampshire residents' views on volatile energy prices, we asked the following question.

Question 2: Think about your monthly electricity bill for a moment. Over the next 10 years, would you prefer …

- Paying an additional $3 per month on your electricity bill and knowing that this price would remain stable for 10 years … OR …
- Not raising electricity prices now, but knowing that prices could change by a greater or lesser amount at any time in the future
- Don't know

Seventy percent of respondents are willing to pay an additional $3 per month for less price volatility, while 23% would rather not pay for more for electricity now, but accept potential volatility in prices in the future (Figure 6.2). The results in both regions are very similar to the statewide results. This response is also consistent across self-reported political ideology with 75%, of liberals, 69% of moderates, and 65% of conservatives willing to pay $3 more per month for stable prices.

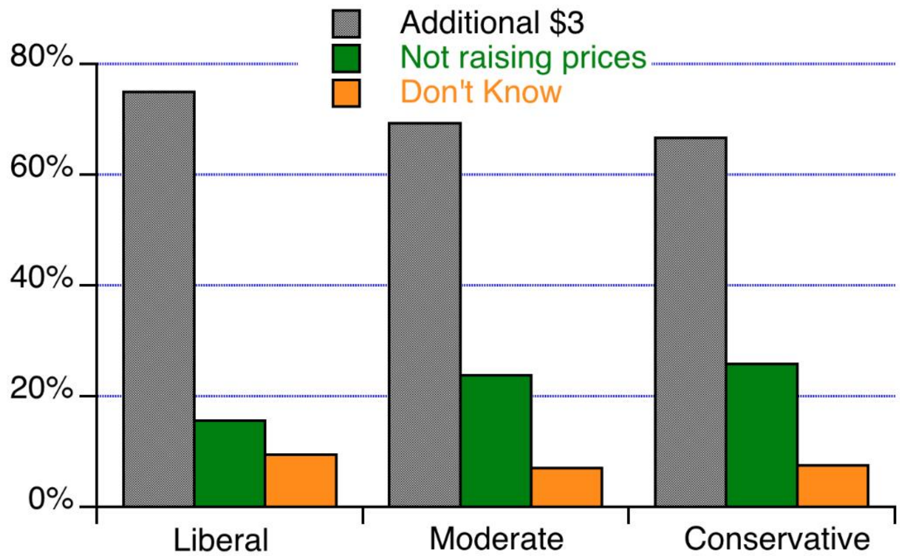

Figure 6.2. Responses from 577 interviews in New Hampshire in October 2016 on a question relating to monthly electric bill preferences between: 1) Paying an additional $3 per month on one's electricity bill and knowing that this price would remain stable for 10 years, or 2) Not raising electricity prices now, but knowing that prices could change by a greater or lesser amount at any time in the future, based on self-reported ideology.

We explored the effects of key demographics on respondent's monthly electric bill preferences using probit model regression. The dependent variable is a binary variable: 1 if the respondent chooses to pay an additional $3 per month on electricity bill for a stable price for 10 years, and 0 otherwise. The results show that only the respondent's income affects the probability of choosing an additional $3 per month for a stable bill for 10 years. An additional income of $20,000 annually reduces the probability that the respondent will choose to pay an additional $3 per month by 5%.

6.3 Paying for a Pipeline on One's Electricity Bill

There have been several recent proposals to build pipelines to bring additional natural gas into New England and New Hampshire, and some of these proposals have requested using rate payer funds to cover the costs of construction of the pipeline. To explore the interest of New Hampshire residents for funding the expansion of natural gas pipelines, we asked the following question.

Question 3: Would you support or oppose paying for the construction of a new natural gas pipeline in New Hampshire through a charge on your electricity bill?

- Strongly Support
- Somewhat Support
- Neutral – Volunteered
- Somewhat Oppose
- Strongly Oppose
- Don't Know

Overall, New Hampshire residents oppose the additional natural gas pipelines at 58%. In terms of political ideology, 63% of liberals, 60% of moderates and 48% of conservatives oppose the construction of new pipelines using rate payer funds (Figure 6.3).

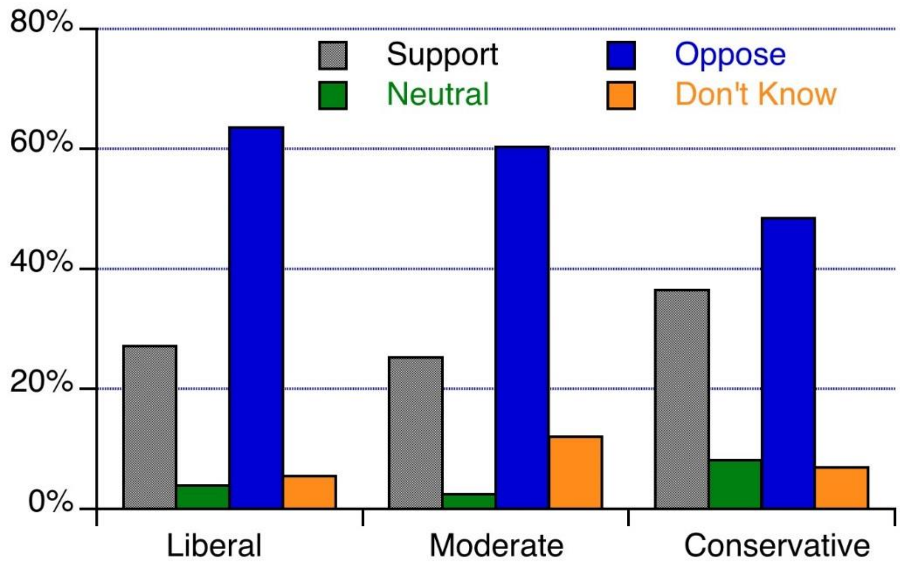

Figure 6.3. Responses from 577 interviews in New Hampshire in October 2016 on the question "Would you support or oppose paying for the construction of a new natural gas pipeline in New Hampshire through a charge on your electricity bill?" based on self-reported ideology.

The oppose-support gap is also distinct across geographic location in New Hampshire. The 3 northern counties of New Hampshire have a 19% gap between those who oppose and support the new natural gas pipelines. However, this gap widens for the southern regions at 31%. Splitting the sample by county shows that a large percentage of this opposition were from Hillsborough and Merrimack, suggesting that local opposition to the recent effort by Kinder Morgan to build a pipelines in southern New Hampshire[214] played a significant role in this gap.

To explore how the key demographics affect the choice to support natural gas pipeline, we performed a simple probit model. The dependent variable is a binary variable: 1 if the respondent supports the paying for construction of new natural gas pipeline through a charge on their electricity bill, and 0 if otherwise. We then computed for the marginal effects of a unit change in key demographics on probability of supporting the construction of new natural gas pipeline.

The results show that gender, years of education, and some news sources were statistically significant. Female respondents decrease the probability of supporting new natural gas pipeline construction by 24%. An additional year of education increases the probability of supporting the new natural gas pipeline by 3%. Reading the Boston Globe and watching WMUR increase the probability of supporting new natural gas pipeline by 24% and 17%, respectively.

7. FINDINGS AND RECOMMENDATIONS

7.1 Findings

Electricity is and will continue to be an essential part of the energy system that supports the quality of life and well-being of New Hampshire's residents. In 2014, electricity expenditures accounted for approximately $1 out of every $4 spent on energy in New Hampshire ($1.7 billion total).[215] Over time, New Hampshire's electric system has increasingly become dependent on natural gas and is experiencing an expansion of new clean energy (both renewable energy and energy efficiency). A specific challenge for New England and New Hampshire is that the region does not have indigenous sources of fossil fuels and therefore must be cognizant of the factors impacting energy imports versus regionally produced energy.

Currently, compared to historical values, global energy prices for oil and natural gas are low and the global storage levels for oil and natural gas are at historic highs. However, there remain significant risks to energy security in global energy markets,[216] which are experiencing a period of rapid change and uncertainty.[217] Two global energy trends that are currently significant factors in driving the energy market place are: 1) rapid growth in the use of natural gas for electric power generation; and 2) rapid growth in clean energy for electric power generation.

An expressed area of concern by the region's electric utility industry has been that rising demand for natural gas in New England—especially for electric power generation—will require new pipeline capacity. Specifically, ISO New England, the organization responsible for coordinating the region's power grid, has issued strong calls for new natural gas infrastructure investment.[218] ISO New England CEO and President Gordon van Welie has called New England's current operating situation "precarious" and said it could become "unsustainable" after 2019 in extreme cold weather.[219] The premise being that future increased natural gas demand will further overburden the existing pipeline infrastructure and may result in power grid failures and increased price volatility.[220]

However, as shown in Section 3.1, none of the natural gas studies (including one performed for ISO New England) covered in our comprehensive review found that grid reliability issues present an immediate threat to New England's energy security. Furthermore, while some studies have indicated the possibility of grid reliability issues emerging after 2021, reliability issues are primarily associated with extreme operating conditions.

Further evidence that supports the finding that near-term power reliability problems are unlikely to emerge is that New England's overall energy consumption has been declining as the region continues to extend its long-term trend as a mature and lower growth region of the country. The growth of new technologies, the overall transition to a more service-based economy, and increased private sector energy efficiency have all combined to reduce total energy demand, even while the overall economy has grown in New England (Figures 2.9 and 2.10).[221] This relationship of economic growth combined with a decrease in energy consumption is not unique to New England, but also part of a national trend; between 2007 and 2015, the overall U.S. economy has grown by 10% while overall energy consumption has declined by 2.4%.[222] Specifically, both overall electricity consumption (Table 2.15 and peak winter demand in New England are expected to decline over the next decade.[223] This projected decline in energy consumption has led to concerns that increased infrastructure development will be unnecessary and result in higher energy costs in the region.[224]

Supporting the concern that additional infrastructure investment may not be cost-effective is the observation that New England appears to currently have more natural gas capacity than required to meet peak demand when factoring in existing pipeline infrastructure, LNG delivery, and above-ground storage (as discussed in Section 2.1.2). However, as discussed in Section 3.3, New England can experience challenges with matching least-cost supply with demand within the existing natural gas system, and this may result in higher natural gas and electricity prices than otherwise would have occurred.

Regional and global markets influence the price and availability of natural gas in New England. Accurately projecting the future global and regional energy mix is challenging. Capital investments in energy infrastructure can be costly and result in stranded costs if energy marketplace fundamentals change prior to recouping the initial cost of the capital investment. There are numerous examples in the New England region of changing energy markets resulting in investments that are unlikely to fully recover initial costs.

In the late 2000s, there was a rush to build LNG infrastructure in New England due to declining domestic production of natural gas. Approximately $750 million in private capital was invested in off-shore LNG terminals off the coast of Massachusetts (Table 2.6). However, shortly after completion of these facilities, natural gas prices declined relative to LNG prices, which significantly reduced LNG delivery activity to New England beginning in 2008 (Table 2.3). If utility rate payers had funded these projects, it is very likely that they would have resulted in significant stranded costs due to them becoming uneconomic.

During this same time period, the expectations were that coal (based in part on projections by the EIA) would be a dominant form of generation through at least 2030.[225] New Hampshire spent $450 million on mercury scrubbers to retrofit the Merrimack Station (a coal-fired power plant in Bow, NH) so that it would meet more stringent air emissions regulations. However, as energy dynamics have changed, coal-fired generation has declined dramatically, including at Merrimack Station, and New Hampshire rate payers now face significant stranded costs for Merrimack Station.

Based on the analysis of interstate natural gas pipeline expansion studies performed (see Section 3.2) there is evidence that new pipeline capacity *may* reduce the marginal difference in natural gas costs between New England and the overall nation.[226] However, this finding is not *conclusive*. Conversely, existing market interventions, such as synchronization of gas and electricity markets, the soon to take effect ISO New England Pay for Performance Program, and new regional pipeline capacity additions (such as the Spectra Algonquin Incremental Market pipeline project currently under construction[227]), could achieve similar or even greater wholesale cost reductions. The region has already taken steps (such as the Winter Reliability Program implemented by ISO New England) to ensure power grid reliability (see Section 2.1.1). A side effect of changing the New England energy landscape through the Winter Reliability Program appears to be that it may also be an effective tool for mitigating energy prices.[228]

A specific risk is that of infrastructure overbuild. The current evolution and uncertainty in global energy markets further increases the risk of stranded costs. Long-term energy investments may not be advised given the rapidly changing and volatile nature of the current global energy market place. This is not an environment that supports significant energy infrastructure expansion, especially given that there is already under-utilized capacity in the existing New England energy system.

The natural gas marketplace is complex, as is its interaction with the electricity markets. Existing studies have not sufficiently examined the marketplace to prove that new pipeline infrastructure will reduce energy costs in New England. Pipeline expansion may encourage further market development of natural gas in New England, but existing analysis (Table 3.1) has relied on a basic *assumption* that building more pipeline will reduce wholesale cost. However, we find that those studies have not provided sufficient and transparent analysis to support the theory that market intervention will achieve any impactful results on natural gas wholesale prices. In particular, as Appalachian Basin gas is opened to global markets through LNG, there is a risk that the price of natural gas may approach more of a global standard price (similar to the market for oil) and become less attractive as a low-cost energy source for the region.

Given the risks of increased energy costs and the uncertainty of benefits associated with additional pipeline infrastructure, we argue that further attention should be given to alternatives, including renewable energy and energy efficiency. Clean energy continues to experience rapid global growth, accounting for 30% of total global energy spending.[229] Clean energy is currently the fastest growing global energy source and is expected to exceed natural gas based energy consumption by 2027.[230] While historically, the capital cost of clean energy has been high compared to conventional fossil-fuel-based generation, that relationship has changed dramatically with the installed cost of clean energy rapidly approaching or exceeding the lower cost threshold of fossil fuels.[231] Some of the most significant decreases in installed cost have been in solar photovoltaic, which has fallen over 80% over the past 6 years.[232]

New Hampshire currently lags the region in investment in energy efficiency (Section 2.2). However, in August 2016, the New Hampshire Public Utilities Commission approved an EERS to reduce energy use in the state. The NH EERS will take effect starting in January 2018, and has established a cumulative goal for 3.1% electric savings relative to 2014 KWH sales. States that have implemented EERS have experienced 3 times the energy savings as states that do not have EERS.[233] This is an example of the type of policy that is expected to help New Hampshire cost-effectively meet its energy needs without paying for large infrastructure projects and the associated stranded costs risk.

If business-as-usual is pursued (meaning no additional large investments in pipeline infrastructure), then the power grid is still expected to still function for New Englanders, even if there is the possibility of elevated prices at times relative to other regions. Therefore, there is not an immediate need to take action on pipeline infrastructure development. It is possible that not building new expensive pipeline infrastructure will cause less “harm” than intervention actions. If New Hampshire feels that the benefits from a significant market intervention outweigh the costs and potential risks, then possible intervention actions include: 1) establishing contracts for LNG and existing pipeline natural gas, 2) cleaning energy investments, and 3) contracting for new pipeline systems. However, based on the analysis performed in Section 3.2, there is no conclusive evidence that current energy wholesale market prices will be improved by any further market intervention action.

How do we then rank the “big picture” of market interventions? The Analysis Group (2015) report identified the least-cost and most immediate impact would be experienced through contracting with existing infrastructure (LNG and existing pipeline).[234] This is a low-risk approach as it does not require long-term financial commitments. Black & Veatch[235] and Analysis Group (2015) specifically considered investment in energy efficiency and demand reduction in lieu of new natural gas pipeline additions. These 2 studies and the scenario analysis performed in this study (Section 5, Figures 5.1 and 5.2, and Table 5.2) indicate that the most cost-effective, long-term strategy is investment in energy efficiency and renewable energy to mitigate peak demand expansion. Across these studies, clean energy demonstrated the best return on investment for rate payers at the lowest risk. This approach also offers commitment flexibility and serves to diversify the energy mix in New England. Clean energy also addresses potential future costs associated with the evolution towards a lower carbon energy system in response to regional, national, and international pressures.

New pipeline expansion consistently emerges as an approach with a medium-sized impact on wholesale power prices, with the expectation it will reduce the marginal difference in natural gas costs for the New England region. However, the long-term commitment and high construction costs potentially reduce the cost-benefit of the project and carries specific risks of overbuild and stranded costs. Another risk with this approach is that it places New England's price dependency on a specific geographic region—the Appalachian Basin. In a scenario where funding is not dependent upon rate payers for risk mitigation but instead on private at-risk capital, additional construction of pipeline for capacity represents a reasonable option as the region is not necessarily any worse off, and potentially better off, from a direct-energy cost perspective.

Clean energy investment in New Hampshire has lagged the overall region. The evidence does not suggest that New Hampshire's lowest in the region level of energy efficiency investment provides any economic advantage to the state. Given the region's susceptibility to external market forces, policies that promote clean energy investment may prove to be a sensible long-term energy policy strategy for the state.

7.2 Recommendations

A controversial area of energy policy has been the use of electric rate payer funds to finance natural gas infrastructure. Independent of the merits of new pipeline additions, private capital is a viable alternative financing option. This would serve to eliminate one of the more divisive aspects of the pipeline by not exposing rate payers to risks of over paying for additional natural gas capacity and stranded costs. On August 17, 2016, the Massachusetts Supreme Court and on October 6, 2016 the NH PUC determined that rate payer funds should not be used to support natural gas pipeline capacity contracts. Furthermore, on October 25, 2016, the Connecticut Department of Energy & Environmental Protection cancelled a request for proposal (RFP) it has issued for natural gas related capacity despite acknowledging that " . . . the New England region is facing volatile electricity prices and significant risks to electric reliability due to limitations in our restructured electricity market that have driven investment in new natural gas-fired power plants, but not in the natural gas delivery infrastructure needed to ensure that those plants can run reliably all year round."[236]

Based on the analysis performed in Section 3.2, the evidence suggests that no action is required to meet short-term energy reliability need. We argue that if New Hampshire wishes to pursue market intervention in an attempt to reduce wholesale electricity costs, an appropriate study should be performed by a neutral third party that models system-wide natural gas flows before obligating rate payer funds. To move ahead without such a detailed study would essentially place the rate payer in a position of being an energy market speculator. Evidence supporting the existence of financial risk associated with new pipeline capacity is that to date, utility companies have not been willing to put shareholder funds at risk to underwrite the contracts for pipeline projects.

Based on the analysis performed in Sections 3 and 4, and given the projected low peak load growth and uncertainty in future energy markets, we find that it is advisable to avoid expensive market interventions or, at minimum, prioritize investments that have projected lowest cost and lowest risk. This will serve to keep rates affordable by reducing spending on more expensive utility infrastructure that has been demonstrated to increase rates. Out of the types of subsidized investments, the findings of this study suggest that clean energy investments, and specifically energy efficiency investments, up to the maximal economic potential (estimated by VEIC to be approximately 6% of total New Hampshire load[237]) are expected to be the most cost effective while also representing low financial risk to NH rate payers. Any policies should consider unintended and potentially disproportionate impacts to the populations identified as most negatively impacted by increased energy prices, including large commercial and industrial users and low-income households.

If New Hampshire policymakers decide to establish contracts for natural gas capacity funded via electric rate payers, then we would support the recommendation of the NH PUC that any contracts for natural gas capacity funded through a rate payer cost recovery mechanism should be conducted through a RFP process.[238] This process should be open to all forms of natural gas infrastructure, including new pipeline proposals, existing pipeline capacity, and LNG capacity. The underlying costs and assumptions from vendor submissions should also be placed in the public domain for review. From the review of studies in Section 3, there is evidence that costs may be lower for existing infrastructure and a RFP process would allow the least-cost option to be revealed through a fair, open, and competitive bidding process.

ANNOTATED BIBLIOGRAPHY

Analysis Group, Inc. (2015) Power System Reliability in New England, Meeting Electric Resource Needs in an Era of Growing Dependence on Natural Gas. Retrieved from: http://www.mass.gov/ago/docs/energy-utilities/reros-study-final.pdf

The region's dependence on natural gas for electricity generation raises concern about electricity reliability during peak winter demand when power generators compete with natural gas heating demand. High utilization of pipelines can lead to spikes in spot market prices, which often increase costs for electric rate payers.

Analysis Group (2015) The Economic Impacts of the Regional Greenhouse Gas Initiative on Nine Northeast and Mid-Atlantic States: Review of RGGI's Second Three-Year Compliance Period (2012-2014). Retrieved from: http://aceee.org/files/proceedings/2012/data/papers/0193-000157.pdf

The IMPLAN economic model and PROMOD power sector model were applied to program expenditures coupled with a social discount rate. Through the RGGI program, power system reliability has been maintained and greenhouse gas emissions from power generation have decreased. Between 2012 and 2014, RGGI generated $520 million in net economic benefits and 5,700 job-years in employment in New England. New England consumers have saved approximately $200 million through decreased energy bills.

Bernstein M, C Pernin, S Loeb, and M Hanson (2002) The Public Benefit of Energy Efficiency to the State of Massachusetts. Prepared by RAND Science and Technology. Retrieved from: http://www.rand.org/content/dam/rand/pubs/monograph_reports/2005/MR1588.pdf

Emissions, Air Quality and Health Benefits: In 1997, past energy efficiency actions resulted in a reduction of: 2.0M tons of CO_2, 11,000 tons of SO_2, 4,000 tons of NOX (Versus the 1997 baseline).

Economic Benefits: From 1977 to 1997, energy efficiency produced $1,644–$2,562 in per capita GSP, $323–$2,322 additional per capita gains by 2015.

Black & Veatch (2013) Natural Gas Infrastructure and Electric Generation: Proposed Solutions for New England. Retrieved from: http://nescoe.com/uploads/Phase_III_Gas-Elec_Report_Sept._2013.pdf

New Interstate pipeline capacity would provide $118 million in economic benefit for consumers with an additional 1.2 Bcf/d. No long-term infrastructure solutions are needed under a low demand scenario and

the outcome of not building any infrastructure under this scenario yields a positive net benefit of $411 million.

Bloomberg (2015) U.S. Ousts Russia as Top World Oil, Gas Producer in BP Data. Retrieved from: http://www.bloomberg.com/news/articles/2015-06-10/u-s-ousts-russia-as-world-s-top-oil-gas-producer-in-bp-report

The United States. has taken Russia's place as the world's largest natural gas oil producer. This is further evidence of the seismic shifts in the world energy landscape resulting from American shale field production. The emergence of the United States as a trop driller has caused the United States to reduce imports, which has caused a slump in global energy prices and a reprioritization in foreign policy priorities.

Bower S, S Huntington, T Comings, and WTJ Poor (2012) Economic Impacts of Efficiency Spending in Vermont: Creating an Efficient Economy and Jobs for the Future. ACEEE Summer Study on Energy Efficiency in Buildings. Retrieved from: http://aceee.org/files/proceedings/2012/data/papers/0193-000157.pdf

The economic benefits of efficiency spending include generation of 370 jobs in 2012, $14 million in personal income/GSP, and an output of $17 million.

BP (2016) BP Energy Outlook 2016 Edition: Outlook to 2035. Retrieved from: https://www.bp.com/content/dam/bp/pdf/energy-economics/energy-outlook-2016/bp-energy-outlook-2016.pdf

Energy demand will continue to grow as the world economy expands. However, there is uncertainty of the growth rate of global GDP. The fuel mix continues to shift. However, fossil fuels are still the dominant energy powering the world economy. The rate of carbon emissions is reducing significantly due to increasing gains in energy efficiency and a shift towards lower carbon fuels.

CNBC (2013) Marcellus Turns Pennsylvania into 'Saudia Arabia' of Natgas. Retrieved from: http://www.cnbc.com/id/100720973

A study by Deloitte and Touche stated that Marcellus is "projected to dominate the Mid-Atlantic natural gas market." Michael Krancer, former Pennsylvania secretary of environmental protection stated, "We literally have the Saudi Arabia of natural gas under our feet" and that the Marcellus shale potential is "enormous…production numbers are off the charts." Pennsylvania's natural gas production increased by 69% in 2012.

BW Research (2015) Massachusetts Clean Energy Industry Report. Retrieved from: http://www.masscec.com/2015-massachusetts-clean-energy-industry-report

The report documents a vibrant and diverse cluster of activities that has demonstrated remarkably strong and consistent growth over the past 5 years. Massachusetts surpassed 1 GW of installed renewable energy capacity in 2015. Annual employment growth of 11.9% is the largest increase in any year since 2010. The number of clean energy jobs has grown by 64% since 2010, cumulatively adding almost 40,000 clean energy workers bringing the statewide total to 98,895. Clean energy jobs pay well, with nearly 75% of full-time workers earning $50,000 or more annually, compared to a median wage of $44,678 for all jobs across Massachusetts. Massachusetts is number 1 in attracting early-stage investments per capita, beating California by more than 149% on a per capita basis. Total public and private investment in the state's clean energy industry exceeded $549 million.

Carbon Solutions New England (2012) The New Hampshire Greenhouse Gas Emissions Reduction Fund: Year 3 (July 2011 – June 2012). Retrieved from: https://www.puc.nh.gov/Sustainable%20Energy/GHGERF/Evaulations/GHGERF_Year%203_annual_report_2011-12_FINAL.pdf

This included a collection and aggregation of grantee program results, economic impact analysis using the IMPLAN model, and direct measurement of full-time equivalent jobs. There were positive economic impacts with a total return of $4.95 for every $1 spent for a total return of $108 million through 2030. Full-time jobs supported ranged by quarter from 2009 through 2012 between 15 and 75.

Competitive Energy Services, LLC (2014) Assessing Natural Gas Supply Options for New England and their Impacts on Natural Gas and Electricity Prices. Retrieved from: http://competitive-energy.com/docs/2014/02/CES_REPORT_NaturalGasSupply_20140131_FINAL.pdf

The addition of 1 Bcf/d of new pipeline capacity will result in $1.9 billion in annual electricity wholesale savings in New England.

Concentric Energy Advisors (2012) New England Cost Savings Associated with New Natural Gas Supply and Infrastructure. Retrieved from: http://www.spectraenergy.com/content/documents/SE/Operations/US_NatGas_Ops/Projects-US/AIM/Project_Benefits_New_England_Cost_Savings_Infrastructure_Report__1_.pdf

The reduction in wholesale energy cost in New England was estimated to range from approximately $240 to $310 million with up to an additional 1.5 Bcf/d of new interstate pipeline.

Connecticut GSC on Climate Change (2005) Connecticut Climate Change Action Plan. Retrieved from: http://www.ctclimatechange.com

Economic Benefits:

Front-loading of costs, 2.5%; energy capacity benefits: use of existing sites and infrastructure, 2.5%; benefits of fuel diversity, 2.5%; other benefits (such as transmission reliability, employment effects, benefits of high level efficiency such as CHP) 2.5%.

As a result of reductions in criteria air pollutants, net benefits from 2005 to 2020 include 2,092 average annual jobs, $3.1 million output, $2.03 million GSP, $1.8 million in real disposable income, and an additional $4 to $1 payback of reduced health costs and public health.

Emissions, Air Quality and Health Benefits:

Emissions, air quality and health benefits: reduced emissions of SO_2, NOx, and CO_2, 5%.

By 2020, oil programs are expected to avoid: 1.89 millions of metric tons of carbon dioxide equivalent (MMTCO2e) and gas programs are expected to avoid: 2.07 MMTCO2e.

DOER (2004) 2002 Energy Efficiency Activities. Massachusetts Division of Energy Resources. Retrieved from: http://www.mass.gov/Eoca/docs/doer/pub_info/ee02-long.pdf

There are economic benefits as electricity bill impacts energy savings. The total program costs $138 million. The total participant energy savings are $21.5 million per year, with $249 million in lifetime savings. The average cost for conserved energy is 4.0 ¢/KWH. The total participant demand savings is $1.2 million per year. Customer savings from lower wholesale energy clearing prices are $19.4 million. The number of new jobs created in 2002 was 2,093. The disposable income from net employment in 2002 was $79 million.

Energyzt Advisors, LLC. (Oct 2014) Winter Reliability Analysis of New England Energy Markets. Retrieved from: http://www.epsa.org/forms/uploadFiles/2CB910000000A.filename.Energyzt_NEPGA_Final_Report.pdf

New England does not have near-term power grid reliability issues and therefore new pipeline capacity is not necessary.

Frankfurt School, FS-UNEP Collaborating Centre for Climate & Sustainable Energy Finance (2016) Global Trends in Renewable Energy Investment. Retrieved from: http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2016lowres_0.pdf

2015 produced a new record for global investment in clean energy. Clean energy investment was double that of new coal and gas generation. Policy support for renewables remains fickle and there is rising interest in energy storage.

GDS Associates (2009) Additional Opportunities for Energy Efficiency in New Hampshire. Retrieved from: https://www.puc.nh.gov/Electric/GDS%20Report/NH%20Additional%20EE%20Opportunities%20Study%202-19-09%20-%20Final.pdf

Energy Capacity Benefits: Technical potential savings are over 27% of projected 2018 KWH sales. The maximum achievable cost effective potential is over 20% (nearly 2,700 GWH annually) of projected 2018 KWH sales and over 16% of projected 2018 non-electric sales (more than 15,440,000 mmbtu).

Emissions, Air Quality and Health Benefits: Emission reductions and costs to achieve over 3 million tons are at nearly $7 billion, based on the combined electric and non-electric technical potential scenarios, or more than 1 million tons and nearly $900 million, based on the potentially obtainable scenarios.

Grady, B (2016) Hawaii's grand experiments in the ag-energy nexus. Green Biz, June 13. Retrieved from: https://www.greenbiz.com/article/hawaiis-grand-experiments-ag-energy-nexus

The article provides examples of solutions to energy and food security. Self-sufficiency and resilience in food and energy are vital to Hawaii.

Heaps, AA (2016) Mind the Gap. Corporate Knights, June 10. Retrieved from: http://www.corporateknights.com/channels/utilities-energy/mind-the-gap-14655384/

Fifty-two oil companies filed for bankruptcy in 2016, and over 1/3 of the world's biggest oil and gas companies could be bankrupt in 2016 under crushing debt load and lack luster oil prices. However, growth in clean energy is booming with the world adding twice as much clean energy capacity as coal, oil, and gas combined. Electric vehicles could be a major game changer.

ICF International (2015) Access Northeast Project – Reliability Benefits and Energy Cost Savings to New England. Retrieved from:

http://www.accessnortheastenergy.com/content/documents/ane/Key_Documents/ICF-Report-on-Access-Northeast-Project1.pdf

New England has increased its reliance on natural gas-fired electricity generation, which now accounts for 50% of all power generated. New England's reliance on interruptible gas supplies for much of its power may be problematic as natural gas-fired plants shoulder more of the load served by retiring nuclear and coal plants. Without new firm sources of gas supply, there will be an increasing probability of gas supply deficits, which under certain conditions could cause costly electric system disruptions. An estimated $2.5 billion could have been saved if the Access Northeast project had been in place.

ICF International (2012) Assessment of New England's Natural Gas Pipeline Capacity to Satisfy Short and Near-Term Electric Generation Needs. Retrieved from: **http://psb.vermont.gov/sites/psb/files/docket/7862relicense4/Exhibit%20EN-JT-15.pdf**

New England's gas delivery system is in tight balance on a winter design day, even before any future gas demand growth is factored in. Through 2020, the estimated winter design day deficit in the Reference Gas Demand Forecast is generally between 0.5 and 0.6 Bcf/d in most years.

ICF International (2014) Assessment of New England's Natural Gas Pipeline Capacity to Satisfy Short and Near-Term Power Generation Needs: Phase II. Retrieved from: https://www.iso-ne.com/static-assets/documents/2014/11/final_icf_phii_gas_study_report_with_appendices_112014.pdf

Natural gas is expected to remain constrained in New England by 1.1 Bcf/d through 2020.

International Energy Agency (2016) Global EV Outlook 2016: Beyond one million electric cars. Retrieved from: http://www.iea.org/topics/transport/subtopics/electricvehiclesinitiative/

In 2015, there were over 1 million electric cars on the road globally. Eighty percent of electric cars are located in the United States, China, Japan, Netherlands, and Norway. Battery technology continues to improve in performance and decrease in cost.

International Energy Agency (2016) Key World Energy Statistics. Retrieved from: **https://www.iea.org/publications/freepublications/publication/KeyWorld2016.pdf**

This report highlights key facts and trends from across the broad number of datasets the IEA produces to provide global statistics on energy supply, consumption, balance, and prices.

International Energy Agency (2016) Medium-Term Gas Market Report 2016: Market Analysis and Forecasts to 2021. Retrieved from: https://www.iea.org/Textbase/npsum/MTGMR2016SUM.pdf

The global gas markets are changing rapidly, which is creating new challenges for the energy industry and policy makers. Slowdown in Asian gas demand began in 2014 and has extended to 2015, which has pushed LNG prices to new lows. Globally, new sources of LNG export are being developed, which will dramatically increase the global supply of LNG available.

International Energy Association (2013) Renewables to surpass gas by 2016 in the global power mix. Retrieved from: https://www.iea.org/newsroom/news/2013/june/renewables-to-surpass-gas-by-2016-in-global-power-mix.html

Electric power generated from renewable resources combined (wind, hydro, solar, and other technologies) is expected to increase by 40%.

International Energy Agency (2016) World Energy Investment 2016. Retrieved from: https://www.iea.org/investment/

In 2015, global investment in energy was $1.8 trillion, which was down 8% from the previous year. The sharp fall was due to a decrease in oil and gas investment. Renewable energy and energy efficiency accounted for 30% of global investment. Renewable energy is expanding rapidly even though overall investment dollars are flat due to a rapid decline in the costs of solar, wind, and hydropower. Energy efficiency increased 6% from 2014. Gas demand growth has been suppressed in North America by the expansion of renewables.

International Finance and Economy (2016) Global Energy Markets in Transition. Retrieved from: https://www.iea.org/newsroomandevents/speeches/160421_Birol_Tokyo.pdf

The global economy and energy are tightly connected. Currently, oil is the most valuable internationally traded commodity, valued at $770 billion in 2015. Current low oil energy market conditions should not lead to complacency in understanding potential energy security risks. The oil and gas industry reacted to the 2015 collapse in oil prices with a historical level of capital investment and personnel cuts.

ISO New England (2016) 2016 Energy-Efficiency Forecast 2020-2025. Retrieved from: https://www.iso-ne.com/static-assets/documents/2016/04/ISO_NE_2016_EE_Forecast_2020_2025_Final.pdf

Economic Benefits: ISO New England forecasts an average of 49 GWH savings for New Hampshire and 43 MW savings.

ISO New England (2016) 2016 Regional Energy Outlook. Retrieved from: https://www.iso-ne.com/static-assets/documents/2016/03/2016_reo.pdf

Three waves of change are impacting New England: 1) natural-gas-fired generation is displacing coal, oil, and nuclear plants, 2) renewable energy and energy-efficiency measures are increasing, and a hybrid grid of large and distributed generation is emerging. These transformative forces are not unique to New England. Wintertime access to natural gas has tightened in the region because the natural gas transportation network has not kept up with demand from generation and heating.

LaCapra Associates (2003) Alternatives to Velco's Northwest Vermont Reliability Project. January 29. Retrieved from: http://207.136.225.66/Downloads/Other/VELCO.pdf

The study determined the cost of transmission upgrade and the cost of a smaller upgrade. The difference in these costs could be used to assess the cost-effectiveness of the alternative resource package.

La Capra Associates & Economic Development Research Group (2015) The Economic Impacts of Failing to Build Energy Infrastructure in New England. Retrieved from: http://media.gractions.com/5CC7D7975DFE1335100A9E9B056042840005CCF0/25e72b85-c007-4b98-a851-8b31563c9559.pdf

Since 2000, New England's reliance on natural gas to generate electricity has increased dramatically and is now used to fuel over 40% of the region's generation, which determines electricity prices a majority of the time. Pipeline infrastructure has not kept pace with this increased demand and is reaching maximum capacity, especially during the winter months, to meet both electricity generation and space heating demands. Investment in infrastructure ensures persistent and increasing energy prices and costs for the region. Wholesale electricity prices are sending investment signals to the market. Lack of new infrastructure will cost the region $5.4 billion in higher energy costs between 2016 and 2020.

Lazard (2015) Lazard's Levelized Cost of Energy Analysis – Version 9.0. Retrieved from: http://www.msn.com/en-us/money/companies/why-billions-in-proven-shale-oil-reserves-suddenly-became-unproven/arAAh4onn?li=BBnbfcL&ocid=SL5BDHP

This report provides levelized cost of energy for both renewable and non-renewable technologies.

Loder, A (2016) Why billions in proven shale oil reserves suddenly became unproven. MSN, June 15. Retrieved from: http://www.msn.com/en-us/money/companies/why-billions-in-proven-shale-oil-reserves-suddenly-became-unproven/arAAh4onn?li=BBnbfcL&ocid=SL5BDHP

Proven gas and oil resources are disappearing across the shale patch with 9.2 billion, or 20%, of inventories removed from books. See Loder's related article on the Bloomberg website: http://www.bloomberg.com/news/articles/2015-12-10/billions-of-barrels-of-oil-vanish-in-a-puff-of-accounting-smoke.

Massachusetts Technology Collaborative (2006) Massachusetts Distributed Generation Collaborative 2006 Report under D.T.E. 02-38-C Investigation by the Department of Telecommunications and Energy on its own Motion into Distributed Generation. June 30, 2006. Retrieved from: http://masstech.org/dg/02-38-C_Attachment-H_DPWG_Report.pdf

Emissions, Air Quality and Health Benefits:

Each scenario was found to achieve reductions of CO_2 emissions relative to the reference case: energy efficiency and CHP combined will have a reduction of 2.4 million short tons CO_2/ year in 2020.

Economic Benefits:

The 250 MW of PV is expected to displace 356 GW of purchases from the wholesale market and reduce prices by 0.4%. Energy efficiency is expected to reduce prices by 1.6%. Energy efficiency and CHP would produce a 5.1% reduction.

Nelder, C (2011) What the Frack? Is there really 100 years' worth of natural gas beneath the United States? Retrieved from: http://www.slate.com/articles/health_and_science/future_tense/2011/12/is_there_really_100_years_worth_of_natural_gas_beneath_the_united_states_.html

There is uncertainty to the actual amount of natural gas economically available from the Marcellus shale. The EIA states that "there is a high degree of uncertainty around the projection, starting with the estimated size of the technically recoverable shale gas resource…the estimates embody many assumptions that might prove to be untrue in the long term." See additional resources on U.S. natural gas reserves on the EIA website: http://www.eia.gov/naturalgas/crudeoilreserves/.

NH Department of Environmental Services (2009) NH Climate Action Plan. Retrieved from: http://des.nh.gov/organization/divisions/air/tsb/tps/climate/action_plan/nh_climate_action_plan.htm

New Hampshire's Climate Action Plan presents an opportunity to spur economic growth through investment in our own state's economy of monies currently spent on energy imports, creating jobs and economic growth through development of in-state sources of energy from renewable and low-emitting resources, and green technology development and deployment by New Hampshire businesses, avoiding the significant costs of responding to a changing climate on the state's infrastructure, economy, and the health of our citizens.

NH Office of Energy & Planning (2014) New Hampshire 10-Year State Energy Strategy. Retrieved from: https://www.nh.gov/oep/energy/programs/documents/energy-strategy.pdf

This report provides background material on NH energy use and broad strategic recommendations for state energy policy in 4 different areas: 1) grid modernization, 2) energy efficiency, 3) fuel diversity, and 4) transportation. Overall, 20 recommendations are made in this report.

New Jersey Board of Public Utilities (2005) New Jersey's Clean Energy Program: 2005 Annual Report. Retrieved from: http://www.njcleanenergy.com/files/file/2005%20Annual%20Report.pdf

Energy Capacity Benefits:

From 2004 to 2005, electric energy savings and renewable energy generation grew by over 22%, and natural gas savings grew by over 42%. Efficient equipment installed and practices put into effect in 2005 will continue to save energy for an average of 15 years. The 5-year program activities resulted in lifetime energy savings of over 14 million MWH of electricity, 38 million Dekatherms of natural gas, 788,000 MWH of renewable generation. The programs have also reduced electric demand by 450 MW.

Emissions, Air Quality and Health Benefits:

Avoided emissions from 2005 activities for 2005–2020 are as follows: 13.2M tons of CO_2, 46,317 tons of SO_2, 21,813 tons of NOX.

Economic Benefits:

From 2001–2006, new solar owners were estimated to have saved $1.1 million annually in total electricity costs.

NYSERDA (2005) New York Energy $MARTSM Program, Evaluation and Status Report for the Year Ending December 2004. Retrieved from: http://www.nyserda.org/Energy_Information/SBC/sbcmay05summary.pdf

NYSERDA (2008) New York Energy $MARTSM Program, Evaluation and Status Report for the Year Ending December 2007. Retrieved from: http://www.nyserda.org/pdfs/Combined%20Report.pdf

Energy Capacity Benefits: There were electricity savings of 1,400 GWH between 1998 and 2004, and 3,000 GWH savings by 2007.

Emissions, Air Quality and Health Benefits: Emissions were reduced nearly 2,600 and 4,700 tons of NOx and SOx respectively. Annual CO_2 emissions decreased by 2 million tons.

Economic Benefits: Between 1998 and 2004, $195 million in energy costs were saved, and annual energy bills were reduced by $570 million. Four thousand, seven hundred jobs were created and retained. By 2027, the program is expected to create more than 7,200 jobs, increase labor income more than $300 million each year, and increase total annual output in the state by $503 million.

NYSERDA (2006) New York Energy $mart Program Evaluation and Status Report: Report to the Systems Benefits Charge Advisory Group. May. Retrieved from: https://library.cee1.org/sites/default/files/library/8861/CEE_Eval_NewYorkEnergySmartProgram2007AnnualEvaluationReport_1Mar2008.pdf

NYSERDA (2008) New York Energy $mart Program Evaluation and Status Report; Year Ending December 31, 2007, Report to the Systems Benefit Charge Advisory Group, Final Report. March. Retrieved from: http://www.nyserda.org/pdfs/Combined%20Report.pdf

NYSERDA (2009) New York Energy $mart Program Evaluation and Status Report; Year Ending December 31, 2008, Report to the Systems Benefit Charge Advisory Group, Final Report. March. Retrieved from: https://library.cee1.org/sites/default/files/library/8867/CEE_Eval_NewYorkEnergySmartProgramMarch2009QuarterlyEvaluationReport_1May2009.pdf

Energy Capacity Benefits: From 1999 to 2005, there was a 1,040 MW reduction in peak demand. And from 1999 to 2005, the number of energy service companies increased from fewer than 10 to over 180 companies.

Emissions, Air Quality and Health Benefits: Actions to date avoid (per year): 1.4 million tons of CO_2, 3,170 tons of SO_2 and 1,750 tons of NOX.

Economic Benefits: The model indicated the Energy $mart Program initiatives from 1999 to 2008 have: created over net 4,900 jobs, increased personal income by $293 million, GSP by $644 million, and total output by $1 billion. Projecting to 2020, the Energy $mart Program is expected to create 86,400 net job-years. From 2008 to 2017, actions to date yield (per year) an average of 4,100 jobs and $182M labor income.

Pletka, R (2004) Economic Impact of Renewable Energy in Pennsylvania. Prepared by Black & Veatch for The Heinz Endowments and Community Foundation for the Alleghenies. March. Retrieved from: https://www.epa.gov/sites/production/files/201508/documents/economic_impact_of_renewable_energy_in_pennsylvania.pdf

Economic Benefits: Over the 2006–2015 period: increase output $10.1B, increase earnings $2.8B and create 85,000 jobs.

PR Newswire (2006) Early August Demand Response Produces $650 Million Savings in PJM. Retrieved from: http://www.prnewswire.com/news-releases/early-august-demand-response-produces-650-million-savings-in-pjm-56192937.html

Economic Benefits: Wholesale prices would have been $300/MWH higher without demand response during a heat wave. Demand response to the heat wave reported savings of about $650 million for energy purchasers.

REMI (2004) Economic Impact of Oil and Natural Gas Conservation Policies. Prepared for U.S. Environmental Protection Agency and the State of Connecticut. November. Retrieved from: http://ctclimatechange.com/documents/Appendix9_REMI_HeatingOilandNaturalGasConservationFunds_CCCAP_2005_000.pdf

Economic Benefits: Benefits to the state include employment (average annual increase) 2,092, Output (Mil '96$): 3,094.90, GSP(Mil '96$): 2,033.01, Real Disposable Personal Income (Mil '96$): 1,749.42, and state revenues (Mil '01$): 382.13. Employment is the average annual increase from the baseline. Employment is not cumulative and is based on output growth.

Research Partnership (2015) 2015 Massachusetts Clean Energy Industry Report. US DOE. Retrieved from: http://www.masscec.com/2015-massachusetts-clean-energy-industry-report

Energy Capacity Benefits: Massachusetts surpassed 1 GW of installed renewable energy capacity in 2015.

Economic Benefits: Annual employment growth of 11.9% is the largest increase in any year since 2010. The number of clean energy jobs has grown markedly by 64% since 2010, cumulatively adding almost 40,000 clean energy workers, bringing the statewide total to 98,895. Clean energy jobs pay well, with nearly 3/4 of full-time workers earning $50,000 or more annually, compared to a median wage of $44,678 for all jobs across Massachusetts. Massachusetts is number 1 in attracting early-stage investments per capita, beating California by more than 149% on a per capita basis. Total public and private investment in the state's clean energy industry exceeded $549 million.

Runnalls, J (2016) Blowing hot air. Corporate Knights, June 16. Retrieved from: http://www.corporateknights.com/channels/clean-technology/blowing-hot-air-14660707/

The cost of wind has dropped 60% and the cost of solar has dropped 80% over past 6 years (source: Lazard's levelized cost). Clean energy investment rose 17% to $44 billion in 2015 (source: Bloomberg New Energy Finance) and accounted for 2/3 of all new generation added to the grid. Republican attitudes have been shifting as it supports 300,000 clean energy jobs in republican controlled states and districts.

Sedano et al. (2005) Electric Energy Efficiency and Renewable Energy: An Assessment of Existing Policies and Prospects for the Future. Regulatory Assistance Project. Retrieved from: http://www.raponline.org/Pubs/RSWS-EEandREinNE.pdf

Energy Capacity Benefits: In 2004, energy efficiency reduced peak demand by 1,421 MW.

Emissions, Air Quality and Health Benefits: From 2000 to 2010, avoid 31.7M tons (6%) of CO_2, 34,200 tons of SO_2, 22,039 tons of NOX.

Economic Benefits: From 2000 to 2010, there was a net increase of $6.1 billion in economic output, $1.04 million in wage income, and in 28,190 job-years.

Summit Blue Consulting (2008) Assessment of the New Jersey Renewable Energy Market, Volume I and II. Prepared for the New Jersey Board of Public Utilities. March. Retrieved from: http://www.njcleanenergy.com/files/file/NJ%20RE%20Mkt%20Assmt%20Svc%20Rpt%20Vol%201%20FINAL%203-24-08.pdf

Energy Capacity Benefits: The electricity growth rate for all sectors from 2005 to 2020 is projected to be 1.52%.

Sussex Economic Advisors (2014) Maine Public Utilities Commission Review of Natural Gas Capacity Options. Retrieved from: https://www.iso-ne.com/static-assets/documents/committees/comm_wkgrps/othr/egoc/mtrls/2014/mar62014/maine_puc_gas_study_022614.pdf

New interstate pipeline capacity would provide $18 million in annual net savings for New England consumers with an additional 1.0 Bcf/d.

Union of Concerned Scientists (2016) Massachusetts's Electricity Future: Reducing Reliance on Natural Gas through Renewable Energy. Retrieved from: http://www.ucsusa.org/clean-energy/increase-renewable-energy/massachusetts-electricity-future

The energy landscape in New England is changing and the state is becoming over-reliant on natural gas. This has created greater risks for consumers, including economic risks from over-investment in natural gas pipelines and exposure to volatile natural gas.

US DOE Building Technologies Program (2012) New Hampshire Energy and Cost Savings for New Single and Multifamily Homes: 2012 IECC as Compared to the 2009 IECC. US DOE. Retrieved from: https://www.energycodes.gov/sites/default/files/documents/NewHampshireResidentialCostEffectiveness.pdf

Economic Benefits:

- Life-cycle cost savings, averaged across climate zones and building types, are $10,635 for the 2012 IECC
- Simple payback period is 3.0 years for the 2012 IECC
- Households save an average of $620 per year on energy costs with the 2012 IECC
- Net annual consumer savings, including energy savings, mortgage cost increases, and other associated costs in the first year of ownership, average $507 for the 2012 IECC
- Energy costs, on average, are 27.3% lower for the 2012 IECC

U.S. Department of Energy (2015) Natural Gas Infrastructure Implications of Increased Demand from the Electric Power Sector. Retrieved from: http://energy.gov/sites/prod/files/2015/02/f19/DOE%20Report%20Natural%20Gas%20Infrastructure%20V_02-02.pdf

The U.S. natural gas sector has been fundamentally altered by technological advances in horizontal drilling and hydraulic fracturing. This has allowed extraction of natural gas from shale formations that

previously were uneconomic to drill. This has unlocked large geographical sources of natural gas resources. Diverse sources of natural gas supply and demand will reduce the need for additional interstate natural gas pipeline infrastructure. Higher utilization of existing interstate natural gas pipeline infrastructure will reduce the need for new pipelines. Incremental interstate natural gas pipeline infrastructure needs in a future with an illustrative national carbon policy are projected to be modest relative to the reference case. While there are constraints to siting new interstate natural gas pipeline infrastructure, the projected pipeline capacity additions in this study are lower than past additions that have accommodated such constraints.

U.S. Energy Information Administration (2016) Annual Energy Outlook 2016 Early Release: An Annotated Summary of Two Cases. Retrieved from: http://www.eia.gov/forecasts/aeo/er/index.cfm

This report features 2 cases: the reference case and a case excluding implementation of the Clean Power Plan. The reference case is a business-as-usual trend estimate, which assumes Clean Power Plan (CPP) compliance modeled using allowances with cooperation across states at the regional level, with all allowance revenues rebated to rate payers. The no-CPP case is a business-as-usual trend estimate that assumes that CPP is not implemented. Coal's share of total electricity generation, which was 50% in 2005 and 33% in 2015, falls to 21% in 2030 and to 18% in 2040. Outcome reflects both low load growth and generation mix changes driven by the extension of key renewable tax credits, reduced PV capital costs, and low natural gas prices. Strong growth in wind and solar generation spurred by tax credits leads to a short-term decline in natural gas-fired generation between 2015 and 2021. However, natural gas generation then grows significantly increasing by more than 67% from 2021 through 2040.

U.S. Energy Information Administration (2016) Natural gas expected to surpass coal in mix of fuel used for U.S. power generation in 2016. Retrieved from: http://www.eia.gov/todayinenergy/detail.cfm?id=25392

Coal has been the dominant source of energy for power generation in the United States. However, growth in natural gas in the power sector is expected to result in total natural-gas-fired generation exceeding that of coal power generation in 2016. Between 2000 and 2008, coal was less expensive than natural gas. However, starting in 2009, the gap narrowed.

U.S. Energy Information Administration (2015) U.S. energy imports and exports to come into balance for first time since 1950s. Retrieved from: http://www.eia.gov/todayinenergy/detail.cfm?id=20812

Predictions in EIA's Annual Energy Outlook 2015 show the potential to eliminate all net U.S. energy imports between 2020 and 2030. This is due both to changes in supply and demand. Fossil fuel supply is being influenced by growth in oil and natural gas. Demand is being mitigated by energy efficiency and renewable energy.

Vermont Department of Public Service (2008) Vermont Comprehensive Energy Plan 2009. Retrieved from: http://www.uvm.edu/~gflomenh/ENRG-POL-PA395/readings/VT-CEP2009DRAFT6-4-08.pdf

Energy Capacity Benefits: Electricity demand is expected to grow an average of 0.93% on an annual basis from 2008 to 2028. When new design structure matrix measures are implemented, the Vermont Department of Public Service anticipates a decline of 0.19% on an average annual basis.

Economic Benefits: Due to forecasts of a large supply gap with high costs to replace power contracts, Vermont committed itself to pursue very aggressive energy efficiency measures.

Vermont Energy Investment Corporation (2013) Increasing Energy Efficiency in New Hampshire: Realizing Our Potential. Retrieved from: https://www.nh.gov/oep/resource-library/energy/documents/nh_eers_study2013-11-13.pdf

The potential for cost-effective reductions in energy use in NH buildings is equivalent to 715 million KWH per year, which is 10 times the savings achieved through current NH energy efficiency programs at a cost of 3.1 cents per KWH. This would require approximately $1 billion in investment and save $3 billion over a 15-year investment life time. This investment would create 2,300 jobs and add $160 million to the NH GSP.

World Energy Council (2016) World Energy Trilemma 2016: Defining measures to accelerate the energy transition. Retrieved from: https://www.worldenergy.org/publications/2016/world-energy-trilemma-2016-defining-measures-to-accelerate-the-energy-transition/

Energy is at a transition point. Actions required include:

1. Transforming energy supply
2. Advancing energy access
3. Enabling customer affordability and industry competitiveness
4. Improving energy efficiency and managing demand
5. Decarbonising the energy sector

There is a trilemma performance paradigm of: 1) energy equity, 2) environmental sustainability, and 3) energy security. Policy choices made now will support a robust energy sector. Policies and investments to change energy supply take time and will likely be disruptive. Countries must act for secure, equitable and sustainable energy to support a thriving energy sector, competitive economy, and healthy society. Policy makers should provide clarity to the market for investors. Change management approach in communicating policies is necessary to avoid stakeholder backlash. Energy 2.0 must be enabled by regulations 2.0, or desired transitions in the energy sector must be stimulated by transitions in the regulatory framework.

ENDNOTES

[1] Wake, C, M Magnusson, C Foreman, and F Wilson (2017) New Hampshire's Electricity Future: Cost, Risk, and Reliability. Carsey Perspectives, UNH Carsey School of Public Policy. https://carsey.unh.edu/publication/perspective/nh-electricity-markets

[2] Birol, F (2016) Global Energy Markets in Transition. Analysis meeting on International Finance and Economy. Available on-line at https://www.iea.org/newsroomandevents/speeches/160421_Birol_Tokyo.pdf

[3] BP (2016) BP Energy Outlook 2016 edition: Outlook to 2035. Available on-line at https://www.bp.com/content/dam/bp/pdf/energy-economics/energy-outlook-2016/bp-energy-outlook-2016.pdf

[4] Birol, F (2016) Global Energy Markets in Transition. Analysis meeting on International Finance and Economy

[5] U.S. Energy Information Administration (2016 March 16) Natural gas expected to surpass coal in mix of fuel used for U.S. power generation in 2016. Available on-line at http://www.eia.gov/todayinenergy/detail.cfm?id=25392

[6] U.S. Energy Information Administration (n.d.) Table 7.2a Electricity Net Generation: Total (All Sectors). Available on-line at http://www.eia.gov/totalenergy/data/monthly/#electricity

[7] Obama, B (2017) The irreversible momentum of clean energy. *Science*, DOI: 10.1126/science.aam6284.

[8] U.S Energy Information Administration (EIA) – December 2016 Monthly Energy Review: Table 1.3 Primary Energy Consumption by Source. http://www.eia.gov/totalenergy/data/annual/index.php#summary. Because there is considerable

interannual variability in the amount of energy used in the U.S, we calculated the percentage decrease in energy use from 2005 to 2015 based on a linear regression.

[9] GDP data from U.S. Department of Commerce – Bureau of Economic Analysis (BEA). https://www.bea.gov/national/index.htm. GDP normalized to $2015 using the BEA – Table 1.1.4 Price Index for GDP https://www.bea.gov/iTable/index_nipa.cfm. The percentage growth from 2005 to 2015 was calculated by subtracting the 2005 real GDP value from the 2015 value and dividing by the 2005 value.

[10] Leiserowitz A, E Maibach, C Roser-Renouf, S Rosenthal, and M Cutler (2016) Politics and Global Warming, November 2016. Yale Program on Climate Change Communication. Survey of registered voters conducted on 18 November 18, 2016. Available on-line at http://climatecommunication.yale.edu/wp-content/uploads/2016/12/Global-Warming-Policy-Politics-November-2016.pdf

[11] U.S. Clean Power Plan. Available on-line at https://www.epa.gov/cleanpowerplan

[12] United Nations Framework Convention on Climate Change (n.d.) 2016 Paris Agreement. Available on-line at http://unfccc.int/2860.php

[13] U.S. Energy Information Administration (n.d.) State Profile and Energy Estimates. Available on-line at http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_prices/tx/pr_tx_NH.html&sid=NH

[14] ISO New England (2016) 2016 Regional Electricity Outlook. Available on-line at https://www.iso-ne.com/static-assets/documents/2016/03/2016_reo.pdf

[15] ISO New England (2016) 2016 Regional Electricity Outlook

[16] van Welie, G (2016) State of the Grid: 2016. ISO on Background Series. Available on-line at https://www.iso-ne.com/static-assets/documents/2016/01/20160126_remarks_2016stateofthegrid.pdf

Gustin, C (2016) Baker is right; we need gas pipeline. CommonWealth Magazine. Available on-line at http://commonwealthmagazine.org/environment/baker-is-right-we-need-gas-pipeline/

[17] ICF International. (2015 February). Access Northeast Project – Reliability Benefits and Energy Cost Savings to New England. Available on-line at http://www.accessnortheastenergy.com/content/documents/ane/Key_Documents/ICF-Report-on-Access-Northeast-Project1.pdf

[18] Stranded costs are costs that must be paid by utility rate payers if infrastructure investments become redundant after a significant change in the energy marketplace, either through market forces or regulation.

[19] van Welie, G (2016) 2016 Regional Electricity Outlook. Available on-line at http://www.iso-ne.com/static-assets/documents/2016/03/2016_reo.pdf

[20] Nikolewski, R (2015) A big fight over a natural gas pipeline project divides Massachusetts. Available on-line at http://watchdog.org/230174/gas-pipeline-massachusetts/

[21] Risky Business Project (2016) *From Risk to Return: Investing in a Clean Energy Economy*. https://riskybusiness.org/site/assets/uploads/sites/5/2016/10/RBP-FromRiskToReturn-WEB.pdf

[22] The reviewed studies are cited in the text and referenced in these endnotes. In addition, the report includes an extensive annotated bibliography and tables that summarize studies on natural gas infrastructure (Table 3.1) and renewable energy and energy efficiency (Table 4.1)

[23] BP (2016) BP Energy Outlook 2016 edition: Outlook to 2035. Available on-line at https://www.bp.com/content/dam/bp/pdf/energy-economics/energy-outlook-2016/bp-energy-outlook-2016.pdf

[24] International Energy Agency (2016) Medium-Term Gas Market Report 2016: Market Analysis and Forecasts to 2016. Available on-line at http://www.iea.org/bookshop/721-Medium-Term_Gas_Market_Report_2016

[25] U.S. Energy Information Administration (2016 October 17) Drilling Productivity Report. Available on-line at http://www.eia.gov/petroleum/drilling/

[26] U.S. Energy Information Administration (2015 April 15) U.S. energy imports and exports to come into balance for first time since 1950s. Available on-line at http://www.eia.gov/todayinenergy/detail.cfm?id=20812.

[27] Katakey, R. (2015 June 10) U.S. Ousts Russia as Top World Oil, Gas Producer in BP Data. Bloomberg. Available on-line at http://www.bloomberg.com/news/articles/2015-06-10/u-s-ousts-russia-as-world-s-top-oil-gas-producer-in-bp-report

[28] U.S. Energy Information Administration (2015 April 28) Projections show U.S. becoming a net exporter of natural gas. Available on-line at http://www.eia.gov/todayinenergy/detail.cfm?id=20992

[29] U.S. Energy Information Administration (2016 August 3) Use of natural gas for power generation hits record highs. Natural Gas Weekly Update. Available on-line at http://www.eia.gov/naturalgas/weekly/archivenew_ngwu/2016/08_04/index.cfm

[30] U.S. Energy Information Administration (2016) Natural Gas Consumption by End Use. Available on-line at https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm

[31] David, JE (2013 May 8) Marcellus Turns Pennsylvania Into 'Saudi Arabia' of Natgas. CNBC. Available on-line at http://www.cnbc.com/id/100720973

[32] U.S. Energy Information Administration (2015 November 23) U.S. Crude Oil and Natural Gas Proved Reserves. Available on-line at http://www.eia.gov/naturalgas/crudeoilreserves/

[33] In its most recent release, the EIA estimated proven reserves in Marcellus shale play at 84.5 trillion cubic feet. PointLogic data estimated New England demand for natural gas in 2015 was 878 billion cubic feet. The division of Marcellus reserves by New England demand equals 96 years.

[34] PointLogic Energy. North American Gas Production. Accessed on September 25, 2016.

[35] PointLogic Energy estimated average wellhead protection in the Marcellus shale play in August 2016 at 18.25 Bcf/d. The EIA estimated New Hampshire demand for natural gas in 2014 was 56.9 billion cubic feet. The division of New Hampshire demand divided by wellhead production equals 3.1 days.

[36] U.S. Energy Information Administration (2015 November 23) U.S. Crude Oil and Natural Gas Proved Reserves. Available on-line at http://www.eia.gov/naturalgas/crudeoilreserves/

[37] U.S. Department of Energy (2015 February) Natural Gas Infrastructure Implications of Increased Demand from the Electric Power Sector. Available on-line at http://energy.gov/sites/prod/files/2015/02/f19/DOE%20Report%20Natural%20Gas%20Infrastructure%20V_02-02.pdf

[38] PointLogic Energy (n.d.) Fundamental Energy Market Data and Analysis. Available on-line at https://pointlogicenergy.com/

[39] SPE International (n.d.) Petrowiki. Available on-line at http://petrowiki.org/Liquified_natural_gas_(LNG)

[40] Cheniere Energy, Inc. (2016 June 20) Liquefaction Facilities: Trains 1-6. Available on-line at http://www.cheniere.com/terminals/sabine-pass/trains-1-6/

[41] Nussbaum, A and N Malik (2016 August 9) A new Trade Route for Natural Gas Opens in Panama. Bloomberg Markets. Available on-line at http://www.bloomberg.com/news/articles/2016-08-09/a-new-trade-route-for-natural-gas-opens-in-panama

[42] Based on data obtained from PointLogic Energy, the average daily pipeline flow into New England was 3.48 Bcf/d between December 1, 2014 and March 31, 2015. Based on a maximum LNG liquefacation capability of 9.9 Bcf/d, the daily liquefactation capability exceeded the average daily New England pipeline flow during the winter of 2014/15 by 2.8 times.

[43] LNG project sponsor web sites:

Cameron LNG Terminal: http://cameronlng.com/
Corpus Christi LNG: http://www.cheniere.com/terminals/corpus-christi-project/
Cove Point: https://www.dom.com/covepoint
Freeport LNG: http://www.freeportlng.com/
Sabine Pass LNG Terminal: http://www.cheniere.com/terminals/sabine-pass/

[44] PointLogic Energy (n.d.) Fundamental Energy Market Data and Analysis. Available on-line at https://pointlogicenergy.com/

[45] National Centers for Environmental Information (n.d.) Quality Controlled Local Climatological Data (QCLCD). National Oceanic and Atmospheric Administration. Available on-line at https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/quality-controlled-local-climatological-data-qclcd

[46] Gillepsie, A (2015 September 25) Winter Reliability Program Updated: Restructuring Roundtable. PowerPoint. Available on-line at https://www.iso-ne.com/static-assets/documents/2015/09/final_gillespie_raab_sept2015.pdf

[47] U.S. Energy Information Administration (2016 October 31) Everett, MA Liquified Natural Gas Total Imports. Available on-line at https://www.eia.gov/dnav/ng/hist/na1278_yevtt_2m.htm

[48] U.S. Energy Information Administration (n.d.) U.S. Natural Gas Imports by Point of Entry. Available on-line at https://www.eia.gov/dnav/ng/NG_MOVE_POE1_DCU_YEVTT-Z00_A.htm

[49] U.S. Energy Information Administration (2017 January 5) Natural Gas Spot and Futures Prices (NYMEX). Available on-line at https://www.eia.gov/dnav/ng/ng_pri_fut_s1_d.htm

[50] U.S. Department of Energy (n.d.) Natural Gas Infrastructure. Appendix B: Natural Gas. Available on-line at http://energy.gov/sites/prod/files/2015/06/f22/Appendix%20B-%20Natural%20Gas_1.pdf

[51] U.S. Energy Information Administration (2016 September 30) Price of U.S. Natural Gas LNG Imports. Available on-line at https://www.eia.gov/dnav/ng/hist/n9103us3m.htm

[52] Reuters (2016 June 21) German government agrees to ban fracking indefinitely. Available on-line at http://www.reuters.com/article/us-germany-fracking-idUSKCN0Z71YY

[53] Bailey, S (2016 May 31) Newfoundland Fracking Report Says There are Too Many Unknowns. Available on-line at http://www.huffingtonpost.ca/2016/05/31/newfoundland-fracking-report_n_10228198.html

[54] Atkin, E (2014 December 17) BREAKING: New York Will Ban Fracking. Available on-line at https://thinkprogress.org/breaking-new-york-will-ban-fracking-d9973e217c34#.b

Cama, T (2015 June 1) Maryland bans fracking. The Hill. Available on-line at http://thehill.com/policy/energy-environment/243625-maryland-bans-fracking

[55] Chow, L (2016 October 31) Doctors Orders: Stop Fracking Pennsylvania. EcoWatch. Available on-line at http://www.ecowatch.com/ban-fracking-pennsylvania-2068004649.html

[56] Raab, J (2015 June 30) New England Overview: A Guide to Large-Scale Energy Infrastructure Issues in 2015. Synapse Energy Economics, Inc. Available on-line at http://www.raabassociates.org/Articles/New-England-Energy-Infrastructure-Issues-GRC.pdf

[57] U.S. Energy Information Administration (2016 June 29) State Energy Data System (SEDS): Table CT8. Electric Power Sector Consumption Estimates, 1960-2014. Available on-line (New Hampshire example) at
http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_use/eu/use_eu_NH.html&sid=NH

[58] PointLogic Energy (n.d.) Fundamental Energy Market Data and Analysis. Available on-line at https://pointlogicenergy.com/

[59] Union of Concerned Scientists (n.d.) Environmental Impacts of Natural Gas. Available on-line at http://www.ucsusa.org/clean_energy/our-energy-choices/coal-and-other-fossil-fuels/environmental-impacts-of-natural-gas.html

[60] ISO New England (n.d.) Energy, Load, and Demand Reports. https://www.iso-ne.com/isoexpress/web/reports/load-and-demand/-/tree/net-ener-peak-load

[61] ICF International. (2014). "Assessment of New England's Natural Gas Pipeline Capacity to Satisfy Short and Near- Term Electric Generation Needs: Phase II," Available online at https://www.iso-ne.com/static-assets/documents/2014/11/final_icf_phii_gas_study_report_with_appendices_112014.pdf.

[62] Northeast Gas Association (n.d.) The Role of LNG in the Northeast Natural Gas (and Energy) Market. Available on-line at http://www.northeastgas.org/about_lng.php

[63] ICF International. (2014). "Assessment of New England's Natural Gas Pipeline Capacity to Satisfy Short and Near- Term Electric Generation Needs: Phase II," Available online at https://www.iso-ne.com/static-assets/documents/2014/11/final_icf_phii_gas_study_report_with_appendices_112014.pdf

[64] LNG terminal information:
Everett Marine Terminal:
http://www.engie.com/wp-content/uploads/2012/05/overview-of-lng-in-new-england-220910.pdf
Neptune Deepwater Port: http://gdfsuezna.tendenci.net/neptunelng/
Northeast Gateway Deepwater Port:
http://excelerateenergy.com/project/northeast-gateway-deepwater-port/
Canaport: http://www.canaportlng.com/

[65] ICF International. (2014). “Assessment of New England’s Natural Gas Pipeline Capacity to Satisfy Short and Near- Term Electric Generation Needs: Phase II,” Available online at https://www.iso-ne.com/static-assets/documents/2014/11/final_icf_phii_gas_study_report_with_appendices_112014.pdf.

[66] U.S. Energy Information Administration. U.S. State-to-State capacity. Updated 12/31/2015. Available on-line at https://www.eia.gov/naturalgas/pipelines/EIA-StatetoStateCapacity.xls

[67] U.S. Energy Information Administration. New England natural gas pipeline capacity increases for the first time since 2010. December 6, 2016. Available on-line at https://www.eia.gov/todayinenergy/detail.php?id=29032

[68] Email correspondence with Warren Waite, PointLogic Energy, May 4, 2017.

[69] Finneran, C (2016 November 29) Letter from Eversource Energy to Ms. Fiona Wilson, University of New Hampshire.

[70] U.S. Energy Information Administration. U.S. State-to-State capacity. Updated 12/31/2015. Available on-line at https://www.eia.gov/naturalgas/pipelines/EIA-StatetoStateCapacity.xls

[71] U.S. Energy Information Administration. New England natural gas pipeline capacity increases for the first time since 2010. December 6, 2016. Available on-line at https://www.eia.gov/todayinenergy/detail.php?id=29032

[72] Hitchins, N, and G Maguire (2015 November 23) Generator’s Appetite to Finance Pipeline Capacity: New England and South Australia. NERA Economic Consulting. Available on-line at http://www.nera.com/content/dam/nera/publications/2015/PUB_Generators_Appetite_to_Finance_Pipeline_Capacity_1115.pdf

[73] ISO New England (n.d.) Key Grid and Market Stats. Available on-line at http://www.iso-ne.com/about/key-stats

[74] ISO New England (n.d.) Power Plant Retirements. Available on-line at http://www.iso-ne.com/about/regional-electricity-outlook/grid-in-transition-opportunities-and-challenges/power-plant-retirements

van Welie, G (2016) State of the Grid: 2016. ISO on Background Series. Available on-line at https://www.iso-ne.com/static-assets/documents/2016/01/20160126_remarks_2016stateofthegrid.pdf

[75] ICF International (2014) How ISO-NE’s Pay-for-Performance Initiative Will Shake Up New England. Avaliable on-line at http://www.ourenergypolicy.org/wp-content/uploads/2014/11/ISO_NE_Pay_for_Performance_Initiative.pdf

[76] ISO New England (n.d.) Interconnection Request Queue. Available on-line at https://www.iso-ne.com/system-planning/transmission-planning/interconnection-request-queue

[77] Callan, W (2016 March 16) Post Winter 2015/16 Review. ISO New England. Available on-line at https://www.iso-ne.com/static-assets/documents/2016/03/post_winter_2015_16_review.pdf

[78] Gillespie, A (2015 September 25) Winter Reliability Program Updated: Restructuring Roundtable. ISO New England. Available on-line at https://www.iso-ne.com/static-assets/documents/2015/09/final_gillespie_raab_sept2015.pdf

[79] International Energy Agency (2016 September 14) World Energy Investment 2016. Available on-line at https://www.iea.org/investment/

[80] U.S. Energy Information Administration (2016 September 14) Global energy investment down 8% in 2015 with flows signalling move towards cleaner energy. Available on-line at https://www.iea.org/newsroomandevents/pressreleases/2016/september/global-energy-investment-down-8-in-2015-with-flows-signalling-move-towards-clean.html

[81] FS-UNEP Collaborating Centre for Climate & Sustainable Energy Finance (2016) Global Trends in Renewable Energy Investment 2016. Available on-line at http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2016lowres_0.pdf

[82] Bloomberg New Energy Finance (2016) New Energy Outlook 2016: Powering a New World. Available on-line at https://www.bloomberg.com/company/new-energy-outlook/?utm_medium=homepage&utm_campaign=NEO2016

Mearian, L (2016 June 14) Renewable energy will overtake natural gas by 2027. Computerworld. Available on-line at http://www.computerworld.com/article/3083825/sustainable-it/renewable-energy-will-overtake-natural-gas-by-2027.html#tk.drr_mlt

[83] FS-UNEP Collaborating Centre for Climate & Sustainable Energy Finance (2016) Global Trends in Renewable Energy Investment 2016. Available on-line at http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2016lowres_0.pdf

[84] Navigant Research (2014 September 18) Energy Storage for the Grid is Expected to Reach $15.6 Billion in Annual Revenue by 2024. Available on-line at http://www.navigantresearch.com/newsroom/energy-storage-for-the-grid-is-expected-to-reach-15-6-billion-in-annual-revenue-by-2024

[85] Shah, V, J Booream-Phelps, and S Min (2014 January 6) 2014 Outlook: Let the Second Gold Rush Begin. Deutsche Bank, Market Research, North America United States. Available on-line at https://www.deutschebank.nl/nl/docs/Solar_-_2014_Outlook_Let_the_Second_Gold_Rush_Begin.pdf

[86] U.S. Energy Information Administration (2016) Annual Energy Outlook (DOE/EIA-0383). Washington, DC: U.S. Government Printing Office. Available on-line at http://www.eia.gov/forecasts/aeo/pdf/0383(2016).pdf

[87] Global Sustainable Energy Partnership (2015) Powering Innovation for a Sustainable Future: An Electric Industry's Perspective. Available on-line at http://www.globalelectricity.org/upload/File/15081_powering_innovation_final.pdf

[88] Bundesministerium fur Wirtschaft und Energie (2014 December) Die Energie der Zukunft. Available on-line at http://www.bmwi.de/BMWi/Redaktion/PDF/Publikationen/fortschrittsbericht,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf

[89] Renewable Energy Policy Network for the 21st Century (n.d.) The First Decade: 2004-2014. ISBN: 978-3-9815934-4-0. Available on-line at http://www.ren21.net/Portals/0/documents/activities/Topical%20Reports/REN21_10yr.pdf

[90] International Energy Agency (2007 April) Contributions of Renewables to Energy Security. Available on-line at https://www.iea.org/publications/freepublications/publication/so_contribution.pdf

[91] United Nations Framework Convention on Climate Change (2016) 2016 Paris Agreement. Available on-line at http://unfccc.int/2860.php

[92] FS-UNEP Collaborating Centre for Climate & Sustainable Energy Finance (2016) Global Trends in Renewable Energy Investment 2016. Available on-line at http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2016lowres_0.pdf

[93] U.S. Energy Information Administration (2016 March) Wind and Solar Data and Projections from the U.S. Energy Information Administration: Past Performance and Ongoing Enhancements. Available on-line at http://www.eia.gov/outlooks/aeo/supplement/renewable/pdf/projections.pdf

[94] U.S. Energy Information Administration (n.d.) Frequently Asked Questions: How much U.S energy comsumption and electricity genration comes from renewable energy sources?. Available on-line at http://www.eia.gov/tools/faqs/faq.cfm?id=92&t=4

[95] U.S. Energy Information Administration (2016 Decmber 22) Monthly Energy Review http://www.eia.gov/totalenergy/data/monthly/pdf/sec10_6.pdf

[96] Ryan, J (2016 February 4) Renewables Revolution Is Toppling the Dominance of Fossil Fuels in U.S. Power. Bloomberg. Available on-line at http://www.bloomberg.com/news/articles/2016-02-04/renewables-top-fossil-fuels-as-biggest-source-of-new-u-s-power.

[97] Alvarez, G (2016 April 7) Bug Brands Buy Big Power. Into the Wind, AWEA Blog. Available on-line at http://www.aweablog.org/big-brands-buy-wind-power/

[98] Kormann, C (2015 February 17) Greening the Tea Party. The New Yorker. Available on-line at http://www.newyorker.com/tech/elements/green-tea-party-solar

[99] Shah, V, J Booream-Phelps, and S Min (2014 January 6) 2014 Outlook: Let the Second Gold Rush Begin. Deutsche Bank, Market Research, North America United States. Available on-line at https://www.deutschebank.nl/nl/docs/Solar__2014_Outlook_Let_the_Second_Gold_Rush_Begin.pdf

[100] Hernandez, M (2014 May 29) Rooftop Solar Adoption in Emerging Residential Markets. Center for American Progress. Available on-line at https://www.americanprogress.org/issues/green/report/2014/05/29/90551/rooftop-solar-adoption-in-emerging-residential-markets/

[101] Hernandez, M (2014 May 29) Rooftop Solar Adoption in Emerging Residential Markets. Center for American Progress. Available on-line at https://www.americanprogress.org/issues/green/report/2014/05/29/90551/rooftop-solar-adoption-in-emerging-residential-markets/

[102] Graziano, M, and K Gillingham (2015) Spatial patterns of solar photovoltaic system adoption: the influence of neighbors and the built environment. Journal of Economic Geography, 15(4), 815-839.

[103] U.S. Energy Information Administration (2016 March) Wind and Solar Data and Projections from the U.S. Energy Information Administration: Past Performance and Ongoing Enhancements. Available on-line at http://www.eia.gov/outlooks/aeo/supplement/renewable/pdf/projections.pdf

[104] Golden, M (2015 March 2) Let's Get Real: The Energy Efficiency Industry Can Do Better. Greentech Media. Available on-line at http://www.greentechmedia.com/articles/read/its-time-energy-efficiency-gets-real

Nadel, S (2016 January 1) 2015 was a good year for energy efficiency. 2016 could be even better. American Council for an Energy Efficient Economy Blog. Available on-line at http://aceee.org/blog/2016/01/2015-was-good-year-energy-efficiency

Nadel, S, A Shipley, and RN Elliott (2004 August) The technical, economic and achievable potential for energy-efficiency in the US–A meta-analysis of recent studies. In Proceedings of the 2004 ACEEE Summer Study on Energy Efficiency in Buildings (pp. 8-215).

[105] International Energy Agency (2015) Energy Efficiency Market Report: Market Trends and Medium-Term Prospects. International Energy Agency, Paris, France. Available on-line at

https://www.iea.org/publications/freepublications/publication/MediumTermEnergyefficiencyMarketReport2015.pdf

[106] International Energy Agency (2015) Energy Efficiency Market Report: Market Trends and Medium-Term Prospects. International Energy Agency, Paris, France. Available on-line at https://www.iea.org/publications/freepublications/publication/MediumTermEnergyefficiencyMarketReport2015.pdf

[107] American Council for an Energy-Efficient Economy (2016 September 26) The 2016 State Energy Efficiency Scorecard. Available on-line at http://aceee.org/research-report/u1606

[108] ClearPath (2015) Republicans, Clean Energy, and Climate Change. Available on-line at https://clearpath.org/docs/clearpath_survey_report.pdf

Leiserowitz A, E Maibach, C Roser-Renouf, S Rosenthal, and M Cutler (2016 November) Politics and Global Warming. Yale Program on Climate Change Communication. Survey of registered voters conducted on 18 November 2016. Available on-line at http://climatecommunication.yale.edu/wp-content/uploads/2016/12/Global-Warming-Policy-Politics-November-2016.pdf

[109] Brown, R (2015 March 11) Senators Portman and Shaheen Reintroduce the Energy Savings and Industrial Competitiveness Act. Alliance to Save Energy. Available on-line at https://www.ase.org/blog/senators-portman-and-shaheen-reintroduce-energy-savings-and-industrial-competitiveness-act

[110] American Council for an Energy-Efficient Economy (2016 June 22) Energy Efficiency to Reduce Pollution and Create Jobs. Available on-line at http://aceee.org/fact-sheet/ee-jobs-pollution

[111] Hayhoe, K et al. (2007) Past and future changes in climate and hydrological indicators in the U.S. Northeast. Climate Dynamics, 28, 381–407.

National Research Council (2011) America's Climate Choices. Washington, DC: The National Academies Press. Available on-line at http://www.nap.edu/catalog.php?record_id=12781

Intergovernmental Panel on Climate Change (2013) Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. T. F. Stocker, et al. (eds.). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. Available on-line at http://www.ipcc.ch/report/ar5/wg1/

Melillo, JM, TC Richmond, and GW Yohe (eds.) (2014) Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 841 pp. doi: 7930/J0Z21WJ2. Available on-line at http://nca2014.globalchange.gov

AAAS Climate Science Panel (2014) What We Know: The Reality, Risks, and Response to Climate Change. Available on-line at http://whatweknow.aaas.org/wp-content/uploads/2014/03/AAAS-What-We-Know.pdf

Wake, CP, E Burakowski, P Wilkinson, K Hayhoe, A Stoner, C Keeley, and J LaBranche (2014) Climate Change in Northern New Hampshire: Past, Present, and Future. Climate Solutions New England Report, Sustainability Institute at the University of New Hampshire. Available on-line at http://climatesolutionsne.org

Wake, CP, E Burakowski, P Wilkinson, K Hayhoe, A Stoner, C Keeley, and J LaBranche (2014) Climate Change in Southern New Hampshire: Past, Present, and Future. Climate Solutions New England Report, Sustainability Institute at the University of New Hampshire. Available on-line at http://climatesolutionsne.org

[112] Georgetown Climate Center (2016) State Leadership Driving the Shift to Clean Energy: 2016 Update. Available on-line at http://www.cap-cpma.ca/data/Signed%2039-1En.pdf

[113] New England Governors and Eastern Canadian Premiers (2001) Climate Change Action Plan 2001. Available on-line at http://www.dem.ri.gov/climate/pdf/negecpp.pdf

[114] The Center for Climate Strategies provides updated information of state climate action planning activities. See a graphic representation of policies by state on their website: http://www.climatestrategies.us/policy_tracker/state/

[115] New England Governors and Eastern Canadian Premiers (2015) Resolution Concerning Climate Change, 39th Annual Conference of New England Governors and Eastern Canadian Premiers, Aug. 31, 2015. Available on-line at http://www.cap-cpma.ca/data/Signed%2039-1En.pdf

[116] Estimates of the emission of carbon dioxide from the burning of fossil fuels were calculated using state based data from the EIA Table CT3. Total End-Use Energy Consumption Estimates (http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_use/tx/use_tx_NH.html&sid=NH) These values were then multiplied by standard emission factors to translate BTUs into carbon dioxide emissions.

[117] Energy data from US EIA – State Profile and Energy Estimates. For example, New Hampshire data from Table CT3: Total End-Use Energy Consumption Estimates, 1960-2014. http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_use/tx/use_tx_NH.html&sid=NH. Because there is considerable interannual variability in the amount of energy used in New Engalnd, we calculated the percentage decrease in energy use from 2005 to 2014 based on a linear regression.

[118] GDP data from U.S. Department of Commerce – Bureau of Economic Analysis (BEA). https://www.bea.gov/national/index.htm. GDP normalized to $2015 using the BEA – Table 1.1.4 Price Index for GDP https://www.bea.gov/iTable/index_nipa.cfm. The percentage growth from 2005 to 2015

was calculated by subtracting the 2005 real GDP value from the 2015 value and dividing by the 2005 value.

[119] More detailed information renewable energy initiatives for each of the 6 New England states is provided by the EIA State Energy Profile. For example, the New Hampshire State Energy Profile can be viewed here: http://www.eia.gov/state/analysis.cfm?sid=NH

[120] Regional Greenhouse Gas Initiative (RGGI): http://www.rggi.org

[121] Massachusetts Global Warming Solutions Act: http://www.mass.gov/eea/air-water-climate-change/climate-change/massachusetts-global-warming-solutions-act/

[122] U.S. Energy Information Administration Table C3. Primary Energy Consumption Estimates, 2014. Available online at http://www.eia.gov/state/seds/sep_sum/html/sum_btu_totcb.html

U.S. Energy Information Administration Table CT8. Electric Power Sector Consumption Estimates, 1960-2014. Available online (New Hampshire example) at http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_use/eu/use_eu_NH.html&sid=NH)

[123] U.S. Energy Information Administration Table CT8. Electric Power Sector Consumption Estimates, 1960-2014. Available online (New Hampshire example) at http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_use/eu/use_eu_NH.html&sid=NH

[124] American Council for an Energy Efficient Economy (2016 September) The 2016 State Energy Efficiency Scorecard. Available on-line at http://aceee.org/research-report/u1606

[125] American Council for an Energy Efficient Economy (2016 September) The 2016 State Energy Efficiency Scorecard. Available on-line at http://aceee.org/research-report/u1606

[126] American Council for an Energy Efficient Economy (2016 September) Appendix B. Electric Efficiency Program Spending per Capita. The 2016 State Energy Efficiency Scorecard. Available on-line at http://aceee.org/research-report/u1606

[127] American Council for an Energy Efficient Economy (2016 September) The 2016 State Energy Efficiency Scorecard. Available on-line at http://aceee.org/research-report/u1606

[128] The Regional Greenhouse Gas Initiative (2016 September) The Investment of RGGI Proceeds through 2014. Available on-line at https://www.rggi.org/docs/ProceedsReport/RGGI_Proceeds_Report_2014.pdf

[129] ISO New England. (2016) Forecast Data 2016 Historical, forecast and weather-normalized energy and loads for the CELT Report 2016 - 2025 in Excel spreadsheet formats, and model inputs supporting the long-run 2016 forecasts. Available on-line at https://www.iso-ne.com/system-planning/system-plans-studies/celt

[130] ISO New England (n.d.) Energy, Load, and Demand Reports. Available on-line at http://www.iso-ne.com/isoexpress/web/reports/load-and-demand/-/tree/net-ener-peak-load

[131] ISO New England- Key Grid and Market Stats. https://www.iso-ne.com/about/key-stats

[132] La Capra Associates & Economic Development Research Group (2015 August) The Economic Impacts of Failing to Build Energy Infrastructure in New England. Available on-line at http://media.gractions.com/5CC7D7975DFE1335100A9E9B056042840005CCF0/25e72b85-c007-4b98-a851-8b31563c9559.pdf

[133] ISO New England (2017 January 1) Interconnection Request Queue https://www.iso-ne.com/system-planning/transmission-planning/interconnection-request-queue

[134] New Hampshire Public Radio (n.d.) Northern Pass. Available on-line at http://nhpr.org/topic/northern-pass

Society for the Protection of New Hampshire Forests (n.d.) The Northern Pass. Available on-line at https://www.forestsociety.org/advocacy-issue/northern-pass

[135] TDI New England (n.d.) New England Clean Power Link: Project Development Portal. Available on-line at http://www.necplink.com

Renewable Energy Word (2016) TDI New England receives major regulatory approval for Clean Power Link. Available on-line at http://www.renewableenergyworld.com/articles/2016/01/tdi-new-england-receives-major-regulatory-approval-for-clean-power-link.html

[136] Hibard, PJ and CP Aubuchon (2015) Power System Reliability in New England: Meeting Electric Resource Needs in an Era of Growing Dependence on Natural Gas. Analysis Group Inc. report. Available on-line at http://www.analysisgroup.com/uploadedfiles/content/insights/publishing/power_system_reliability_in_new_england.pdf

[137] ISO New England (n.d.) Power Plant Retirements. Available on-line at https://www.iso-ne.com/about/regional-electricity-outlook/grid-in-transition-opportunities-and-challenges/power-plant-retirements

Harmon, E (2016 November 21) New England's nuclear power plants are shutting down, and that's bad news for cutting carbon pollution. New England Climate Change Review. Available on-line at https://www.northeastern.edu/climatereview/?p=189

[138] U.S. Energy Information Administration (2016 June 16) New Hampshire: State Profile and Energy Estimates. Available on-line at http://www.eia.gov/state/?sid=NH

[139] U.S. Energy Information Administration (2016 June 29) State Energy Data System (SEDS): Table CT8. Electric Power Sector Consumption Estimates, 1960-2014, New Hampshire. Available on-line at http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_use/eu/use_eu_NH.html&sid=NH

[140] U.S. Energy Information Administration (2016 June 29) State Energy Data System (SEDS): Table CT8. Electric Power Sector Consumption Estimates, 1960-2014, New Hampshire. Available on-line at http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_use/eu/use_eu_NH.html&sid=NH

[141] Bosse, G (2011 February 15) RGGI in New Hampshire: The First Two Years. Policy Matters. The Josiah Bartlett Center for Public Policy. Available on-line at http://www.jbartlett.org/wp-content/uploads/2011/07/RGGI-in-New-Hampshire-The-First-Two-Years-02-15-11.pdf

[142] Magnusson, M and CP Wake (2012) The New Hampshire Greenhouse Gas Emissions Reduction Fund: Year 3 (July 2011–June 2012) Evaluation. Carbon Solutions New England. https://www.puc.nh.gov/Sustainable%20Energy/GHGERF/Evaulations/GHGERF_Year%203_annual_report_2011-12_FINAL.pdf

[143] New Hampshire Public Utility Commission (2015 October 30) RE: RSA 125-O:21 RGGI annual report required of the Department of Environmental Services (DES) and the Public Utilities Commission (PUC). Available on-line at http://www.puc.state.nh.us/Sustainable%20Energy/GHGERF/RGGI%20Annual%20Reports/2015%20RGGI%20ANNUAL%20RPT%20TO%20LEG%20Final.pdf

[144] New Hampshire Public Utility Commission (2016 August 2) DE 15-137 Gas and Electric Utilities Energy Efficiency Resource Standard: Order Approving Settlement Agreement. Order No. 25,932. Available on-line at https://www.puc.nh.gov/Regulatory/Docketbk/2015/15-137/ORDERS/15-137_2016-08-02_ORDER_25932.PDF

[145] Nowak, S, B Baatz, A Gilleo, M Kushler, M Molina, and D York (2015 May) Beyond Carrots for Utilities: A National Review of Performance Incentives for Energy Efficiency. American Council for an Energy-Efficient Economy. Available on-line at http://kms.energyefficiencycentre.org/sites/default/files/u1504.pdf

[146] New Hampshire Public Utilities Commission (n.d.) Electric Renewable Portfolio Standard (RPS). Available on-line at https://www.puc.nh.gov/Sustainable%20Energy/Renewable_Portfolio_Standard_Program.htm

[147] New Hampshire Public Utilities Commission (2016 October 1) New Hampshire Renewable Energy Fund Annual Report. Page 14. Available on-line at https://www.puc.nh.gov/Sustainable%20Energy/Renewable%20Energy%20Fund/2016%20REF%20Report%20to%20Legislature%20FINAL%202016-09-30.pdf

[148] Eversource (2017 January 9) Net Metering Program Capacity Cap. Available on-line at https://www.eversource.com/Content/nh/about/doing-business-with-us/builders-contractors/interconnections/new-hampshire-net-metering/new-hampshire-net-metering-program-capacity-cap

[149] ISO New England (2016) 2016 Forecast Report of Capacity, Energy, Loads, and Transmission (the CELT Report). Available on-line at https://www.iso-ne.com/system-planning/system-plans-studies/celt

The forecast for electricity consumption in New Hampshire was developed by taking the baseline ISO New England Forecast Report of Capacity, Energy, Loads, and Transmission (CELT forecast) for New Hampshire from 2014 to 2025 and calculating an annual growth rate. The demand forecast differs slightly from figures presented by the electric utilities to the NH Public Utility Commission. In 2014, (historic data), ISO New England reported NH electricity consumption of 11.7 million MWH, while the utilities reported 10.7 million MWH, or a 7.8% difference. This difference is explained by transmission losses that are included in the ISO New England figure but not the utilities. The annual growth rate from the ISO New England forecast was applied to the 2014 utility-based consumption figure from 2015 through 2025. The forecast was extended to 2030 by assuming the 2025 electricity consumption for each remaining year. Total projected load growth over this time period is 4.6%, or 0.3%, annually. In other words, electric load growth is expected to be very modest and is best described as relatively flat over the forecast period.

[150] U.S. Energy Information Administration (2016 June 29) State Energy Data System (SEDS): 1960-2014 (complete) Table ET2. Total End-Use Energy Price and Expenditure Estimates, 1970-2014, New Hampshire.
http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_prices/tx/pr_tx_NH.html&sid=NH

[151] Vermont Energy Investment Corporation (2013 November 15) Increasing our Energy Efficiency in New Hampshire: Realizing our Potential. Available on-line at https://www.nh.gov/oep/resource-library/energy/documents/nh_eers_study2013-11-13.pdf

[152] U.S. Energy Information Administration (2016 June 29) State Energy Data System (SEDS): 1960-2014 (complete) Table ET2. Total End-Use Energy Price and Expenditure Estimates, 1970-2014, New Hampshire.
http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_prices/tx/pr_tx_NH.html&sid=NH

[153] Household spending on utilities, fuels, and public services is a statistic collected by the U.S. Bureau of Labor Statistics in its consumer expenditure survey. This is the most relevant category for benchmarking overall household energy consumption, but would also include some expenditures that are not related to energy usage. 2013–2014 is the most current reported consumer expenditure survey data available at the time of this report. Using the Boston Metropolitan survey (which includes New Hampshire), data for 2013–14 is available on-line at http://www.bls.gov/cex/tables.htm#annual.

[154] The American Community Survey 1-year survey shows that the median family income for New Hampshire was $80,581 in 2014.

Department of Numbers (2016) New Hampshire Household Income. Available on-line at http://www.deptofnumbers.com/income/new-hampshire/

[155] The latest natural gas cost data that was easily accessible was in 2015, available on the U.S. Energy Information Administration website: https://www.eia.gov/dnav/ng/ng_pri_sum_a_EPG0_PCS_DMcf_a.htm.

[156] Inflation is the general overall increase in prices that occurs over time. Adjusting for inflation allows comparison of current prices with past prices. Inflation was calculated from the U.S. consumer price index available through the U.S. Bureau of Labor Statistics available on-line at http://www.bls.gov/data/

The average rate for each New England state was weighted by its total proportion of electricity use to calculate the overall regional average rate.

[157] U.S. Energy Information Administration (n.d.) 2015 Average Monthly Bill: Residential. Available on-line at https://www.eia.gov/electricity/sales_revenue_price/pdf/table5_a.pdf

[158] U.S. Energy Information Administration (n.d.) Electricity: Sales (consumption), revenue, prices & customers. Available on-line at http://www.eia.gov/electricity/data.cfm#sales

[159] Solomon, D (2016 January 9) New England electric rates to be investigated. New Hampshire Union Leader. Available on-line at http://www.unionleader.com/apps/pbcs.dll/article?AID=/20160110/NEWS05/160119977

[160] ISO New England (2015 November 5) Regional System Plan. Available on-line at http://www.iso-ne.com/system-planning/system-plans-studies/rsp

[161] U.S. Energy Information Administration (n.d.) 2015 Average Monthly Bill: Commercial. Available on-line at https://www.eia.gov/electricity/sales_revenue_price/pdf/table5_b.pdf

[162] Bureau of Economic Analysis (2015 June 10) Broad Growth Across States in 2014. Available on-line at http://www.bea.gov/newsreleases/regional/gdp_state/gsp_newsrelease.htm

[163] Raab, J, and P Peterson (2015 June 30) New England Overview: A Guide to Large-Scale Energy Infrastructure Issues in 2015. Raab Associates, Ltd. Available on-line at http://www.raabassociates.org/Articles/New-England-Energy-Infrastructure-Issues-GRC.pdf

[164] Hansen, Lee (n.d.) Factors Behind Connecticut's High Electricity Rates. Connecticut OLR. Available on-line at https://www.cga.ct.gov/2015/rpt/2015-R-0108.htm

[165] Brooks, D (2016 October 5) Growing transmission costs are raising region's electricity rates. Concord Monitor. Available on-line at http://www.concordmonitor.com/energy-summit-NH-5137402

[166] Clemente, J (2016 June 26) New England's Known Need For More Natural Gas Pipelines. Forbes. Available on-line at http://www.forbes.com/sites/judeclemente/2016/06/26/new-englands-known-need-for-more-natural-gas-pipelines/#5b98ad327d6f

[167] PJM Interconnection serves 61 million electric customers in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and the District of Columbia.

[168] North American Electric Reliability Corporation (2014 September) Polar Vortex Review. Available on-line at http://www.nerc.com/pa/rrm/January%202014%20Polar%20Vortex%20Review/Polar_Vortex_Review_29_Sept_2014_Final.pdf

[169] Hibard, PJ and CP Aubuchon (2015) Power System Reliability in New England: Meeting Electric Resource Needs in an Era of Growing Dependence on Natural Gas. Analysis Group Inc. report. Available on-line at http://www.analysisgroup.com/uploadedfiles/content/insights/publishing/power_system_reliability_in_new_england.pdf

[170] List, JA, S Sadoff, and M Wagner (2010 Jan 5) So you want to run an experiment, now what? Some simple rules of thumb for optimal experimental design. Experimental Economics.

[171] Wiseman, M (2013 June 30) The Path to the Prize: Two Perspectives on Counter-Factual Evaluation. George Washington Institute of Public Policy. Draft. Available on-line at http://mlwiseman.com/wp-content/uploads/2015/01/Wiseman_2013_PrizePath.pdf

[172] U.S. Energy Information Administration (n.d.) Natural Gas Pipeline Capacity & Utilization. Available on-line at https://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/usage.html

[173] Oliver, ME, CF Mason, and D Finnoff (2014) Natural Gas Expansion and the Cost of Congestion. International Association for Energy Economics, First Quarter 2014, 31-32.

[174] U.S. Department of Energy (2015 February) Natural Gas Infrastructure Implications of Increased Demand from the Electric Power Sector. Available on-line at http://energy.gov/sites/prod/files/2015/02/f19/DOE%20Report%20Natural%20Gas%20Infrastructure%20V_02-02.pdf

[175] Gillespie, A (2015 September 25) Winter Reliability Program Updated: Restructuring Roundtable. ISO New England. Available on-line at https://www.iso-ne.com/static-assets/documents/2015/09/final_gillespie_raab_sept2015.pdf

[176] Federal Energy Regulatory Commission (2015 April 16) FERC Approves Final Rule to Improve Gas-Electric Coordination. Available on-line at https://www.ferc.gov/media/news-releases/2015/2015-2/04-16-15-M-1.asp#.V_0j5sk7Bdx

[177] Turkel, T (2016 July 20) Maine regulators approve expansion of gas pipeline capacity. Portland Press Herald. Available on-line at http://www.pressherald.com/2016/07/19/utility-regulators-approve-expansion-of-gas-pipeline-capacity/

[178] Crawford, J, and N Malik (2016 August 17) Massachusetts Plan to Fund New Gas Lines Rejected by Court. Bloomberg Markets. Available on-line at http://www.bloomberg.com/news/articles/2016-08-17/massachusetts-plan-to-fund-new-gas-lines-rejected-by-court

[179] Brooks, D (2016 October 8) Regulators reject Eversource's funding proposal for natural gas. Available on-line at http://www.concordmonitor.com/eversource-gas-access-northeast-5250101

[180] Kirby, S (2016 October 8) PUC stays National Grid pipeline proposal, denies motion to dismiss. The NK Standard-Times. Available on-line at http://www.ricentral.com/nk_standard_times/news/local_news/puc-stays-national-grid-pipeline-proposal-denies-motion-to-dismiss/article_0f585950-8be4-11e6-a693-0f27a7ffcf0a.html

[181] ISO New England (2016 February 11) ISO-NE Capacity Auction Secures Sufficient Power System Resources, At a Lower Price, for Grid Reliability in 2019-2020. Available on-line at https://www.iso-ne.com/static-assets/documents/2016/02/20160211_fca10_initialresults_final.pdf

[182] U.S. Energy Information Administration (2007 February) Annual Energy Outlook 2007 with Projections to 2030. Available on-line at http://www.eia.gov/oiaf/archive/aeo07/pdf/0383(2007).pdf

[183] U.S. Energy Information Administration (2016 September 29) Form EIA-923 detailed data. Available on-line at http://www.eia.gov/electricity/data/eia923/

[184] Solomon, D (2016 July 4) Eversource deal signals end to coal power in NH. New Hampshire Union Leader. Available on-line at http://www.unionleader.com/Eversource-deal-signals-end-to-coal-power-in-NH-07052016

[185] NH Public Utilities Commission (2015 September 15) IR 15-124 Report on Investigation into Potential Approaches to Mitigate Wholesale Electricity Prices. Available on-line at http://www.puc.state.nh.us/Regulatory/Docketbk/2015/15-124/LETTERS-MEMOS-TARIFFS/15-124%202015-09-15%20STAFF%20REPORT.PDF

[186] U.S. Department of Energy (2015 February) Natural Gas Infrastructure Implications of Increased Demand from the Electric Power Sector. Available on-line at http://energy.gov/sites/prod/files/2015/02/f19/DOE%20Report%20Natural%20Gas%20Infrastructure%20V_02-02.pdf

[187] IMPLAN is a commonly used economic model that provides estimates of the change in economic value and employment in a region for a specific policy. REMI is a commonly used economic model that provides estimates of the change in economic value and employment in a region for a specific policy.

[188] Vermont Energy Investment Corporation (2013, November) A1:I19 Energy Efficiency in New Hampshire: Realizing Our Potential.

[189] Curtis, M (2014 May 21) Estimating the Impact of the NOx Budget Trading Program on Manufacturing Employment. Georgia State University. Available on-line at http://economics.appstate.edu/sites/economics.appstate.edu/files/Curtis_Oct4.pdf

[190] U.S. Environmental Protection Agency (n.d.) Fact Sheet: Overview of the Clean Power Plan. Available on-line at https://www.epa.gov/cleanpowerplan/fact-sheet-overview-clean-power-plan

[191] Loris, N (2015 July 7) The Many Problems of the EPA's Clean Power Plan and Climate Regulations: A Primer. The Heritage Foundation. Available on-line at http://www.heritage.org/research/reports/2015/07/the-many-problems-of-the-epas-clean-power-plan-and-climate-regulations-a-primer

[192] Finneran, C (2016 September 14) Fw: Follow up on Advisory Board Report Con Call. Email correspondence.

[193] ISO New England (2016) ISO New England's s Internal Market Monitor Summer 201 Quarterly Markets Report. Available on-line at https://www.iso-ne.com/static-assets/documents/2016/11/qmr_2016_q3_summer_11_15_2016.pdf

[194] NEPOOL Participants Committee (2016 September 9) OP-4 Event. PowerPoint

[195] ISO New England (2017). 2017 Regional Electricity Outlook. Available on-line at https://www.iso-ne.com/static-assets/ documents/2017/02/2017_reo.pdf

[196] Magnusson, M, C Wake, and C Johnson (2013 September) An Evaluation of the NH BetterBuildings Program. Performed for NH Office of Energy and Planning. Available on-line at https://www.nh.gov/oep/energy/programs/betterbuildings/documents/betterbuildings_economic_study.pdf

[197] Executive Office of Energy and Environment Affairs (n.d.) Energy Storage Initiative (ESI). Available on-line at http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/energy-storage-initiative/

[198] Gardner, P (2016 January) E-Storage: Shifting from Cost to Value Wind and Solar Applications. DNV GL. Available on-line at https://www.worldenergy.org/publications/2016/e-storage-shifting-from-cost-to-value-2016/

[199] Liberty Utilities (2016 January 15) Least Cost Integrated Resource Plan. Available on-line at http://www.puc.state.nh.us/regulatory/Docketbk/2016/16-097/INITIAL%20FILING%20-%20PETITION/16-097_2016-01-15_GSEC_DBA_LIBERTY_LCIRP.PDF (pg. ~50)

[200] Garofolo, C (2015 January 25) Bill resurfaces to pull NH from Regional Greenhouse Gas Initiative. The Telegraph. Available on-line at http://www.nashuatelegraph.com/news/statenewengland/1055979-469/bill-resurfaces-to-pull-nh-from-rggi.html

[201] Gittell, R, and M Magnusson (2008 January) Economic Impact in New Hampshire of the Regional Greenhouse Gas Initiative (RGGI): An Independent Assessment. University of New Hampshire.

[202] Liberty Utilities (2016 January 15) Least Cost Integrated Resource Plan. Available on-line at http://www.puc.state.nh.us/regulatory/Docketbk/2016/16-097/INITIAL%20FILING%20-%20PETITION/16-097_2016-01-15_GSEC_DBA_LIBERTY_LCIRP.PDF (pg. 64)

[203] Neme, C, and R Sedano (2012 February) US Experience with Efficiency As a Transmission and Distribution System Resource. Regulatory Assistance Project. Available on-line at http://www.raponline.org/wp-content/uploads/2016/05/rap-neme-efficiencyasatanddresource-2012-feb-14.pdf

[204] ISO New England (2012 March 15) Follow Up Analysis to the New Hampshire/Vermont Solutions Study. Planning Advisory Committee.

[205] U.S. Energy Information Administration (2016 August) State Historical Tables for 2015.

[206] Hibard, PJ and CP Aubuchon (2015) Power System Reliability in New England: Meeting Electric Resource Needs in an Era of Growing Dependence on Natural Gas. Analysis Group Inc. report. Available on-line at http://www.analysisgroup.com/uploadedfiles/content/insights/publishing/power_system_reliability_in_new_england.pdf

[207] New Hampshire Public Utility Commission (2015 September 15) IR 15-124: Report on Investigation into Potential Approaches to Mitigate Wholesale Electricity Prices. Available on-line at http://www.puc.state.nh.us/Electric/Wholesale%20Investigation/IR%2015-124%20Staff%20Report.pdf

[208] ISO New England (2016 May 1) 2016 Energy-Efficiency Forecast 2020-2025. Available on-line at https://www.iso-ne.com/static-assets/documents/2016/04/ISO_NE_2016_EE_Forecast_2020_2025_Final.pdf

[209] Martin, R (2016 August 29) Why We Still Don't Have Better Batteries. MIT Review. Available on-line at https://www.technologyreview.com/s/602245/why-we-still-dont-have-better-batteries/

[210] Massachusetts Energy and Environmental Affairs (n.d.) Energy Storage Initiative (ESI). Available on-line at http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/energy-storage-initiative/

[211] Safford TG, and LC Hamilton (2009) Ocean Views: Coastal Environmental Problems as Seen by Downeast Maine Residents. New England Policy Brief No. 3. Carsey Institute, University of New Hampshire. Available on-line at http://scholars.unh.edu/cgi/viewcontent.cgi?article=1094&context=carsey

[212] Pew Research Center (2015 July 1) Americans, Politics and Science Issues.

[213] Hamilton, LC, and CP Wake (2013) Granite Staters Weigh in on Renewable Energy Versus Drilling. New England Policy Brief No. 33. Carsey Institute, University of New Hampshire. Available on-line at http://scholars.unh.edu/cgi/viewcontent.cgi?article=1197&context=carsey

[214] Solomon, D (2016 April 20) Kinder Morgan pipeline project suspended. New Hampshire Union Leader. Available on-line at http://www.unionleader.com/Kinder_Morgan_pipeline_suspended

[215] U.S. Energy Information Administration (2016 June 29). State Energy Data System (SEDS): 1960-2014 (complete). Available on-line at http://www.eia.gov/state/seds/seds-data-complete.cfm#CompleteDataFile

[216] Birol, F (2016 April 21) Global Energy Markets in Transition. Analysis meeting on International Finance and Economy. Available on-line at https://www.iea.org/newsroomandevents/speeches/160421_Birol_Tokyo.pdf

[217] BP (2016) BP Energy Outlook 2016 edition: Outlook to 2035. Available on-line at https://www.bp.com/content/dam/bp/pdf/energy-economics/energy-outlook-2016/bp-energy-outlook-2016.pdf

[218] ISO New England (2016) 2016 Regional Electricity Outlook. Available on-line at https://www.iso-ne.com/static-assets/documents/2016/03/2016_reo.pdf

[219] Okun, E (2016 September 16) New England's energy situation 'precarious,' ISO leader says. Union Leader. Available on-line at http://www.unionleader.com/energy/New-Englands-energy-situation-precarious-ISO-leader-says-092916

[220] Gustin, C (2016 August 31) Baker is right; we need gas pipeline. CommonWealth. Available on-line at http://commonwealthmagazine.org/environment/baker-is-right-we-need-gas-pipeline/

[221] Raab, J, and P Peterson (2015 June 30) New England Overview: A Guide to Large-Scale Energy Infrastructure Issues in 2015. Raab Associates, Ltd. Available on-line at http://www.raabassociates.org/Articles/New-England-Energy-Infrastructure-Issues-GRC.pdf

[222] Bloomberg New Energy (2016) 2016 Sustainable Energy in America Factbook. Available on-line at http://www.bcse.org/sustainableenergyfactbook/

[223] ISO New England. (2016) Forecast Data 2016 Historical, forecast and weather-normalized energy and loads for the CELT Report 2016 - 2025 in Excel spreadsheet formats, and model inputs supporting the long-run 2016 forecasts. Available on-line at https://www.iso-ne.com/system-planning/system-plans-studies/celt

[224] Shattuck, P, and J Howland (2016) The case against gas pipelines: There's too much risk and not enough need. CommonWealth. http://commonwealthmagazine.org/environment/the-case-against-gas-pipelines/

[225] U.S. Energy Information Administration (2007 February) Annual Energy Outlook 2007 with Projections to 2030. Available on-line at http://www.eia.gov/oiaf/archive/aeo07/pdf/0383(2007).pdf

[226] ICF International (2015 February) Access Northeast Project – Reliability Benefits and Energy Cost Savings to New England.

[227] Spectra Energy (n.d.) The Algonquin Incremental Market (AIM) Project. Available on-line at http://www.spectraenergy.com/Operations/US-Natural-Gas-Operations/New-Projects-US/Algonquin-Incremental-Market-AIM-Project/

[228] Gillepsie, A (2015 September 25) Winter Reliability Program Updated: Restructuring Roundtable. PowerPoint. Available on-line at https://www.iso-ne.com/static-assets/documents/2015/09/final_gillespie_raab_sept2015.pdf

[229] International Energy Agency (2016 September 14) World Energy Investment 2016.

[230] Mearian, L (2016 May11) Renewables fastest-growing energy source, feds say. Computerworld. Available on-line at http://www.computerworld.com/article/3068599/sustainable-it/renewables-fastest-growing-energy-source-feds-say.html

[231] Lazard (2015 November) Lazard's Levelized Cost of Energy Analysis—Version 9.0. Available on-line at https://www.lazard.com/media/2390/lazards-levelized-cost-of-energy-analysis-90.pdf

[232] Lazard COE figures

[233] Nowak, S, B Baatz, A Gilleo, M Kushler, M Molina, and D York (2015) Beyond Carrots for Utilities: A National Review of Performance Incentives for Energy Efficiency. American Council for an Energy-

Efficient Economy. Available on-line at
http://kms.energyefficiencycentre.org/sites/default/files/u1504.pdf

[234] Analysis Group (2015) Power System Reliability in New England, Meeting Electric Resource Needs in an Era of Growing Dependence on Natural Gas. Available on-line at
http://www.mass.gov/ago/docs/energy-utilities/reros-study-final.pdf

[235] Black & Veatch (2013) Natural Gas Infrastructure and Electric Generation: Proposed Solutions for New England. Available on-line at http://nescoe.com/uploads/Phase_III_Gas-Elec_Report_Sept._2013.pdf

[236] Connecticut Department of Energy & Environmental Protection (2016 October 25) Public Act 15-107 Section 1(D) Natural Gas Capacity, Liquefied Natural Gas (LNG), and Natural Gas Storage Procurement: Notice of Cancellation. Available on-line at
http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/0db222228c36cbcb852580570070ec28/$FILE/DEEP%20Notice%20%20of%20RFP%20Cancellation_10.25.16_Final.pdf

[237] Vermont Energy Investment Corporation (2013) Efficiency in New Hampshire: Realizing Our Potential. Available on-line at https://www.nh.gov/oep/resource-library/energy/documents/nh_eers_study2013-11-13.pdf

[238] NH Public Utilities Commission (2015 September 15) IR 15-124 Report on Investigation into Potential Approaches to Mitigate Wholesale Electricity Prices. Available on-line at
http://www.puc.state.nh.us/Regulatory/Docketbk/2015/15-124/LETTERS-MEMOS-TARIFFS/15-124%202015-09-15%20STAFF%20REPORT.PDF

ABOUT THE AUTHORS

Cameron Wake is a research professor with the Earth Systems Research Center, Institute for the Study of Earth, Oceans, and Space, and Department of Earth Sciences at the University of New Hampshire. He is also the Josephine A Lamprey Professor in Climate and Sustainability at UNH’s Sustainability Institute (cameron.wake@unh.edu).

Matt Magnusson is a doctoral student in the College of Engineering and Physical Sciences at the University of New Hampshire and MBA from the UNH Peter T. Paul School of Business and Economics.

Christina Foreman is an affiliate research professor with the Earth Systems Research Center, Institute for the Study of Earth, Oceans, and Space at the University of New Hampshire. She now works as an economist in the Economic Analysis Division at the Volpe National Transportation System Center in Cambridge, Massachusetts.

Fiona Wilson is executive director of the Center for Social Innovation and Enterprise; and clinical associate professor of Social Innovation, Social Entrepreneurship, and Sustainability, Department of Management at the Peter T. Paul College of Business and Economics at the University of New Hampshire (fiona.wilson@unh.edu).