Clean Energy Resource Options for Massachusetts to Meet GHG Reduction Goals under the Global Warming Solutions Act (GWSA)

A Synthesis of Relevant Studies

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I. Introduction

The long-term energy policy of the Commonwealth of Massachusetts has been hotly debated for the past few years. During the current legislative session, Massachusetts policymakers will be deciding how the Commonwealth will enact policies to guide the development of clean energy resources to meet the near-term and long-term greenhouse gas ("GHG") emissions reductions of the 2008 Global Warming Solutions Act ("GWSA") while providing reliable electricity at a reasonable cost.[1] The purpose of this paper is to inform the Massachusetts policy makers of the resource options and the key policy considerations.

A. Massachusetts Policy Objectives

The Massachusetts GWSA mandates a 25% reduction in GHG emissions relative to 1990 levels by 2020 and an 80% reduction by 2050.[2] Other New England states have set similar targets for GHG emissions reduction. For example, Connecticut passed a 2008 law that targets 80% reductions relative to 2001 emissions by 2050, and Rhode Island established an Executive Climate Change Coordinating Council to develop a plan to meet 80% reductions relative to 1990 levels by 2050.[3]

Massachusetts is already on its way toward meeting its goals but will need to maintain its progress and achieve further GHG emissions reductions in the long term. The most recent release of the Massachusetts GHG inventory reports that the GHG emissions decreased from 95 million metric tons ("MMT") in 2000 to 72 MMT in 2012.[4] Figure 1 below shows the trend in GHG emission reductions since 2000 from the electric and non-electric sectors. The graph in Figure 1 shows that overall emissions have declined by 23 MMT (or 24%) over that time, with 11 MMT of reductions from the electric sector and 12 MMT of reductions from the non-electric sector. As of

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1 Consistent with most of the proposed legislation, we define "clean energy resources" as new large-scale hydroelectric and renewable generation resources, including offshore wind, onshore wind, energy efficiency, and solar photovoltaics ("PV").

2 For a summary of the Global Warming Solutions Act of 2008, see: http://www.mass.gov/eea/air-water-climate-change/climate-change/massachusetts-global-warming-solutions-act/global-warming-solutions-act-background.html.

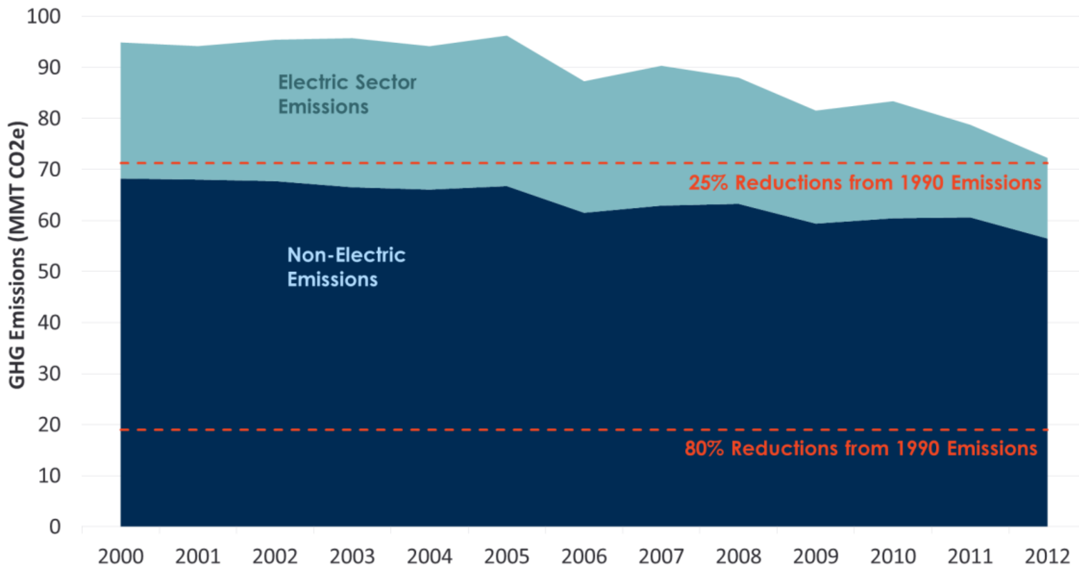
3 For the Connecticut Global Warming Solutions Act (PA No. 08-98), see: https://www.cga.ct.gov/2008/ACT/PA/2008PA-00098-R00HB-05600-PA.htm

For more on the Rhode Island Executive Climate Change Coordinating Council, see: http://www.planning.ri.gov/statewideplanning/climate/

4 Released in November 2015, the updated GHG inventory accounts for GHG emissions within Massachusetts and from electricity imports through 2012. Executive Office of Energy and Environmental Affairs, Statewide Greenhouse Gas Emissions Level: 1990 Baseline & 2020 Business As Usual Projection Update, Appendix D: GHG Inventory Spreadsheet (AR5 Global Warming Potentials), November 2015. Available at: http://www.mass.gov/eea/agencies/massdep/news/comment/ghg-emissions-update.html

2012, the electric sector accounted for 16 MMT of GHG emissions in Massachusetts, or 22% of total Massachusetts GHG emissions. The emissions from other economic sectors come from transportation (41% of total Massachusetts GHG emissions), residential/commercial (24%), industrial (10%), and other sectors (3%).[5] This paper focuses on the policies considered in reducing the GHG emissions further from the electric power sector.

Figure 1: Massachusetts GHG Emissions (2000 – 2012)



Source: Executive Office of Energy and Environmental Affairs, Statewide Greenhouse Gas Emissions Level: 1990 Baseline & 2020 Business As Usual Projection Update, Appendix D: GHG Inventory Spreadsheet (AR5 Global Warming Potentials), November 2015. Available at: http://www.mass.gov/eea/agencies/massdep/news/comment/ghg-emissions-update.html

Projections of future GHG emissions by the Executive Office of Energy and Environmental Affairs ("EEA") in December 2015 found that Massachusetts was on track to meet the 2020 target of 71 MMT.[6] However, the recent announcement of the closure of the Pilgrim Nuclear Power Station, scheduled for 2019, is expected to increase the challenge of meeting that 2020 requirement.[7] Furthermore, the Independent System Operator-New England ("ISO-NE") found that New England-wide electric sector emissions increased from 2014 to 2015 for the first time in five years, indicating that the overall GHG emissions reduction trend may be slowing.[8]

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5 Other sectors include agriculture, waste, and natural gas systems.

6 "The results of these efforts support the conclusion that if the policies included in this [Clean Energy and Climate Plan] Update are fully implemented by 2020, emissions should be at least 25% below the 1990 level in 2020." EEA, Massachusetts Clean Energy and Climate Plan for 2020: 2015 Update, December 31, 2015, p. 10. ("MA Clean Energy and Climate Plan")

7 Entergy, the operators of Pilgrim Nuclear Power Station, estimates the annual generation from Pilgrim avoids 1.6 million ton of GHG emissions if replacing natural gas generation. http://www.pilgrimpower.com/environment/local-environment.html

8 Patricio Silva, "Greenhouse Gas Regulatory Update," ISO-NE, April 5, 2016.

Looking further into the future, the GWSA requires the EEA to set interim 2030 and 2040 GHG reduction targets that will "maximize the ability of the [C]ommonwealth to meet the 2050 emissions limit."[9] The Baker administration proposed an interim target of 35% to 45% below the 1990 emissions level by 2030.[10]

The long-term GHG emissions reduction requirements and goals pose a much greater challenge than meeting the 2020 requirement. Achieving both the 2030 reductions of 35% to 45% and 80% by 2050 will require a long-term commitment by Massachusetts policymakers to transition the economy away from GHG-emitting fuels. The EEA emphasizes the challenge in its recently-released *Massachusetts Clean Energy and Climate Plan for 2020 (2015 Update)*. EEA found that "the only viable path to deep reductions in GHG emissions is through a combination of reduced energy consumption (through increased energy efficiency in vehicles and buildings), expanded availability of clean electricity, and electrification of the transportation and heating sectors."[11] The proposed energy bills currently being debated in the Legislature focus on taking the next steps necessary to achieve at least one of the priorities: reduce GHG emissions from the electric power sector.

Keeping energy costs as low as possible while meeting the Massachusetts GWSA requirements is a paramount goal for the Legislature. When considering the cost of clean energy, the total resource costs of policy options need to be compared to the total value of adding clean energy resources to the region's generation portfolio. This value includes the avoided costs of building and utilizing alternative power generating resources, net impact on the local economic activities and employment, and the net reductions in GHG emissions.

B. PROPOSED CLEAN ENERGY LEGISLATION

Several legislators and Governor Baker have proposed new legislation to require the state's electricity distribution companies to enter into long-term contracts with new clean energy resource providers for the supply of electricity over the next two decades, assuming reasonable proposals are received.[12] One of the bills (S.1757) also proposes to increase the 2030 Renewable Portfolio Standard ("RPS") from the current 25% to 35%.[13]

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9 An Act Establishing the Global Warming Solutions Act, 2008 Mass. Acts 298 §3 (approved Aug. 7, 2008). https://malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter298. ("2008 Mass. Acts 298 §3")

10 "Governor Baker took an important first step in August 2015 when he joined fellow New England Governors and Eastern Canadian Premiers in adopting a 2030 GHG emissions reduction marker range of 35–45% below the 1990 level." MA Clean Energy and Climate Plan, p. 50.

11 *Ibid.*

12 The proposed bills include those introduced by Governor Baker (S.1965), which requires large-scale procurements of Canadian hydroelectric power and Class I renewables resources, and by Representative Cabral (H.2851), which requires procurement of offshore wind generation. Bills proposed by Representative Haddad (H.2881), Representative Golding (H.4336), Senator Downing (S.1757), and Representative Cusack (H.2861) require the procurement of a mix of large-scale hydro

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One of the bills, H.4377, introduced by Representative Dempsey, has passed the Massachusetts House of Representatives on June 8. If passed into law, this bill would require electricity distribution companies to enter into long-term contracts with offshore wind facilities for 1,200 megawatts ("MW") and other clean energy resources for 9,450,000 megawatts-hours ("MWh"), including large-scale hydroelectric power ("hydro") and Class I renewables, if the proposals received are deemed reasonable. That bill includes the following criteria for determining whether the proposals in response to the procurements are reasonable:

- Provide enhanced electricity reliability within the Commonwealth;
- Contribute to reducing winter electricity price spikes;
- Be cost effective to Massachusetts electric ratepayers over the term of the contract;
- Avoid line losses and mitigate transmission costs to the extent possible;
- Adequately demonstrate project viability in a commercially reasonable timeframe;
- Provide reliability, price, economic, and environmental benefits that outweigh any costs to ratepayers; and
- Where feasible, create additional employment and economic development in the Commonwealth.

Specifically for the procurement of hydro and Class I renewables, the bill includes the following additional criteria:

- Allow the long-term contract price to be indexed to the wholesale market prices, as determined by the Department of Public Utilities, and decrease in periods of low wholesale prices;
- Guarantee energy delivery in winter months; and
- Give preference to proposals that combine more than one renewable energy generating source.

C. Purpose of This Paper

The purpose of this paper is two-fold. First, to help Massachusetts legislators and executive agencies evaluate the clean energy resources being considered during the current legislative session, we reviewed the most recent and relevant other studies of policy and resource options for the Commonwealth. Where possible, we identified studies that are specific to the clean energy resources available to Massachusetts. In some cases, we reviewed studies that provide information on regional and national trends that are relevant to Massachusetts, such as studies conducted by the National Renewable Energy Laboratory ("NREL") and by other federal and state agencies. We provide a summary of studies in Appendix A.

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and Class I renewable resources (including onshore wind and solar), and a second procurement specifically for offshore wind.

13 The current RPS sets the Class I (New Resources) requirement to be 15% of electricity supply by 2020 and an additional 1% each year thereafter.

Second, to help formulate the specific policies before the legislature, we discuss various policy considerations when setting them to reach the requirements established by the GWSA, including discussing the advantages and disadvantages of using long-term contracts to procure large-scale renewable resources, and approaches for minimizing the cost impacts to ratepayers.

This paper presents a summary of other studies, including their various analytical approaches and findings, organized in a way to facilitate comparisons and drawing of insights. We provide some qualitative observations about the preconditions for achieving reductions in GHG emissions and a number of policy considerations. However, this paper does not offer a comprehensive critique of the completeness, quality, or accuracy of the other studies summarized herein. Specifically, we do not analyze and evaluate the merits of the studies' various assumptions or methods; or how the different purposes and timing of those analyses affect the study results. Therefore, we do not provide any judgment of the benefits and costs presented in these studies, nor have we presented our own benefit-cost analysis for specified policy options.

II. Clean Energy Resource Options for Massachusetts

A. General Observations on the Relevant Studies

The majority of the studies we reviewed are aimed at supporting a position or providing information relative to a specific clean energy resource type. Of those we reviewed, only one study, conducted by the Union of Concerned Scientists ("UCS"), considers a portfolio of clean energy resources and their potential impact on the electricity market in New England. None of the studies we reviewed conducts a comprehensive analysis of the long-term resource mix that the state or the region is considering or assesses the policy instruments that could be used to meet the state's or New England's 2030 and 2050 GHG reduction requirements.

Most analyses we reviewed estimate the impacts of the clean energy resources based on their ratepayer bill impacts. However, they do not estimate the impact on total resource costs and total societal costs associated with adding such resources. The impact on total resource costs would include all changes of costs across the entire power system, including system-wide fuel costs, operation and maintenance ("O&M") costs, and capital costs. The impact on societal costs would include changes in total resource costs and other societal metrics, such as changes in the societal costs of GHG emissions. Analysis of impact on societal costs instead of ratepayers' bills provides insight into which clean energy resources can provide the maximum *societal* value, including value to both suppliers and ratepayers. Analysis of ratepayer bill impacts provides a narrower and incomplete view of the impacts of new clean energy resources. If the apparent benefit in a ratepayer bill analysis is derived from reductions in wholesale electricity prices, such price reduction is easy to overestimate if not fully accounting for suppliers' responses to lower prices, such as retiring of existing resources. Thus, such benefits would largely reflect wealth transfers from suppliers to ratepayers, not necessarily whether a specific project or resource creates economic and environmental value for society overall. For these reasons, total resource costs and societal costs can be more informative than ratepayer metrics. Massachusetts uses total resource cost metrics for evaluating energy efficiency programs, as does ISO-NE for analyzing the economic benefits of transmission investments.[14]

To understand the impacts of a new resource, it is also important to clearly define the alternative case that is being compared. Several studies we reviewed analyze the addition of clean energy resources and compare the results to an alternative future scenario that does not meet the GHG emission reduction requirements of the GWSA, but are nonetheless labeled as a "business as usual." The recent Supreme Judicial Court ("SJC") ruling on compliance with the GWSA indicates that the state must take additional action to ensure these requirements are achieved. For that reason, only cases that meet the GWSA requirements are appropriate alternative compliant futures. Consideration of non-compliant cases would be useful only for evaluating the implications of meeting the GWSA requirements versus failing to meet them.

For the remaining part of this section, we summarize the most significant findings from the studies we reviewed and highlight the salient points of each. In addition to the studies of large-scale Canadian hydro, offshore wind, and onshore wind, we summarize updated analyses of energy efficiency programs, which can contribute to reducing GHG emissions but are currently not the focus of pending legislation. We also provide a brief description of the current status of solar photovoltaic capacity growth in Massachusetts. We do not, however, review the many "value of solar" studies that have been performed across utilities and states over the past several years, as solar-specific legislation is not currently included in the proposed bills, except as a Class I renewable resource. We also provide a summary of the potential role for energy storage in a future system with significantly greater clean energy resources.

We do not address the state's energy policy initiatives other than those intended for clean energy resources. For example, there has been significant recent debate and analyses concerning the need for additional natural gas pipeline capacity in Massachusetts and New England. A regulatory and judicial process is underway in Massachusetts that may determine the approach for attracting and financing the development of additional natural gas pipeline capacity in New England.[15] We do not discuss the gas pipeline issue in this paper.

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14 For Massachusetts energy efficiency analysis, see: Massachusetts Department of Public Utilities, Order, Three-Year Energy Efficiency Plans, acting together as the Cape Light Compact. Mass. Department of Public Utilities. Docket Nos. D.P.U. 15-160 through D.P.U. 15-169 (Jan. 28, 2016). For ISO-NE transmission planning analysis, see: ISO-New England, 2015 Regional System Plan, November 5, 2015, p. 18.

15 Chesto, Jon, "Baker, Healey to face off over pipeline tariff," *The Boston Globe*, May 5, 2016. Available at: https://www.bostonglobe.com/business/2016/05/05/governor-baker-pipeline-tariff-faces-challenge-state-highest-court/iCwg13xMuhytsWv3qXv8iI/story.html

B. CLEAN ENERGY RESOURCE PORTFOLIO STUDY

1. Summary of UCS Study

A study by UCS titled *Massachusetts's Electricity Future: Reducing Reliance on Natural Gas through Renewable Energy* was released in April 2016. It analyzes a portfolio of additional clean energy resource options available to Massachusetts to evaluate its impact on natural gas demand, electricity bills, and GHG emissions.[16] UCS constructs a future scenario reflecting the mix of clean energy resources considered in the proposed bills being discussed by the Legislature.[17] UCS relies on an energy market analysis conducted by Sustainable Energy Advantage ("SEA") and Daymark Energy Advisors ("DEA"). Their analysis includes a simulation of the New England energy market with and without the addition of the assumed portfolio of clean energy resources to evaluate the potential impact of large-scale hydro imports, offshore wind, and Class I renewables on energy prices and GHG emissions.[18] The UCS/SEA/DEA analysis does not consider the potential impacts of large-scale procurements on either retirement decisions by existing facilities or new entry of conventional resources.

In the UCS study, the "Proposed Policies Case" assumes that a total of 26,300,000 MWh of clean energy resources are procured through long-term contracts by the electric distribution companies. The portfolio of resources includes 13,200,000 MWh of Canadian hydro (from 1,590 MW of capacity), 7,400,000 MWh of offshore wind (from 2,000 MW of capacity), and 5,700,000 MWh of onshore wind (from 647 MW of capacity).[19] The study assumes that offshore wind capacity is built gradually between 2021 and 2030, with additions of 200 to 300 MW per year. In total, the clean energy resource procurements by 2030 would provide over 45% of Massachusetts' projected future electric energy demand.[20] The Proposed Policy Case assumes no incremental

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16 Union of Concerned Scientists, Massachusetts's Electricity Future: Reducing Reliance on Natural Gas through Renewable Energy, April 2016. ("UCS, 2016") Available at: http://www.ucsusa.org/clean-energy/increase-renewable-energy/massachusetts-electricity-future?_ga=1.29464312.691185099.1460052989#.V04xGPkrLmg

17 "The combination reflects an amalgam of several competing proposals—H.2881, S.1965, and S.1757, for example—each of which contains aspects that may be slated for inclusion in a forthcoming "omnibus" energy bill that will be the subject of legislative debate in spring 2016." *Ibid.*, p. 4.

18 Sustainable Energy Advantage ("SEA"), An Analysis of the Potential Cost of Increasing MA RPS Targets and RE Procurements, March 2016 ("SEA, 2016"), p. 9.

19 UCS assumes 2,000 MW of offshore wind is procured with a capacity factor (representing the potential output relative to operating at 100% all the time) of 45–47% that generates 7,400,000 MWh in 2030. The total capacity of the hydro resource additions is assumed to be 1,590 MW, and of onshore wind, 647 MW. *Ibid.*, pp. 16–20.

20 The latest ISO-NE Forecast Report of Capacity, Energy, Loads, and Transmission ("the CELT report") projects load through 2025 with slightly declining load growth. Because the CELT report does not project load to 2030, we use Massachusetts' projected 2025 load net of passive demand response and distributed solar for this calculation, which is 57,500,000 MWh. ISO-New England, Forecast Report of

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energy efficiency or solar capacity above the Reference (business as usual or "BAU") case. Both cases use the ISO-NE load forecast, which includes projected energy efficiency savings and an expanded solar capacity penetration reaching of 3,460 MW by 2025.[21]

UCS develops the cost assumptions for each clean energy resource in the analysis in the following ways:

- Contract prices for Canadian hydro costs are estimated to be about $80/MWh in 2020.[22] UCS assumes that hydro energy will be priced above the wholesale energy market prices, which are estimated to be $42/MWh in 2020 in the study, but not as high as the revenues that Class I renewables would receive by selling energy and Renewable Energy Credits (or RECs) at current market prices.[23]
- The study assumes that the contract price for Canadian hydro (noted above) includes the costs of building sufficient transmission capacity for delivering the energy into Massachusetts, i.e. incremental transmission costs are embedded in the assumed $80/MWh hydro costs.
- Contract prices for Class I renewable additions (primarily onshore wind) range from $60 to $120 per MWh.[24] The projected onshore wind costs include the costs associated with transmission upgrades necessary to support the integration of resources that otherwise would not be able to be delivered reliably across the system.[25]
- Contract prices for offshore wind costs are estimated to be $200/MWh in 2020 and $120/MWh in 2030, based partially on the bottom-up cost analysis in the University of Delaware study discussed in more detail below.[26]

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Capacity, Energy, Loads, and Transmission (CELT), April 28, 2016. ("CELT, 2016") Available at: http://www.iso-ne.com/system-planning/system-plans-studies/celt

21 The load projection is from the ISO-NE's CELT 2015 report, which incorporates projected energy efficiency measures. SEA, 2016, p. 8. UCS assumes in both the Reference Case and the Proposed Policies Case that solar capacity increases from 1,600 MW (direct current) in 2020 to 3,460 MW (direct current) in Massachusetts by 2025 via a "post-SREC policy." SEA, 2016, p. 26.

22 We assume the "Levelized" costs presented in slide 19 are the base assumptions used by the SEA to calculate the impact on ratepayers. The "Escalating" costs for hydro start near $60/MWh and rise to $90/MWh in 2030.

23 SEA, 2016, p. 19.

24 *Ibid.*, p. 12.

25 50% of the costs of the transmission required to overcome existing constraints (on a $/MWh basis) are included in the onshore wind costs and the other 50% are assumed to be regionally allocated based on load.

26 SEA, 2016, p. 7, 22.

The UCS study finds that the addition of the assumed resource portfolio will result in the following system impacts:

- Regional GHG emissions decrease by 5.2 MMT in 2030 relative to 2017 emissions (prior to the addition of the clean energy resource procurements). These reductions are a third of the reductions that would be necessary between 2020 and 2030 for Massachusetts to achieve 40% reductions by 2030 (relative to 1990 emissions), assuming Massachusetts is credited with the full reduction in regional GHG emissions.[27]
- Massachusetts average electricity bills increase in 2030 by less than 3% for residential customers ($3 per month), 3.8% for commercial customers ($32 per month), and 5.5% for industrial customers ($333 per month) relative to the BAU case.[28]
- Regional natural gas usage decreases from 52% of the energy mix in the 2030 BAU case to 42% in the 2030 Policy Case.[29]

2. Main Takeaways of the UCS Study for Policymakers

Below, we highlight the main takeaways that we find most useful from the UCS study:

1. The UCS study reports that the addition of a large portfolio of clean energy resources (equivalent to 45% of Massachusetts demand) will displace generation from natural gas, will reduce GHG emissions, and is likely to increase ratepayer bills. This finding is consistent with our expectations.
2. We are less confident about the scale of the electricity bill, natural gas usage, and GHG emissions impacts estimated in the UCS study because the study did not consider the impact of the large procurement on how existing resources will respond to the resulting wholesale energy and capacity market prices. Retirements of existing resources due to the procurements will be likely. Thus, as existing generation retires, wholesale market energy and capacity prices will likely increase, offsetting the lower energy market prices identified in the analysis. In addition, any incremental retirements of nuclear generation due to lower market prices could offset the impact of the procurements on GHG emissions reductions.
3. Clean energy resources will likely decrease the use of natural gas in New England and thereby put downward pressure on gas prices, thus delivering additional benefits to New England natural gas users.
4. The UCS study includes an assumption that the hydro contract prices, including the cost of transmission, will be priced above the expected average wholesale market prices. It will not be possible to determine whether hydro contract prices are reasonable until

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27 UCS, 2016, p. 5

28 *Ibid.*, p. 6.

29 *Ibid.*, p. 5.

there are actual contract prices offered by suppliers. For this, and the other reasons mentioned above, the actual costs and benefits of hydro imports are still uncertain.

5. The UCS study estimates that onshore wind contract costs are at around $80/MWh, similar to the reported results from the most recent large-scale procurement in New England.[30]

6. The UCS study estimates that near-term offshore wind contract prices are significantly higher than other clean energy resources and would start above the current estimates for offshore wind projects in the UK coming online in 2019 and 2020 (see further discussion below). The UCS study assumes that the contract prices for incremental offshore wind generation that are developed gradually over time will decrease by approximately 40% over a ten-year time horizon. This estimate is consistent with projections included in another study focused on offshore wind (summarized later under the section on the Delaware Offshore Wind Study).

C. Canadian Hydro Imports

Several of the proposed bills before the Legislature include requirements for long-term contracts with large-scale hydro resource providers in Canada. The Baker bill (S.1965) proposes procurements from Canadian resources of up to 18,900,000 MWh of hydro (approximately 2,200 MW), or 33% of projected 2025 electricity demand in Massachusetts.[31] The House bill (H.4377) includes a procurement of up to 9,450,000 MWh of either large-scale hydro imports or Class I renewables.

In addition to the UCS study summarized above, we reviewed the following studies and public materials related to large-scale Canadian hydro procurements:

- The Massachusetts Clean Electricity Partnership ("MCEP"), a coalition of hydro, renewable energy (*i.e.*, wind and solar PV), and transmission developers, released a study titled *Analysis of Benefits of Clean Electricity Imports Benefits to Massachusetts Customers* analyzing the impacts of 18,900,000 MWh of annual Canadian imports into the New England system.[32]

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30 The most recent procurement of large-scale renewables by a state in New England occurred when Connecticut selected a 250 MW wind farm in Maine and a 20 MW wind farm in Connecticut. The combined costs of the energy and REC procurement were reported to be "under eight cents per kilowatt hour." Connecticut Department of Energy and Environmental Protection, Gov. Malloy: State Selects Two Large-Scale Clean Energy Projects Furthering Connecticut's Commitment to Renewable Energy, September 20, 2013.

31 Massachusetts projected 2025 load net of passive demand response and distributed solar is 57.5 TWh. CELT 2016.

32 Power Advisory, Analysis of Benefits of Clean Electricity Imports Benefits to Massachusetts Customers, Prepared for Massachusetts Clean Electricity Partnership, April 25, 2016, p. 22. ("Power

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- London Economics International ("LEI") conducted a study for Northern Pass Transmission, LLC titled *Cost-Benefit and Local Economic Impact Analysis of the Proposed Northern Pass Transmission Project,* analyzing the impact that access to Canadian hydro via the 1,090 MW Northern Pass transmission line would have on energy and capacity markets and GHG emissions in New England.[33]
- Susan Tierney of Analysis Group published a report titled *Proposed Senate Bill No. 1965: An Act Relative to Energy Sector Compliance with the Global Warming Solutions Act*, which describes the potential for detrimental impacts of large-scale hydro procurements including higher rates, limited GHG emissions reductions due to potential nuclear retirements, and an erosion of confidence in the regulatory and market framework in New England.[34]

We also reviewed additional information concerning the development of two proposed transmission projects for accessing Canadian hydro, including the Northern Pass project and the Clean Power Link, to supplement the information about the transmission options associated with the large hydro imports. Lastly, we reviewed a Synapse Energy Economics study related to the GHG emissions of large-scale hydro resources.

1. Summary of Large-Scale Hydro Import Studies

The MCEP study, prepared by Power Advisory LLC, analyzes the potential market impacts of additional hydro from Canada through long-term contracts with Massachusetts electric distribution companies, which in the study are referred to as "Clean Energy Imports."[35] MCEP assumes that the imports from Canada occur "around-the-clock" (essentially acting as baseload generation), totaling 18,900,000 MWh per year starting in 2020 with a capacity of 2,100 MW, similar to the procurements proposed in the Baker bill (S.1965), but twice as large as proposed in

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Advisory, 2016"). MCEP includes Brookfield, Emera, Hydro Québec, Nalcor, Énergie NB Power, SunEdison, and TDI New England, see: http://www.masscleanelectricity.org/

33 Frayer, Julia, Eva Wang, Ryan Hakim and Adnan Cheema, Cost-Benefit and Local Economic Impact Analysis of the Proposed Northern Pass Transmission Project, Prepared for Northern Pass Transmission, LLC, October 16, 2015. ("Frayer, *et al.*, 2015")

34 Tierney, Susan, Proposed Senate Bill No. 1965: An Act Relative to Energy Sector Compliance with the Global Warming Solutions Act, September 2015. ("Tierney, 2015") In footnote 1, the report states: "Knowing that she is a supporter of efforts to both lower the carbon emissions from the power sector as well as support competitive markets, the New England Power Generators Association approached her to assess and write a report analyzing the potential implications for Massachusetts of Senate Bill 1965."

35 Although the study suggests the imports could be provided by onshore wind facilities, the analysis was completed assuming that 100% of the imports are from hydro generation facilities. Power Advisory, 2016, pp. 1, 4.

the Haddad bill (H.2881).[36] MCEP compares this case to a reference case in which "no additional action is taken to achieve the GWSA mandates."[37]

For the MCEP study, Power Advisory developed an iterative model that analyzes impacts to the energy market (similar to UCS) as well as the additions and retirements of conventional resources (through an electric capacity model) and natural gas prices (through a gas capacity model). Power Advisory's models interact in the following ways: (1) the daily natural gas prices in the energy market simulation are estimated based on the daily utilization of the natural gas pipelines from the electric and non-electric sectors; (2) new gas pipeline capacity is added when the annual average gas prices reach a threshold indicating new gas pipeline capacity will result in lower costs to consumers, which in turn reduces daily gas prices;[38] (3) the electricity capacity model forecasts capacity prices by taking into consideration estimated revenue from the production cost simulations (which are based on the updated gas prices), and adding either a Combustion Turbine ("CT") or a Combined-Cycle ("CC") power plant based on their projected net revenues from the market simulations. MCEP assumes that lower energy market prices result in some coal plants retiring earlier with the addition of the hydro imports than they would have otherwise.[39]

Power Advisory develops three cases for the "net infrastructure costs" of the hydro imports, which they define as the average annual cost of the incremental hydro generation and transmission facilities (both in Canada and the U.S.) to ratepayers above the New England market energy prices. Power Advisory estimates the annual average net infrastructure costs in the "Base Delivered Costs" case to be $431 million per year, reflecting the combined net costs of a new hydro generation facility and transmission (associated with existing transmission in Canada and two new high-voltage direct current ("HVDC") lines in the U.S.).[40,41] The combined cost of the hydro resource and transmission is $23/MWh above the estimated market price of energy from

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36 *Ibid.*, pp. 5, 10.

37 *Ibid.*, p. 7.

38 Power Advisory assumes that new natural gas pipeline capacity is added when the difference between natural gas prices in Massachusetts and the national trading hub (known as Henry Hub) rise above $2.50/MMBtu. They state that $2.50/MMBtu is around the costs of a new pipeline. *Ibid.*, p. 9.

39 *Ibid.*, p. 25.

40 Hydro costs are based on the cost estimates for a new hydro facility, including capital costs of $3,200/kW and fixed O&M costs of $30/kW-year. They assumed a 40-year economic life, 60% capacity factor, and 8% losses for delivery to Massachusetts. *Ibid.*, p. 12. Capital costs are from Olson, Arne, Nick Schlag, Kush Patel, and Gabe Kwok, Capital Cost Review of Generation Technologies: Recommendations for WECC's 10- and 20-Year Studies, Prepared for the Western Electric Coordinating Council, March 2014, p. 21.

41 Transmission costs include building two HVDC lines from Canada that will cost $2.8 billion in the U.S. based on the estimated costs of Northern Pass and Clean Power Link and the costs of the existing transmission capacity in Canada based on the current Hydro-Quebec TransEnergie transmission tariff. The costs are assumed to be incurred solely by Massachusetts ratepayers. Power Advisory, 2016, p. 13.

the New England energy market.[42] Based on forecasted 2020 wholesale electricity prices of about $55/MWh in the report,[43] the total contract price for hydro would be $78/MWh.

Power Advisory presents two additional estimates for the contract price of delivered hydro.[44] The "Low Delivered Cost" case assumes that the hydro contracts (for generation and transmission in Canada) will be priced at New England market prices. In this case, the annual net costs to Massachusetts ratepayers are $291 million, or $15/MWh above market prices (approximately $70/MWh total price, assuming a market price of $55/MWh).[45] The "High Delivered Cost" case assumes higher capital costs for hydro (25% higher) and transmission (100% higher), and results in annual net costs to ratepayers of $718 million, or $38/MWh above market prices (approximately $93/MWh total price, assuming a market price of $55/MWh).[46]

The MCEP study concludes that the additional hydro imports from Canada result in the following:

- The large-scale hydro procurement would reduce the wholesale electricity and natural gas prices for Massachusetts electric and gas consumers. Thus, the authors conclude that the consumers would save money from paying lower wholesale electricity and natural gas prices such that those savings would exceed their payments for procuring the large scale renewables and in turn, consumers would receive a total *net* benefit of $171 million per year on average.
- The authors find that the net benefits will differ depending on the actual net infrastructure costs of the hydro energy and transmission capacity. For instance, the

42 We calculated the average annual cost in terms of dollars per MWh by dividing the total incremental costs of $431 million by the total energy procured of 18,900,000 MWh ($431,000,000 / 18,900,000 MWh = $23/MWh).

43 Power Advisory, 2016, Figure 6, p. 18..

44 "Recognizing the uncertainty associated with the costs of [Clean Energy Imports] and that it will be procured in a competitive process where sellers will be incented to meet "the market" may incent suppliers to accept a lower return or a longer amortization period given that these are long-lived assets. Therefore, Power Advisory developed low, base and high delivered cost estimates of the [Clean Energy Imports] to Massachusetts load centers." *Ibid.*, p. 21.

45 Power Advisory reports that in the Low Delivered Cost case the annual net savings increase to $311 million per year or $140 million more than the base case net savings. Keeping the benefits constant, the net infrastructure costs in this case are $140 million lower than the Base Delivered Cost case, which is $291 million. We calculated the average annual cost in terms of dollars per MWh by dividing $291 million by the total energy procured of 18,900,000 MWh ($291,000,000 / 18,900,000 MWh = $15/MWh).

46 Similarly, Power Advisory reports that in the High Delivered Cost case the annual net savings decrease to negative $116 million or $287 million less than the base case net savings. Keeping the benefits constant, the net infrastructure costs in this case are $287 million higher or $718 million. We calculated the average annual cost in terms of dollars per MWh by dividing $718 million by the total energy procured of 18,900,000 MWh ($718,000,000 / 18,900,000 MWh = $38/MWh).

authors estimate the net savings to ratepayers to increase to $311 million per year in the Low Delivered Cost case. In the High Delivered Cost case, the analysis finds ratepayers will pay $116 million more per year on average.

- The MCEP study estimates net resource cost savings (including fuel costs, GHG allowance costs, O&M costs, and capital costs) of $379 million per year in New England with the addition of the hydro imports.[47]
- The authors estimate that the additional hydro imports will reduce GHG emissions in New England by 7.2 MMT per year relative to the baseline that assumes no further efforts to reduce GHG emissions.

The LEI report was prepared to support the approval of the Northern Pass transmission project in New Hampshire and includes an analysis of the potential impacts that additional access to Canadian hydro will have on the New England energy and capacity markets.[48] The study assumes Northern Pass will increase New England's use of Canadian hydro imports over the 1,090 MW capacity of the transmission line, with the hydro generation bidding into the energy market starting in 2019. In the study, LEI assumes 1,000 MW of transmission import capacity will qualify to meet New England peak demand capacity requirements in the forward capacity market starting in 2020.[49]

The LEI report also includes the assumption that some costs of the Northern Pass transmission line will be paid for by ratepayers in Massachusetts, Rhode Island, and Connecticut, as a result of the ongoing Clean Energy request for proposal process.[50]

The LEI study concludes that the additional access to hydro imports from Canada (due to the addition of 1,090 MW of addition transfer capability provided by the Northern Pass) results in the following:

- LEI estimates $851 million to $866 million in annual wholesale energy and capacity market benefits to New England ratepayers based on price reductions.[51] These estimated

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47 Power Advisory, 2016, p. 21

48 The LEI analysis was not specific to Massachusetts ratepayers, primarily focusing on New Hampshire and New England-wide ratepayer impacts. Frayer, *et al.*, 2015, p. 14.

49 "LEI assumed that [Northern Pass transmission project] would create an opportunity for shippers to qualify and sell 1,000 MW of new capacity into the FCM, based on the line's nominal rating. LEI further assumed that this new capacity created by [Northern Pass transmission project] will first bid into ISO-NE's FCA#11, for which capacity obligations would then begin in June 2020." *Ibid.*, p. 16.

50 "New Hampshire's customers will not bear the costs of building [Northern Pass transmission project]. If [Northern Pass transmission project] is selected as part of the Clean Energy and Transmission Request for Proposal, as discussed further in Section 4 of this Report, Connecticut, Massachusetts, and Rhode Island customers will pay for transmission charges associated with [Northern Pass transmission project]." *Ibid.*, p. 15.

51 *Ibid.*, p. 14.

benefits include $80 million to $100 million per year of energy market savings (over 11 years) and $843 million to $848 million per year of capacity market savings (over 10 years).[52]

- LEI estimates the production cost savings in New England to be $300 million to $425 million per year (over 11 years), assuming the hydro energy is costless.[53]
- LEI estimates that building Northern Pass transmission project will help reduce GHG emissions and provide an estimate of 3.3 to 3.4 MMT per year of avoided GHG emissions across New England. The estimate takes into account incremental GHG emissions from Canadian hydro resources.[54] Assuming a social cost of carbon of $71/metric ton, LEI estimates that the GHG emissions reduction is equivalent to $207 million to $208 million in annual average societal benefits (over 11 years).[55]

In contrast to the last two studies, the **Tierney report** highlights four areas of concern for large-scale procurement of Canadian hydro resources through long-term contracts, as included in S.1965 (18,900,000 MWh or 2,200 MW). Tierney concludes:

1. The GHG emissions in Massachusetts are declining at a pace that will meet targets listed under the GWSA without large-scale hydro. While significant reductions will be necessary to meet the 2050 target, existing electric sector policies will continue to reduce emissions.[56]
2. Long-term contracts for large-scale hydro will not reduce electric consumers' rates. An existing contract between Hydro Québec and the state of Vermont is priced based on projected energy market prices at $58/MWh. Assuming new contracts would be priced around forward energy market prices, a new hydro contract would cost Massachusetts

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52 "Wholesale market benefits represent an 11-year average of energy and capacity market benefits, whereby the capacity market benefits in 2019 are $0." *Ibid.*

53 "The level of estimated production cost savings depends on the marginal costs of production for the hydroelectric based imports on [Northern Pass transmission project] (as hydroelectric resources have essentially negligible physical marginal cost of production, we have assumed a $0 per MWh offset in the above calculations). But even under alternative assumptions, where there is an additional opportunity cost assigned to the imported energy that is transmitted on [Northern Pass transmission project] (we assumed for example, $25/MWh), the production cost savings for ISO-NE's power system are still substantial, at over $232 million p.a. under the LCOP/HH gas scenario and $137 million under the GPCM/MS gas scenario." *Ibid.*, p. 16.

54 "Based on studies conducted by Hydro Québec scientists, it has been forecast that a large hydroelectric complex such as Eastmain 1/1A had a lifecycle emissions profile of greenhouse gases of 136 lbs/MWh. This figure is higher than the actual historical system-wide profile of CO_2 emissions reported by Hydro Québec of 239 metric tonnes/MWh (approximately 0.5 lbs/MWh)." *Ibid.*, p. 68.

55 *Ibid.*, p. 14.

56 As noted above, GHG emissions in ISO-NE increased in 2015 relative to 2014. Patricio Silva, "Greenhouse Gas Regulatory Update," ISO-NE, April 5th, 2016.

ratepayers $55/MWh *plus* $42/MWh for transmission capacity for a total of $92/MWh.[57] This contract price for hydro "represents $777 million in above-market costs that Massachusetts consumers would be paying every year."[58]

3. Procurement of hydro on the scale proposed in S.1965 will decrease energy market prices and reduce the economic viability of the existing generator fleet.[59] Lower market prices could lead to accelerated retirement of existing nuclear plants, which would offset some of hydro's GHG emissions reduction benefit.[60]

4. Large-scale procurements through long-term contracts are inconsistent with the competitive structure of electricity markets in New England and will shift risk from developers to ratepayers.

The Tierney report recommends alternative policy mechanisms that rely on market-based approaches and "allow any resource that can qualify to compete," including: (1) development of a state plan to meet U.S. Environmental Protection Agency's Clean Power Plan standards, (2) reviewing and revising the existing electric sector GHG emission cap-and-trade program through the Regional Greenhouse Gas Initiative ("RGGI"); (3) the adoption of a resource-neutral Clean Energy Standard; and (4) allowing market reforms to have a chance to accomplish their intended outcomes.[61]

Separately, we reviewed additional information about two of the transmission projects that are under development to provide Canadian hydro access to the New England market: (1) the Northern Pass 1,000 MW DC line through New Hampshire and (2) the Clean Power Link 1,000 MW DC line through Vermont.[62,63] The costs of these lines are estimated to be $1.2 billion to 1.6 billion.[64] Based on recent press releases, the Clean Power Link is planned to be built starting in

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57 Tierney, 2015, p. 5. Analysis Group cites a PA Consulting study that estimated transmission costs of $42/MWh, split between the new line in the US ($28/MWh) and in Canada ($14/MWh).

58 *Ibid.*, p. 6.

59 "This amount of power is not needed in the region at this time, and 'out-of-market' contracts would serve to artificially suppress wholesale energy prices and undermine the financial viability of other, more cost effective generating assets (*e.g.*, nuclear plants) that are otherwise important for a low-carbon electricity supply." *Ibid.*, p. ES-2.

60 "Moreover, it may hasten the retirement of existing nuclear power plants that produce power with no carbon emissions, thus undermining the stated objective of Senate Bill 1965 to help Massachusetts meet its goal to reduce GHG emissions by 25 percent below 1990 levels by the year 2020." *Ibid.*, p. 6.
Following the retirement of Vermont Yankee and Pilgrim, the remaining nuclear plants in New England will be Seabrook in New Hampshire (1,300 MW) and Millstone in Connecticut (2,100 MW).

61 *Ibid.*, p. ES-3.

62 See details of Northern Pass here: http://www.northernpass.us/project-overview.htm

63 See details of Clean Power Link here: http://www.necplink.com/about.php

64 See estimate of Northern Pass Transmission cost here: http://www.utilitydive.com/news/nh-regulators-delay-eversource-proposed-northern-pass-transmission-line/420109/

Continued on next page

spring 2017 and paid for on a merchant basis.[65] The Northern Pass project is still seeking final approval from the U.S. Department of Energy ("DOE") and the state of New Hampshire.[66] A recent New Hampshire ruling further extended the deadline for taking regulatory action on the project by nine months to the end of September 2017.[67]

Finally, a 2012 study by Synapse Energy Economics reviews GHG emissions resulting from new hydro power projects. The study finds that hydro generation emits GHGs at rates lower than fossil plants but higher than wind, solar PV, and nuclear. Depending on the type of hydro facility (*i.e.*, run-of-the-river vs. flooded reservoir), average lifecycle GHG emissions can range from near zero emissions to 250 kilograms per MWh (or 550 pounds per MWh).[68] The report finds that during the first several years after reservoir creation, the GHG emissions may be higher than annual emissions for some fossil fuel sources before declining over a project's lifetime.[69] LEI, in its report summarized above, discusses its analysis of the lifecycle GHG emissions from hydro resources. LEI assumes 136 pounds of GHG emission per MWh hydro generation.[70]

2. Main Takeaways of Large-Scale Hydro Imports Studies for Policymakers

Each hydro study we reviewed employs a different framework to estimate the impact of the imports of additional large-scale hydroelectricity on the New England power system and Massachusetts. The studies assume different levels of hydro imports and additional clean energy resources, and analyze different markets (covering just the energy market versus covering the energy, capacity, and natural gas markets) and different ratepayers (Massachusetts versus New England consumers). In this section, we discuss the main takeaways for policymakers that are based on the comparable sections in each analysis:

1. The MCEP, UCS, and Tierney studies use different approaches for estimating hydro contract prices, which range from \$70/MWh to \$97/MWh. These estimated hydro contract prices are all above the authors' estimated wholesale energy prices. In some of

Continued from previous page

See estimate of Clean Power Link cost here, p. 3: http://www.iso-ne.com/static-assets/documents/2015/12/clg_meeting_jessome_panel_presentation_12_3_2015.pdf

65 TDI New England, a Blackstone portfolio company, is providing funding for the Clean Power Link transmission project.

66 See permit approval status for Northern Pass here: http://www.northernpass.us/permit-approvals.htm

67 Trabish, Herman K., "NH regulators delay Eversource proposed Northern Pass transmission line," The Utility Dive, June 1, 2016. http://www.utilitydive.com/news/nh-regulators-delay-eversource-proposed-northern-pass-transmission-line/420109/

68 Steinhurst, William, Patrick Knight, and Melissa Schultz, "Hydropower Greenhouse Gas Emissions," February 14, 2012, p. 2.

69 *Ibid.*, p. 2

70 Frayer, *et al.*, 2015, p. 68.

the studies, the assumed contract prices are based on estimated resource costs and in others they are based on the authors' estimated future energy market prices. The most relevant considerations for Massachusetts in evaluating hydro contracts will be the contract price offered during a competitive solicitation process, as well as how the contract prices compare to alternative sources of energy procured from the ISO-NE wholesale market and alternative combinations of clean energy resources.

2. The MCEP, UCS, and Tierney studies assume that Massachusetts ratepayers would pay for the costs of additional transmission needed to enable the delivery of new hydro generation from Canada to New England. Due to the nature of transmission infrastructure, major new lines, such as those necessary to deliver Canadian hydro to New England, can provide additional benefits across the entire region simultaneously. Thus, many projects are worth evaluating from a regional perspective. However, some new transmission projects can raise significant local environmental concerns and difficulties in how their costs can be allocated to be commensurate with the benefits they provide. These studies do not address the environmental and cost allocation issues of transmission projects.
3. The studies all agree that large-scale hydro contracts will put downward pressure on wholesale electricity market prices for energy and capacity, until a time when additional generation will be needed for reliability. While lower prices may be perceived to provide benefit ratepayers in the short term, reducing wholesale prices is not guaranteed to be a long-term benefit to ratepayers. Reduced (or "suppressed") wholesale energy and capacity prices can affect existing generating facilities that need market prices to be high enough to pay for their going-forward operating costs, and new generation will need the prices to be high enough to pay for the necessary investment. This is a topic that will require further analysis to ensure that additional large-scale hydro imports, like all other contracted resources that do not rely on market prices to pay for the going-forward costs, will not adversely affect the long-term wholesale market and its ability to attract and retain conventional generation when needed or to retain existing non-emitting generation resources.
4. Though not discussed in the studies that we have reviewed, incorporating more hydro power into the New England power system can provide renewable integration value. Depending on the operating characteristics of the facilities, many hydro resources can help balance the system, particularly where a significant amount of intermittent renewable resources are deployed.

D. Offshore Wind

Large-scale procurements of offshore wind have been proposed in the current legislative session. The recently passed House bill (H.4377) includes a procurement of up to 1,200 MW, across three solicitations if costs are reasonable.

In addition to the UCS study that included discussion of offshore wind (summarized above), we review the following studies related to offshore wind procurements:

- The National Renewable Energy Laboratory ("NREL") released in 2015 the *2014–2015 Offshore Wind Technologies Market Report* that provides an overview of the current status of the global offshore wind industry and progress in the U.S. to build offshore wind projects.[71]
- The University of Delaware Special Initiative on Offshore Wind released a study in 2016 titled *Massachusetts Offshore Wind Future Cost Study,* which estimates the potential for contract prices for offshore wind off the coast of Massachusetts to decline assuming a commitment to procuring a total of 2,000 MW spread over three tranches from 2023 to 2029.[72]
- ISO-NE released draft results in March 2016 of an economic analysis of offshore wind additions in New England titled *2015 Economic Study Offshore Wind—Draft Results.*[73]

1. Summary of Offshore Wind Studies

The 2015 NREL Offshore Wind report assesses the status of the global and U.S. offshore wind industry and an outlook for offshore wind costs, performance, and projects. In 2015, the cumulative offshore wind installed capacity was 9,000 MW globally, 96% of which was installed in Europe.[74] The first offshore wind facility in the U.S. will be the 30 MW Block Island Wind Farm being developed by Deepwater Wind, which is projected to be completed in 2016.[75] The DOE's Advanced Technology Demonstration program is currently supporting three additional projects designed to reduce the cost of offshore wind in the U.S. (12 MW in Virginia, 24 MW in New Jersey, and up to 25 MW in Oregon) by developing and demonstrating innovative technology, with the goal of completing construction by the end of 2017.[76]

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71 Smith, Aaron, Tyler Stehly, and Walter Musial, 2014–2015 Offshore Wind Technologies Market Report, Technical Report NREL/TP-5000-64283, September 2015. ("Smith, *et al*., 2015")

72 Kempton, Willett, Stephanie McClellan, and Deniz Ozkan, Massachusetts Offshore Wind Future Cost Study, Prepared by University of Delaware Special Initiative on Offshore Wind, March 2016. ("Kempton, *et al*., 2016")

73 Wang, Haizhen and Wayne Coste, 2015 Economic Study Offshore Wind—Draft Results, Planning Advisory Committee Meeting, March 28, 2016. ("Wang and Coste, 2016")

74 Smith, *et al*., 2015, pp. 6, 21.

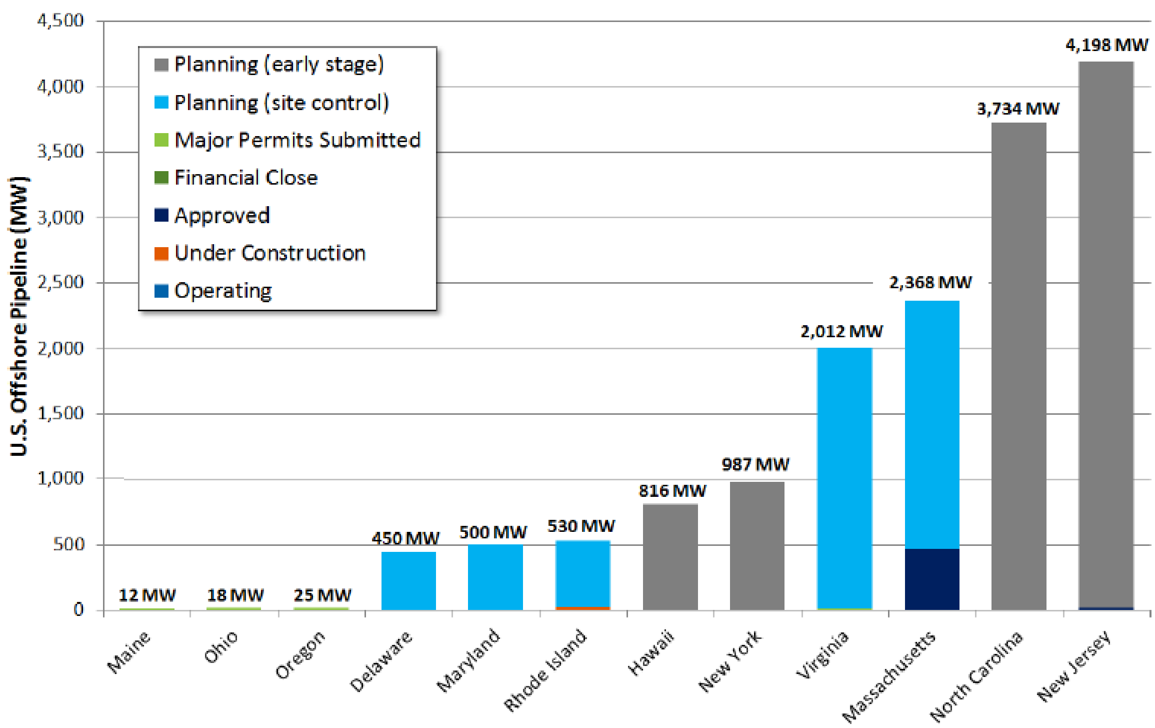
75 For additional information on the Block Island Wind Project, see: http://dwwind.com/project/block-island-wind-farm/

76 "The primary goal of the [Advanced Technology Demonstration] projects is to demonstrate innovative offshore wind systems in U.S. waters in a rapid and responsible manner that have the potential to lower the levelized cost of energy. In addition, the program seeks to establish test capabilities, validate infrastructure, exercise the state and federal regulatory processes relevant to offshore wind, and address investor risk perceptions…All projects are targeted to achieve commercial operation by the end of 2017; however, recent events suggest that the projects may need more time to work through the development process than originally anticipated" Smith, *et al*., 2015, p. 7.

The Bureau of Ocean Energy Management ("BOEM") held lease sales in 2014 and 2015 that resulted in two leases off the coast of Maryland and two leases off the coast of Massachusetts, with the potential of 5,280 MW of offshore wind.[77] As of the release date of the NREL report, the developers holding the leases announced projects for 1,900 MW.[78] NREL states that although the U.S. has had limited experience with offshore wind, the U.S. market can benefit from the technological development that has occurred in Europe.[79] For example, NREL points out that one of the holders of the BOEM leases in Massachusetts is DONG Energy, a company that has installed over 30% of offshore wind farms globally…."[80]

Overall, NREL finds that there are 13 proposed projects along the Atlantic coast, representing 5,939 MW, which have achieved site control or a more advanced phase of development (including the lease holders from the BOEM auction). Approximately 3,305 MW of capacity has an announced commercial operation date by 2020.[81] Figure 2 below shows the status and location of the 13 offshore wind projects.

Figure 2: U.S. Offshore Wind Project Pipeline by State and Development Status



Source: Smith, et al., 2015, Figure 8, p. 36.

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77 *Ibid.*, p. 30.

78 *Ibid.*

79 *Ibid.*, p. 8

80 *Ibid.*, p. 27

81 *Ibid.*, p. 7.

NREL projects that the capacity factors for offshore wind (representing the estimated actual generation output relative to the potential output operated at full installed capabilities 100% of the time) would be 40% to 50%.[82] For example, the Block Island Wind Farm is projected to achieve capacity factors of 47.5%.[83] As a comparison, NREL reports average onshore wind capacity factors of 30% in the Northeast region.[84]

The 2015 NREL Offshore Wind study includes a summary of recent and projected costs for offshore wind installations. Recent trends in Europe have resulted in higher capital costs over the past decade for offshore wind, with average 2014 capital costs rising to $5,925 per kilowatt ("kW") from $2,000/kW in the early 2000s.[85] Future capital costs, however, are projected to decline and stabilize in the range of $4,500/kW to $5,200/kW through 2020.[86] The current levelized costs of energy of offshore wind projects in the UK is greater than $200/MWh. Cost reduction goals in the UK range between $190/MWh to $120/MWh for projects coming online in 2019 and 2030, respectively.[87] While there is significant opportunity to capture the expertise developed through the European experience in developing offshore wind, NREL highlights several differences that will result in different costs in the U.S., including supply chain maturity, vessel availability, workforce readiness, and physical characteristics of the offshore wind siting environment.[88]

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82 *Ibid.*, p. 73.

83 *Ibid.*, p. 74.

84 Wiser, Ryan and Mark Bolinger, 2014 Wind Technologies Market Report, DOE/GO-102015-4702, August 2015. , p. 44 ("Wiser and Bolinger, 2015")

85 Smith, *et al.*, 2015, p. 69. NREL notes the following factors that led to a tripling of capital costs: (1) increasing technical difficulties of installing turbines in deeper water, farther from shore, and in more demanding conditions; (2) shortages in the supply chain (*e.g.*, components, vessels, and skilled labor); (3) increasing prices for commodities and energy; (4) macroeconomic trends including movements in exchange rates, commodity prices, and energy prices; and (5) an improved appreciation of the costs and risks associated with offshore wind project implementation, leading to more conservative pricing strategies from equipment suppliers and installation contractors.

86 *Ibid.*, pp. 69–70.

87 *Ibid.*, p. 80.

88 "It is clear that the U.S. market will leverage European technology and experience, developed over more than 20 years, which suggests that the cost structure will likely be similar between the two markets and, further, that cost reductions achieved in Europe should translate to the U.S. market. Still, there are several key differences between the markets that contribute to the uncertainty about cost levels for the initial set of commercial projects in the United States. These factors include currency exchange rates, infrastructure improvements, supply chain maturity, vessel availability, workforce readiness, and physical characteristics of the offshore wind siting environment. Further, the cost level could be influenced by U.S.-specific political considerations, including regulatory structure, the tax code, and the design of incentive programs." *Ibid.*, p. 67

NREL identifies challenges and uncertainties within the industry that must be overcome for development to occur. First, there are limited viable revenue mechanisms that can support commercial projects in the near term. Second, there is a lack of long-term market visibility, which is necessary to foster and sustain the development of a domestic offshore wind supply chain.[89]

A **2016 University of Delaware study** estimates the potential for the levelized costs of energy (a proxy for contract prices) for offshore wind in Massachusetts to decline in the future assuming a commitment to procuring a total of 2,000 MW spread over three tranches from 2023 to 2029.[90] To conduct the study, the authors elicited projections of costs from industry experts who are actively receiving bids for components and services.[91] For cost components for which they did not receive long-term cost estimates, they assume a cost reduction based on the expected efficiency attributable to an increasingly more experienced workforce and more established supply chain than currently is present in the region.[92]

Using these survey results and cost assumptions, the authors of the University of Delaware study project declining long-term levelized costs of energy when policies are set to provide "market visibility" to offshore wind projects. Such policies would include a commitment of procuring 2,000 MW of offshore wind resources in New England. The declining levelized costs of energy estimates are: (1) 400 MW at $162/MWh in 2023, (2) 800 MW at $128/MWh in 2026, and (3) 800 MW at $108/MWh in 2029.[93]

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89 *Ibid.*, p. 8.

90 Kempton, *et al.*, 2016. The authors note the following about estimating the levelized costs of energy for offshore wind: "The metric of this study is calculated [levelized cost of energy], which does not consider any Federal production tax credit, state renewable energy credits (RECs) or potential carbon fees, any of which would lower the actual price below our [levelized cost of energy] projection. The study does not address the overall comparative value of the technology versus other ways of producing electricity. This is because [levelized cost of energy] does not consider system benefits, job creation, environmental, or health benefits, any of which would improve the relative cost of offshore wind power."

91 *Ibid.*, p. 6.

92 "In this study, we applied this intermediate learning rate of 5% per doubling of capacity only to its estimates for support structure, installation and O&M costs. We did not apply the learning rate to the wind turbine system (rotor-nacelle assembly and tower) because those are manufactured by OEMs (for many customers), so the learning rate is already included in their price quotations." *Ibid.*, pp. 30–31. These assumptions concerning the learning curve for offshore wind in the U.S. are based on Weiss, Jurgen, Mark Sarro and Mark Berkman, A Learning Investment-based Analysis of the Economic Potential for Offshore Wind: The case of the United States, Prepared for the Center for American Progress, the U.S. Offshore Wind Collaborative, the Clean Energy States Alliance and the Sierra Club, February 28, 2013.

93 Kempton, *et al.*, 2016, p. 5. The contracts for previous projects were $300/MWh for Block Island project developed by Deepwater Wind and $240/MWh for Cape Wind.

The authors highlight the benefits of providing market visibility through a commitment to building a sequence of projects over time, including the cost reductions that are likely to occur by generating competition among developers and their suppliers. Such commitment to building a sequence of project would create a community of experienced project investors, and build an experienced and efficient workforce for subsequent projects. In the study, the authors note that, based on analysis by the European Wind Energy Association, offshore wind has the potential to create a new industry and jobs that would remain in the region.[94]

The draft **ISO-NE offshore wind economic study** analyzes the impacts of two sizes of offshore wind deployment, 1,000 MW and 2,000 MW, on the New England energy market in 2021. The ISO-NE study includes an analysis of the impact of these levels of offshore wind capacity across five different future scenarios that are of varying degrees of favorability to offshore wind. The scenarios have different assumptions for natural gas prices, CO_2 costs, onshore wind capacity, and retirement of existing generation resources. The most favorable scenario to offshore wind assumes the highest gas and CO_2 prices and additional nuclear retirements. The least favorable scenario to offshore wind assumes low gas and CO_2 prices and no nuclear retirements. The study estimates potential savings from reductions in wholesale electricity energy market but does not account for the costs of procuring offshore wind resources through long-term contracts, or higher prices that may occur in the capacity market due to reduced energy market revenues if the procured wind resources indeed reduce energy prices or if existing generation retires, driving up the need for additional capacity resources.

The ISO-NE analysis provides the following findings:

- Offshore wind capacity is expected to decrease wholesale energy market prices due to its zero variable cost generation and reduced dispatch of higher cost generation that typically sets higher market prices. ISO-NE finds that because of the reduced dispatch of conventional generation there will likely be a decrease in congestion on the transmission system in other regions of New England. ISO-NE estimates that the addition of offshore wind is likely to reduce total constrained hours in two areas, the southeast Massachusetts/Rhode Island ("SEMA/RI") Import Interface and the North-South Interface.[95]
- In ISO-NE's BAU scenario, the addition of 1,000 MW of offshore wind in 2021 results in $163 million in lower ratepayer costs due to estimated reductions in the wholesale electricity energy prices (without accounting for the cost of procuring the offshore wind resources at costs that are above the wholesale market prices). The study estimates savings to increase to $348 million with 2,000 MW of offshore wind.[96]

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94 *Ibid.*, p. 8.

95 Wang and Coste, 2016, p. 13.

96 *Ibid.*, p. 19.

- For the 1,000 MW offshore wind capacity case, the annual ratepayer savings range from $56 million in the most unfavorable scenario (66% lower than BAU) to $241 million in the most favorable scenario (48% higher than BAU).[97]
- ISO-NE estimates that the total revenues to offshore wind owners will range from $83 million to $376 million in the 1,000 MW case and from $160 million to $732 million in the 2,000 MW case.[98]
- ISO-NE estimates that the GHG reductions due to the addition of offshore wind generation ranges from 1.5 MMT to 2.1 MMT in the 1,000 MW case and from 3.0 MMT to 4.2 MMT in the 2,000 MW case.[99]

2. Main Takeaways of Offshore Wind Studies for Policymakers

Based on the studies on offshore wind that we reviewed, below are the main takeaways for policymakers:

1. Offshore wind is an expensive resource with current costs of over $150/MWh compared to less than $100/MWh for hydro and onshore wind, all inclusive of transmission costs. The costs of offshore wind are projected to approach $100/MWh by 2030.
2. To achieve near-term costs that are similar to those of the projects currently under development in the UK and long-term cost reductions projected by the Delaware study, offshore wind in the U.S. will likely require a significant long-term commitment in the form of procurement contracts that provides "market visibility" to developers. Providing market visibility requires commitment to sufficient scale and several tranches of procurements for consumers to capture benefits of declining costs over time as the industry in Massachusetts and elsewhere in the U.S. matures.
3. Developing offshore wind off the coast of Massachusetts and other eastern states will provide opportunities for new types of local employment and economic development. Aside from direct jobs associated with the construction and operation of offshore wind projects, development of the upstream supply chain for materials and equipment could induce new types of economic activities in the state or region.

E. Onshore Wind

Onshore wind capacity in New England has increased over the past decade in response to increasing RPS mandates. Currently, more than 800 MW of onshore wind are installed and 3,500 MW are proposed in New England, with the majority located in Maine and New Hampshire.[100]

97 *Ibid.*

98 *Ibid.*, p. 21.

99 *Ibid.*, p. 22.

100 ISO-NE 2016 Regional Electricity Outlook, p. 10

The House bill (H.4377) includes a procurement of up to 9,450,000 MWh of either large-scale hydro imports or Class I renewables.

In addition to the UCS study summarized above, we reviewed the following studies related to onshore wind procurements:

- In March 2016, ISO-NE released draft results of an economic analysis of additional transmission capacity for delivering increasing quantities of onshore wind resources from Maine into southern New England titled *Strategic Transmission Analysis—Onshore Wind Integration*.[101]
- In 2015, NREL released the *2014 Wind Technologies Market Report*, which provides an overview of the current status of the onshore wind industry in the U.S., including the capacity, performance, and costs of onshore wind facilities.[102]

1. Summary of Onshore Wind Studies

The draft results of the **ISO-NE transmission economic analysis** for increasing onshore wind deployment finds that the existing transmission system will limit the generation from additional wind farms in northern Maine from reaching load in Massachusetts due to constraints at three locations between northern Maine and Massachusetts.[103] There is currently 450 MW of onshore wind operating in Maine.[104] ISO-NE finds that wind capacity above 1,150 MW in Maine (an additional 700 MW) will lead to an increasingly constrained transmission system that would be unable to deliver all of the output from the wind farms to the system. If the system becomes highly constrained, the onshore wind production would be curtailed in significant quantities.[105,106]

To address this problem, ISO-NE analyzes the extent to which transmission upgrades in Maine at the three areas of constraints would be needed to reduce the curtailments and provide associated value to customers in southern New England, relative to a system that builds the wind in Maine but must curtail a significant portion. The ISO-NE study shows that in the case where 3,730 MW of total onshore wind capacity is built in Maine (which is approximately 3,280 MW of additional capacity beyond the current installed capacity), transmission upgrades will reduce wind curtailments in northern Maine and offset production costs on the New England system by $75

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101 Lau, Jessica and Wayne Coste, 2015 Economic Study Strategic Transmission Analysis: Onshore Wind Integration Draft Results, Presentation to the Planning Advisory Committee Meeting, March 28, 2016, p. 8. ("Lau and Coste, 2016")

102 Wiser and Bolinger, 2015.

103 Lau and Coste, 2016, p. 7.

104 *Ibid.*, p. 8

105 *Ibid.*, pp. 12–13.

106 Wind curtailments are reductions in wind farm generation below its potential output, which can occur due to either economic or reliability reasons.

million per year.[107] These production cost savings occur because with the additional transmission capacity, the wind generation will be able to displace higher cost generation from conventional power plants. These production cost savings do not consider the cost of procuring the wind resources.

The 2014 NREL Wind Technologies (released in 2015) market report states that one of power purchase agreements in the Northeast had a price of $55/MWh for a new onshore wind in 2012 (based on a single 69 MW facility).[108] The NREL study does not include any contracts signed since 2012 for the Northeast. However, NREL reports that the costs of onshore wind have declined by about 40% nationally since 2012.[109] NREL's low cost estimates are primarily from wind generation built in the windiest parts of the country, such as in the Great Plains in the Midwest, and they do not include any incremental transmission costs.

The 2016 UCS study, summarized earlier, assumes that the levelized onshore wind costs will decline with newer resources built, but also may increase as more remote and lower quality resources are connected.[110] Further, considering the cost of transmission, the total costs for onshore wind are likely to increase due to the need to build additional transmission to reach remote resources and/or locate wind farms in areas with lower quality wind resources.

2. Main Takeaways of Onshore Wind Studies for Policymakers

Based on the two most recent and relevant studies of onshore wind described above, we highlight the following takeaways for policymakers:

1. Onshore wind is a relatively low cost clean energy resource, with the UCS study assuming near-term costs of $60 to $120/MWh, inclusive of transmission. The higher end costs likely account for the costs of additional transmission.
2. The ISO-NE economic analysis indicates that up to 1,150 MW of wind generation can be installed in northern Maine without significant "bottled in" energy due to transmission constraints. With the current capacity in northern Maine of 450 MW, this analysis indicates that an additional 700 MW can be installed before experiencing significant transmission constraints.
3. Beyond 700 MW of additional onshore wind, incremental wind additions will face the risk of increasing curtailments due to transmission constraints between northern Maine and the load centers in southern New England. The most cost-effective approach to plan

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107 *Ibid.*, pp. 12–13. ISO-NE did not report the costs of this transmission project but rather calculated only the benefits of the low marginal cost resource bidding into the New England wholesale market.

108 Wiser and Bolinger, 2015, p. 57.

109 *Ibid.* NREL reports that the costs of onshore wind have declined nationally from a national average of $39/MWh in 2012 to $24/MWh in 2014. Northeast wind costs are higher due to the region's higher project costs and lower wind capacity factors.

110 SEA, 2016, p. 12.

and upgrade New England's transmission system to overcome these constraints will require regional coordination.

4. New England lacks a regional transmission plan for meeting the long-term RPS and GHG reduction objectives of all of the states combined. The lack of a regional transmission plan for meeting RPS targets marks a clear difference between New England and other regions that proactively identify the transmission necessary to meet RPS targets and provide the transmission capability to deliver renewable resources.[111] Despite the challenges of regional planning, new transmission related to clean energy resources will require the New England states to work together.

F. Energy Efficiency

Energy efficiency is a central focus of Massachusetts's GHG emissions reduction policies. In Massachusetts, electric distribution companies are required under the Green Communities Act to submit plans every three years that "provide for the acquisition of all available energy efficiency and demand reduction resources that are cost effective or less expensive than supply."[112] The Green Communities Act created the Energy Efficiency Advisory Council ("EEAC") to assist utility program administrators in submitting the plans. The energy efficiency programs implemented to date have earned Massachusetts the highest ranking by the American Council for an Energy-Efficiency Economy ("ACEEE") for the past five years, with an approach that the ACEEE describes as "one of the most aggressive" in the country.[113] In the updated Massachusetts Clean Energy and Climate Plan, energy efficiency continues to be a central focus for future Massachusetts GHG reduction policies, listed as a priority along with emissions reductions in the electric power sector and electrification of transportation.[114]

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111 All of these regions have identified the necessary transmission projects to address the needs across large and/or multi-state systems. New England, unlike the regions covered by the Midcontinent ISO and the Southwest Power Pool, has not yet captured the opportunities that transmission can bring to the region in the context of simultaneously increasing the system reliability, improving the economics of the New England power system, addressing public policy needs, and reducing customers' costs of meeting the states' collective RPS and GHG reduction goals. Regional transmission planning analyses have been developed in the Midwest (including the Midcontinent ISO and the Southwest Power Pool), California (through the California ISO and the Renewable Energy Transmission Initiative), and Texas (through the Competitive Renewable Energy Zone process).

112 Order, Three-Year Energy Efficiency Plans, acting together as the Cape Light Compact. Mass. Department of Public Utilities. Docket Nos. D.P.U. 15-160 through D.P.U. 15-169 (Jan. 28, 2016), p. 4. ("Mass. Order, 2016")

113 "Massachusetts has one of the most aggressive energy efficiency resource standards in the country. Utility revenues are decoupled from sales, and performance incentives are in place to encourage program administrators to meet or exceed energy savings targets." ACEEE, Massachusetts & The 2015 State Scorecard, 2015, http://aceee.org/sites/default/files/pdf/state-sheet/2015/massachusetts.pdf

114 MA Clean Energy and Climate Plan, p. 50.

Demand response ("DR") is sometimes discussed in combination with energy efficiency (both are referred to as "demand-side resources" in New England). DR helps meet peak demand conditions, but it does not significantly reduce energy consumption or associated GHGs, so we do not address it further here.

We reviewed the following documents related to energy efficiency in Massachusetts:

- The joint filing by the Massachusetts Electric Distribution Utilities to the Department of Public Utilities ("DPU") concerning the *Three-Year Energy Efficiency Plan for 2016–2018* approved in January 2016.
- The Massachusetts Energy Efficiency Advisory Council *Preliminary Assessment of Potential 2016–2018* from March 2015.
- The 2014 Electric Power Research Institute ("EPRI") analysis of the technical and economic potential for energy efficiency titled *U.S. Energy Efficiency Potential Through 2035*.

1. Summary of Energy Efficiency Studies

The Massachusetts electric distribution companies jointly filed the most recent **Three-Year Energy Efficiency plans** in January 2016. The plans include an estimated total annual increase in electricity savings of 1,370,000 MWh for each year across the distribution companies from 2016 to 2018, for a total of 4,120,000 MWh incremental savings by the end of the three-year period.[115] The energy efficiency program savings will reduce an additional 2.94% of aggregate statewide energy demand in each year.[116] The program will be implemented at a $2.5 billion cost, with an expected total resource cost savings of $6.2 billion, for a net present value of $3.7 billion.[117] Based on the 2015 ISO-NE projections of Massachusetts energy demand and existing energy efficiency programs, the Massachusetts program will achieve a 10% load reduction relative to gross load in 2016, 11% by 2017, and 13% by 2018.[118] Analysis of the cost-effectiveness of the proposed programs found that the benefit-to-cost ratio of the programs is 2.48. Energy efficiency programs

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115 MassSave, 2016–2018 Massachusetts Joint Statewide Three-Year Electric and Gas Energy Efficiency Plan, Appendix C: Statewide Energy Efficiency Data Tables, October 30, 2015. ("MA EE Data Tables, 2015") IV.D. Cost-Effectiveness, 3.2.i. Savings Summary Table.

116 Mass. Order, 2016, p. 14.

117 The "total resource costs" include total program costs, performance incentives, and participant costs. *Ibid.*, p. 166, Table 13.

118 We calculated the percentage reduction of gross MA load based on data provided in ISO-NE 2016 CELT. "Gross load" accounts for reduction in retail demand due to distributed solar, but not savings due to utility energy efficiency programs. ISO-NE, Capacity, Energy, Loads, and Transmission Report: 2015 ISO New England Forecast Data File, 2015 CELT & RSP Forecast Detail: ISONE Control Area, New England States, RSP Sub-areas, and SMD Load Zones, May 2015. Available at: http://www.iso-ne.com/system-planning/system-plans-studies/celt

that provide financial incentives for more efficient lighting and construction of new commercial and industrial buildings result in savings that are more than three times greater than the costs.[119]

The Massachusetts EEAC released its **Preliminary Assessment of Potential 2016–2018** in March 2015. The report highlights that energy efficiency programs have been increasing annually since 2010 and are approaching the goal of reducing aggregate statewide electricity demand by 3% of projected sales each year.[120] The EEAC review of recent evaluation, measurement, and verification ("EM&V") studies finds that "over half of [the commercial and industrial] customers are unaware and rarely engage" with the programs and that there remains "low residential customer awareness of some [energy efficiency] brands."[121] They find that analyses conducted by other states identify the cumulative achievable potential to reduce energy demand as 17–23%,[122] which is above the current projected savings from the Three-Year Energy Efficiency Plan.

The **EPRI report** estimates the regional potential for energy savings for the northeastern U.S. through increased efficiency based on the technical, economic, and achievable economic potentials. EPRI's analysis is based on a bottom-up approach that estimates the "equipment stock turnover and adoption of energy efficiency measures at the technology and end-use levels."[123] EPRI estimates the potential for energy efficiency programs to reduce energy demand based on a "baseline" forecast derived from the EIA Annual Energy Outlook.[124] EPRI finds that in 2025 the economic potential in the Northeast is 15% of the baseline forecast and the technical potential is 24%. EPRI estimates that by 2035, the economic potential is 15% and the technical potential is 27%.[125] As mentioned above, ISO-NE load forecast projections find that MA will achieve 13% reductions relative to gross load in 2018.

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119 Mass. Order, 2016, p. 166, Table 13.

120 MA EEAC, Preliminary Assessment of Potential 2016–2018, March 10, 2015, p. 5.

121 *Ibid.*, p. 7.

122 Based on studies completed for Pennsylvania, Delaware, and New York. *Ibid.*, p. 8.

123 "This approach is grounded in actual technology efficiencies and costs gathered by technology experts at EPRI as well as observations from industry experts concerning best practices in program design. This approach is consistent with most potential studies conducted for utilities or states, but is unique in its application to the United States as a whole, yielding detailed, granular results by division, sector, building type, end-use, and technology." EPRI, U.S. Energy Efficiency Potential Through 2035, Final Report, April 2014, p. vi.

124 The baseline forecast is the Energy Information Agency's ("EIA") 2012 Annual Energy Outlook ("AEO") projection adjusted upward for existing programs. The baseline does include the impact of existing federal and state codes and standards that will continue to increase energy efficiency without any incremental energy efficiency programs. *Ibid.*, p. xvi.

125 *Ibid.*, Figure A-2, p. A-3.

2. Main Takeaways of Energy Efficiency Studies for Policymakers

Based on the studies we have reviewed, these are the main takeaways for policymakers concerning energy efficiency:

1. The most recent three-year energy efficiency plans result in $2.57 billion in investment and a net present value of $3.65 billion. These results show that further energy efficiency investments remain a cost-effective option for reducing GHG emissions and reducing ratepayer costs based on total resource cost savings estimates, with an average benefit-to-cost ratio of above 2.0, with several specific programs above 3.0.
2. The EEAC report highlights that additional savings are possible by increasing the exposure of customers, primarily commercial customers, to the energy efficiency programs.
3. Energy efficiency can be expected to continue to play a significant role in the state's approach to reducing GHG emissions as long as further investments remain a cost effective option.

G. Solar Photovoltaic

Installed solar PV generation capacity in Massachusetts has increased dramatically over the past decade with support from net metering policies and the solar carve-out in the RPS. Currently, the solar carve-out aims to achieve 1,600 MW of solar capacity in Massachusetts by 2020.[126] EEA data shows 1,405 MW are projected to be online in 2016, putting Massachusetts just 195 MW short of reaching its 2020 goal.[127] In addition, the net metering cap was raised by 3% in April 2016 (to 7% of a distribution company's load for private entities and 8% for public entities) to accommodate continued growth in solar PV installations.[128] While additional changes to solar PV policy do not appear to be the subject of the legislation that is currently under consideration, the role of solar PV is likely to continue to expand in reducing GHG emissions in Massachusetts and supporting local economic development.

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[126] See: http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/solar/rps-solar-carve-out-2/about-solar-carve-out-ii.html

[127] The Solar Carve Out I program resulted in 648 MW of solar PV generation capacity. See: http://www.mass.gov/eea/docs/doer/rps-aps/solar-carve-out-units.xlsx

DOER estimates that the Solar Carve Out II program will have attracted 757 MW of solar PV capacity by the end of 2016. See 2017 Managed Growth Capacity Block available here: http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/solar/rps-solar-carve-out-2/current-statis-solar-carve-out-ii.html

[128] MA General Laws, Chapter 164, Section 139: https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXXII/Chapter164/Section139

H. Electricity Storage

While electricity storage is not currently a part of the proposed legislation and, therefore, not a focus of this white paper, electricity storage has the potential to be transformative in integrating variable generation resources like wind and solar generation into the system. There is an abundance of prior analysis that describes the potential value of electricity storage, ranging from renewable integration, to providing supply adequacy, to improving distribution and transmission system reliability.

Various storage technologies are currently being improved and tested. While the costs of storage devices are very high, the industry anticipates technological breakthroughs and manufacturing efficiency improvements that are likely to make available cost-effective storage solutions. Cost-effective storage deployment, where feasible, can provide system-wide benefits.[129] While we do not include a review of all the relevant storage studies conducted, we emphasize that the future mix of resources will likely include cost-effective storage technologies.

III. Policy Considerations

The studies outlined in the previous section analyze some of the clean energy resource options available to Massachusetts to decarbonize its electricity system. Many of these resources can be part of the solution, with several potential pathways to achieving the GHG reduction requirements of the GWSA that differ with respect to portfolio mix, costs, and timing. The challenge facing policymakers is to determine what kinds of resources and what kinds of policy mechanisms can meet both near- and long-term GHG reduction objectives at the lowest cost possible while maintaining system reliability and meeting economic development goals.

A. Existing GHG Reduction Measures and Future Challenges

In recent years, Massachusetts has enacted several policies and programs aimed at reducing the GHG emissions from the electricity sector. These policies, which have contributed to the decline in GHG emissions shown above in Figure 1, include:

- Nation-leading energy efficiency programs;
- A regional electricity sector GHG emissions cap imposed by RGGI;
- An RPS of 11% in 2016, increasing 1% per year such that the RPS will be 15% in 2020 and 25% in 2030;

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[129] The Massachusetts Clean Energy Center has been conducting an energy storage analysis: See http://www.masscec.com/energy-storage-study. Many studies have quantified the potential benefits of electricity storage resources on the power system, including: Chang, Judy, Johannes Pfeifenberger, Kathleen Spees, Matthew Davis, Ioanna Karkatsouli, Lauren Regan, and James Mashal, The Value of Distributed Electricity Storage in Texas: Proposed Policy for Enabling Grid-Integrated Storage Investments, March 2015.

- A solar carve-out in the RPS aimed to attract 1,600 MW of solar capacity by 2020;
- Net metering to incent specified behind-the-meter renewable generation; and,
- Long-term contracting for a portion of load served with Class I RPS resources.

These existing policies have been successful in attracting new clean energy resources. For example, energy efficiency measures have been deployed through utility programs; solar PV have been deployed through the support of RPS solar carve-out and net metering policies; and onshore wind resources have been developed based on the existing RPS and long-term contracts requirements. The existing approaches to GHG reductions, including the RGGI program, the RPS and the solar carve-out, net metering, and the energy efficiency programs, are crucial components of the state's strategy. They should continue to the extent they remain cost-effective approaches to reducing GHG emissions.

Additional regulations to reduce GHG emissions from the electricity sector and the wider economy will be necessary. On May 17, 2016, the Massachusetts SJC ruled that existing regulations "did not fulfill the duty of the Department of Environmental Protection…to promulgate regulations setting declining annual aggregate limits for regulated sources or categories of sources of [GHG] emissions."[130] The court interpreted the GWSA to require that regulations be promulgated that set declining annual aggregate limits on categories of regulated sources of GHG emissions. As a result, Governor Baker's administration has stated that an advisory group will be convened and public hearings will be held before deciding how to comply with the court's ruling.[131]

Moving forward, challenges remain in ensuring that sufficient clean energy resources are deployed to enable Massachusetts to meet the state's GHG reduction requirements. For example, transmission constraints and other challenges limit additional wind resources from northern New England and additional hydro imports from Canada. The current high cost of offshore wind and the litigation surrounding the Cape Wind project have delayed the development of offshore wind. In addition, the uncertainties around public policies such as the federal production tax credit have created a "stop-and-go" effect on project development across major clean energy resources and uncertainty in investment markets.

B. Policy Considerations Going Forward

None of the studies we have analyzed charts an obvious path for the Legislature to solve these problems. This is because, among other things, most of the studies address only one type of resource (hydro or wind), rather than evaluating portfolios of resources. And none of them

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130 Massachusetts Supreme Judicial Court, *Isabel Kain & others vs. Department of Environmental Protection*, SJC-11961, Decided May 17, 2016.

131 Mohl, Bruce, "Baker administration mum on emission plans," *Commonwealth Magazine*, May 31, 2016. Available at: http://commonwealthmagazine.org/environment/baker-administration-mum-on-emission-plans/

adequately evaluates the advantages and disadvantages of all of the available policy options for the Legislature. By contrast, long-established least-cost planning principles in the electricity sector show that the best long-term plans are created by exploring different portfolios of options and allowing for tradeoffs among different sources.[132]

But even without an obvious path laid out in the studies, the following is clear:

- The Commonwealth (and the region) needs more low- and zero-carbon resources. If this was not clear before the closing of Vermont Yankee nuclear plant, it is clear now, following the announced closure of Pilgrim nuclear plant, the recent SJC decision on compliance with the GWSA, and the recent change in the trajectory of electric sector GHG emissions in New England,.
- Clean energy resources are valuable not just for decarbonization purposes, but also because of our growing dependence on natural gas, a fossil fuel that presents shortage risks in the winters.
- Energy efficiency is and will remain for some time the most cost-effective clean resource.
- The current low price of natural gas and the failure of the market to internalize the cost of carbon emissions with a sufficiently high price on carbon together send exactly the wrong signals to achieve the objectives of the GWSA and other state policy requirements. In the absence of appropriate carbon pricing, meeting the state's emissions reduction requirements will require the adoption of policies that advance clean energy resources.
- Increasing clean energy resources is not the state's and the region's only objective. Other important objectives are maintaining reliability and minimizing costs. Thus, policymakers will need to set policies to meet environmental objectives while maintaining reliability and limit the cost impact on ratepayers.

Given the observations above, all of the clean energy resources the Legislature is considering at this time—large-scale hydro from Canada, offshore wind, and onshore wind—could contribute to meeting state energy needs if procured appropriately. However, none of the resources presents a clear solution on its own at an affordable price. For instance, until a contract price is proposed, it is unclear how cost-effective additional hydro imports would be compared to other clean energy resources such as onshore wind from northern New England. For additional on-shore wind resources, the availability of low-cost large quantities of onshore wind is not a certainty and the existing transmission system has limited capability. Additional system upgrades are needed to support further large additions of onshore wind to the New England system (particularly between Maine and southern New England).[133] As for offshore wind, given the

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132 Wilson, Rachel and Bruce Biewald, Best Practices in Electric Utility Integrated Resource Planning, June 2013.

133 Because solar PV has been addressed in separate legislation, we have not included a review of solar studies in this paper. We are aware that, at a minimum, issues related to the appropriate

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European experience and the players who have now entered the New England market, it appears that offshore wind in New England would enter only if supported by long-term contracts. The potential offshore wind cost declines highlighted above could result in growth similar to that of the solar sector over the past ten years, although local experience is almost nonexistent and cost estimates for this resource diverge widely.

IV. Recommendations and Conclusions

A. Policy Design

For reasons discussed above, the state's and region's objectives require pursuing a balanced portfolio of options. Large hydro, offshore wind, onshore wind, solar, storage, and energy efficiency will all likely be needed for Massachusetts to meet its GHG emissions reduction requirements. Since the studies do not sufficiently explore the tradeoffs across different portfolio combinations, we are unable to reach conclusions concerning an optimal mix of resources. However, we emphasize that careful policy design, with attention to competitive mechanisms and the magnitude and sequencing of procurements, will minimize the costs of achieving the state's policy objectives.

Fundamentally, developers and the financiers of large capital-intensive power plant projects require some level of assurances that there will be customers for their power production and a financing mechanism to address their up-front capital costs. The studies that we reviewed indicate that the developers of large-scale hydro, offshore and onshore wind projects for use in New England need a level of revenue certainty beyond the level that the current market conditions and policy mechanisms provide to develop the resources. In practical terms, this means that the clean energy developers need a requirement that utilities purchase a significant amount of their power through long-term contracts, or what the House bill refers to for hydropower as a "delivery commitment agreement." Long-term contracts provide the most certainty in attracting the development of clean energy resources because they can secure revenue for project developers before they make large capital investments. For example, if policy makers want to kick-start the offshore wind industry in Massachusetts and establish the local expertise and knowledge to reduce the cost of offshore wind projects, long-term contracts appear to be necessary.

These are among the takeaways from the NREL and University of Delaware studies of offshore wind discussed above. Specifically, the studies find that having a policy that requires utilities to purchase a significant and well-specified portion of their power through long-term contracts over time provides the "market visibility" for the offshore wind industry, which induces competition among potential developers and their suppliers. Market visibility derives from a

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valuation of solar, the size of the net metering cap, and the availability of incentives for community solar require further attention, but we do not address them in this white paper.

commitment to a build-out of projects in sequence, rather than providing incentives for one-off projects. These studies address offshore wind, but the principles they articulate are applicable to other renewable resources.

The Massachusetts Legislature is considering proposed bills that would require the procurement of clean energy resources by electric distribution companies through long-term contracts and an increase in the RPS requirements, if they are determined to be cost-effective. Except for energy efficiency resources, the studies reviewed above have included clean energy resource cost assumptions that are more expensive than current and projected market prices, at least in the near term. Thus, if the total resource costs are included, customers' rates may increase compared to a case without the clean energy procurements or a case in which the GWSA's emissions reductions are not met. Of course not achieving the GWSA emissions reductions is not an option per the SJC's recent order. Thus, a more comprehensive comparison to a non-compliant scenario would have to account for the environmental costs associated with the use of conventional resources.

As summarized in the previous section, both supporters and opponents of large hydro procurements who conducted analyses agree that large new imports under long-term contracts will place downward pressure on wholesale energy and capacity prices. Large procurements of other resources under long-term contracts would likely have a similar impact. Supporters of using long-term contracts discuss the impact on market prices as a benefit, while detractors focus on the risks of signing above-market contracts and interfering with the market. They raise concerns about the financial viability of existing resources (including other carbon-free generation), which may in turn increase prices again. They also raise the concern that reductions in wholesale electricity prices may deter future investment absent even more long-term contracts with above-market-prices. The studies that conclude customers' rates will decrease based on significant downward pressure on wholesale energy and capacity market prices may not have fully considered these effects.

As such, long-term contracts can provide benefits as well as risks, which need to be carefully weighed and managed. The risk of increasing customers' costs is an especially salient concern, given that one of the chief objectives of electric industry restructuring was to balance the risks associated with electric generation between developers and customers rather than to place them entirely on customers, as may occur with fixed-price long-term contracts.

In committing to long-term contracts as a policy mechanism, policymakers need to consider their risks, particularly when the contracts are large and the durations are long. The risks include:

1. Over-paying for resources if there is insufficient competition at the resource selection/contract formation stage;
2. Shifting the risks of cost recovery to ratepayers; and
3. Reducing wholesale market prices, which reduce the economic viability of existing and new conventional generation units and in turn can increase the challenge of meeting the resource adequacy needs of the region.

While long-term contracts are necessary to induce entry of some resources, policymakers will need to consider how contract solicitations can be structured in terms of competition, timing, and quantities to achieve the overall GHG reduction, system reliability, resource diversity, economic impact, and cost goals. It will be important to craft the use of long-term contracts to ensure that a diverse set of resources is developed, but to limit customers' risk of over-paying for them.

There are several considerations we suggest the Legislature take into account to mitigate risks of long-term contracts:

1. A clear vision of what resources are needed and what timeframe is necessary. Such vision should be reflected in the planning process, as discussed below. Any procurement solicitation must reflect that vision, in terms of the intent of the procurement (*e.g.*, GHG reduction, costs, local industry growth, and knowledge and skill development).
2. The development of a well-structured competitive process for soliciting proposals will ensure the lowest pricing possible, given the policy goals to be achieved.
3. Large-scale procurements can have significant impacts on existing wholesale and retail markets for better or worse. Policymakers should be aware of the potential tradeoffs between creating revenue assurance for developers to finance the new clean energy resources against the possibility of transferring the costs and risks of those contracts to ratepayers over the term of the contracts and the potential impairment to the wholesale market that is currently used to compensate the existing generating resources.

B. DEVELOPMENT OF A COMPREHENSIVE ENERGY PLAN

One of the reasons the state faces the challenges before it is that no individual or entity has the authority or the mandate to conduct comprehensive energy planning for Massachusetts or the region. To help effectively navigate policy options in the future, Massachusetts should consider developing a comprehensive energy planning process. For the region, ISO-NE is responsible for planning the transmission network and operating capacity markets to maintain the reliability of the electricity system, including some cost considerations at the level of the wholesale electricity market. However, ISO-NE does not consider climate or other emission issues and has no responsibility for planning for or even considering the thermal uses of gas (*i.e.*, for building heating and manufacturing) or for transportation. The authority of the New England States Committee on Electricity ("NESCOE") extends only to the electricity sector and does not include comprehensive long-term planning for the needs of Massachusetts or the region, covering electric, thermal, and transportation issues. At the state level, the Secretary of the Energy and Environmental Affairs, the Department of Energy Resources, and the Department of Public Utilities all have some components of energy planning authority, but neither the Secretary nor the agencies have a comprehensive planning mandate extending to the range of energy resources and uses.

It appears that the closest that the existing Massachusetts law comes in this regard is the language contained in the Global Warming Solutions Act, which provides:

> (f) The secretary shall collaborate with other state agencies to reduce greenhouse gas emissions to achieve the greenhouse gas emission limits established in chapter 21N.[134]

Considering the importance of energy to the state (and the regional, national, and global) economy, and the need to plan for reducing GHG emissions from all sectors of the economy, the fact that no entity is charged with comprehensive energy planning authority makes it almost impossible to create optimal solutions to meet Massachusetts' energy challenges. This gap in planning leaves the Legislature in exactly its current position: with the need to make choices about energy policy without a comprehensive proposal covering electric and thermal supply and demand, as well as transportation.

A planning process could fill this gap and help the state identify the proportion and timing of resources to reduce GHG emissions while balancing tradeoffs among other objectives. It would allow for state policymakers to integrate electricity, thermal, transportation, and other energy sectors to most effectively and efficiently avoid counterproductive policies in "competing" sectors and seize opportunities when synergies exist. Having a comprehensive planning process would allow greater agility in the face of changing technologies and could better spur innovation. Such a planning process would provide the necessary analytical support for policy decisions and provide potential investors with directional certainty.

Ideally, planning would be conducted at the regional level because New England is a close-knit region with a single interconnected power system. However, recognizing the challenges of conducting regional planning across six states, even for electricity system alone, it seems useful for Massachusetts to undertake comprehensive planning for the state while taking into consideration the needs and resource potential across the New England region. In such a state planning process, Massachusetts' efforts would feed into any regional planning processes, particularly for the electricity system, in light of the fact that the electricity grid is managed at a regional level.

C. Overall Recommendations

Given our understanding of the state's energy-related objectives, we suggest the following approaches to minimize customer cost and risk and to ensure reliability:

- The state's clean energy policy should be characterized by a diversity of resources, (including hydro, offshore wind, onshore wind, solar, energy efficiency, and storage) and by the ability to facilitate the entry of promising new technologies into the market. Such a portfolio approach will be important for Massachusetts to comply with the emissions reduction requirements of the GWSA and to help the Commonwealth reach its goals of reliability, affordability and sustainability.

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[134] 2008 Mass. Acts 298 §3.

- The procurement requirement for hydro, offshore wind, and onshore wind should be sufficiently robust to give a clear signal to developers about the size and durability of the state's commitment. This is the "market visibility" to which the NREL and University of Delaware studies refer in the context of offshore wind.
- The condition that a procurement requirement be large enough to create market visibility is one appropriate guidepost for Massachusetts policymaking. A second guidepost is that the aggregate procurements of offshore wind, onshore wind, and hydropower—when integrated with projected existing power resources, new storage, energy efficiency programs, and other determinants of Massachusetts GHG emissions—meets the requirements of the GWSA. Although we have not done an independent analysis of either the precise total amount or the least-cost combination of additional carbon-free resources required to meet this important state requirement, it appears to us that the procurements that have been suggested in various pieces of legislation and analyzed in various studies—2,000 MW for offshore wind and 2,200 MW of hydropower/onshore wind by 2030—seem consistent with this requirement if purchased using the efficient, risk-balancing mechanisms we recommend.[135]
- Procurement mechanisms should utilize competition to the maximum extent feasible. The potential for vigorous competition is one of the chief benefits of market visibility.
- The procurement design should specify the use of purchase tranches, rather than simply mandating a total purchase amount. This will allow subsequent tranches to take advantage of technology improvements and benefit from increasing market visibility and growing workforce experience, and will allow for a "glide path" of decreasing emissions and decreasing costs.
- Timing of tranche purchases should be carefully considered to allow for sufficient experience, but also for opportunities to make adjustments that can be applied to subsequent tranches. For instance, the procurement requirement should be sufficiently flexible to allow for increases and decreases in the magnitude and timing of the tranches of procurement to protect ratepayers from persistent high costs for certain technologies and to capture the value faster when cost reduction materializes.

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135 A simplified estimate of the clean energy resources necessary to meet long-term 2050 goals for GHG reductions finds that the GHG reductions necessary to achieve 80% reduction of electric power sector GHG emissions from 1990 levels requires an additional 3,200 MW of clean energy resources with a 90% capacity factor (similar to hydro), 6,500 MW of 45% capacity factor clean energy resources (similar to offshore wind), or 8,300 MW of 35% capacity factor clean energy resources (similar to onshore wind). Critically, this estimate does not yet account for that to achieve the 80% GHG emissions reduction economy-wide is actually likely to require further reduction of GHGs from the electricity sector and then electrify a significant portion of our transportation, heating and industry sectors. The above estimate assumes that clean energy resources displace natural gas generation with GHG emissions of 0.4 metrics tons per MWh of generation. Deeper reductions and therefore more clean energy resources will be needed to displace coal generation.

In addition to the recommendations related to resource procurement, we make the following three long-term planning-related policy recommendations:

- First, the fact that the Commonwealth has struggled with these complex issues on a regular basis without the benefit of **comprehensive energy planning** recommendations from a highly qualified and credible source, exposes the need for a planning mechanism. We suggest that the legislation under consideration include the creation of such a mechanism.
- Second, the addition of more renewable resources requires an **increase in the RPS requirement** or, more precisely, an increase in the rate of increase of future RPS requirements. With more renewable resources entering the market supported by long-term contracts, the price of RECs will inevitably decrease, which in turn creates risks for those resources that have relied or will rely on the REC market for their entry. To prevent a crash in the REC market, the rate of increase in the RPS will need to escalate to maintain the price signals for additional renewable resource needs. Thus, increasing the RPS requirement is consistent with the overarching clean energy objectives. We note that the Massachusetts RPS requirement is currently lower than that of many other states that have stringent GHG emissions reduction mandates.
- Third, although not addressed in the studies we have reviewed, energy storage can help integrate variable renewable energy generation. The addition of more variable resources, such as wind and solar, argues for the development and deployment of cost-effective **energy storage** technologies. For this reason, we recommend that the Commonwealth explore policy options that continue to support research and development in storage technologies and to advance the maturation of energy storage.

Electricity rates are not the only cost considerations for customers or for the economy. For instance, energy policy should focus not just on rates, but also on total customer bills. Comparatively high rates may translate into relatively low bills when progressive energy efficiency policies enable customers to use less electricity, or when rates are designed to provide customers incentives to reduce electricity use at times of system peak demand. Finally, certain energy policies, like those mandating energy efficiency, solar PV, and offshore wind, can be engines of economic growth as new opportunities for employment are created in Massachusetts.

Appendix: Comparison of Studies

Authors	Report Title	Date	Funded By	Description	Resources Addressed	Analysis	Base Case	Alternative Cases
Union of Concerned Scientists (with analysis by Sustainable Energy Advantage and Daymark Energy Advisors)	Massachusetts's Electricity Future: Reducing Reliance on Natural Gas through Renewable Energy	April 2016	Union of Concerned Scientists	Analyzes a portfolio of additional clean energy resource options available to Massachusetts	Hydro imports, onshore wind, offshore wind	Wholesale energy market simulation	Forecasted load based on ISO-NE CELT, increased solar targets, existing RPS. Natural gas prices not reported.	Hydro, offshore wind, and onshore additions by 2030, including: 13,200,000 MWh of hydro (1,590 MW), 7,400,000 MWh of offshore wind (2,000 MW), and 5,700,000 MWh of onshore wind (647 MW)
Massachusetts Clean Electricity Partnership and Power Advisory	Analysis of Benefits of Clean Electricity Imports Benefits to Massachusetts Customers	April 2016	Massachusetts Clean Electricity Partnership	Analyzes addition of hydro imports from Canada into New England market	Hydro imports	Wholesale energy market simulation with electric capacity expansion model, gas price model, and gas pipeline expansion model	Forecasted load based on ISO-NE CELT, existing RPS, natural gas prices based on Annual Energy Outlook 2015.	Starting in 2020, addition of 18,900,000 MWh of hydro imports (2,100 MW)
London Economics International	Cost-Benefit and Local Economic Impact Analysis of the Proposed Northern Pass Transmission Project	October 2015	Northern Pass Transmission, LLC	Analyzes addition of hydro imports from Canada into New England market	Hydro imports	Wholesale energy market simulation with electric capacity expansion model and economic development analysis	Forecasted load based on ISO-NE CELT, existing RPS, natural gas prices based on Annual Energy Outlook 2015.	Starting in 2019, addition of transmission line that provides 1,100 MW of capacity for hydro imports from Canada into New England market
Susan Tierney, Analysis Group	Proposed Senate Bill No. 1965: An Act Relative to Energy Sector Compliance with the Global Warming Solutions Act	September 2015	New England Power Generators Association	Discussion of the risks to consumers and the New England electricity markets of long-term contracts for hydro imports	Hydro imports	Compared costs to market prices and trend in GHG emissions	Not applicable	Not applicable
University of Delaware Special Initiative on Offshore Wind	Massachusetts Offshore Wind Future Cost Study	March 2016	Rockefeller Brothers Fund, New York Community Trust, John Merck Fund and Mertz Gilmore Foundation	Analyze potential cost decline for offshore wind in Massachusetts based on a long-term commitment to developing the resource	Offshore wind	Develop future cost estimates of offshore wind levelized costs of energy based on industry sources and assumptions on future cost declines	Not applicable	Not applicable
ISO-New England	2015 Economic Study Offshore Wind—Draft Results	March 2016	ISO-New England	Analyzes addition of 1,000 MW and 2,000 MW of offshore wind	Offshore wind	Wholesale energy market simulation	Model 2021 based on forecasted load in CELT, EIA fuel prices	Offshore wind additions of 1,000 MW and 2,000 MW; consider alternative scenarios for fuel prices, imports/exports, conventional resource retirements, GHG prices, onshore wind capacity
ISO-New England	Strategic Transmission Analysis—Onshore Wind Integration	March 2016	ISO-New England	Analyzes impact of transmission upgrades on system with increasing capacity of onshore wind in northern Maine	Onshore wind and transmission	Wholesale energy market simulation	Increasing amounts of onshore wind in northern Maine without transmission upgrades	Increasing amounts of onshore wind in northern Maine with transmission upgrades to overcome constraints between Maine and southern New England
Massachusetts Electric Distribution Utilities	Three-Year Energy Efficiency Plan for 2016–2018	January 2016	Massachusetts Electric Distribution Utilities	Reports impacts of EE programs for 2016 to 2018, including total energy savings, program costs, and resource cost savings	Energy efficiency	Analyzes net reduction in costs due to energy efficiency programs	Not provided	Addition of energy efficiency measures to reduce 2018 load by 4,118,000 MWh

Authors	Transmission Need?	Forecasted Electricity Price	Resource Costs	Benefits Considered	Estimated Benefits	Net Benefits
Union of Concerned Scientists (with analysis by Sustainable Energy Advantage and Daymark Energy Advisors)	Not explicitly stated. Assume transmission costs are included within resource costs.	Base Case: 2020 - $42/MWh; 2030 - $70/MWh	Hydro: $80/MWh (2020) Offshore wind: $200/MWh (2021), $120/MWh (2029) Onshore Wind: $60 - 120/MWh (2020-2030)	Electricity bill impact due to lower energy market prices; GHG emissions; natural gas usage	Natural gas generation decreases from 52% of regional generation to 42%; regional GHG emissions decrease by 6.6 million tons compared to 2030 base case	Monthly bills increase by $3 for Residential, $33 for Commercial, and $341 for Industrial
Massachusetts Clean Electricity Partnership and Power Advisory	Yes, include transmission costs related to hydro imports in their analysis	Base Case: 2020 - $60/MWh; 2030 - $70/MWh	Base delivered costs: $431 million annual costs ($78/MWh); Low delivered costs: $291 million annual costs ($70/MWh); High delivered costs: $718 million ($93/MWh)	Electricity bill impacts due to lower energy market prices and capacity market prices; Resource costs; Natural gas bills, GHG emissions	$603 million annual Massachusetts consumer savings compared to 2030 base case	Electricity and gas consumers in Massachusetts save $171 million annually assuming Base Delivered Costs. total resource costs decrease by $379 million per year, and regional GHG emissions decrease by 7.2 million tons compared to 2030 base case
London Economics International	Yes, add Northern Pass transmission project	Redacted	Transmission line: $1.6 billion; assume "some project costs…may be passed through and paid for by consumers of the electric distribution utilities in the states sponsoring the Clean Energy RFP for some period of time"; hydro imports bid into energy market at $0/MWh	Electricity bill impacts due to lower energy and capacity market prices; production costs; GHG and other air emissions; economic development (GDP, jobs)	Over 11 years, $851-866 million annual wholesale market benefits, $330 - 425 million production cost savings, 3.3 - 3.4 million tons GHG emissions reductions, $489 million in GDP during construction and $1,156 million during operation, and 5,574 jobs during construction and 6,820 during operation	Net benefits that take into account contracts for hydro and transmission are not included
Susan Tierney, Analysis Group	Not applicable	Notes 2012 to 2015 energy prices averaged and current forward market prices are around $55/MWh	Hydro from Hydro Quebec or Nalcor: $97/MWh	Not applicable	Not applicable	Highlights potential for adverse market impacts, including significantly higher costs for consumers, potentially limited GHG reductions if nuclear plants retire, and decreased confidence in wholesale electricity markets
University of Delaware Special Initiative on Offshore Wind	Yes, include costs of transmission to connect to existing system onshore	Not applicable	Project future levelized costs of energy from offshore wind: 2023 - $162/MWh; 2026 - $128/MWh; 2029 - $108/MWh	Not applicable	Not applicable	Not applicable
ISO-New England	Yes, assume transmission built to interconnect into existing system	BAU Case: $47/MWh in 2021; alternative cases range from $22 to $101/MWh	Not considered	Reduction in load payments for energy, production cost savings, transmission congestion, and GHG emissions	Annual production cost savings range from $104 to $807 million/year; LSE expense savings range from $56 to $491 million/year; reduces total constrained hours on transmission system; GHG emissions decrease by 2 - 4 MMT	Analysis does not consider costs of procuring offshore wind
ISO-New England	Yes	BAU Case: $47/MWh in 2021; alternative cases range from $45 to $48/MWh	Not considered	Reduction in load payments for energy, production cost savings and GHG emissions	Annual production cost savings range from $0 at low pentration of wind capacity to $75 million per year with 4,405 MW of wind capacity in Maine; $1 to $76 million per year LSE expense savings; and 0 - 0.7 MMT reduction in GHG emissions	Analysis does not consider costs of procuring onshore wind or building transmission
Massachusetts Electric Distribution Utilities	No	Not provided	Total resource costs of $2.6 billion (including program costs, participant costs, and performance incentives)	Avoided energy costs, generation capacity costs, transmission and distribution costs	Total resource cost savings of $6.2 billion	Net total resource costs savings of $3.6 billion

List of Acronyms

BOEM	U.S. Bureau of Ocean Energy Management
CC	Combined-Cycle Natural Gas Plant
CELT	Capacity, Energy, Loads, and Transmission
CT	Combustion Turbine
DOE	U.S. Department of Energy
DOER	Department of Energy Resources
DPU	Department of Public Utilities
DR	Demand Response
EE	Energy Efficiency
EEA	Massachusetts Office of Energy and Environmental Affairs
EM&V	Evaluation, Measurement, and Verification
GHG	Greenhouse Gas
GWSA	Global Warming Solutions Act
HVDC	High-Voltage Direct Current
LEI	London Economics International
MCEP	Massachusetts Clean Electricity Partnership
MMT	Million Metric Tons
NESCOE	New England States Committee on Electricity
NREL	National Renewable Energy Laboratory
O&M	Operations and Maintenance
PV	Photovoltaic
REC	Renewable Energy Credit
RGGI	Regional Greenhouse Gas Initiative
RPS	Renewable Portfolio Standard
SEA	Sustainable Energy Advantage
SREC	Solar Renewable Energy Credit
UCS	Union of Concerned Scientists

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