Comments on Expanding CES Eligibility to Existing Nuclear Units

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Executive Summary

The state of Massachusetts aims to reduce its economy-wide GHG emissions 25% by 2020 and 80% by 2050, relative to the 1990 levels. As part of the regulations to achieve this goal, Massachusetts has recently introduced a new regulation, the Clean Energy Standard (or "CES"), that requires load-serving entities in Massachusetts to procure electricity from low-emitting resources that came online after 2010.[1] The Massachusetts Executive Office of Environmental Affairs (EEA) and the Massachusetts Department of Environmental Protection (DEP) are seeking stakeholder input on the implications of potentially shifting the commercial operating date requirement to an earlier date so that some of the existing clean generators (such as the Seabrook nuclear plant) can also participate in the CES program. In particular, the EEA and the DEP requested comments on an option to expand the CES program by implementing a separate requirement ("CES-E") in addition to the current CES requirements to support clean generators that came online between 1990 and 2010, and are located in a region or state that has been consistently exporting clean energy to Massachusetts. Based on our review of the historical generation and import data provided in Massachusetts' GHG inventory and other public data, we estimated that there would be 17 TWh of existing clean generation meeting the extended vintage and locational requirements, of which approximately 9 TWh would serve Massachusetts' load and thus qualify for the proposed CES-E program.

In this study, as summarized in Figure 1, we evaluate the cost and emission impacts of retaining existing clean generators through a CES-E program, compared to two scenarios: (a) without these existing clean generators and (b) without these existing clean generators, but with additional new clean resources replacing their output.

1 Massachusetts DEP, "310 CMR 7.75 Clean Energy Standard", August 2017, posted at: http://www.mass.gov/eea/docs/dep/air/climate/3dregc-ces.pdf

Figure 1: 2017–2030 Average Cost and Emission Impact of Retaining Seabrook and Other Existing Clean Generation under the CES-E Program

	Relative to Existing Clean Offline	Relative to Existing Clean Replaced w/ New Renewables
ISO-NE Total CO_2 Emissions	6.8–7.0 MMT/yr ↓	0.4 MMT/yr ↓
Massachusetts' Share of CO_2 Emissions	3.6 MMT/yr ↓	0.1 MMT/yr ↓
ISO-NE Total System Costs	$71–$210 million/yr ↓	$1,105–$2,382 million/yr ↓
Massachusetts Customer Costs		
With $7/MWh ACP	$136–$157 million/yr ↓	$481–$1,200 million/yr ↓
With $35/MWh ACP	$120–$141 million/yr ↑	$203–$922 million/yr ↓

We conclude that retaining the existing clean generators under the CES-E program (including the Seabrook nuclear plant) would result in the following impacts on average during the period 2017-2030:

- A reduction of 6.8–7 million metric tonnes of CO_2 emissions per year for the entire ISO-NE region, relative to a scenario without the existing clean generators.
- A reduction of 3.6 million metric tonnes of CO_2 emissions per year to serve Massachusetts electric load relative to a scenario without the existing clean generators, which would allow the state to keep its electric sector-emissions below the 2020 target of 11–14 million metric tonnes and help towards meeting its long-term economy-wide emission reduction goals beyond 2020.
- ISO-NE system cost savings of $71–$210 million per year relative to a scenario without the existing clean generators, driven by the reduced production costs from fossil-fuel generation more than offsetting the cost of existing clean generation. The system cost savings would be $1,105–$2,382 million per year relative to a scenario where the output of existing clean generators is replaced with new renewable generation, due to the avoided new renewable procurement and transmission costs associated with the 17 TWh of additional wind generation.
- $136–$157 million lower annual electric customer costs in Massachusetts relative to a scenario without the existing clean generators, assuming that the generators eligible under the CES-E program are paid $7/MWh on average (equal to 10% of RPS Class I Alternative Compliance Payment, or ACP) for their clean energy attributes. The estimated savings in customer costs are driven by the reduced energy and capacity prices

over the period 2017-2030. If the price paid on clean energy credits were set higher at $35/MWh (equal to 50% of RPS Class I ACP), Massachusetts customer costs would increase by $120-$141 million per year.

Note that the reduction in energy and capacity prices would also lead to lower generator revenues, which would offset these savings from a Massachusetts system cost perspective.

- $481–$1,200 million lower annual electric customer costs in Massachusetts relative to a scenario in which the output of existing clean generators is replaced with new renewable generation, assuming that the generators eligible under the CES-E program are paid $7/MWh for their clean energy credits. The estimated savings in customer costs are largely driven by the higher cost of building and operating new renewable generation and the associated new transmission allocated to Massachusetts, relative to the cost of existing clean generation under the CES-E program. The range of savings in customer costs would be lower at $203–$922 million per year if the price paid on clean energy credits is higher at $35/MWh.

  The simulated market price levels are similar in the two scenarios we analyzed (retaining existing clean generators vs. replacing their output with new renewables), therefore, the effects on generator revenues would be limited and savings from a Massachusetts system perspective would be comparable to the range of estimated customer cost savings shown above.

I. Overview and Conclusions

The Global Warming Solutions Act (GWSA) signed in 2008 requires state economy-wide GHG emissions in Massachusetts to be reduced 25% by 2020 and 80% by 2050, relative to the 1990 levels. In order to achieve these targets, Massachusetts will need significant emission reductions across all sectors and its electricity sector may have to decarbonize more deeply on a percentage basis than other sectors. Accordingly, state legislation has introduced various policies and programs including increased energy efficiency goals, renewable portfolio standards (RPS), participation in the Renewable Greenhouse Gas Initiative (RGGI), and most recently the Clean Energy Standard (CES) under the regulation 310 CMR 7.75. Under the new policy, the CES requires load-serving entities in Massachusetts to procure electricity from eligible clean resources with a target that starts at 16% of load served in 2018 and grows 2% per year until it reaches 80% by 2050. The current CES rules allow low-emitting generators with lifecycle GHG emissions of at least 50% below those from the most efficient natural gas generator to qualify towards meeting CES if they commenced operation after December 31, 2010.[2] Due to this vintage requirement, clean generation resources that came online prior to December 31, 2010 are currently not eligible to meet the state's CES targets.

The Massachusetts Executive Office of Environmental Affairs (EEA) and the Massachusetts Department of Environmental Protection (DEP) are seeking stakeholder input on the implications of potentially moving the commercial operating date requirement to an earlier date so that some of the existing clean generators (such as the Seabrook nuclear plant) are included as part of the CES program.[3] In particular, the EEA and the DEP requested comments on an option to expand the CES program by implementing a separate requirement ("CES-E") to support clean generators that came online between 1990 and 2010, and are located in a region or state that has been consistently exporting clean energy to Massachusetts.[4] The quantity of requirements under the CES-E program would be set at recent historical levels of electricity imported from existing clean generators to Massachusetts. The primary driver of this consideration is to align the CES

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[2] Massachusetts DEP, "Fact Sheet, Electricity Sector Regulations", August 2017, posted at: http://www.mass.gov/eea/docs/dep/air/climate/3dfs-electricity.pdf.

[3] Massachusetts EEA and DEP, "Review of Options for Expanding the CES Stakeholder Discussion Document", which will be referred at "Stakeholder Discussion Document" in the rest of this study, posted at: http://www.mass.gov/eea/docs/dep/air/climate/shp-ces.pdf

[4] *Id.*, pp. 4-5.

with the state's decarbonization goals, recognizing that without expanding CES eligibility some of the existing clean generation may not have sufficient economic incentives to remain online going forward, which would be detrimental to achieving the state's long-term GHG reduction targets.

In this study, we evaluate the cost and emission impacts of retaining existing clean generators through a CES-E program, compared to two scenarios: (a) without these existing clean generators ("Existing Clean Offline" scenario) and (b) without these existing clean generators, but with additional new clean resources replacing their output ("Existing Clean Replaced" scenario). In particular, we estimate the contributions of these potential CES-E eligible resources towards achieving Massachusetts' GHG reduction targets through 2030. We also present our findings on the estimated costs associated with the CES-E program, in comparison to the costs of replacing the clean generation from these existing resources with additional new renewable resources needed to achieve similar GHG emission levels.

We quantify two separate cost metrics in our study: The first metric is the impact on total system costs in ISO-NE, which includes changes in system-wide production costs, market purchase costs for imports from external regions, investment costs for new resources, other fixed costs (FOM and ongoing CapEx) for new and existing resources, and transmission costs associated with incremental renewable buildout. The second metric is the impact on customer costs in Massachusetts, which reflects market price effects (energy and capacity) as well as the changes in Massachusetts' clean energy procurement costs including state's share of costs for the associated transmission needs.

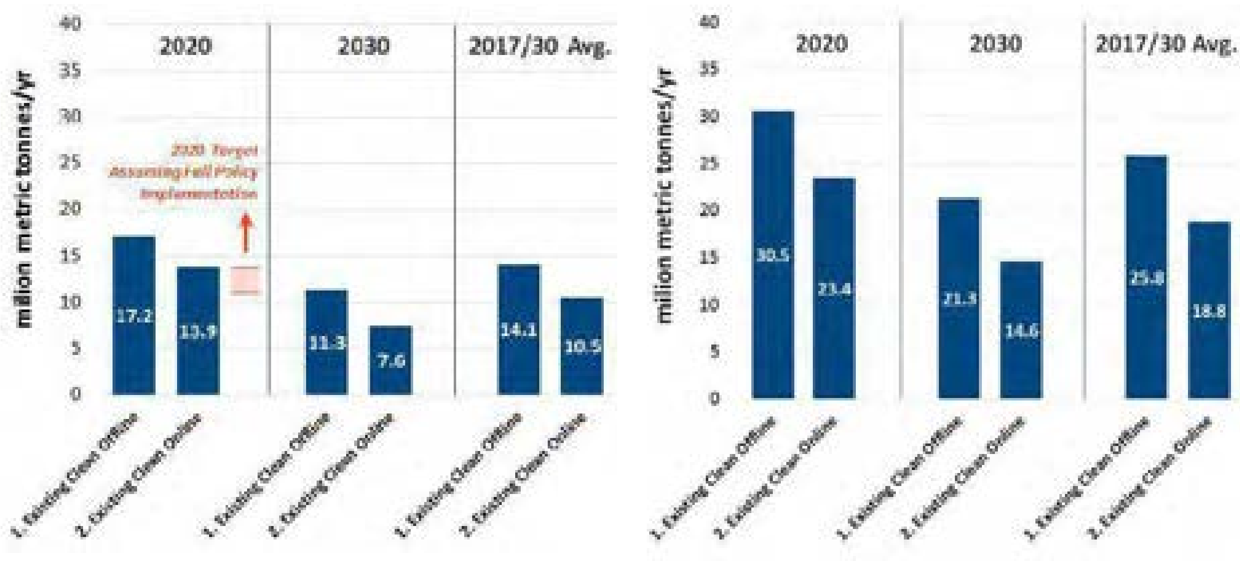
Our key conclusions are as follows:

- **Existing clean generators serving load in Massachusetts, including a portion of Seabrook, are contributing to achieving Massachusetts' GHG reduction targets by 2020 and lowering emissions in the ISO-NE region, and can continue to do so in the future.**

  Massachusetts' GHG emissions from electric sector would increase by 3.3 million metric tonnes in 2020 and by 3.8 million metric tonnes in 2030 unless the output from existing clean energy generators is replaced by additional new renewables. Without the existing clean generators, Massachusetts' GHG emissions from the electric sector would reach 17.2 million metric tonnes in 2020, and exceed the target of 11-14 million metric tonnes to achieve the economy-wide GHG reductions under the GWSA. Retention of existing clean generators also reduces GHG emissions in the ISO-NE region by about 7 million metric tonnes per year.

Figure 2: Projected CO_2 Emissions in Massachusetts and the ISO-NE Region

(a) MA's Share of Emissions (b) ISO-NE Total



Sources and Notes:

Brattle analysis.

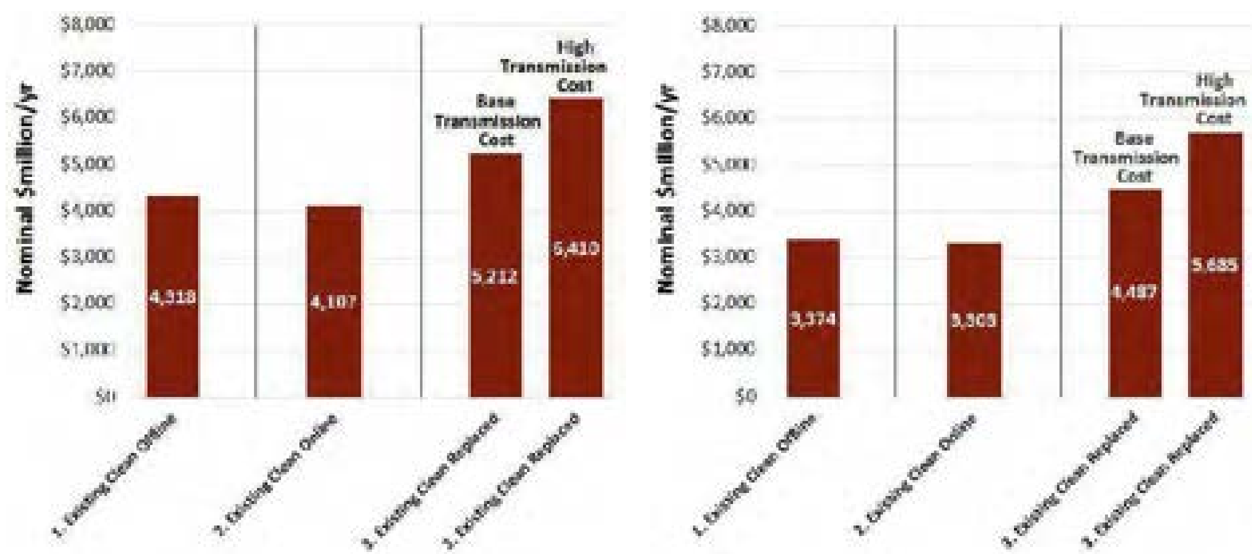
The targets for Massachusetts electric-sector GHG emissions in 2020 reflect full policy implementation projections from Massachusetts Executive Office of Energy and Environmental Affairs (EEA)'s "2015 Update of the Clean Energy and Climate Plan for 2020", posted at: http://www.mass.gov/eea/docs/eea/energy/cecp-for-2020.pdf

- **Total system costs in the ISO-NE region would be lower under the proposed CES-E program by $1.1- $2.4 billion per year on average during the period 2017-2030 relative to the cost of replacing the output of the existing clean generators with 5 GW of additional new renewables.**

The range in total system cost savings reflects the assumed prices of natural gas and RGGI GHG allowances in the future, and the uncertainty in the cost of new renewables and associated new transmission investment.

Figure 3: Total System Costs in the ISO-NE Region

(a) Base Market Outlook (b) Low Gas/RGGI Prices



Sources and Notes:

Brattle analysis.

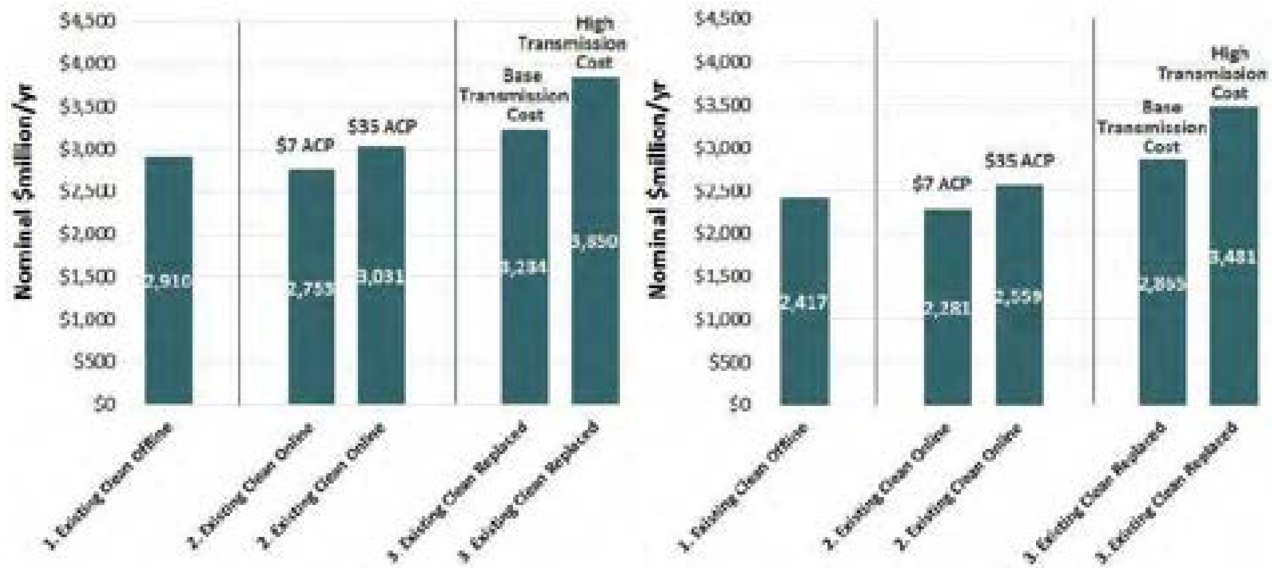
Transmission costs are assumed to be $500/kW under the base case, and $2,000/kW under the high case.

- **Retaining the existing clean generators under the CES-E program would reduce Massachusetts customer costs by $0.2-$1.2 billion per year on average during the period 2017–2030 relative to the Massachusetts' share of cost of replacing the generation output of existing clean generators with 5 GW of additional new renewables.**

The range in customer cost savings reflects the assumed level of ACP for the CES-E program set at either $7/MWh (10% of the Class I ACP) or $35/MWh (50% of the Class I ACP), the assumed prices of natural gas and RGGI GHG allowances in the future, and the uncertainty in the cost of new renewables and associated new transmission investment. The estimated customer cost savings are net of the payments to existing clean generators for about 9 TWh per year of CES-E eligible output. Such payments would be $69 million per year under the $7/MWh ACP and $345 million per year under the $35/MWh ACP.

Figure 4: Massachusetts Customer Costs

(a) Base Market Outlook (b) Low Gas/RGGI Prices



Sources and Notes:
Brattle analysis.
Transmission costs are assumed to be $500/kW under the base case and $2,000/kW under the high case.

- **The amount of energy imported from potential CES-E eligible existing clean generators to Massachusetts (approximately 9 TWh per year) is roughly equal to the amount of new clean generation that needs to be added between 2020 and 2030 to meet the CES targets.**

This means that if CES-E eligible existing clean generation no longer served Massachusetts' load, it could "undo" all of the progress that would be made under the existing CES rules over the 10-year horizon. To stay on track with long-term decarbonization efforts, the state would need to add new resources to replace the *lost* energy from these existing clean generators, which would require approximately doubling the clean energy additions during 2020–2030.

In addition, building new transmission infrastructure to integrate these incremental renewables would take years to complete, resulting in higher emissions in the near term even if the existing clean generation is eventually replaced by incremental renewables.

II. Proposed CES-E Program

In the Stakeholder Discussion Document, Massachusetts EEA and DEP provided an example for potential expansion of the current CES program, which they called "CES-E".[5] The CES-E program would aim to maintain the amount of electricity imported to Massachusetts from existing clean generators. The CES-E would require electricity sellers in Massachusetts to purchase clean energy certificates ("CEC-Es") from existing clean generators that came online after 1990, do not participate in other clean energy programs, and are located in regions that have been exporting significant quantities of clean generation into Massachusetts. The amount of certificates purchased on an annual basis would be set at levels that are consistent with recent imports into Massachusetts from the existing clean generation. We understand that the potentially eligible generation would need to satisfy the same eligibility conditions with respect to GHG emissions as in the CES program, *i.e.*, net lifecycle GHG emissions 50% below those from the most efficient natural gas generator. The CES-E rules would likely include an alternative compliance payment (ACP) option to demonstrate compliance with the CES-E program, where the ACP price would serve as a cap on CEC-E prices. While the level of ACP prices for the CES-E program are yet to be determined, the Stakeholder Discussion Document suggests that it could be below the ACP for the RPS Class I because operating costs of CES-E eligible existing clean resources would likely be lower than the operating plus capital costs associated with RPS-eligible new clean resources.

In order to determine the potentially eligible generation resources for the CES-E program, we reviewed the Massachusetts GHG inventory data on historical imported energy into Massachusetts from other states in New England and from regions outside New England. As shown in Figure 5, annual energy imported into Massachusetts has increased significantly over time largely due to increased hydro imports from Canada. In 2014, Massachusetts imported about 22 TWh of energy, of which 15 TWh were from Québec and New Hampshire accounting for two-thirds of state's net imports in that year. The remaining 7 TWh of imports came from Rhode Island, New York, Prince Edward Island (PEI), and New Brunswick (NB):

- Came into service between 1990 and 2010;
- Have GHG emission rates of at least 50% below those from the most efficient natural gas generator;

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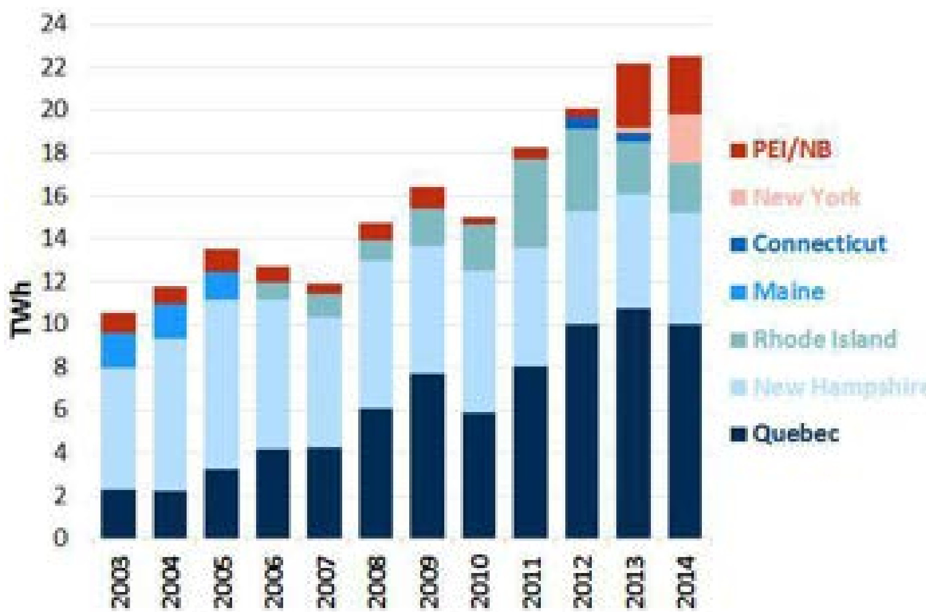
5 Stakeholder Discussion Document, pp. 4-5.

- Are not remunerated in other clean energy programs (such as state RPS programs); and
- Are located in regions that have been exporting significant quantities of clean generation into Massachusetts, with their portion of deemed imports consistent with the accounting methodology used by Massachusetts GHG inventory.

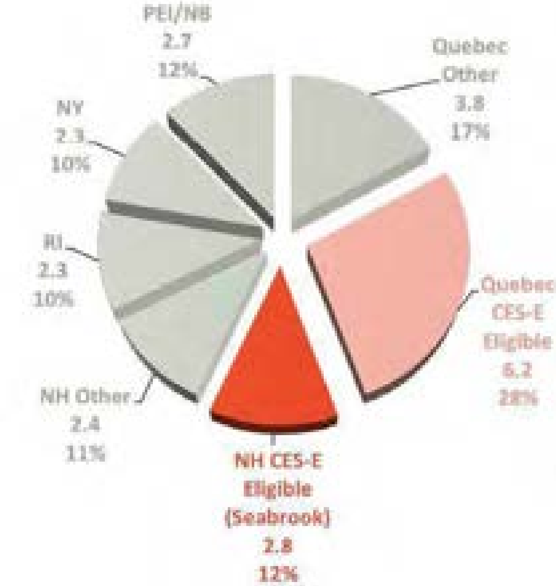
Figure 5: Energy Imports into Massachusetts



Sources and Notes:
Brattle analysis.
Calculated based on data provided in Massachusetts GHG Emissions Inventory.

Accordingly, we estimated that 9 TWh of the energy imported into Massachusetts would be eligible for the CES-E program including: (a) 6.2 TWh from hydro plants in Québec, Canada; and (b) 2.8 TWh from the Seabrook nuclear plant in New Hampshire. As illustrated in Figure 6 below, this corresponds to approximately 40% of the annual imports into Massachusetts based on 2014 levels.

Figure 6: Potential MA CES-E Eligible Resources of Existing Imports (Values Indicate 2014 Import Levels into MA in TWh and % of Total)



For imports from Québec into Massachusetts, we estimated that the portion attributed to resources added during 1990-2010 would be 6.2 TWh by applying Massachusetts' share of New England imports from external markets (~80%) to the increase in New England's imports from Québec between 1990 and 2010 (7.8 TWh).[6] This accounts for 62% of the 10 TWh of Québec imports into Massachusetts, with the remaining 38% attributed to resources that were online prior to 1990 or installed after 2010.

For imports from New Hampshire, we identified Seabrook to be the only existing clean generation that would qualify for the CES-E program, assuming that other clean resources would be already participating in a clean energy program (*e.g.*, state RPS). Historically, Seabrook has generated about 10 TWh/year, which reflects 55% of New Hampshire's total in-state generation. Using the same ratio, we estimated that Seabrook would account for 2.8 TWh of the 5 TWh of energy imports from New Hampshire into Massachusetts.

We assumed that existing clean generation resources other than hydro imports and Seabrook would fail to meet CES-E eligibility criteria as they are likely to participate in other clean energy

[6] Based on Brattle analysis of 1990-2016 electricity import and export data from the National Energy Board of Canada, "Commodity Statistics", posted at: https://apps.neb-one.gc.ca/CommodityStatistics/Statistics.aspx?language=english

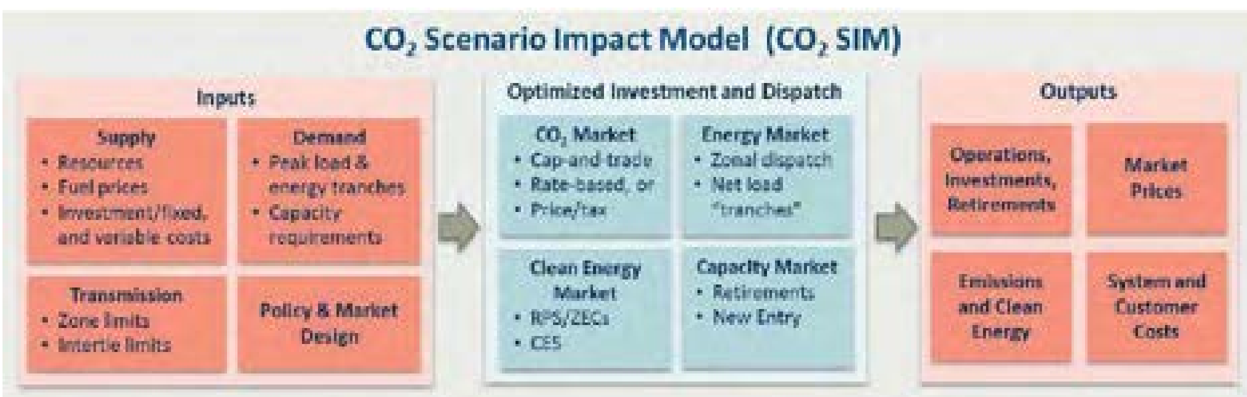
programs, or are located in a state or region from which Massachusetts does not import a significant amount of energy, or came online before 1990.

III. Study Approach and Scenarios

A. Model Description

We analyzed the New England electricity market using Brattle's "CO_2 SIM" expansion planning model to evaluate cost and CO_2 emission impacts of the existing clean generators that could potentially qualify for CES-E. The CO_2 SIM is a least-cost optimization model that simulates generation dispatch and capacity expansion over a modeling horizon of several decades. It minimizes the total production and investment costs over time, subject to meeting the projected energy and capacity requirements by using existing and new resources, and satisfying the state RPS and Massachusetts CES targets. The model groups hours in each year into 50 tranches with similar levels of load and uses a zonal representation of the ISO-New England grid.

The diagram below summarizes the key inputs, outputs, and capabilities of the model:



B. Scenarios

We analyzed the future production costs, customer costs, and CO_2 emissions in Massachusetts and New England under three scenarios:

1. **Existing Clean Offline (New-Only CES):** This scenario reflects the implementation of the current CES program relying on new clean generation placed in service after 2010. The existing clean generation resources that came online between 1990 and 2010 are not eligible to participate in the CES program and they no longer provide their clean energy output to Massachusetts or the rest of the New England system starting in 2017.

2. **Existing Clean Online (Proposed CES-E):** This scenario includes additional requirements for retail electricity suppliers to purchase clean energy certificates (CEC-Es) from eligible existing clean generators that came online after 1990. The annual requirement is set at 9 TWh, based on our estimates of the clean energy imported into Massachusetts from CES-E eligible resources in 2014. The alternative compliance payment (ACP) prices under the CES-E program are assumed to be 10% of RPS Class I ACP, with a sensitivity at 50% of RPS Class I ACP.

3. **Existing Clean Replaced:** As an alternative to expanding the current CES through the CES-E approach in order to retain the contributions of the <u>existing</u> clean generation towards achieving the Massachusetts' GHG reduction goals under GWSA, this scenario assumes *additional* procurement of <u>new</u> renewable generation to replace the output from existing clean generators.

Figure 7 below illustrates the amount of clean generation included across the three scenarios we analyzed in this study. Accordingly, Scenarios 2 and 3 have approximately 17 TWh more clean generation in ISO-NE relative to Scenario 1. Of this, we assumed 9 TWh would serve Massachusetts' load, which reflects the amount of CES-E eligible clean generation we identified consistent with the guidelines in the Stakeholder Discussion Document and Massachusetts GHG accounting methodology.

Figure 7: Illustration of Clean Generation Assumed in Three Scenarios

IV. Key Model Assumptions

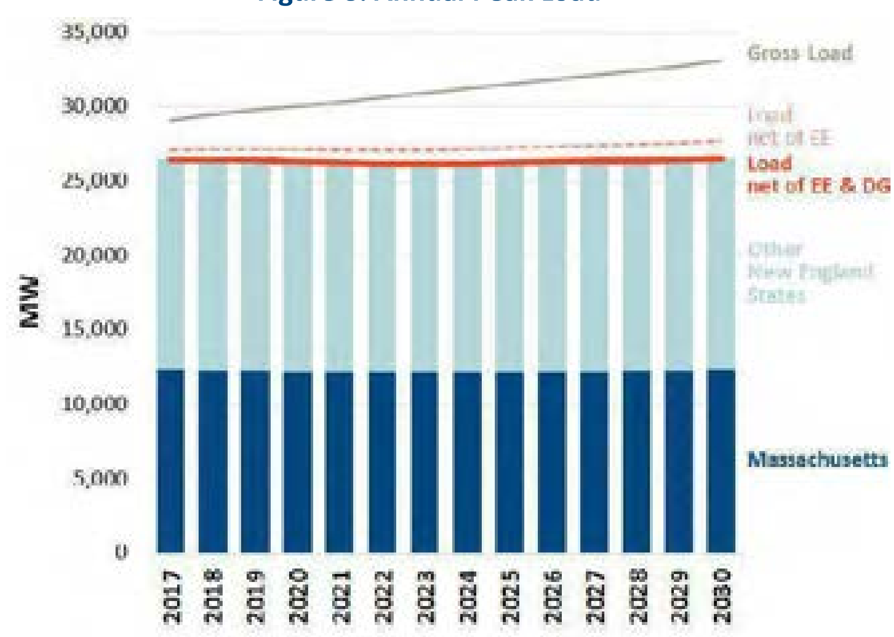
We relied on publicly available data to develop assumptions on market outlook, regional load forecast, clean energy requirements, and operating and capital costs for existing and new generation units.

We describe our key assumptions by category below.

A. Load Forecast

Our outlook on future electricity demand in New England, including demand reductions from energy efficiency and distributed generation, is developed based on ISO-NE's 2017 Forecast Report of Capacity, Energy, Loads, and Transmission (CELT).[7] Figures 8 and 2026 below show the annual peak load and energy projections in ISO-NE region and Massachusetts' share of the regional load.

Figure 8: Annual Peak Load



Sources and Notes:
Brattle estimate based on ISO-NE's load forecast in the 2017 CELT report.

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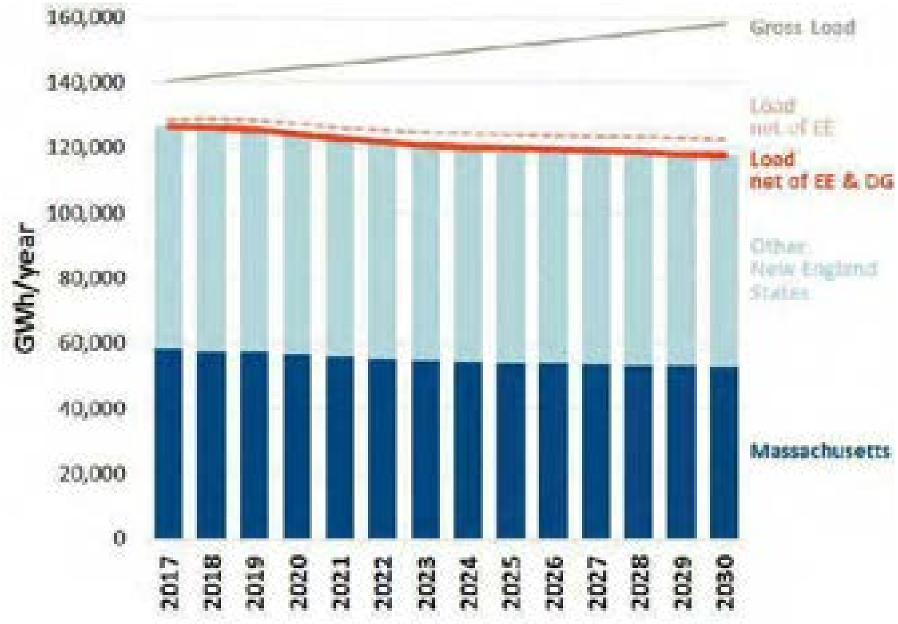
7 ISO-New England, "2017 Forecast Report of Capacity, Energy, Loads, and Transmission (CELT)", May 2017, posted at: https://www.iso-ne.com/system-planning/system-plans-studies/celt

Figure 9: Annual Energy



Sources and Notes:
Brattle estimate based on ISO-NE's load forecast in the 2017 CELT report.

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In our model, we used the load values net of energy efficiency and distributed solar generation (shown in solid red). ISO-NE's load forecast is available through 2026, after which we extrapolated by applying long-term growth rates assuming that energy efficiency savings would continue to increase at the same pace. Accordingly, the region's net peak load and associated capacity requirements remain relatively flat, while annual energy requirements decline slightly over the study horizon.

B. Clean Energy Requirements

We modeled Massachusetts' Clean Energy Standard (CES) as well as Massachusetts and other New England states' Class I renewable portfolio standards (RPS).

Massachusetts' CES sets a target starting at 16% in 2018 and growing 2% annually until it reaches 80% by 2050. As shown in Figure 10, the amount of eligible clean generation needed to satisfy the CES targets would be approximately 10 TWh in 2020 and 18 TWh in 2030.

Figure 10: Clean Generation Needed to Meet Massachusetts' CES Requirements

	2020	2030	2040	2050
CES Target (%)	20%	40%	60%	80%
Net Load Excl. Munis (TWh/yr)	48.9	45.5	45.5	45.5
Clean Generation Need (TWh/yr)	9.8	18.2	27.3	36.4

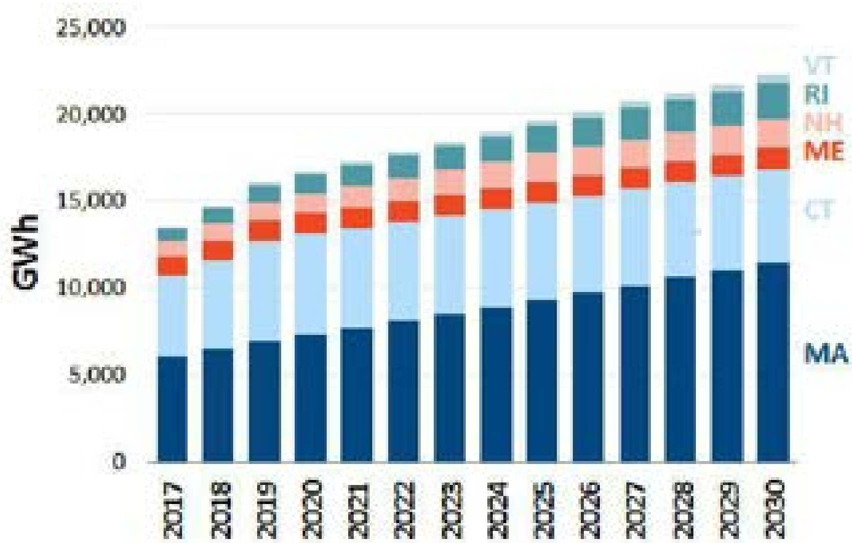
Sources and Notes:

Brattle estimate based on ISO-NE's load forecast (net of EE & DG) in the 2017 CELT report. Load values extrapolated for 2026–2030 based on long-term growth rates and kept it constant after 2030. Excludes municipal load accounting for 14% of state's load.Calculated based on ISO-NE's load forecast (net of EE & DG) in the CELT 2017-2026 report. Load values extrapolated for 2026–2030 based on long-term growth rates and kept it constant after 2030. Excludes municipal load accounting for 14% of state's load.

In addition to the CES, the increasing state RPS targets will also require significant amounts of new clean generation in New England. Within Massachusetts's Class I RPS targets, there is a solar carve-out requiring 1,600 MW of qualified in-state solar by 2020. We do not explicitly model this as a constraint because the total behind-the-meter solar PV assumed in the 2017 CELT load forecast plus planned additions is sufficient to meet the carve-out requirements.

Figure 11 below shows the renewable energy required to meet Class I RPS targets in New England states grow from 13.5 TWh in 2017 up to 22 TWh by 2030. Massachusetts accounts for more than half of the expected growth in regional RPS demand during the 2017–2030 period.

Figure 11: Class I RPS Demand in New England States



Sources and Notes:

Brattle estimate based on New England states' RPS targets and ISO-NE's load forecast (net of EE & DG) in the 2017 CELT report.

Massachusetts electric distribution companies (EDCs), in collaboration with Department of Energy Resources (DOER), issued three Requests for Proposals (RFPs) for long-term contracts to procure clean energy pursuant to Sections 83A, 83C, and 83D of Chapter 169 of the Green Communities Act.[8] The resulting procurements will help the region meet its increasing clean energy requirements, including RPS and CES.

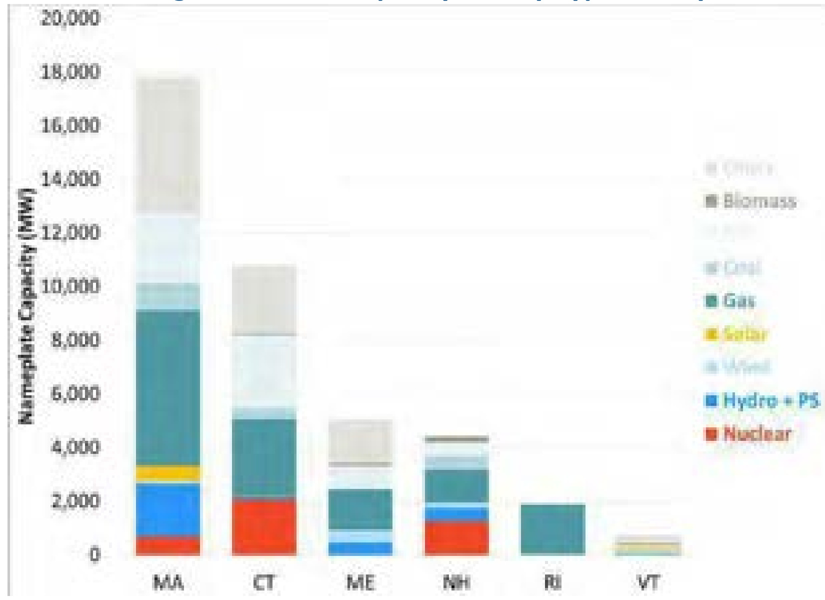
- 83A concluded with the selection of projects in the New England Clean Energy RFP (also known as the Tri-State RFP) with a total capacity of 460 MW that would provide approximately 0.8 TWh/yr of generation annually. In our model, we included each of the selected solar and wind projects as planned builds entering the generation fleet between 2018 and 2020.
- 83C authorizes the procurement of 1,600 MW of offshore wind by 2027 that would provide approximately 6 TWh of generation annually. We assume that this procurement is fully met, starting with 400 MW in 2022, growing by 240 MW each year until reaching the full 1,600 MW in 2027.
- 83D authorizes the procurement of 9,450 GWh of firm clean energy from incremental clean imports or Class I RPS resources by 2022. We assume that this procurement is met through 8,500 GWh (1,100 MW at 90% capacity factor) of incremental hydro imports from Québec and 950 GWh (285 MW at 38% capacity factor) of additional onshore wind resources built in Maine.

C. Supply of Electricity Generation Resources

We model the existing fleet of generating units in ISO-NE using an aggregated unit list based on generator data from ABB Velocity Suite, and benchmarked the capacity by unit type against ISO-NE's public generation capacity data from 2016. Figure 12 below shows the capacity of the existing unit list separated by state and by resource type.

[8] Sections 83A, 83C, and 83D were promulgated through Department of Public Utilities regulations 220 C.M.R. 21.00, 220 C.M.R. 23.00, and 220 C.M.R. 24.00, respectively. Posted at: https://www.mass.gov/service-details/laws-governing-long-term-contracts-for-renewable-energy.

Figure 12: Existing Generation Capacity Mix by Type and by State in 2016



After 2016, the existing unit list is modified to capture planned additions and retirements announced as of May 2017. This includes planned unit additions and retirements assumed in ISO-NE's CONE and ORTP Updates filing and selected projects from the recent New England (Tri-State) RFP.[9] A summary of these planned additions and retirements is shown in Figure 13.

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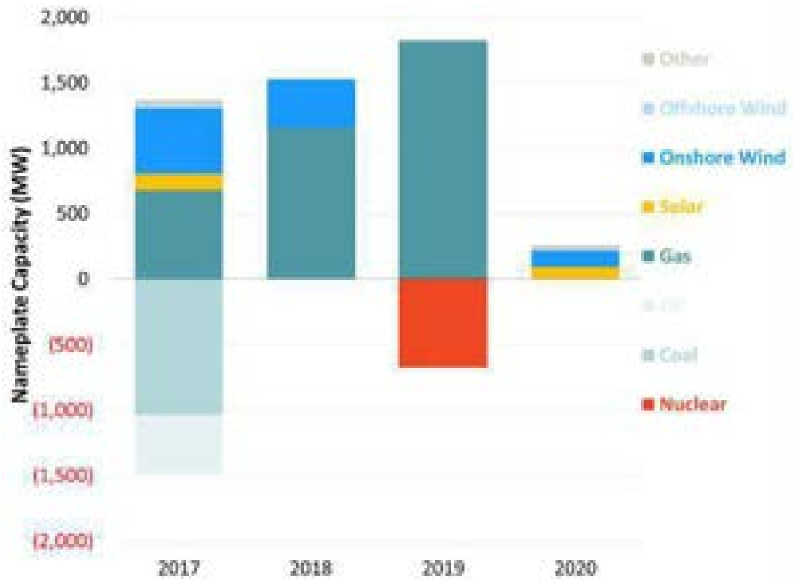
[9] ISO-NE, "Filing of CONE and ORTP Updates", January 13, 2017, posted at: https://www.iso-ne.com/static-assets/documents/2017/01/cone_and_ortp_updates.pdf, and New England Clean Energy RFP, posted at: https://cleanenergyrfp.com/

Figure 13: Planned Additions and Retirements by Type



In addition to existing units and planned additions and retirements, we model the Massachusetts 83C and 83D procurements as described in Section IV.B. Lastly, the model can choose to build new gas, renewable, and demand response resources, and retire existing fossil plants if they become uneconomic. The capital and going-forward cost assumptions for builds and retirements are described in the following section.

D. Plant and Transmission Cost Assumptions

Existing Plant Going-Forward Costs

Our model allows for economic retirements based on existing plants' going-forward costs relative to plants' market revenues. Figure 14 below summarizes our assumptions of the fixed costs (FOM + CapEx) for existing fossil plants. We adopted the cost values from EPA's IPM model and assumed that they increase over time with plant age.[10]

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10 U.S. Environmental Protection Agency, "Documentation for EPA Base Case v.5.13 Using the Integrated Planning Model", November 2013, posted at: https://www.epa.gov/sites/production/files/2015-07/documents/documentation_for_epa_base_case_v.5.13_using_the_integrated_planning_model.pdf

Figure 14: Fixed Going-Forward Costs of Existing Fossil Plants
(FOM + CapEx in 2017 $/kW-yr)

Plant Age	Gas/Oil ST	Coal ST
30	$23	$53
40	$39	$67
50	$65	$85
60	$109	$109

We assumed fixed going-forward costs of the Seabrook nuclear plant based on publicly available estimates, from EPA's IPM modeling assumptions for FOM and EIA's AEO2017 assumptions for ongoing CapEx. Accordingly, the total fixed costs of Seabrook would be around $250/kW-yr in 2017, increasing over time with inflation and by age. We assume that Seabrook's license extension application, currently under review by the Nuclear Regulatory Commission, will be approved and would extend the unit's operating license from 2030 to 2050.

We have not explicitly considered the fixed costs of other nuclear plants (Millstone and Pilgrim) as they are assumed to operate until current license expiration or announced retirement across all of our scenarios.

New Plant Costs

Our model considers cost of new entry for gas-fired CC and CTs, demand response, and renewables to determine the least-cost solution for meeting the region's energy, capacity, and clean generation needs.

Figure 15 summarizes our assumptions for the new gas-fired plants developed based on the ORTP values and plant parameters used in ISO-NE's CONE and ORTP Updates filing in January 2017.[11]

[11] ISO-NE, "Filing of CONE and ORTP Updates", January 13, 2017, posted at: https://www.iso-ne.com/static-assets/documents/2017/01/cone_and_ortp_updates.pdf

Figure 15: Performance and Cost Characteristics of New Gas-Fired Plants

		Gas CC	Gas CT
Capacity	*(ICAP MW)*	491	338
w/ Duct firing		533	
Heat Rate	*(Btu/kWh)*	6,381	9,220
w/ Duct firing		6,546	
Levelized CapEx + FOM	*($2017/kW-yr)*	$149	$109
VOM	*($2017/MWh)*	$3.2	$4.2

For new demand response, we constructed three tiers assuming that the unit costs would go up based on DR penetration as a share of system's peak load. Figure 16 summarizes our assumptions for each of these tiers with the lowest costs for up to 12% penetration and increased costs at higher DR penetration levels.

Figure 16: Cost Assumptions for New Demand Response

		Inexpensive	Middle	Expensive
Percent of Peak Load	*(%)*	0-12%	12-16%	16-24%
Levelized CapEx + FOM	*($2017/kW-yr)*	$37	$92	$135
VOM	*($2017/MWh)*	$1,000	$2,000	$3,000

For new renewables, we relied on a combination of ISO-NE's CONE and ORTP Updates filing and the NESCOE/London Economics study to develop all-in costs and used NREL data to determine capacity factors at the state level.[12] Figure 17 summarizes our assumptions for wind and solar resources.

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12 NREL's System Advisor Model was used to generate hourly profiles and capacity factors for solar resources, and NREL's Wind Prospector Tool was used to generate profiles for wind resources. For onshore wind, we used the all-in cost from the ORTP study as the initial cost estimate, and interpolated to meet the 2025 and 2030 cost estimates from the NESCOE study. For offshore wind and solar, we used the 2025 and 2030 cost estimates from the NESCOE study, and applied the same cost decline trend to years prior to 2025. See New England States Committee on Electricity (NESCOE)/London Economics International (LEI), "Renewable and Clean Energy Scenario Analysis and Mechanisms 2.0 Study, Phase I, Scenario Analysis Report", March 2017, posted at: http://nescoe.com/resource-center/mechanisms-scenario-analysis-mar2017.

Figure 17: All-in Cost and Capacity Factors for New Renewables

	Onshore Wind	Offshore Wind	Utility Solar
All-in Costs (2017$/kW-yr)			
2020	$309	$696	$200
2025	$240	$616	$168
2030	$221	$545	$141
Capacity Factor			
CT	34%		15%
MA	34%	42%	16%
ME	38%	40%	14%
NH	32%		16%
RI	31%	42%	15%
VT	34%		15%

The costs in Figure 17 do not reflect any reductions from tax credits. In our model, we incorporated the federal tax credits (PTC and ITC) and their expected phase-out over the next several years. Accordingly, we assumed that PTC would be available for wind resources commencing construction prior to 2020, with credits declining to $19/MWh in 2017, $14/MWh in 2018, and $9/MWh in 2019. We also assumed that ITC would be available for solar resources at 30% until 2019, 26% in 2020, 22% in 2021, and 10% after 2022.

Incremental Transmission Costs

Expansion of renewable generation needed to meet Massachusetts and other New England states' clean energy goals would likely require substantial amounts of investments in new transmission to be able to access low-cost resources and address increased congestion at higher renewable penetration levels.

While the level of transmission investment need is highly uncertain and it would depend on the amount, type, and locations of renewables added, as well as other market drivers, various recent industry studies suggest that the costs could be significant especially for the best, more remote sites. For example, ISO-NE recently analyzed the transmission costs to integrate wind resources in Maine and estimated that it would require $1.3 billion for 1,118 MW of wind in northern

Maine and $575 million for 777 MW of wind in western Maine.[13] These cost estimates translate to $750–$1,150 per kW-wind. A separate ISO-NE study focusing on high-level costs of transmission development to facilitate renewables in New England found that adding 2,955 MW of wind in Maine to meet region's RPS goals would require $5.2–$6.7 billion of investments in transmission ($7.8–$10 billion including 50% contingency) which translates to $1,700–$3,300 per kW-wind.[14] The same study found that adding approximately 10,000 MW in addition to amount needed to meet RPS would require $15–$20 billion of investments in transmission incrementally, which corresponds to $1,500–$2,000 per kW-wind.

In our study, we consider only transmission costs for the incremental wind resources added in Scenario 3 since the other transmission costs would be common across all three scenarios. In our base outlook, we conservatively assumed transmission costs to be $500/kW-wind. Accordingly, we estimated that levelized cost of transmission needed to integrate the 5,300 MW of wind added in Scenario 3 to replace existing clean generation would be $350 million/yr (in 2017$) assuming a 13% charge rate. We allocated about half of these costs to Massachusetts based on the share of CES-E eligible portion of the existing clean generation that gets replaced (9 TWh out of 17 TWh).

Recognizing the highly uncertain nature in future transmission needs and costs, we also tested a sensitivity in which we used $2,000/kW-wind consistent with the higher end of the cost range estimated in the recent ISO-NE wind integration studies. This translates to a levelized cost of $1.4 billion/yr (in 2017$) for the 5,300 MW added in Scenario 3, of which $0.7 billion/yr is allocated to Massachusetts based on the share of CES-E eligible portion of the existing clean generation replaced.

E. Fuel Prices

Fuel cost is a major component of the variable cost of generation and a key driver of market outcome in Massachusetts and the rest of the ISO-NE region. Although electric generators rely on a variety of fuels, ISO-NE's system relies most heavily on natural gas-fired plants. Electricity

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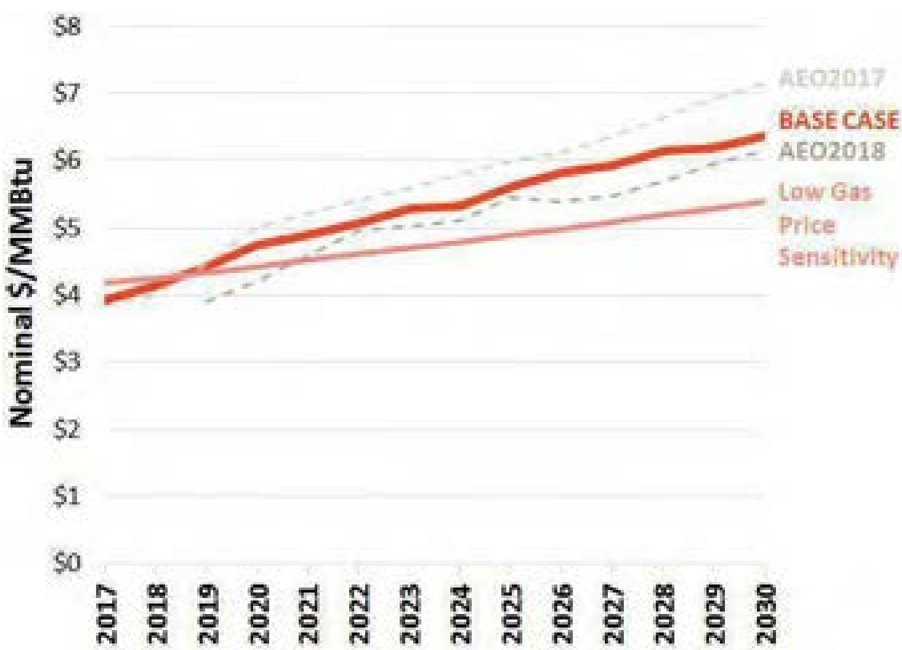
13 ISO-NE, "2016/17 Maine Resource Integration Study–Scenarios and Cost Estimates," Planning Advisory Committee, August 3, 2017.

14 ISO-NE, "2016 Economic Study: NEPOOL Scenario Analysis–Implications of Public Policies on ISO New England Market Design, System Reliability and Operability, Resource Costs and Revenues, and Emissions", July 24, 2017

prices are therefore highly sensitive to variation in natural gas prices. Although the region has substantial amounts of oil-fired generation (including plants with dual-fuel capability), these plants often run very little and they are kept primarily as capacity resources towards meeting reserve margin targets.

Figure 18 below shows our natural gas prices assumptions, compared to EIA's projections in AEO2017 and AEO2018 (Early Release). For our base outlook, we relied on inputs developed for NESCOE/London Economics International's Renewable and Clean Energy Scenario Analysis and Mechanisms 2.0 Study.[15] Annual average gas prices in New England start at around \$4/MMBtu in 2017 and rise over time to \$4.7/MMBtu in 2020 and \$6.3/MMBtu in 2030. In our Low Gas/RGGI Price sensitivity, we assumed that gas prices would grow more slowly (based on 2% inflation) reaching \$4.4/MMBtu in 2020 and \$5.4/MMBtu in 2030.

Figure 18: Annual Average Natural Gas Prices in New England



Sources and Notes:

Brattle analysis comparing gas prices from the NESCOE/LEI study (used for base case and adjusted for the sensitivity) against prices from EIA's AEO 2017 and preliminary AEO 2018.

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15 New England States Committee on Electricity (NESCOE)/London Economics International (LEI), "Renewable and Clean Energy Scenario Analysis and Mechanisms 2.0 Study, Phase I, Scenario Analysis Report", March 2017, posted at: http://nescoe.com/resource-center/mechanisms-scenario-analysis-mar2017.

For other fuels, we used the inputs developed for the same NESCOE/London Economics study. Accordingly, we assumed coal prices to start at \$3.5/MMBtu in 2017 and rise steadily to \$5.5/MMBtu by 2030, and fuel oil prices to start at \$10.1/MMBtu in 2017 and grow over time reaching \$18.6/MMBtu by 2030.

F. RGGI GHG Allowance Prices

In our base outlook, we used the RGGI GHG prices from a recent ICF study, increasing from about \$6/metric tonnes in 2017 up to \$7.2/metric tonnes in 2020 and \$13.4/metric tonnes in 2030 (nominal \$).[16] This price projection reflects the recent program changes, including an additional 30% decline in emissions cap by 2030. Under our low gas/RGGI price sensitivity, we assumed that the RGGI GHG prices would remain constant at \$5.6/metric tonnes in 2017\$, which translates to \$6/metric tonnes in 2020 and \$7.3/metric tonnes in 2030 (nominal \$).

Figure 19 below shows our assumed GHG prices over the 2017–2030 period:

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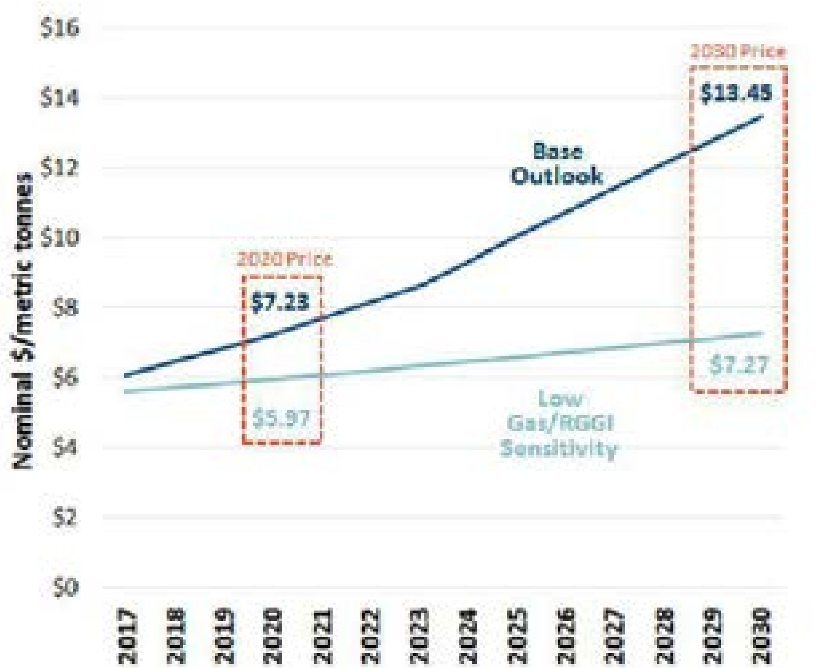
[16] ICF International, "Draft 2017 Model Rule Policy Scenario Overview", September 2017, posted at: https://rggi.org/docs/ProgramReview/2017/09-25-17/Draft_IPM_Model_Rule_Results_Overview_09_25_17.pdf

Figure 19: RGGI GHG Allowance Prices



Sources and Notes:

Projections under base outlook based on RGGI GHG prices from the 2017 ICF study. Low price sensitivity assumes RGGI GHG prices would remain at $5.6/metric tonnes in 2017$.

G. Transmission

CO_2 SIM is a zonal pipes-and-bubble model as illustrated in Figure 20 below. The transmission limits are adopted from the 2016 ISO-NE economic study.[17] Imports from external markets are modeled as fixed schedules subject to transfer limits (*e.g.*, 800 MW between WCMA and NY). Internal transfers between zones are constrained by limits on individual interties (*e.g.*, 1,900 MW between ME and NH) as well as limits applied on various interfaces shown in dashed lines and bubbles (*e.g.*, 2,725 MW North-South).

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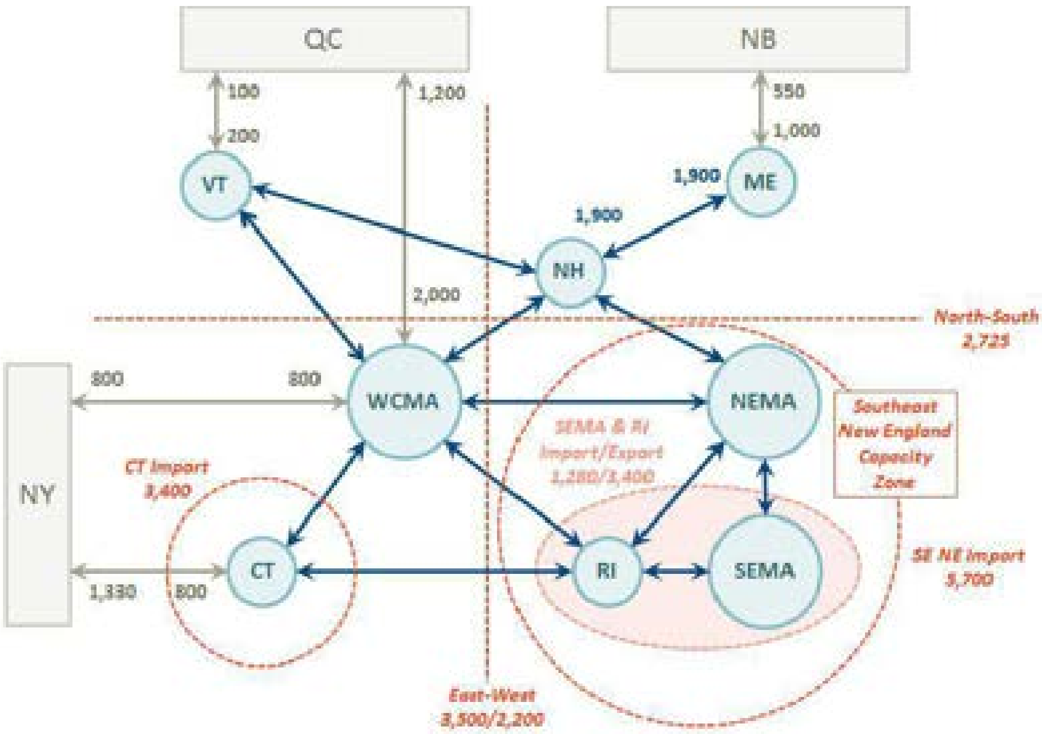
17 ISO-NE, "Transmission Transfer Capabilities & Capacity Zone Development", March 2016, posted at: https://www.iso-ne.com/markets-operations/markets/forward-capacity-market/fcm-participation-guide/capacity-zone-development

Figure 20: Summary of Transmission Assumptions



Sources and Notes:
Adapted from 2016 ISO-NE Economic Study.

In addition to the transfer limits shown above, we included additional transmission capability to between ME and WCMA zones to accommodate the substantial new wind development in northern ME. We set this incremental transfer capability to 2,400 MW under Scenarios 1 and 2 based on inputs from the NESCOE/London Economics study and further increased to 7,400 MW under Scenario 3 due to the additional wind resources included in this scenario to replace existing clean generation.

V. Study Results under Base Market Outlook

The value of existing clean generation in New England can be evaluated in two ways: 1) the additional GHG emissions that would occur if these resources were offline, or 2) the incremental costs of meeting Massachusetts and New England decarbonization goals without the benefit of these resources. We quantify both types of impacts in our study. Without existing clean resources, Massachusetts GHG emissions would increase by 3–3.5 million tonnes per year on average between 2017 and 2020 and New England emissions would increase by about 7 million tonnes per year, assuming the generation from these facilities *was not* replaced by new clean resources. If the output of existing resources *was* replaced with new renewables, Massachusettswide customer costs would increase by $200–$480 million per year, depending on the assumed price of CEC-E credits. Total resource costs in New England would increase by approximately $1.1 billion per year under our base case estimate of the costs of developing new clean resources and the transmission necessary to deliver it to New England load.

Differences in CO_2 emissions and costs across our three scenarios are driven by differences in the generation fleet and in the mix of resources meeting load. Figure 21 shows the composition of the generation fleet in 2020 and 2030 under each scenario. Comparing the Existing Clean Online to the Existing Clean Offline scenario, there are several key differences. Seabrook's 1,250 MW are online in both 2020 and 2030. The presence of Seabrook allows some oil-fired capacity to retire early in 2020. Additionally, the impact of Seabrook on both capacity and energy prices results in less gas capacity in both 2020 and 2030. The reductions in gas and oil capacity entirely offset Seabrook's additional capacity, ensuring that capacity market requirements are achieved but not exceeded.

Comparing the Existing Clean Online to the Existing Clean Replaced scenario, the most significant differences are in nuclear and onshore wind capacity. As we discussed in Section III, 5,300 MW of onshore wind (1,583 MW on a de-rated basis for meeting resource adequacy needs) was added in the Existing Clean Replaced scenario to replace the clean energy from Seabrook and the portion of existing hydro imports that would be eligible for CES-E. The Existing Clean Online scenario also has somewhat more oil, gas, and DR capacity compared to the Existing Clean Replaced scenario (though it has less than the Existing Clean Offline scenario), making up for the difference in the capacity value of the 5,300 MW of wind and the capacity value of Seabrook.

Figure 21: ISO-NE Generation Capacity De-Rated Based on Availability

	2020					2030				
	[1] Existing Clean Offline (New-Only CES) (MW)	[2] Existing Clean Online (Proposed CES-E) (MW)	[3] Existing Clean Replaced (MW)	[2]-[1] Delta (MW)	[2]-[3] Delta (MW)	[1] Existing Clean Offline (New-Only CES) (MW)	[2] Existing Clean Online (Proposed CES-E) (MW)	[3] Existing Clean Replaced (MW)	[2]-[1] Delta (MW)	[2]-[3] Delta (MW)
Gas	17,703	16,954	16,935	(749)	19	18,916	17,667	17,333	(1,249)	334
Coal	383	383	383	0	0	0	0	0	0	0
Oil	4,047	3,548	3,328	(500)	220	1,829	1,829	1,829	0	0
Nuclear	2,082	3,331	2,082	1,249	1,249	2,082	3,331	2,082	1,249	1,249
Hydro + PS	3,130	3,130	3,130	0	0	3,151	3,151	3,151	0	0
Onshore Wind	798	798	2,381	0	(1,583)	884	884	2,467	0	(1,583)
Offshore Wind	9	9	9	0	0	489	489	489	0	0
Utility Solar	137	137	137	0	0	137	137	137	0	0
Other Renewables	975	975	975	0	0	997	997	997	0	0
Net Imports	1,235	1,235	1,235	0	0	2,311	2,311	2,311	0	0
DR	3,157	3,157	3,061	0	95	3,157	3,157	3,157	0	0
Total	**33,657**	**33,657**	**33,657**	**(0)**	**(0)**	**33,952**	**33,952**	**33,952**	**0**	**0**

Sources and Notes: Brattle analysis. Reflects capacity values qualified for meeting resource adequacy needs.

Figure 22 shows changes in annual generation across the three scenarios. The additional nuclear generation in the Existing Clean Online scenario is entirely driven by the additional 1,249 MW of Seabrook capacity. Net imports are also higher in the Existing Clean Online scenario, as hydro imports from existing resources are fully available. Gas generation is lower under the Existing Clean Online scenario, reflecting both the reduced gas capacity shown in Figure 21 and the impact of lower energy prices on the utilization of remaining gas capacity. Similarly, oil generation decreases in the Existing Clean Online case relative to both the other cases, reflecting the impact of lower energy prices. In the Existing Clean Replaced case, additional onshore wind generation is sufficient to make up for the generation of Seabrook and eligible hydro imports.

Figure 22: ISO-NE Annual Generation

	2020					2030				
	[1] Existing Clean Offline (New-Only CES) (GWh)	[2] Existing Clean Online (Proposed CES-E) (GWh)	[3] Existing Clean Replaced (GWh)	[2]-[1] Delta (GWh)	[2]-[3] Delta (GWh)	[1] Existing Clean Offline (New-Only CES) (GWh)	[2] Existing Clean Online (Proposed CES-E) (GWh)	[3] Existing Clean Replaced (GWh)	[2]-[1] Delta (GWh)	[2]-[3] Delta (GWh)
Gas	69,854	52,188	52,832	(17,666)	(644)	47,918	30,772	31,561	(17,145)	(788)
Coal	414	379	402	(36)	(23)	0	0	0	0	0
Oil	96	10	88	(86)	(78)	3	0	15	(3)	(15)
Nuclear	16,448	26,318	16,448	9,870	9,870	16,448	26,318	16,356	9,870	9,961
Hydro + PS	7,374	7,374	7,374	0	0	7,510	7,510	7,510	0	0
Onshore Wind	8,513	8,513	25,982	0	(17,469)	9,457	9,457	26,926	0	(17,469)
Offshore Wind	111	111	111	0	0	6,032	6,032	6,032	0	0
Utility Solar	1,182	1,182	1,182	0	0	1,182	1,182	1,182	0	0
Other Renewables	8,308	8,308	8,308	0	0	8,489	8,145	8,169	(344)	(24)
Net Imports	12,913	20,738	12,913	7,826	7,826	21,419	29,245	21,419	7,826	7,826
DR	0	0	1	0	(1)	0	0	0	0	(0)
Total	**125,213**	**125,120**	**125,640**	**(92)**	**(520)**	**118,458**	**118,662**	**119,171**	**204**	**(509)**

Sources and Notes: Brattle analysis. Total amount of generation varies slightly across scenarios due to differences in losses.

A. Environmental Impacts

CES-E eligible resources contribute substantial quantities of clean energy generation to Massachusetts and New England. Seabrook is responsible for nearly 10 TWh per year of zero carbon generation and Canadian hydro imports add an additional 14 TWh. A portion of this clean energy is used to serve Massachusetts load. Approximately 2.8 TWh of Seabrook's annual generation is deemed to serve Massachusetts load under the GHG inventory methodology adopted by Massachusetts, and would be eligible for CES-E. About 6.2 TWh of Canadian hydro imports serve Massachusetts load are incremental to 1990, and are not eligible for CES, and would likely be eligible for CES-E.

Massachusetts CO_2 emissions would be substantially higher in the absence of these existing clean resources. Accounting for both emissions from in-state generation and imports of fossil energy from out of state, Massachusetts CO_2 emissions would be 3–3.5 million tonnes per year higher in the absence of CES-E resources. Figure 23 shows Massachusetts electric sector emissions in 2020 and 2030 across the three cases we evaluated in our modeling, compared with historical emissions. In 2020, emissions with Existing Clean Offline would likely be approximately 17 million tonnes per year, 3 million tonnes per year higher than the other two scenarios, and well above the levels projected in the Massachusetts Clean Energy & Climate Plan. By 2030, emissions with Existing Clean Offline are expected to fall to 11 million tonnes per year due to a combination of RPS, CES, and renewable procurements. However, emissions in this case would still be approximately 3 million tonnes per year higher than with Existing Clean Online.[18]

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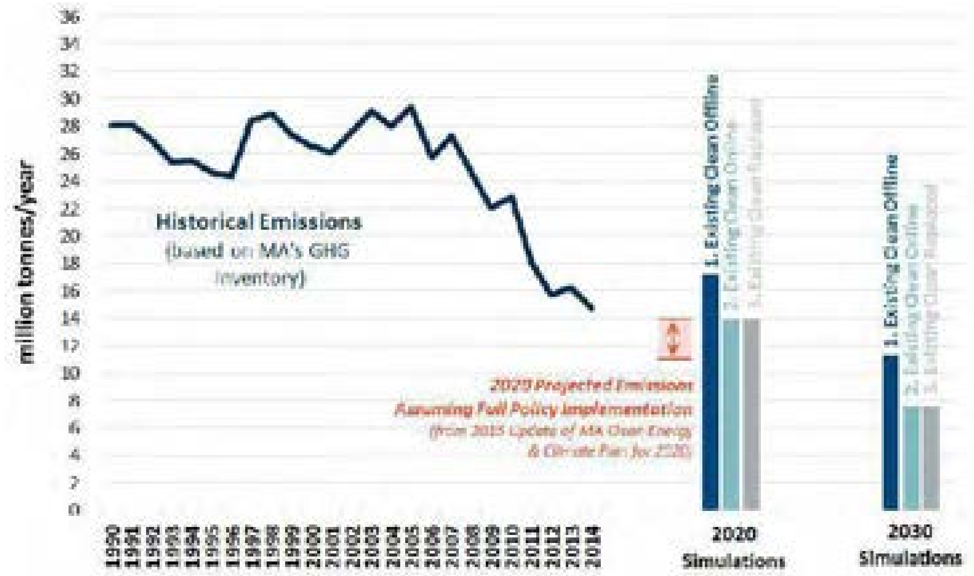
[18] Our analysis considered the impact of the Massachusetts electricity sector CO_2 emission limit under 310 CMR 7.74. We found that this limit is not binding in any of the three cases we considered. This finding is consistent with Synapse Energy Economics' August 2017 study. Since the electric sector emissions cap is not binding, removing existing clean generation without replacing it will indeed increase emissions. See Pat Knight *et al.*, "Analysis of Massachusetts Electricity Sector Regulations: Electricity Bill and CO_2 Emissions Impacts," August 2017, posted at: http://www.mass.gov/eea/docs/dep/air/climate/3dapp-study.pdf

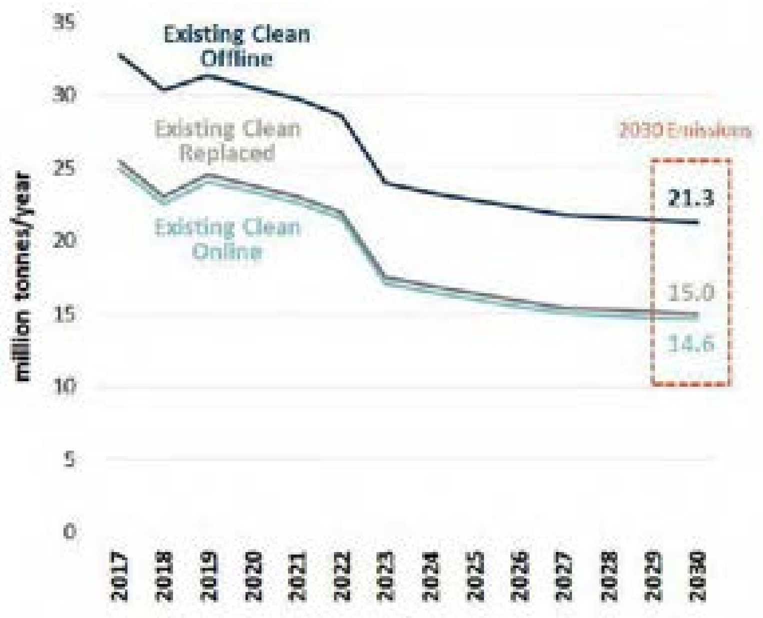
Figure 23: CO_2 Emissions to Serve MA's Electric Load



Sources and Notes:
Brattle analysis.
Calculated based on model outputs and historical data provided in Massachusetts GHG Emissions Inventory.

Existing clean resources have additional GHG benefits across New England. While locking-in Massachusetts' emissions reductions achievements is the primary objective of the CES-E policy, the New England-wide GHG reduction benefits are approximately twice as large as the Massachusetts-only benefits. As we illustrate in Figure 24, New England-wide CO_2 emissions would be 6–7 million tonnes per year higher in the Existing Clean Offline case relative to the Existing Clean Online case. As shown in the figure, these emission reductions are approximately constant through 2030, even as total system emissions decline.

Figure 24: ISO-NE System-Wide CO_2 Emissions



In the case without the existing clean resources, new renewables could be brought online in order to replace their clean energy and achieve Massachusetts' decarbonization goals.[19] Massachusetts could replace this generation with new clean resources, keeping the state on target to achieve its decarbonization goals. To illustrate the impact of this replacement, we modeled an additional Existing Clean Replaced scenario, in which the generation from Seabrook and Canadian hydro imports are replaced by new onshore wind. Figure 23 and Figure 24 show that this strategy could achieve approximately the same level of GHG emissions in Massachusetts and New England as the Existing Clean Online case. However, this scenario would result in additional costs as described in section V.B below.

B. ECONOMIC AND CUSTOMER COST SAVINGS

Existing clean resources provide low-cost generation to serve load in Massachusetts and across New England. Without this generation, Massachusetts and other New England states would have to procure additional clean energy from new resources to meet their decarbonization goals.

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19 Our modeling results show approximately equal levels of emissions under the Existing Clean Replaced and Existing Clean Online scenarios across all years assuming that the output from existing clean generators are immediately replaced. However, it might be practically difficult to replace the clean energy from Seabrook and Canadian hydro before 2020, as it would take many years to plan for and develop renewables and associated transmission. Thus, in the absence of the existing clean resources, Massachusetts would not likely reach its 2020 emissions goal.

We quantify the cost impacts of this additional requirement in two ways. The first is the impact on total system costs in ISO-NE, which includes production costs, fixed costs, investment costs, and import costs as discussed below. The second is the impact on customer costs in Massachusetts, which reflect market prices of energy and capacity as well as the state's clean energy procurement costs. We estimate these cost impacts by comparing the Existing Clean Online and Existing Clean Replaced cases.[20]

We evaluated the total cost of producing electricity in New England in four components:

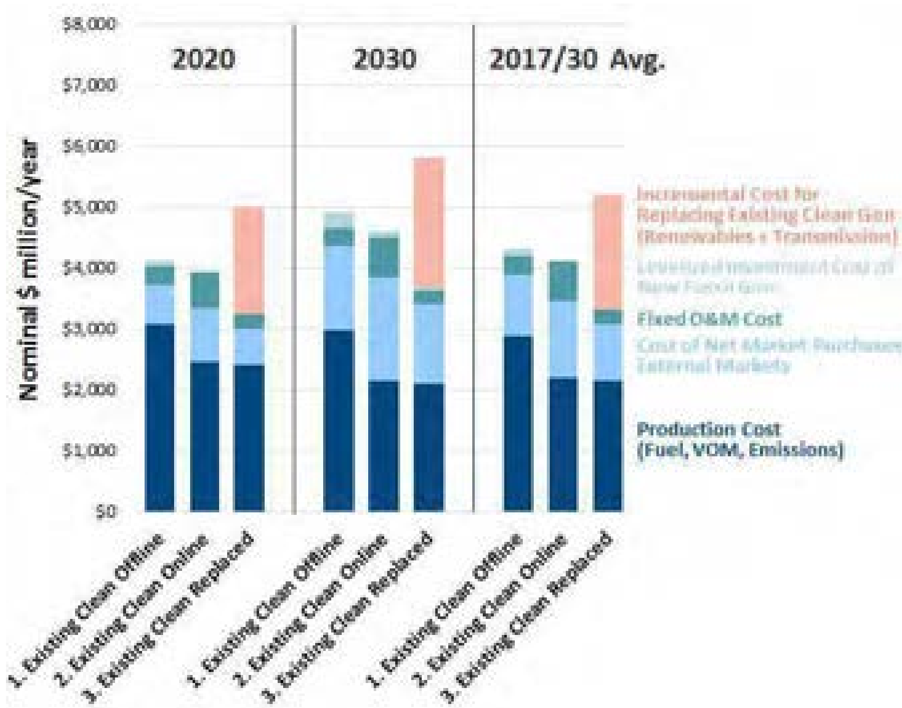
- **Production Costs** reflect the cost of fuel, variable operations and maintenance expenses, and the costs of RGGI allowances for New England generators;
- **Cost of Net Market Purchases from External Markets** reflect the cost of importing power from neighboring regions, valued at market prices for energy and capacity.
- **Fixed Operations and Maintenance (O&M) Costs** reflect the fixed going-forward costs of certain existing units in New England. We report fixed O&M costs only for nuclear and fossil plants that might economically retire. Fixed operations and maintenance costs for new resources are included as a part of the levelized investment costs and incremental cost for replacing the existing clean generation.
- **Levelized Investment Costs of New Fossil Generation** reflect capital and financing costs of developing new fossil resources, levelized over the lifetime of the asset. We report investment costs only for new fossil plants built after 2017 and do not report any of the sunk costs for the existing generating fleet.
- **Incremental Cost for Replacing Existing Clean Generation (Renewables and Transmission)** reflects the cost of replacing the clean generation in the Existing Clean Replaced scenario. These costs include levelized investment costs and annual operating costs for new onshore wind facilities, and the cost of incremental transmission needed to deliver their output to Massachusetts load.

As Figure 25 shows, the total ISO-NE system cost of replacing existing clean generation with new renewables is higher by approximately $1.1 billion per year. These costs correspond to the

[20] Note that the cost savings and emissions savings of existing clean resources cannot both be achieved together. If states choose to replace energy from existing clean resources with new clean generation, the existing clean resources drive cost savings. If states do not replace this energy, the existing clean resources drive emissions savings.

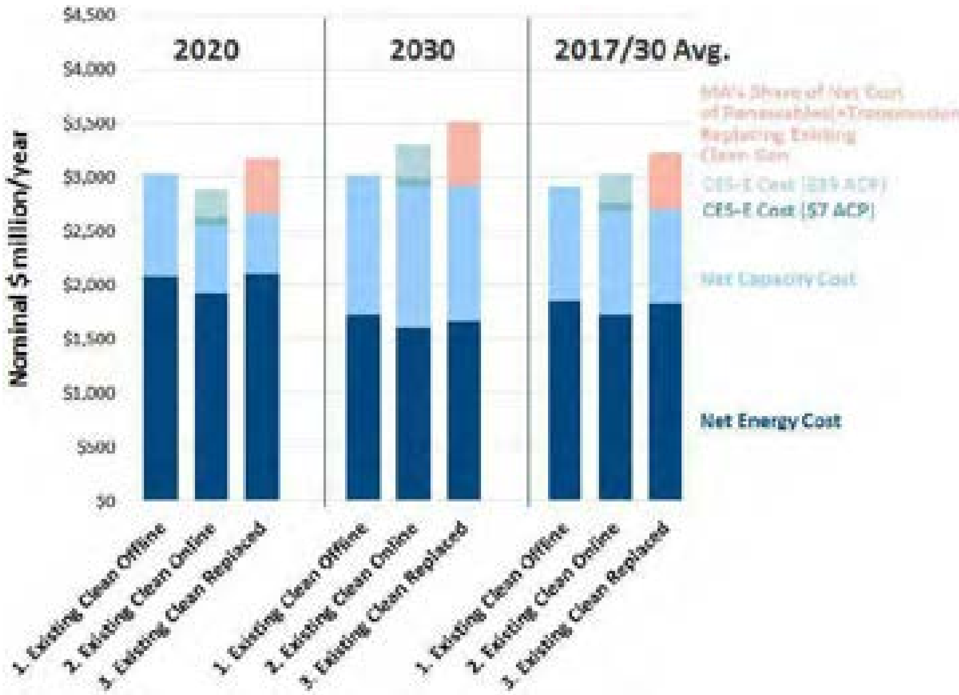
difference between total costs under the Existing Clean Replaced and the Existing Clean Online scenarios. The largest component of these additional costs is the incremental investment cost in new renewables. The size of these investment costs is sensitive to the cost of developing wind resources and the incremental transmission needed to reach them, as discussed in Section III. The incremental investment costs are offset by the higher fixed operations and maintenance costs under the Existing Clean Online case.

Figure 25: ISO-NE Total Annual System Costs



Replacing existing clean resources also increases costs to Massachusetts customers, as shown in Figure 26. Although Massachusetts customers would only pay for the portion of incremental renewables serving Massachusetts load, these renewables are the primary driver of customer costs. The additional renewables costs are offset by CES-E payments to existing clean resources under the Existing Clean Online case. We have assumed that existing clean resources receive the ACP, either at a level of 10% of the RPS Class 1 ACP (~$7/MWh) or 50% of the RPS Class 1 ACP (~$35/MWh). Under these assumptions, the increase in Massachusetts customer costs under the Existing Clean Replaced case range from $200 to $480 million/year.

Figure 26: Massachusetts Customer Costs



VI. Sensitivity Analysis

To test the robustness of our findings, we examined sensitivity cases with alternative input assumptions. We examined two cases focusing on key drivers affecting the impact of CES-E on costs and CO_2 emissions:

- **Low Gas and RGGI Price:** Assumes that natural gas and RGGI allowance prices grow only at the rate of inflation across the model time horizon. Lower gas and RGGI prices result in lower energy prices compared to our base case assumptions.
- **Increased Renewable and Transmission Cost:** Assumes higher investment costs and transmission costs for developing renewables to replace clean energy generated by existing clean resources in the Existing Clean Replaced scenario. In this scenario, transmission costs increase from the base case value of $500/kW of wind to $2,000/kW of wind, consistent with the ISO-NE's Draft 2016 Economic Study: NEPOOL Scenario

Analysis.[21] This case provides an upper bound on the cost of the Existing Clean Replaced scenario.

A. Low Gas and RGGI Prices

Figure 27 compares the results of the Low Gas and RGGI Price sensitivity to Base Case results. The Figure shows that the CO_2 emissions benefits of retaining existing clean resources are essentially the same in the Base Case and Low Gas and RGGI Price cases. Emissions savings are approximately 3.6 million tonnes of CO_2 per year for MA and approximately 7 million tonnes of CO_2 per year for the New England region as a whole on average over 2017–2030. This can be seen by comparing emissions under the Existing Clean Online and Existing Clean Offline scenarios ("[2]-[1] Delta" column in the Figure).

Figure 27 also shows the cost savings of retaining existing clean resources rather than replacing them. Comparing MA customer costs and ISO-NE total resource costs under the Existing Clean Online and Existing Clean Replaced scenarios ("[2]-[3] Delta" column in the Figure) shows that savings are somewhat larger under the Low Gas and RGGI Price sensitivity relative to the Base Case. Across all cost categories (MA Customer Costs at $7 ACP, MA Customer Cost at $35 ACP, and ISO-NE Total System Costs), savings are $80–$100 million per year higher on average between 2017–2030 under the Low Gas and RGGI price sensitivity relative to the Base Case due primarily to the lower cost of imports at the market price of energy.

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21 ISO-NE, "2016 Economic Study: NEPOOL Scenario Analysis–Implications of Public Policies on ISO New England Market Design, System Reliability and Operability, Resource Costs and Revenues, and Emissions", July 24, 2017. $2,000/kW-wind is estimated based on the incremental transmission cost of about $20 billion to facilitate 10 GW of additional onshore wind in Scenario 2 relative to Scenario 1.

Figure 27: CO_2 Emissions and Costs
Low Gas/RGGI Price Sensitivity

		2017-2030 Average				
		[1] Existing Clean Offline (New-Only CES)	[2] Existing Clean Online (Proposed CES-E)	[3] Existing Clean Replaced	[2]-[1] Delta	[2]-[3] Delta
ISO-NE CO2 Emissions						
Base	(MMTCO2)	25.8	18.8	19.2	(7.0)	(0.4)
Low Gas/RGGI	(MMTCO2)	26.4	19.6	20.0	(6.8)	(0.4)
MA's Share of CO2 Emissions						
Base	(MMTCO2)	14.1	10.5	10.6	(3.6)	(0.1)
Low Gas/RGGI	(MMTCO2)	14.5	10.9	11.0	(3.6)	(0.1)
ISO-NE Total System Costs						
Base	(nom.$MM)	$4,318	$4,107	$5,212	($210)	($1,105)
Low Gas/RGGI	(nom.$MM)	$3,374	$3,303	$4,487	($71)	($1,184)
MA Customer Costs						
Base $0	(nom.$MM)	$2,910	$2,684	$3,234	($227)	$324
Base $7 ACP	(nom.$MM)	$2,910	$2,753	$3,234	($157)	($481)
Low Gas/RGGI $7 ACP	(nom.$MM)	$2,417	$2,281	$2,865	($136)	($584)
Base $35 ACP	(nom.$MM)	$2,910	$3,031	$3,234	$120	($203)
Low Gas/RGGI $35 ACP	(nom.$MM)	$2,417	$2,559	$2,865	$141	($306)

B. Increased Transmission Costs

The Increased Renewable and Transmission Costs sensitivity provides an upper-bound estimate of the cost of replacing existing clean resources with new renewables. In this sensitivity case, we assume transmission costs consistent with ISO-NE's 2016 Economic Study Scenario Analysis.[22] Under the study's scenario considering renewables in excess of RPS, the authors determined that integrating 10 GW of wind beyond RPS would require an additional transmission investment of $20 billion, or $2,000/kW of incremental wind. This value is four times larger than the $500/kW of wind transmission cost assumed in our base case.

Applying the higher transmission cost to our analysis, we find that ISO-NE total system costs would increase by approximately $1.2 billion per year under the Existing Clean Replaced scenario compared to our base case transmission cost assumptions. The implied ISO-NE total

[22] ISO-New England, "Transmission Transfer Capabilities & Capacity Zone Development", 2016.

system cost savings of retaining existing clean resources, rather than replacing them with new clean resources, would increase from $1.1 billion per year in our base case to $2.3 billion in the high transmission cost sensitivity case. Costs to Massachusetts customers would not increase to the same extent, since some of the replaced clean energy is consumed outside of Massachusetts. Massachusetts customer costs would increase by approximately $500 million relative to the base case transmission assumptions. The implied Massachusetts customer cost savings of retaining existing clean resources rather than replacing them would increase from about $500 million per year under the base case (with $7/MWh ACP) to $1.1 billion per year with higher transmission costs.

VII. Conclusions

In this study, we evaluate the cost and emission impacts of retaining existing clean generators through a CES-E program, compared to scenarios without these existing clean generators and replacing existing clean generators with additional new clean resources. We conclude that retaining the existing clean generators under the CES-E program (including the Seabrook nuclear plant) would result in 3–4 million metric tonnes lower GHG emissions per year in Massachusetts over the period 2017–2030 relative to a scenario without the existing clean generators, which would help the state keep its electric sector-emissions below the 2020 GWSA target of 11–14 million metric tonnes. If the output from existing clean generators is replaced with additional new renewables, the costs to Massachusetts customers would be higher on average by $0.2–$1.2 billion per year relative to the customer costs of retaining the existing clean generators under the CES-E program.

For the ISO-NE system as a whole, total system costs would be higher on average by $1.1–$2.4 billion per year if the existing clean generation is replaced with additional new renewable generation.

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